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Climate change impacts and urban green space adaptation efforts: Evidence from U.S. municipal parks and recreation departments

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ABSTRACT

Municipal parks and recreation departments (PRDs) have a crucial responsibility for stewarding urban and peri-urban ecology given they manage the majority of urban green spaces. However, the extent of climate adaptation planning and management activities by such agencies at the national level is unknown. This study aimed to fill this gap by conducting a national survey of the directors of PRDs ($n = 413$) to understand the progress and drivers of climate change adaptation efforts for urban green spaces. Overall, we found that while measured impacts of climate change were positively correlated with PRDs' climate-change adaptation plans and actions, most PRDs perceived few impacts of climate change on urban green spaces. We also found that levels of adaptation varied across ecoregions, with direct experiences with climate change impacts being a primary contributor to action. These findings indicate that U.S. municipal PRDs are unprepared for the changing climate and are unlikely to initiate urban green space adaptation planning and action until substantial climate change impacts are experienced firsthand.

1. Introduction

Parks, street trees, urban nature preserves, and other urban green spaces are of great importance for habitability and quality of life in cities (Boulton et al., 2018). In fact, urban green spaces are increasingly considered essential "green infrastructure" because they provide numerous ecosystem services that generate diverse socioeconomic and environmental benefits, from improving health inequalities to reducing urban heat-islands (Allen, 2012, Mitchell and Popham, 2008; Memon and Leung, 2010).

Urban green spaces are also a growing strategy for promoting climate change resilience (Reynolds et al., 2020), where resilience refers to a socio-ecological system's ability to persist, transition or transform so as to maintain functioning and well-being in response to disturbance (Biggs et al., 2015; Walker and Salt, 2012). For example, several scholars have posited parks are a top option for lowering urban heat island effects (Rizwan et al., 2008; Chow et al., 2011) as they are found to have lower air temperatures than the surrounding, built landscape, often times emitting a spillover cooling effect (Slater, 2010). Urban forests promote water absorption and purification (Yang et al., 2015), soil stabilization (Asadian and Weiler, 2009), and pollution filtration (Brantley et al., 2014), with

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effects depending on species composition (Janhäll, 2015). Urban green infrastructure is highly multifunctional, and aside from the foregoing services, diverse forms of green spaces including parks, urban forests, green roofs, food gardens, and pocket prairies collectively provide many other services important for maintaining quality of life in a changing climate, including food production, carbon storage, and cultural services such as aesthetics, recreational opportunities, and community cohesion (Reynolds et al., 2020).

With two-thirds of the planet's population projected to be city dwellers by the year 2050 (United Nations, Department of Economic and Social Affairs, Population Division, 2015) and 80% of the U.S. population being already urban (Dwyer et al., 2000), careful stewardship of green spaces is critical (Nowak and Greenfield, 2010). In addition to population pressure, the management of urban green spaces is further compounded by continued climate change. Altered precipitation patterns, changes in the timing of seasons, and increased frequency and severity of extreme events (e.g. storms, floods, droughts) are among many climatic changes (Stott, 2016) that management planning will need to consider in order to safeguard the integrity of urban green space and associated ecosystem services (Reynolds et al., 2020). Indeed, operating expenditures of America's state park systems are forecasted to increase 756% by midcentury due to climate change (Smith et al., 2019).

To better manage urban green spaces in response to climate change, scholars and policymakers are advocating for more integrated coordination among various local government departments to take the leadership in climate change adaptation and mitigation (Betsill and Bulkeley, 2007; Kousky and Schneider, 2003). The functional fragmentation embedded in the administrative structure of U.S. local governments, however, makes it very challenging to develop coordinated city-level efforts (Feiock et al., 2017), particularly when financial and personnel decisions reside in individual departments. Therefore, amidst the push for a city-level coordination of climate-change adaptation, it is critical to examine how individual functional departments are responding to climate change. Our study focuses on U.S. municipal parks and recreation departments (PRDs), which often manage the largest and most critical urban green space parcels (Crompton, 2008). PRDs not only manage urban green space aggregated in formal parks, but also considerable public green infrastructure assets, such as street trees and riparian corridors that are decentralized across the urban landscape. Despite their critical role in managing urban green spaces, compared to other functional departments in U.S. local governments, parks and recreation departments often face significant budget cuts in the time of a crisis and their capacity to manage these critical urban green infrastructures is diminished (Cheng, 2019a; Cheng and Yang, 2019). The gap between the critical role PRDs play in urban climate-change adaptation and their decreasing capacity in fulling these functions makes it critical to develop a baseline benchmark about what PRDs are doing about climate-change adaptation and the factors associated to its progress.

Climate-adaptation policies and strategies for urban green spaces require both technical and managerial components. Technical aspects include the application of scientific knowledge regarding how urban ecosystems work and how they may be affected by a changing climate, such as developing a climate-smart tree species-planting list (National Wildlife Federation, 2014). Additionally, PRDs operate in particular institutional and managerial environments that require specific strategies to secure necessary financial, political, and human resources for subsequent actions. Recent theoretical frameworks of climate-change adaptation and urban sustainability studies confirm that an effective implementation of an adaptation plan needs to overcome multiple barriers, including uncertainty, large initial investment, leadership commitment, and institutional and behavioral barriers (Burns et al., 2003; Krause, 2011; Kates et al., 2012; Moser and Ekstrom, 2010; Ostrom, 2009; Portney, 2013; Shi et al., 2015). Understanding the motivations, perceived impacts and adaptation actions of municipal PRDs towards climate change is thus essential to a more holistic understanding of the role of government agencies in climate change adaptation. Remarkably, there is no national level data available about the actions and strategies of PRD agencies.

To fill in this gap of knowledge, we conducted a national survey of U.S. municipal PRDs ($N = 1498$; $n = 413$) to investigate the strategies PRDs have taken, and are planning to take to adapt to climate change. The specific objectives or this study were to (1) understand the perceived impacts of climate change on urban ecology and greenspaces among PRDs (which tend to manage the bulk of urban ecology), (2) understand the adaptation preparation and experiences among PRDs, (3) analyze how observed climate events relate to current adaptation by PRDs, and (4) to understand how self-reported impacts of climate change differ by ecological region via results from a national survey of US PRDs.

This study contributes to the existing literature by presenting national level evidence of the perceptions and actions of local public managers and connecting them to the geographical and ecological conditions of the localities. Our main findings suggest that U.S. municipal PRDs are unprepared for the changing climate and are unlikely to initiate urban green space adaptation planning and action until substantial climate change impacts are experienced firsthand.

2. Methods

2.1. Participant selection & recruitment

To assess urban green space adaptation efforts at the national level, we surveyed all municipal PRDs in the United States whose municipality's population exceeded 25,000 inhabitants ($N = 1498$). In total, 413 completed and useable surveys were garnered from PRD agencies (27.6% response rate). We studied the current climate change conditions agencies are facing, the current adaption strategies underway, and agency plans for future adaptation to climate change.

2.2. Data collection

Data was collected using a modified Tailored Design online survey approach (Dillman et al., 2009). We compiled a list of all cities in the United States with greater than 25,000 residents and built a database of contacts for each PRD located in each municipality (summer 2016). We set a threshold of 25,000 residents in order to capture moderate- to large-sized municipalities likely to have extensive public urban green spaces and thus substantial needs for climate change adaptation activities. A research assistant was hired to collect the email and physical addresses of parks departments and their directors via online searches or phone calls to the agencies. In cases when we could not acquire specific contact information, we used generic email addresses provided by parks department websites. In the fall of 2016, we sent out four rounds of online surveys (using Qualtrics online surveying software) following procedures recommended by Dillman et al. (2009). A fifth and final step was used to solicit data from non-respondents, which included a mailed, paper questionnaire that contained a study information sheet/letter, a blank questionnaire, and a postage paid return envelope ($N = 1266$). In sum, 232 participants responded to the online survey and 181 responded to the paper form, representing a total response rate of 27.6%.

The mean participant age was 33.39 (M = 35), with individuals having been employed with their agency on average for 14.21 years (M = 12). Participants had lived in the general area where their agency is located for 27.95 years (M = 26). The vast majority (91.6%) of respondents had at minimum a bachelor's degree, with 36% of the total holding a graduate degree. Over a third (34.4%) of respondents held a degree in recreation administration or a related field, while 8% held a degree in biology/ecology, 14.8% in natural resources/forestry, 13.1% in business, 6.5% in education, and 31.5% in another area not defined in the survey. Park directors/superintendents comprised 68.6% of the sample, with city foresters accounting for 7.1%, assistant directors/superintendents 6.4%, natural resource managers/naturalists 5.1%, and those in the "other" category amounting to 12.7%.

The agencies responding to our survey managed on average 40.17 (M = 30) discrete park units and 78.7% were located in cities with 25,000–100,000 residents. Cities with 100,001 to 250,000 residents comprised 14.2% of participating PRDS, while 6.5% were located in cities with 250,001 to 1,000,000 residents. Two cities responded that had over 1,000,000 persons living in their defined boundary. The map of responding PRDs' eco-regions is shown in Fig. 1. Table 1 shows the number of PRDs by U.S. EPA ecoregions.

2.3. *Survey instrument*

Data was collected on parks agency characteristics, climate change related problems experienced by the agency, perception of problems associated with weather and climate related events, perspective on impact of weather and climate on urban ecology in the near future, perceived change to urban forests and tree health conditions, adaptation actions taken, adaptation actions planned, data concerning short through long range planning, barriers to implementing and developing climate change adaptation plans, and survey-taker characteristics and demographics (see supplemental materials for complete instrument). To ensure the close match between our survey questions and actions taken by municipal park departments, we used specific terms such as "in city parks" or "for park and recreation facilities" in each of the survey items where we asked them the level of completeness of various climate-adaptation activities.

New variables were added for city-size classes and United States ecological-regional categories (Van der Schrier et al., 2013). A total of thirty-four questions were asked in the survey, for an expected survey length of 15–20 min (see the supplementary documentation for the survey instrument).

2.4. *Measurements and variable construction*

We used SPSS version 24 to analyze the data. Nine prompts on the survey [Q14][1] asked responders to rate the "problem level" of potential climate change impacts, rated from "Not at all a problem" (1) to "Extreme problem" (5). Three items represented problems due to heat and drought; three described problems from storms, floods, and sewer overflows; and three represented loss of ecosystem services, biodiversity, and pests. Summary scores were created by averaging the three items in each subscale. Reliability analysis via Cronbach's alpha showed reasonably high internal consistency across the three items on each of the three scales, respectively (alpha = 0.787, alpha = 0.622, alpha = 0.728). Reports on the physical condition of the trees in the city and trees in the parks [Q11 & 12] were also combined into an average score (alpha = 0.878), where tree condition was rated from "Greatly improved" (1) to "Greatly declined" (7).

For survey items regarding adaptation action plans and strategies, exploratory factor analysis was performed to identify which items could be grouped into a small number of factor scores that summarize PRDs' adaptations. Nine items [Q18 & 22_8] assessing PRD's completion of adaptation action plans and strategic plans for climate change were rated from "Not completed, not currently pursuing or interested" (1) up to "Yes, complete" (5). Exploratory factor analysis revealed all nine items to load on a single underlying factor, with high reliability (alpha = 0.914), so that a corresponding average score was created.

Eleven additional items [Q22] assessed completion of various adaptation strategies, and these loaded into two main factors in the exploratory factor analysis. The first factor measured action towards developing infrastructure for storm water capture, downspout disconnection, water efficiency, and permeable surfaces (alpha = 0.726). The second factor measured reduced water use for irrigation and water audits at parks facilities (alpha = 0.767). Planting trees appropriate for long-term climate forecast did not load with other items and was used as a separate measure.

We used the Palmer Drought Severity Index (PDSI) as an integrative measure of each city's most extreme climatic conditions over the last 10 years. PDSI is an index of soil moisture that combines both moisture supply (precipitation) and moisture demand

[1] The numbers in the brackets refer the specific questions on the survey instrument. The survey instrument is provided as the supplementary document of this article.

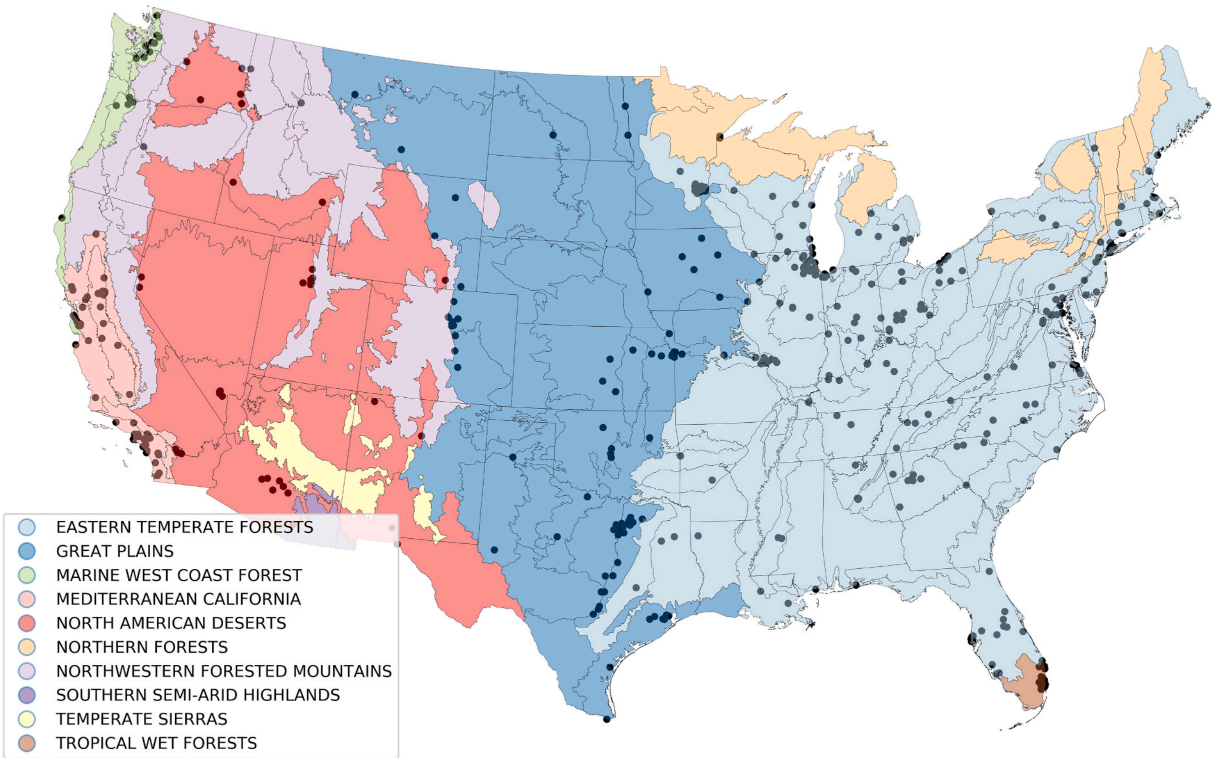

Fig. 1. Location of PRDs in our sample by Ecoregion.

Table 1
Number of PRDs by U.S. EPA Ecoregion.

Ecoregion	n
Eastern Temperate Forests	214
Great Plains	81
Marine West Coast Forest	14
Mediterranean California	48
North American Deserts	34
Northern Forests	2
Northwestern Forested Mountains	4
Tropical Wet Forests	14
Total	411

PRDs in Northern Forests and Northwestern Forested Mountains were excluded from comparisons due to small sample sizes.

(evapotranspiration) components. The PDSI value for a given month is a weighted combination of conditions for the current month and those leading up to that month. Data are available monthly from 1901 to 2016 on a 0.5 × 0.5 degree latitude-longitude grid for all terrestrial (land) locations (the version of the data used here often is referred to as self-calibrating PDSI or scPDSI, but we use the more general abbreviation of PDSI) (van der Schrier et al., 2013). A 0.5 × 0.5 latitude-longitude grid has dimensions of approximately 55 × 43 km at the latitudes where we are working (one-degree latitude-longitude grid boxes are about 110 × 110 km at the equator and go to 110 × 0 km at the poles).

The monthly PDSI time series at the grid point closest to each PRD headquarters was used for analysis. We used each site's lowest monthly PDSI from 2007 to 2016 to indicate the most severe drought and the highest monthly PDSI over the same period to indicate the wettest interval (Fig. 2). PDSI generally ranged from −6 to +6, where negative values denote long-term drought, and positive values denote long-term wet patterns.

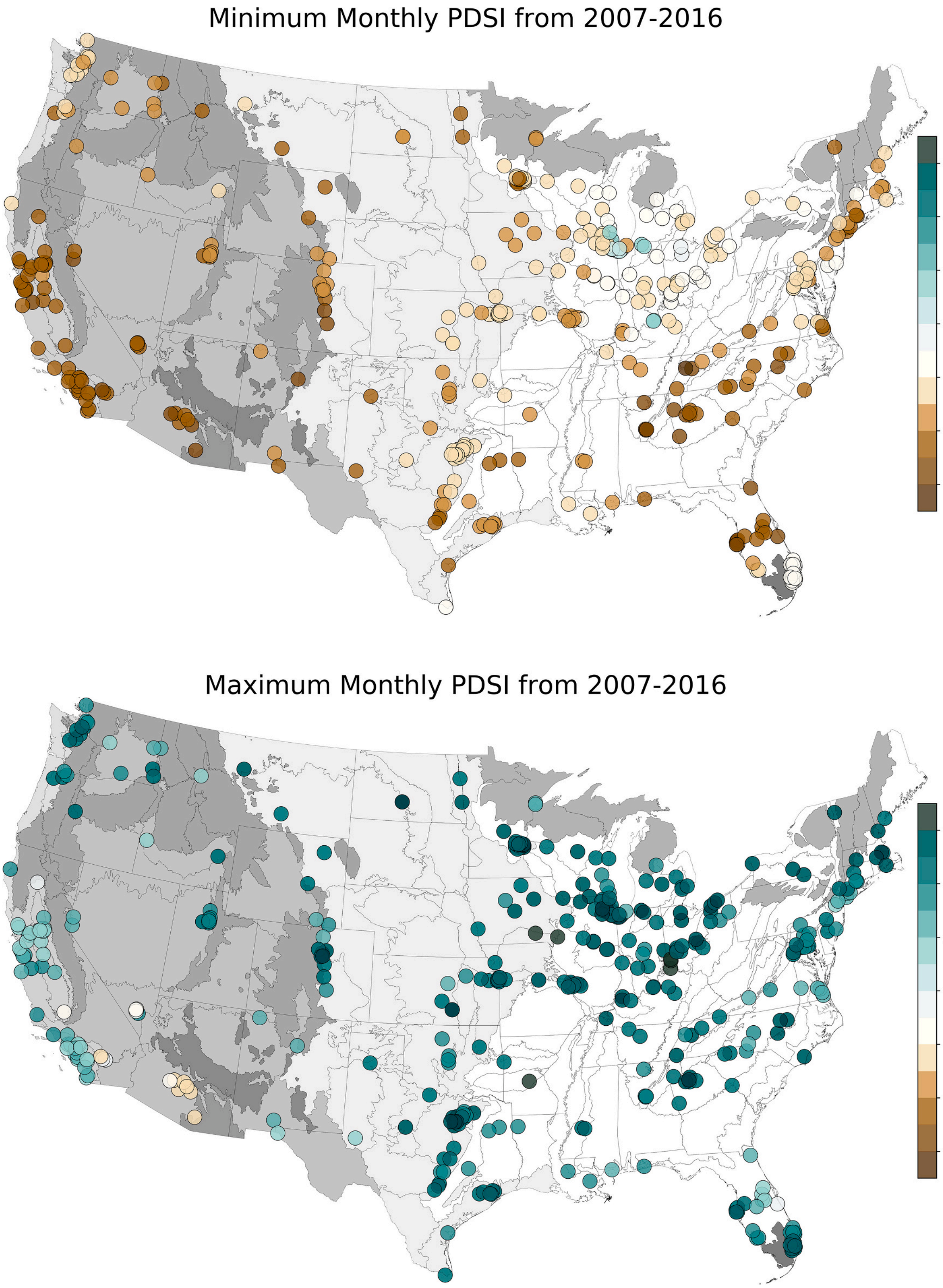

Fig. 2. Monthly extremes of low soil moisture (minimum PDSI; Palmer Drought Severity Index) and high soil moisture (maximum PDSI) for the most recent ten-year period (2007–2016) at sampled Parks and Recreation Department locations.

3. Results

3.1. How do self-reported impacts of climate change relate to current adaptation by PRDs?

Pearson correlations were performed to evaluate the strength of the relationship between reported impacts of climate change (Heat/Drought, Storms/Floods, Tree condition, Ecosystem service, Biodiversity, and Pests) and PRD's completion of adaptation action plans and strategic plans (Adaptation Action Plans, Water Infrastructure, Reduced Water Use, Planting Appropriate Trees).

Overall, the self-reported problems from extreme weather and climate conditions such as heat, droughts, storms, floods, and climate related declines in ecosystems and biodiversity were generally viewed as minor to moderate problems, with cities reporting broad variability from not at all to extreme problems (Table 2; Figs. 3 and 4). Reports on the physical condition of trees ranged widely, but on average cities reported small declines or no change (Table2; Fig. 3). PRDs showed very low levels of climate adaptation planning or implementation. The highest activity level was for planting trees that are appropriate for long-term climate scenarios, with a mean value of 3.54 – between just starting (3) and in progress (4). On average, PRDs had not started developing progressive water infrastructure (storm water capture, downspout disconnection, water efficiency improvements, installation of permeable surfaces) or made strides to reduce water usage (Table 2). These findings suggest that U.S. municipal PRDs have not yet fully recognized the impacts of climate change and development of climate change adaptation plans and/or taking action is in a nascent state.

Pearson correlations indicated that PRDs reporting higher impacts from heat and droughts were more likely to have completed adaptation action plans ($r = 0.301, p < .001$), to be reducing water use ($r = 0.337$, $p < .001$), and to be planting trees for the long term ($r = 0.147, p = .003$) (Table 3). Likewise, those reporting fewer impacts were less likely to make adaptations. PRDs reporting more impacts from storms and floods, as well as those reporting problems with declines in ecosystems and biodiversity, were also more likely to have made progress completing adaptation action plans ($r = 0.129, p = .009$; $r = 0.230, p < .001$, respectively). A weak correlation was found between PRDs that reported the physical condition of trees as declining and those taking action towards water infrastructure development ($r = -0.113, p = .023$).

3.2. How do observed climate events relate to current adaptation by PRDs?

To evaluate how observed climate events related to current adaptation activities by PRDs, we used Pearson correlations to analyze how a PRD's minimum PDSI and maximum PDSI was associated with reported impacts (Heat/Drought, Storms/Floods, Tree condition, Ecosystem service, Biodiversity, and Pests). Two-sided independent samples *t*-tests also were performed to evaluate whether cities reported to be engaging in short-term (1–10 years), intermediate (11–25 years), and long-term (26–50 years) planning had experienced higher or lower extremes of PDSI.

Our analysis demonstrates that PRDs impacted most by severe climate events, as measured by the PDSI, self-reported higher climate change impacts in our survey. Cities with more severe drought (more negative minimum PDSI) reported more impacts from Heat, Drought, and Water shortage ($r = -0.346, p < .001$), suggesting that respondents were both seeing and recognizing direct impacts from severe drought conditions (Table 4). Similarly, cities experiencing wetter conditions (higher maximum PDSI) reported more impacts from Storms, Floods, and Sewer Overflows ($r = 0.155, p = .002$).

Cities with more severe drought (negative minimum PDSI) also reported more progress on adaptation, such as developing action plans ($r = -0.172$, $p < .001$), reducing water use ($r = -0.246$, $p < .001$), and engaging in short-term (1–10 years) ($t_{398} = 2.59, p = .010$) and intermediate planning (11–25 years) ($t_{398} = 2.25, p = .025$), but no correlation with long-term planning (Table 4). Likewise, those with less drought reported less progress on adaptation. Cities with recent extremes of wet conditions (higher maximum PDSI) were less likely to complete action plans ($r = -0.174, p < .001$), reduce water use ($r = -0.294$, $p < .001$), or to expect the adverse effects of weather and climate related events to have a major impact on the ecology overseen by their agency ($r = -0.106, p = .033$). These cities were also less likely to engage in short-term ($t_{398} = 2.975, p = .003$) and intermediate planning ($t_{398} = 2.577, p = .011$).

Table 2
Reported impacts and adaptation among PRD respondents.

	n	Mean	SD	Min	Max
Impacts and Problem level					
Heat, Drought, Water Shortage[1]	412	2.69	0.95	1.00	5.00
Storms, Floods, Sewer Overflows[1]	412	2.10	0.73	1.00	4.67
Tree condition[2]	410	4.35	1.25	1.00	7.00
Ecosystem Service & Biodiversity Decline, Increased Pest Pressure[1]	412	2.38	0.86	1.00	5.00
Adaptation[3]					
Action plans	410	1.59	0.71	1.00	4.33
Planting trees appropriate for long-term climate forecast	404	3.54	1.25	1.00	5.00
Water Infrastructure Development	403	2.96	0.94	1.00	5.00
Reduced Water Use	402	2.80	1.27	1.00	5.00

[1] 1 = Not at all a problem; 3 = Moderate problem; 5 = Extreme problem.
[2] 1 = Greatly improved; 4 = Remained the same; 7 = Greatly declined.
[3] 1 = Not completed, not currently pursuing or interested; 3 = Just starting; 5 = Complete.

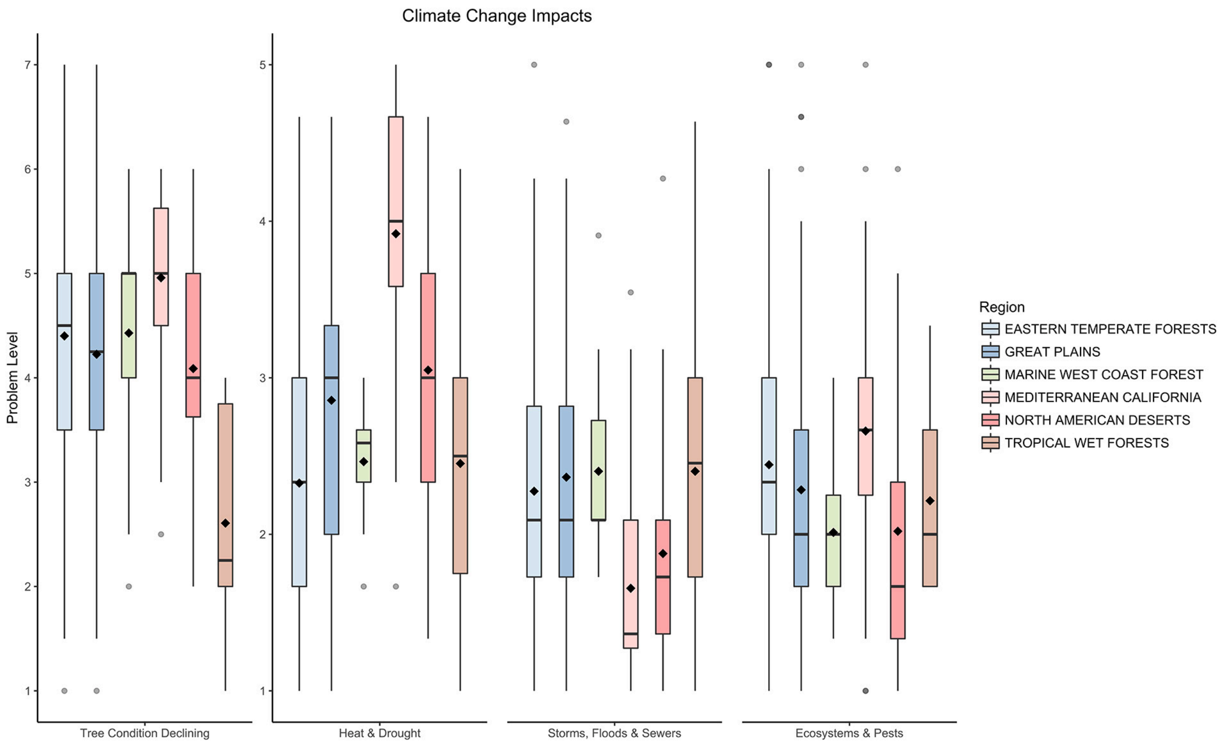

Fig. 3. PRDs and climate change impacts, as reported by ecoregion. Tree condition is scaled from "Greatly improved" (1) to "Greatly declined" (7). Heat & Drought, Storms, Floods & Sewers, and Ecosystems & Pets are scaled from "Not at all a problem" (1) to "Extreme problem" (5).

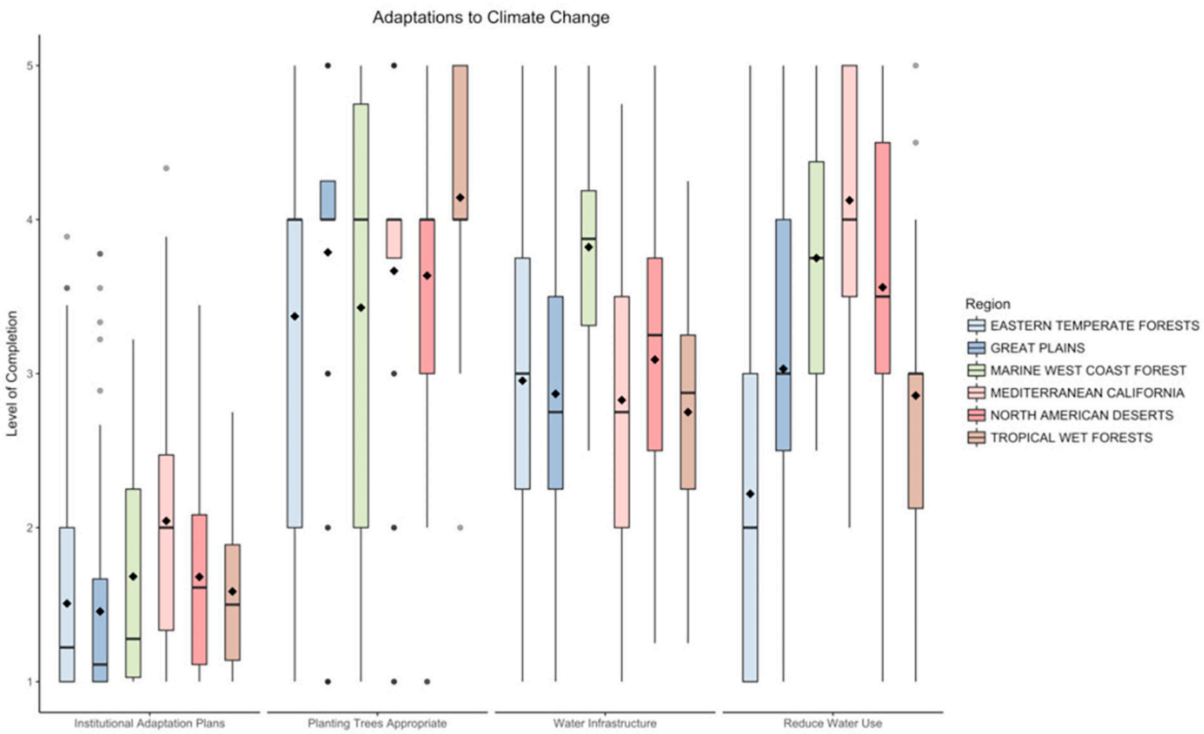

Fig. 4. Adaptation strategies by PRD locations grouped by eco-region. Adaptation action plans and strategic plans for climate change were rated from (1) "Not completed, not currently pursuing or interested" to (3) … to (5) "Yes, complete.

Table 3
Pearson correlation of reported impacts on adaptation plans and actions.

Impacts	Adaptation Action Plans	Water Infrastructure	Reduced Water Use	Planting Appropriate Trees
Heat, Drought, Water	0.301**	−0.090	0.337**	0.147**
Storms, Floods, Sewer Overflows	0.129**	0.036	−0.124*	−0.015
Tree condition	0.026	−0.113*	−0.048	−0.084
Ecosystem Service & Biodiversity Decline, Increased Pest Pressure	0.230**	0.044	0.006	0.054

*$p < .05$, **$p < .01$.
Note: Our findings are consistent when excluding municipalities in California. Results are available upon request.

Table 4
Pearson Correlation of Dry and Wet Weather (PDSI) on Climate Change Impacts and Adaptations.

	Minimum PDSI (drought)	Maximum PDSI (wet)
Impacts: Heat, Drought, Water	−0.346**	−0.335**
Impacts: Storms, Floods, Sewers	0.084	0.155**
Impacts: Ecosystems, Biodiversity & Pests	0.009	0.022
Impacts: Tree condition declining	−0.014	−0.061
Adaptation and Action plans	−0.172**	−0.174**
Adaptation: Planting trees appropriate for long-term climate forecast	0.041	−0.023
Adaptation: Water Infrastructure Development	0.028	0.076
Adaptation: Reduced Water Use	−0.246**	−0.294**

*$p < .05$, **$p < .01$.

3.3. How do self-reported impacts of climate change and adaptation differ by ecological region?

ArcGIS was used to identify the United States Environmental Protection Agency (EPA) Ecoregion of each PRD city. There are 12 Level I ecoregions in the continental U.S. In our sample, one PRD in Alaska and one in Hawaii, as well as two PRDs in Northern Forests and four in Northwestern Forested, were removed from the analysis of ecoregions due to small sample sizes ($n < 5$). One-way analysis of variance (ANOVA) were performed to compare the responses from PRDs in different ecoregions. PRDs in Northern Forests and Northwestern Forested Mountains were excluded from comparisons due to small sample sizes.

Our results demonstrate that there were significant differences between the six analyzed ecoregions in all four of the perceived impacts of climate change (Heat, Drought, Water problems, $F = 33.15$, $df = 5$, $p < .001$; Storms, Floods, Sewers, $F = 7.45$, $df = 5$, $p < .001$; Tree condition decline, $F = 8.96$, $df = 5$, $p < .001$; Ecosystem/Biodiversity Decline and Pests, $F = 3.22$, $df = 5$, $p = .007$) and three adaptation strategies (Adaptation and action plans, $F = 5.39$, $df = 5$, $p < .001$; Water infrastructure, $F = 3.05$, $df = 5$, $p = .010$; Reduced water use, $F = 33.04$, $df = 5$, $p < .001$) (Figs. 3 and 4).

Problems from heat, drought, shortage of water supply, and overall problematic climate events were rated to be the highest in Mediterranean California ($M = 3.92$, where 1 = No Problem to 5 = Extreme Problem); whereas the PRDs in the Eastern Temperate Forests reported the least overall impacts ($M = 2.33$) (Fig. 3). Considering the attention given to the recent severe drought in much of California (Robeson, 2015; Griffin and Anchukaitis, 2014) the standout of California is not surprising.

PRDs in Mediterranean California and North American Deserts reported the least problems from storms, floods, and sewer overflows ($M = 1.60$ and $M = 1.82$, respectively), while there were more problems reported in Tropical Wet Forests ($M = 2.29$) and Marine West Coast Forests ($M = 2.29$). PRDs in Mediterranean California reported the most decline in tree condition ($M = 4.96$, where 1 = Greatly improved to 7 = Greatly declined), whereas tree condition in Tropical Wet Forests (South Florida) was almost always reported to be improved ($M = 2.61$). PRDs in the Tropical Wet Forests eco-region were more often observed to engage in tree plantings appropriate for future climates than PRDs from other regions.

Problems with a decline in Ecosystems and Biodiversity and threats from pests were higher in Mediterranean California ($M = 2.66$), followed by Eastern Temperate Forests ($M = 2.43$) and North American Deserts ($M = 2.04$). All three areas have experienced significant droughts within the last 10 years (Robeson, 2015; Griffin and Anchukaitis, 2014; Mallya et al., 2013; MacDonald, 2010). When coupled with pressure from invasive species, ecosystem functioning and biodiversity declines can be exacerbated (Crowl et al., 2008).

4. Discussion

Overall, our data underscores critical gaps in adaptation preparation that may have fundamental repercussions on the ecological health of urban green spaces, cities' resilience, and the future health and well-being of urban dwellers. Constrained resources often mean that the most immediate needs receive attention. This lack of adaptation preparation might stem, therefore, from relatively low climate change impacts experienced by cities so far. For example, when queried about PRD experience with climate change impacts, most respondents indicated minimal observed impacts. One exception was frequent reference to declining tree condition, which may suggest that trees are an important, easily recognizable integrator of differing climate change impacts.

Regarding the implementation of adaptation strategies, respondents indicated most frequently engaging in planting appropriate tree species, followed by to a much lesser extent developing green water infrastructure, reducing water usage, and developing climate action plans, respectively. Still, most PRDs either have not started or have just started to implement climate change adaptation planning and strategies, with PRDs appearing to take a reactionary approach to climate change adaption (i.e., adaptation is triggered by a recent observed event). This finding is consistent with empirical findings in other countries which demonstrate that weak climate change adaptation planning by local governments is more likely to be observed despite awareness of climate change impacts (Baker et al., 2012).These results also suggest an institutional inertia with respect to climate change awareness and action that aligns with research on public opinion of climate change (Leiserowitz et al., 2015). Plausible explanations for limited adaptation efforts by PRDs include lack of available resources (personnel, financial, and expertise) (Measham et al., 2011) and the isolation created by administrative boundaries hindering more suitable collective actions across sectors and spaces (Nalau et al., 2015).

Although the general level of climate adaptation by PRDs is low, we do find a statistically significant, moderately positive correlation between self-reported climate change impacts and adaptation actions. This finding is consistent with research demonstrating that direct experience manifests in higher risk perception, stronger leadership commitment and awareness of climate change, and more frequent action (Whitmarsh, 2008; Hamilton and Keim, 2009; Shi et al., 2015). Our results also highlight that while the perceived impacts of extreme drought conditions and water surplus are positively associated with greater adaptation among PRDs, perceived impacts of extreme drought tend to motivate climate actions among PRDs more. Topographic variation likely generates more localized water surplus conditions compared to heat and drought. Thus, many individuals and institutions are able to escape the ramifications of water surplus conditions by nature of the geographic location (Few, 2003). In addition, water surplus often presents a less problematic issue for urban green space management than drought as parks are intentionally positioned in urban flood plains (Crompton, 2008).

We found a high correlation between PDSI data (actual meteorological observations) and self-reported observations of climate change impacts. Generally speaking, such comparisons between actual and perceived climate change impacts are challenging to make given the complexity of climate change and the contextualized nature of its effect on local areas (Lorenzoni and Pidgeon, 2006). One explanation for the high correlation we found may be that the responding participants' demographics, in particular their educational attainment level, has been found to be a strong predictor, if not the strongest predictor, of climate change awareness (Lee et al., 2015). Additionally, PRDs generally, as in this case, attract those whose post-secondary education often includes courses in natural resources and areas management that prepare them to be aware of climate change. A final predictive variable from the literature that aligns well with our results is civic engagement (Lee et al., 2015). Lee et al. (2015) found that apart from educational attainment, level of civic engagement was a significant predictor of climate change actions. Thus, it is plausible that PRD professionals are more conversant and observant about climate change issues due to their educational attainment, baseline eco-knowledge, and, given their role in municipal government, their inherent engagement in community civics.

Our findings about the differences in climate change adaptation efforts and perceived climate change impacts across U.S. ecoregions demonstrate that the U.S. is not monolithic in its acceptance of and action on climate change. These findings also confirm the supposition that a strong link exists between perceived local impacts of climate change and differences between ecological regions (Hamilton and Keim, 2009). Our results about the high correlation between institutional actions and perceptions coincide with the literature on individual beliefs, acceptance, and action regarding climate change (Leiserowitz et al., 2015; Spence et al., 2011; Zahran et al., 2006), suggesting the potential transferability of scientific understanding from individuals to institutions. However, we do recognize that national level policy variations have a significant impact on local actions towards climate change. For example, research shows that the Dutch system of climate adaption differs significantly with the U.S. model of climate change in terms of whether policies are reactionary or proactive in nature (Wagner et al., 2014). Therefore, cross-country applications need to be applied with caution.

This study, like other institutional survey research, has important limitations to consider. Our response rate of 27.6% leaves an important percentage of non-respondents of which we are uninformed. While we tried to combat social desirability bias through the use of objective rather than value-laden questions, such bias can still emerge in this type of survey work. Furthermore, while participation among PRDs reflected the proportional equivalent based on city-population size, PRD respondents in New England U.S. were somewhat lower than expected, and participation from the Midwest U.S. somewhat higher than expected. Monetary incentives were not used, given we were soliciting data from governmental employees. However, such incentives have been found to significantly improve survey response rates. On-the-ground field site visits and ecological data collection would provide important confirmatory data on current ecological conditions. Future research that is able to capture a larger proportion of PRDs, conduct on-site data collection for ecological conditions, and solicit qualitative data on PRD adaptation planning would strengthen the inferences possible from a study of this nature. Finally, our study only targeted municipal park departments and has not considered climate-adaptation activities taken by other functional departments. As a result, some adaptation activities may have been implemented by other government units. Future studies should examine further how climate-adaptation efforts taken by individual departments may be shaped by activities taken by other functional departments or overall city-level climate adaptation activities.

5. Conclusions & implications

Modern urban problems are increasingly complex and multi-dimensional. As a result, they often span the expertise and functional responsibilities of multiple agencies or departments within a city government, requiring broad input and cooperation. Studies of urban policy and management have examined how city governments can overcome challenges caused by inter-departmental fragmentation (Krause et al., 2016). However, little attention has been paid to understanding how individual departments within a municipal government are taking actions to adapt to climate change, especially those departments whose core mission is heavily influenced by climate change. Our results collectively suggest that U.S. municipal PRDs are not adapting soon enough to the changing climate, although when PRDs experience climate change impacts, they are moved to action. Scholars and policy makers often regard city governments as unified institutional actors in urban climate change adaptation planning and actions (Hughes, 2015), and individual departments within city governments may therefore play important leadership roles. Unfortunately, U.S. municipal PRDs appear to adapt to immediate problems, rather than taking a preventative approach to put climate adaptation strategies and systems in place. Local climate change adaptation efforts are likely to fail without a more systematic and comprehensive understanding of how key functional departments within local governments are planning for and taking actions towards to climate change.

Furthermore, our results indicate a strong correlation between the perceived impacts of climate change among PRD professionals and the observed and measured climate events associated with change. Future research that examines the role of climate modeling in motivating climate adaptation actions among institutions and evaluates the success of implementation activities is needed to improve policy directives, media campaigns, and adaptation strategies that will support resilient and habitable cities. More systematic knowledge is needed to understand how cross-agency and city level urban sustainability initiatives influence the action and strategies of individual agencies for climate change adaptation. As nonprofits and other nongovernmental actors are likely to be involved in the planning and design of serviced offered by these agencies (Cheng, 2019b), future research should also go beyond actions taken by local governments and incorporate a cross-sector understanding of urban climate change adaption.

The professional implications of this research are threefold and could be considered by individual parks, state associations, or regional and national organizations. First, this research highlights the need for PRDs to begin engaging in climate planning and adaptation implementation processes. Even our relatively small data set represents PRDs responsible for managing systems affecting nearly 50,000,000 people, over 1/6 of the US population. Participatory and collaborative approaches which integrate stakeholder perspectives from multiple knowledge domains seem to be a promising strategy for governmental agencies to build adaptive capacities (Frazier et al., 2010). Considering what other agencies within similar eco-regions are doing, or those experiencing similar events (drought or flood) may also prove beneficial in streamlining process and furthering implementation at a more rapid pace.

Second, a more systematic understanding about vulnerability to climate change is needed in urban green space adaptation efforts. The actions of public managers and local decision-makers seem to be mainly triggered by physical exposure. However, socio-economic vulnerability is not taken into consideration for urban green space adaptation efforts. This structural limitation poses great challenges for public managers to build adaptive capacity in regions which may be the most vulnerable to climate change, as vulnerability is a combination of physical exposure and socio-economic characteristics (Jeffers, 2013).

Finally, this research points out the practical need for investment in parks and urban natural areas if the present urban ecology and associated ecosystem services are to be maintained and enhanced in the face of ongoing climate change.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Survey instruments for U.S. municipal PRDs

Q1 Dear Park and Recreation Professional: I am writing to invite you to participate in a research study about how weather/climate is affecting the ecology of municipal parks, and how departments are responding. Your participation in this study will help scientists and professionals better understand what weather-related issues are occurring and steps to consider for future strategic planning. This survey should take approximately 15–20 min to complete and is entirely voluntary. All information gathered from the enclosed questionnaire will be kept confidential, with only aggregated totals being shared. Thank you again for your assistance with this important research project. Sincerely, James Farmer, Dept. of Recreation, Park, and Tourism Studies, Indiana University.

Q37 What is the PID on the survey?

Q2 What is your current position in the agency?

o Director/Superintendent (1)
o Assistant Director/Assistant Superintendent (2)
o Natural Resource Manager (3)
o Forester (4)
o Naturalist (5)
o Other (Please specify) (6) ______________

Q3 How many years have you been employed by the agency?

o Less or equal than 1 year (1)
o 2 years (2)
o 3 years (3)
o …etc
o 40 years (40)
o 41+ years (41)

Q4 How many years have you lived in the general area where your agency is located?

o Less or equal than 1 year (1)
o 2 years (2)
o 3 years (3)
o …etc
o 79 years (79)
o 80+ years (80)

Q5 How many people live in the city that your agency serves?

o less than 25,000 (1)
o 25,001–50,000 (2)
o 50,001–75,000 (3)
o 75,001–100,000 (4)
o 100,001–150,000 (5)
o 150,001–200,000 (6)
o 200,001–250,000 (7)
o 250,001–375,000 (8)
o 375,001–500,000 (9)
o 500,001–750,000 (10)
o 750,001-1,000,000 (11)
o 1,000,001–2,500,000 (12)
o 2,500,001 + (13)

Q6 In what state is your agency's district located (or mostly located if it crosses state lines)?

o AL (1)
o AK (2)
o …
o WI (49)
o WY (50)
o Washington, D.C. (51)

Q7 What is the number of discrete park units (individual properties) managed by your agency?

o 1 (1)
o 2 (2)
o 3 (3)
o …
o 99 (99)
o 100+ (100)

Q8 Which of the following types of elements is your agency responsible for? Please select all that apply.

- City/County multi-purpose parks (1)
- Nature reserve/preserve (2)
- Habitat/species management area (3)
- Protected lake or seashore (4)
- Forest for recreational use (5)
- Street trees/urban visitor area (6)
- County government land and landscaping (7)
- Other city-owned land outside of the normal unit responsibilities (8)
- Other (Please specify) (9) ______________

Q9 What are the three most dominant tree species on your park lands (i.e. maple, birch, oak, etc.)?

Q10 Please explain any major changes (i.e. high mortality of one or more species, tree planting initiatives, canopy loss due to wind damage, etc.) to the urban forest in your city that have occurred throughout the past 10 years.

Q11 Overall, how has the physical condition of the trees in your *city* changed throughout the past 10 years?

o Greatly declined (1)
o Declined (2)
o Somewhat declined (3)
o Remained the same (4)
o Somewhat improved (5)
o Improved (6)
o Greatly improved (7)

Q12 Overall, how has the physical condition of the trees in your *parks* changed throughout the past 10 years?

o Greatly declined (1)
o Declined (2)
o Somewhat declined (3)
o Remained the same (4)
o Somewhat improved (5)
o Improved (6)
o Greatly improved (7)

Q13 Please rate your level of agreement with the following statements: The agency's allocated budget for tree maintenance is adequate.

o Strongly disagree (1)
o Somewhat disagree (2)
o Neither agree nor disagree (3)
o Somewhat agree (4)
o Strongly agree (5)

Q14 For each of the statements below, please indicate the problem level as it relates to your park(s):

	Not at all a problem (1)	Minor problem (2)	Moderate problem (3)	Serious problem (4)	Extreme Problem (5)
Longer and hotter heat waves (1)	❍	❍	❍	❍	❍
More damaging storms (2)	❍	❍	❍	❍	❍
Greater flooding (3)	❍	❍	❍	❍	❍
Increased frequency and intensity of combined sewer overflows (CSOs) (4)	❍	❍	❍	❍	❍
More extended and intense duration of droughts (5)	❍	❍	❍	❍	❍
Water supply shortages (6)	❍	❍	❍	❍	❍
Declines in local ecosystem services, such as the loss of coastal wetlands that buffer communities against hurricanes, loss of trees that cool the city, absorb rainfall, stabilize soils, etc. (7)	❍	❍	❍	❍	❍
Loss of biodiversity (8)	❍	❍	❍	❍	❍
More threats from pests, including insect outbreaks and invasive species (9)	❍	❍	❍	❍	❍
Other (Please specify) (10)	❍	❍	❍	❍	❍

Q15 How problematic have weather and climate related events become for your agency within the last 10 years? (considering the properties your agency manages)

o No problem (1)
o Minor problem (2)
o Moderate Problem (3)
o Serious Problem (4)
o Extreme Problem (5)

Q16 Please note your level of agreement with the following statement: In the near future (1–15 years), the adverse effects of weather and climate related events will have a major impact on the ecology overseen by your agency.

o Strongly disagree (1)
o Disagree (2)
o Neutral (3)
o Agree (4)
o Strongly agree (5)

Q17 Does your agency complete a parks master plan every 5 to 10 years?

o Yes (1)
o No (2)

Q18 Please indicate your agency's level of completion on the following activities:

	Not completed, not currently pursuing or interested (1)	Not completed, but considering (2)	Just starting (3)	In progress (4)	Yes, complete (or initial implementation is complete, but on going) (5)
Analyzed the (potential) impact of climate change on city parks and related ecosystems (1)	❍	❍	❍	❍	❍
Developed a climate change adaptation plan for your department (2)	❍	❍	❍	❍	❍
Formally adopted a local climate action plan for your department (3)	❍	❍	❍	❍	❍
Incorporated climate change adaption in the department's strategic plan or long-term management plan (4)	❍	❍	❍	❍	❍
Designated money in your departmental budget to fund climate adaptation activities (5)	❍	❍	❍	❍	❍
Requested from city government for more climate change adaptation funding and policies (6)	❍	❍	❍	❍	❍
Collaborated with other governmental agencies to carry out climate action initiatives (7)	❍	❍	❍	❍	❍
Collaborated with non-governmental organizations to carry out climate action initiatives (8)	❍	❍	❍	❍	❍

Q19 Is your agency engaging in short term (1–10 years) planning to adapt to climate change issues?

o Yes (1)
o No (2) - > recoded to 0

Q20 Is your agency engaging in an intermediate term (11–25 years) planning to adapt to climate change issues?

o Yes (1)
o No (2) - > recoded to 0

Q21 Is your agency engaging in long term (26–50 years) planning to adapt to climate change issues?

o Yes (1)
o No (2) - > recoded to 0

Q22 Please indicate your agency's level of completion on the following activities- based on the five choices:

(*continued on next page*)

(*continued*)

	Not completed, not currently pursuing or interested (1)	Not completed, but considering (2)	Just starting (3)	In progress (4)	Yes, complete (or initial implementation is complete, but on going) (5)
	Not completed, not currently pursuing or interested (1)	Not completed, but considering (2)	Just starting (3)	In progress (4)	Yes, complete (or initial implementation is complete, but on going) (5)
Planting trees and/or other vegetative species appropriate for your region's long-term climate forecast (1)	❍	❍	❍	❍	❍
Integrated climate change information into pest and invasive species management (2)	❍	❍	❍	❍	❍
Developed storm water capture and green infrastructure components in city parks (3)	❍	❍	❍	❍	❍
Better adhered to sustainability guidelines for park design (improved water efficiency and recharge, renewable energy sources, recycled materials, native/low water use plants). (4)	❍	❍	❍	❍	❍
Engaged in downspout disconnection from storm-water infrastructure for park and recreation facility roof spaces (5)	❍	❍	❍	❍	❍
Reduced water use for irrigation (6)	❍	❍	❍	❍	❍
Targeted sites based on water audits on all parks/recreation facilities (7)	❍	❍	❍	❍	❍
Developed and/or supported policies for climate change adaptation (8)	❍	❍	❍	❍	❍
Acquired urban properties that encounter repetitive losses due to climate change and associated rain events (9)	❍	❍	❍	❍	❍
Installed permeable surfaces for parking/site hardening infrastructure (for parking lots, trails, etc.) (10)	❍	❍	❍	❍	❍
Removed dead/dying, diseased, or insect impacted trees (11)	❍	❍	❍	❍	❍

Q23 Which of the following descriptions best details how the head of your agency is appointed:

o By the mayor (1)
o By a park board (2)
o By the city council (3)
o By a public election (4)
o By a park board foundation (5)
o Other (Please specify) (6) ________________

Q24 What is the governance structure of your agency?

o Commission/board separate from city or county government (1)
o Commission/board that is part of city or county government (2)
o Other (Please specify) (3) ________________

Q25 What is the level of importance of each of the following factors in your agency's decision to become involved in climate change adaptation actions and plans (i.e. plan development, tree plantings, green infrastructure development, etc.)?

	Not at all important (1)	Slightly important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
The effects of climate change on city parks are too severe to be ignored (1)	❍	❍	❍	❍	❍
Reducing the impact of weather-related disasters (flooding, drought, storm, etc.) affecting local communities and city parks (2)	❍	❍	❍	❍	❍
Interest group and/or citizen demands (3)	❍	❍	❍	❍	❍
The preference and priorities of particular city official(s) (4)	❍	❍	❍	❍	❍
The influence of neighboring or peer departments or cities that were involved in climate change adaptation (5)	❍	❍	❍	❍	❍

(*continued on next page*)

(*continued*)

	Not at all important (1)	Slightly important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
Requirements or mandates from city or state governments (6)	❍	❍	❍	❍	❍
Other (Please specify) (7)	❍	❍	❍	❍	❍

Q26 What is your level of involvement with developing policy concerning the ecology under your agency's purview?

o Highly involved (1)
o Somewhat involved (2)
o Not at all involved (3)

Q27 Please evaluate the importance of the following barriers and limitations that your agency has encountered in the process of considering, developing, or implementing the climate change adaptation plan.

	Not at all important (1)	Slightly important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
Lack of climate change information for effective decision making (1)	❍	❍	❍	❍	❍
Lack of resources to begin and sustain adaptation efforts (2)	❍	❍	❍	❍	❍
Fragmentation of decision making (such as lack of coordination among agencies and/or jurisdictional boundaries) (3)	❍	❍	❍	❍	❍
Lack of supporting legislation and legal frameworks for action (4)	❍	❍	❍	❍	❍
Lack of institutional flexibility (5)	❍	❍	❍	❍	❍
Lack of political leadership (6)	❍	❍	❍	❍	❍
Lack of general consensus around the issue (7)	❍	❍	❍	❍	❍
Other: (Please specify) (8)	❍	❍	❍	❍	❍

Q28 Please specify the top three jurisdictions or cities that your agency has drawn lessons from in the process of considering, developing, or implementing the climate change adaptation plan.
City 1: City/State (1)
City 2: City/State (2)
City 3: City/State (3)
Others (Please specify): (4)
Q29 If your agency has developed and/or implemented a climate change adaptation plan and has received instrumental assistance from nongovernmental organizations, such as private businesses, nonprofits, and local citizen groups, please list those below:
Organization 1 (1)
Organization 2 (2)
Organization 3 (3)
Others (Please specify): (4)
Q30 What is your age?

o 18 (1)
o …
o 100+ (83)

Q31 What is your gender?

o Female (1)
o Male (2)
o Other (3)

Q32 What is the highest level of education that you have attained?

o Some schooling, but no diploma or degree (1)
o High school diploma or GED (2)
o Some college or technical training (3)
o College degree (4)
o Some graduate school (5)

o Graduate level degree (6)

Q33 Do you have an associate, bachelor, or graduate degree in any of the following content areas? Please select all that apply.

- Recreation Admin. or related (1)
- Biology/Ecology (2)
- Forestry/Natural Resources (3)
- Business (4)
- Education (5)
- Other: (Please specify) (6) ______________

Q34 Do you have any additional thoughts or comments about the survey that you would care to share with us?

Q35 Thank you again for taking part in this very important survey. A report on the results will be issued once analysis has been completed. You may contact the researchers at any time by telephone, e-mail, or post with questions concerning this study: James Farmer, 1025 E. 7th St., SPH 133, Bloomington, IN 47405; 812–856-0969; jafarmer@indiana.edu.

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