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Research Paper

Tools for evaluating and monitoring effectiveness of urban landscape water conservation interventions and programs

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HIGHLIGHTS

- Intervention research was connected to delivery of landscape water checks.
- We distinguished change due to water checks from other factors affecting water use.
- We developed several landscape water conservation assessment and monitoring tools.
- These tools can direct and tailor conservation programs for greater effectiveness.
- Results have implications for water conservation program design and delivery.

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ABSTRACT

Our research objective was to investigate ways to evaluate landscape water use to help cities more effectively direct water conservation programs to locations with capacity to conserve. Research was conducted in connection with a landscape irrigation evaluation delivered through a city-sponsored Water Check Program. Research efforts led to development of several assessment and monitoring tools including: Landscape Irrigation Ratio (LIR), Participant Outcome Evaluation Tool, and Program Evaluation Tool. We utilized these tools to identify locations with capacity to conserve water applied to landscapes, compare water use before and after the water check, and evaluate Water Check Program effectiveness. We found the LIR approach successfully distinguished residential locations efficiently or acceptably using water applied to landscapes from ones with use considered inefficient or excessive. In analyzing change in participants' water use and eliminating explanations other than the water check, we found factors influencing landscape water use tend to be highly contextualized and the intervention itself needed to be analyzed. The majority of participants who adopted the water check recommendations successfully reduced their landscape water use, but results indicate water check programs can be designed for greater effectiveness by accommodating participants' differing knowledge and skill levels. We argue that the tools we developed provide the water conservation field with a needed set of common assessment methods. We conclude that landscape water checks have the potential to provide people with the information and problem-solving skills necessary to maintain residential landscapes using appropriate amounts of water if they are well designed, delivered, and monitored.

1. Introduction

One of the greatest challenges in conducting behavioral change research related to water conservation is determining how to assess effectiveness of programs at the household level. The water conservation field does not have common assessment tools, making it difficult to compare program results among cities worldwide and over time (e.g., Inman & Jeffrey, 2006; Jorgensen, Graymore, & O'Toole, 2009; Rockaway, Coomes, Joshua, & Barry, 2011; Syme, Nancarrow, & Seligman, 2000). Historically, conservation has been

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assessed by tracking changes in gallons per capita per day (gpcd), which does not fully capture geographic differences in contextual variability and conservation challenges unique to indoor water use as well as outdoor urban landscape irrigation. City-wide water conservation efforts through replacing aging infrastructure and improving water delivery system efficiency are distinct from behavioral change in consumer water use patterns. Yet, both forms of water saving actions are reflected in measures like gpcd and influence geographic and temporal comparisons (Bellamy, Walker, McDonald, & Syme, 2001; Friedman, Heaney, & Morales, 2014; Jorgensen, Martin, Pearce, & Willis, 2013; Larson, Wiek, & Withycombe, 2013; Saurí, 2013).

Contextual variability is especially problematic for assessing and comparing water use and conservation effectiveness across urban locations in various parts of the world. Variations in size and arrangement of urban lots, landscape plant material, and climate greatly influence geographic and temporal variability in residential water use (Cook, Hall, & Larson, 2012; Endter-Wada, Kurtzman, Keenan, Kjelgren, & Neale, 2008; Gregory & Di Leo, 2003; Kilgren, Endter-Wada, Kjelgren, & Johnson, 2010; Runfola et al., 2013; Saurí, 2013; St. Hilaire et al., 2008). While indoor water use is primarily a function of occupant number and water appliance/fixture efficiency (Friedman et al., 2014; Mayer et al., 1999), residential outdoor water need and use is a function of more complex bio-physical and technical factors: plant species selection, weather-based demand (evapotranspiration), soil-based water supply, and irrigation system design, maintenance, and operation. This complexity challenges researchers and water providers to develop methods for evaluating landscape water use and supporting people's ability to understand and integrate contextual variability in their landscape management decisions.

Urban residents face various challenges in attempting to water residential landscapes, internationally referred to as 'domestic gardens,' efficiently. These challenges include: careful maintenance and operation of static sprinkler systems in biologically dynamic residential landscapes (Bremer, Keeley, Jager, Fry, & Lavis, 2012; Cook et al., 2012); problem solving skills that enable them to assess, identify, and fix water problems (Corral-Verdugo, 2002; Gifford, 2014; Kaiser & Fuhrer, 2003; Kurz, Donaghue, & Walker, 2005); and assessing their conservation performance (Fazey et al., 2007; Grantham et al., 2010; Lehman & Geller, 2004). Specific and timely feedback to end users is crucial to equip them in setting goals, making decisions, and planning for conservation success (Doron, Teh, Haklay, & Bell, 2011; McCalley, 2006). For instance, infrequent and limited billing information impedes feedback effectiveness regarding water use, while time and financial constraints can limit the best intentions (Abrahamse, Steg, Vlek, & Rothengatter, 2007; Diekmann & Preisendörfer, 2003; Kenney, Goemans, Klein, Lowrey, & Reidy, 2008).

Landscape irrigation evaluations or "water checks" (sometimes called "water audits") are widely used in the United States as a water demand management tool intended to promote efficient water use on existing landscapes while maintaining aesthetic standards. Water checks can potentially save water, but research is scarce that evaluates information effectiveness or monitors water savings (Baum, Dukes, & Miller, 2005; Mecham, 2004; Nelson, 1992; Olmsted & Dukes, 2011; Thomas, Harrison, Dukes, Seymour, & Reed, 2009).

The conservation field recognizes the need for monitoring programs that assess goal attainment and promote better program evaluation (Knight, Cowling, & Campbell, 2006; Pullin & Stewart, 2006; Stem, Margolouis, Salafsky, & Brown, 2005). Evaluating conservation in landscape irrigation is further challenged by changes in water use arising from the complex interplay of how users interpret ecological cues, understand climatic variability, and utilize irrigation technology to irrigate appropriately. Complex factors influencing landscape water use are highly contextualized (Endter-Wada et al., 2008; Kilgren et al., 2010). Larson, Cook, Strawhacker, and Hall (2011) concluded future research was needed to better understand the context of urban water management decisions and practices. Critical questions need to be answered in designing landscape irrigation conservation assessment and monitoring programs. What constitutes appropriate landscape water use? What constitutes water conservation success? How do we describe and measure these two phenomena?

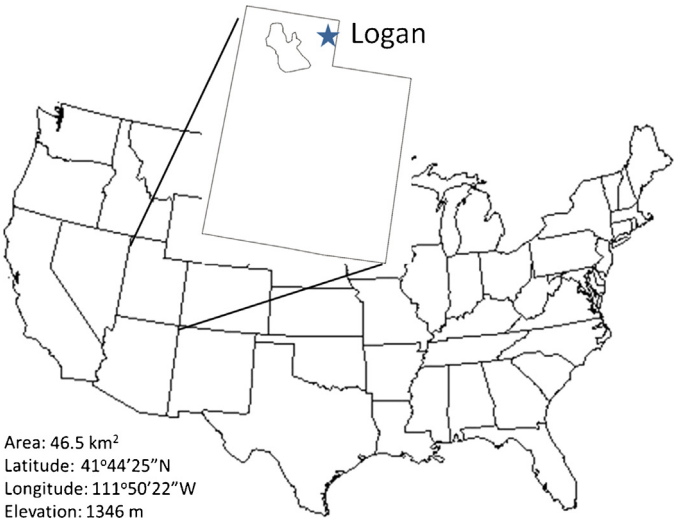

Fig. 1. Study site is located in Logan City, Cache Valley, Utah, the United States on the Great Basin's northernmost boundary in the Bear River Watershed.

We report on research conducted in connection with administration of a city-sponsored but university-delivered landscape water check program. Our research design tested both the effectiveness of landscape water checks as a conservation tool and different approaches for encouraging conservation program participation (volunteers or recruits). We developed assessment and monitoring tools to analyze results. We take an in-depth look at water check programs and lessons learned that are broadly applicable to development of water check/audit programs in any locale. The topic will be of particular interest to water researchers and managers in water-scarce regions experiencing growth of low-density urban developments, increasing prevalence of domestic gardens, and recurrent drought.

Our research objective was to evaluate and monitor urban landscape water use. With cities' limited conservation program budgets, it is important to understand when, where and how to focus conservation efforts to increase overall efficiency and yield water savings (Kilgren et al., 2010; Lehman & Geller, 2004). Cities need to plan for future municipal water demand in socially equitable ways that fairly assess water use. They also need effective management tools to help them identify inefficient water use and deliver programs to people with different user profiles.

2. Methods

2.1. Water conservation interventions

2.1.1. Participant recruitment for landscape water checks

In 2004, Utah's sixth year of cyclic drought, we offered free landscape water checks to all single-family residential households that relied on city-provided potable water in Logan, Utah, the United States (Fig. 1; study site described in paragraph A1 of Appendix A). The free service was widely publicized. Water checks included a detailed evaluation of households' sprinkler system and landscape,