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Local- and landscape-scale land cover affects microclimate and water use in urban gardens

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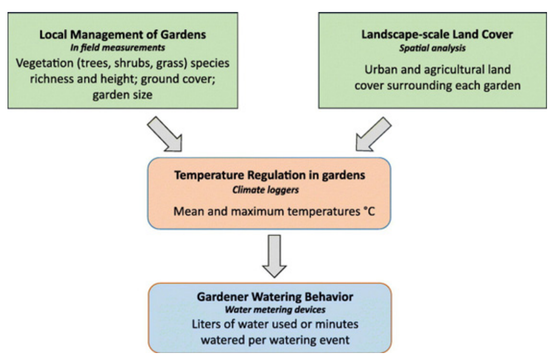
HIGHLIGHTS

- Extreme temperature and drought affect urban gardens in California, forcing gardeners to ration water supplies.
- Information from all 5 spheres was used to investigate local and landscape factors on garden temperatures and water use.
- Using climate loggers, we examined how vegetation, ground cover, and land cover affect temperature within the gardens.
- Vegetation and ground cover reduced temperatures, while built environment factors increased temperatures. Water use was correlated temperatures.
- Local management of vegetation and ground cover can reduce temperatures and potentially water use in gardens.

GRAPHICAL ABSTRACT



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ABSTRACT

Urban gardens in Central California are highly vulnerable to the effects of climate change, experiencing both extended high heat periods as well as water restrictions because of severe drought conditions. This puts these critical community-based food production systems at risk as California is expected to experience increasing weather extremes. In agricultural systems, increased vegetation complexity, such as greater structure or biodiversity, can increase the resilience of food production systems from climate fluctuations. We test this theory in 15 urban gardens across California's Central Coast. Local- and landscape-scale measures of ground, vegetation, and land cover were collected in and around each garden, while climate loggers recorded temperatures in each garden in 30 min increments. Multivariate analyses, using county as a random factor, show that both local- and landscape-scale factors were important. All factors were significant predictors of mean temperature. Tallest vegetation, tree/shrub species richness, grass cover, mulch cover, and landscape level agricultural cover were cooling factors; in contrast, garden size, garden age, rock cover, herbaceous species richness, and landscape level urban cover were warming factors. Results were similar for the maximum temperature analysis except that agriculture land cover and herbaceous species richness were not significant predictors of maximum temperature. Analysis of gardener watering behavior to observed temperatures shows that garden microclimate was significantly related to the number of minutes watered as well as the number of liters of water used per watering event. Thus

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gardeners seem to respond to garden microclimate in their watering behavior even though this behavior is most probably motivated by a range of other factors such as water regulations and time availability. This research shows that local management of ground cover and vegetation can reduce mean and maximum temperatures in gardens, and the reduced temperatures may influence watering behavior of gardeners.

1. Introduction

Urban community gardens (UCG), land set aside for the collective production of food and livestock in urban areas, have experienced a renaissance since the beginning of this century due to their unique environmental, social, and health benefits for urban dwellers (Zezza and Tasciotti, 2010). As such, their role in the urban space is multifunctional (Lovell, 2010; Lin et al., 2015). Environmentally, community gardens can significantly increase biodiversity in urban neighborhoods by providing space for urban greening, but also by allowing a wide range of different species to exist in a single location (Lin et al., 2015). Socially, urban community gardens provide spaces where community members of different cultures, ages, and background can gather over shared interests. This increased social interaction can have benefits for community cohesion and resilience, and for building a space for identity and belonging (Hancock, 2001; Kingsley and Townsend, 2006; Alaimo et al., 2010). Gardens also provide health benefits for gardeners and the local community. Besides increasing food security and the availability of nutritional foods (Alaimo et al., 2008; Guitart et al., 2014), urban gardens provide space for people to connect back to nature and to be physically active (Mckenzie, 2008; Dallimer et al., 2012).

However, there may be challenges faced when conducting outdoor activities within cities. Due to a phenomenon called urban heat island (Oke, 1997), cities register 5–11 °C warmer than surrounding areas (Kalnay and Cai, 2003). Thus, people in urban areas are often exposed to higher heat, and generally for longer periods because the built environment absorbs heat during the day and releases it at night. The urban heat island has been highlighted as a factor in exacerbating several health problems within urban areas including cardiovascular disease and diabetes (Kovats and Hajat, 2008; Luber and McGeehin, 2008). Since gardening, like other outdoor activities, increases people's exposure to extreme weather, especially high heat, it could potentially have negative health impacts (Patz et al., 2005; Tan et al., 2010). Moreover, extreme heat can also affect crop production in gardens, as it does in agricultural systems, thus decreasing yield and harming production levels if plants do not have enough water during high heat periods (Lin, 2011). This may be especially true for gardens that are highly dependent on irrigation (Eriksen-Hamel and Danso, 2010).

Vegetation cover, such as trees, shrubs, and grasses within parks and other urban green spaces can reduce the impact of rising temperatures and heatwaves by providing shade and shelter (Bowler et al., 2010; Gill et al., 2007; Shashua-Bar et al., 2009). Vegetation also has a key role in reducing the amount of solar radiation that is absorbed into building materials such as pavement during the day and released at night (Rizwan et al., 2008). For example, increasing the proportion of tree canopy cover in the urban environment may reduce surface and air temperatures (Gill et al., 2007; Huang et al., 2008). Further, a model of vegetation impacts on future climate change scenarios in Glasgow shows that a 20% increase in green cover could reduce surface temperatures by 2 °C in 2050 (Emmanuel and Loconsole, 2015). However, as with other urban green spaces, the cooling potential in community gardens will depend on the design and management of the system. It is important to understand how effective these shade and shelter effects may be in urban gardens, where people spend large periods of time exposed to the elements and spend large amounts of water to maintain their crops. In this study, we propose to examine how local- and landscape-scale vegetation, ground and land cover affects UCG microclimate in the Central Coast of California.

California presents an important area to study these patterns of land cover and microclimate because California is highly affected by climatic changes that specifically increase the frequency, magnitude, and duration of drought (Mann and Gleick, 2015). Much of the time droughts co-occur with elevated temperatures and heat waves, and the combination of the two climate effects can increase overall drought intensity and heat stress on individuals (AghaKouchak et al., 2014; Mann and Gleick, 2015). Due to this climate cycle and the lack of water storage accumulated through the past decade of drought, water supply reductions have been mandated in California and are expected to become more extreme in the upcoming decades (Pagan et al., 2016). This has led to increased local regulations of water supply that also affect the UCGs, with water restrictions applied by garden managers onto the gardeners (for example, Community Garden Program, 2016).

While increasing climate extremes may put more strain on the community, restrictions of water use may further threaten food production in these systems. Thus, in this study, we examine first, if and how garden management and vegetation characteristics at the local- and landscape-scale are contributing to garden microclimate, and second, if microclimate is predictive of the water use patterns of gardeners.

2. Methods

2.1. Site background

We selected 15 urban community gardens in California across three counties: Monterey (36.2400° N, 121.3100° W), Santa Clara (37.3600° N, 121.9700° W), and Santa Cruz (37.0300° N, 122.0100° W) (Fig. 1).

The gardens represent a spectrum of management systems, with a range of vegetative diversity, structural diversity, and ground management (e.g. mulch, grass cover). The gardens also represent a gradient in landscape heterogeneity, where varying mixes of natural, agricultural, open green space, and urban land cover surround each garden. Gardeners carefully select crops for food, ornamental, and medicinal purposes and manage the groundcover with various organic amendments. The study took place from July to September 2016 during which time, despite a previous wet winter, the region was experiencing a fourth year of drought conditions. More than 80% of land cover within the three studied counties was classified as under drought (Rippey, 2016) and there were state-wide water restrictions in place.

2.2. Collection of climate data

Two temperature loggers (Onset HOBO UA-001-08) were placed in each of the 15 gardens at two locations >10 m apart. They were hung on garden posts and wireframe infrastructures within the gardens based on permissions granted from the gardeners. The loggers were hung at a height of 1.5 to 2 m above the garden beds next to vegetation and were set to record averaged temperature data (°C) every half an hour from July to September 2016.

Data loggers were checked and maintained throughout the survey period to ensure that they were in good working order. Data were downloaded and collected at the end of the survey period and quality checked and cleaned. For each garden, mean and maximum