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Temperature variability influences urban garden plant richness and gardener water use behavior, but not planting decisions

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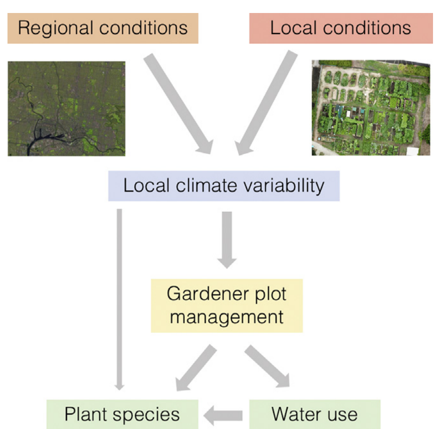
HIGHLIGHTS

- Temperature variability affects urban garden management and resource use.
- Three scale approach examined drivers of variability and social-ecological effects.
- Landscape affects temperature variability to effect plant richness in plots.
- Climate changes prompt gardeners to adjust water use, but not plant selection.
- Plant survival mitigation strategies may still be climate-dependent in cities.

GRAPHICAL ABSTRACT



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ABSTRACT

Urban environments are being subject to increasing temperatures due to the combined effects of global climate change and urban heat. These increased temperatures, coupled with human planting preferences and green space management practices, influence how urban plants grow and survive. Urban community gardens are an increasingly popular land use, and a green space type that is influenced by unique climate-human behavior interactions. Despite ongoing rapid temperature changes in cities, it is unknown how gardeners are adapting to these changes, and to what extent changes influence planting decisions and patterns of urban plant diversity. In this study, we monitored the variation in daily air temperatures and measured plant species richness at the garden and garden plot scale in 11 community gardens in Melbourne, Australia. We surveyed >180 gardeners to better understand the relationships between temperature variation, garden plant species diversity, and gardener management practices. We found that garden scale temperature variability is driven by regional context, and temperatures are more stable in landscapes with higher impervious surface cover. Gardeners agreed that climatic/temperature changes are influencing their watering behavior, but not their plant selection. Instead plant selection is being driven by desired food production. Yet, when comparing two bioregions, temperature did have a measurable relationship with garden plant composition in the region with more temperature variation. Temperature variability negatively related to plant species richness within garden plots, providing evidence that plant survival is related to climate at this scale in such regions. Although gardeners may be able to water more in

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response to regional climate changes, gardeners are unlikely to be able to completely control the effects of temperature on plant survival in more variable conditions. This suggests the inner city with more stable temperatures (albeit potentially hotter for longer due to heat island) may accommodate more species diverse gardens.

1. Introduction

Climatic gradients often predict species distribution across natural landscapes (Soberon, 2007). Species have temperature and moisture thresholds that allow or inhibit their survival in an ecosystem. Plants in particular are often found along temperature and moisture/precipitation gradients. Consequently, the distribution of plant species are changing with global climate change as temperatures become hotter, and in some places drought events become more extreme (Kelly and Goulden, 2008; Lenoir and Svenning, 2014; Neilson et al., 2005). This can limit plant water availability and thus survival (Breshears et al., 2005; Galiano et al., 2011; Martínez-Vilalta and Piñol, 2002; McDowell et al., 2010). Temperature is a strong predictor of species diversity in natural communities (Grubb, 1977) because of species traits related to species performance (Kleidon and Mooney, 2000; McGill et al., 2006). Climate extremes are having profound impacts on trophic interactions, food webs and the general ecology of regions (Brose et al., 2016; Tylianakis et al., 2008; Walther, 2010; Walther et al., 2002).

Human dominated environments such as cities, are often perceived to be shaped by drivers other than the climatic and biophysical drivers that shape natural landscapes. Human preferences influence resource management decisions that affect plant species distribution beyond natural bioclimatic barriers (Kendal et al., 2018). Vegetation within urban ecosystems is shaped by habitat transformation, as well as unique socioecological filters including biophysical conditions of the urban environment and individual human preference (Pataki et al., 2013; Williams et al., 2008). While, temperature gradients remain a strong filter of urban cultivated plant richness (Kendal et al., 2012a), supplemental irrigation and nutrients can be common in urban residential landscapes (Faeth et al., 2005) and allow some plants preferred by people to thrive through human intervention (Clarke and Jenerette, 2015; Hope et al., 2003; Jenerette et al., 2016). Within urban ecosystems, the diversity and distribution of plant species are therefore influenced by both environmental filters at a regional scale and local scale as well as through socioecological interactions at the level of the individual (Aronson et al., 2016; Avolio et al., 2015; Williams et al., 2008).

Changes in temperature and precipitation due to global climate change (Freitag et al., 2018) and intensifying urban heat island effects (Oke, 1973) are therefore likely to affect the composition and diversity of urban gardens (Eriksen-Hamel and Danso, 2010). Irrespective of human intervention in the form of irrigation and fertilizer application, higher temperatures and evapotranspiration are likely to affect the plant species grown in urban environments where they are sensitive to heat and water stress (Albrecht and Haider, 2013; Jenerette et al., 2016). In addition, more intense heat and drought may therefore affect the way that people use resources to manage urban green spaces such as gardens (Balling et al., 2008; Jenerette et al., 2013).

Urban gardens are places where there are unique and complex interactions between temperature, precipitation, watering behavior and plant selection. Urban gardening is a popular past time around the world (Galluzzi et al., 2010; Lawson, 2005; Mougeot, 2000; Zezza and Tasciotti, 2010), and is one of the important ways in which people interact with urban nature (Andersson et al., 2007; Egerer et al., 2018; Okvat and Zautra, 2011) and shape the plants of the urban environment (Galluzzi et al., 2010; Loram et al., 2008; Smith et al., 2006). Ambient temperatures in gardens can be influenced by region-scale urbanization as well as by local garden-scale plant cover, and this can also influence watering behavior (Lin et al., 2018). Greater amount of impervious surface cover surrounding and within urban gardens increases mean and maximum temperatures (Lin et al., 2018), probably because impervious surfaces retain heat due to low albedo (Oke, 1973). In contrast, greater plant ground cover and higher tree density is associated with cooler temperatures and climate mitigation within urban green spaces (Bowler et al., 2010; Gill et al., 2007; Huang et al., 2008; Shashua-bar et al., 2009) including within urban gardens (Piacentini et al., 2014). Local temperatures likely affect the degree to which plants are stressed in this managed environment (Eriksen-Hamel and Danso, 2010), due to effects of temperature on soil moisture retention (Craul, 1992; Pickett et al., 2011). Climate conditions and the potential temperature effects on plants within garden plots may lead gardeners to think that they need to supplement more or less water in response (Avolio et al., 2015; Lin et al., 2018). Yet we know less about how urban temperatures may affect plants cultivated in gardens and their care, as provided by gardeners, within and between gardens. If and how gardener resource management of water and plants within gardens responds to climate variability is critical to urban sustainability.

It is important to assess how climate variability – in the form of temperature fluctuations, extreme heat and drought conditions – may affect the composition and distribution of urban plant communities as cities, and therefore urban plant distributions, expand (Jenerette et al., 2016). It is of particular importance to understand these relationships in urban agroecosystems because variability in temperature, precipitation and their interaction significantly influence crop plant yield (Ray et al., 2015) and consequently ecosystem service provisioning. Increasing temperatures and drought patterns in urban environments will likely negatively affect crop plant productivity and survivorship in urban agriculture (Lobell et al., 2011) because of higher urban temperatures (Eriksen-Hamel and Danso, 2010; Kalnay and Ming, 2003) and water use restrictions on outdoor irrigation implemented during times of drought (Kendal et al., 2012b). If urban gardeners are unable to maintain crop irrigation during heat events, water limitation when plants are most susceptible to evapotranspiration can increase plant vulnerability to sun scorch, disease and pest damage (Gourdji et al., 2013; Meineke et al., 2013). Thus temperature and precipitation variability are still likely to affect species survival and distribution within urban garden plant communities, but there is still much to understand in the context of current urban environmental change.

In this study, we explore the relationships between temperature variability, urban gardener decision making, and plant species richness in garden plots in community gardens across the city of Melbourne, Australia. Community gardens, or gardens managed by a collective of individuals who are each allocated a plot, are popular in urban Melbourne, which is a city known for its temperature and precipitation fluctuations. Climate events over the past decade (e.g., the "Millennium Drought") indicate that climate patterns are becoming more extreme, in tandem with urbanization (Coutts et al., 2007). However, there is little knowledge of if and how this variability is experienced by green space managers, such as urban gardeners. There is also little knowledge of if and how gardeners are adapting to these proposed changes within their individual garden plots. We aim to fill this research gap through a mixed-method study that uses field-collected measurements of garden temperatures and garden plants at both the garden scale and at the individual plot scale, and quantitative and qualitative survey responses on gardener decision making at an individual level. We focused our study at these multiple scales because individual people do different things at their plots in the same garden. Thus, the plot scale and individual level analyses focus on individual gardener behavior; and the garden scale analyses focus on the response of temperature variability and