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The role of urban vegetation in temperature and heat island effects in Querétaro city, Mexico

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RESUMEN

La alteración de las condiciones climáticas y el efecto de isla urbana de calor (EIC) son resultado del incremento de la población y de sus actividades en las zonas urbanas. En ciudades medianas como Querétaro es importante determinar la magnitud del EIC y promover la planeación del crecimiento urbano. Conservar y aumentar las áreas con vegetación es una buena opción para mitigar el EIC. En este estudio se analizaron la intensidad del EIC y el efecto de la cobertura vegetal sobre la regularización de la temperatura del aire. Se definieron cuatro zonas climáticas locales para el estudio, tres urbanas y una rural. En cada zona se ubicó una parcela de medición en la cual se consideraron dos niveles de cobertura vegetal en función del índice de área foliar: bajo y alto (0.5 y 2.0, respectivamente). La temperatura del aire se midió con recolectores de datos a intervalos de 30 min entre junio de 2012 y mayo de 2013. También se analizaron datos climáticos de seis estaciones meteorológicas. La temperatura media diaria aumentó a razón de 0.75 ºC por década ($r^2 = 0.38$, $P < 0.0001$); este aumento se relacionó con la dinámica poblacional ($r^2 = 0.52$, $P < 0.0001$). Los patrones estacionales de temperatura se describieron como temporada fría de julio a marzo y temporada cálida de abril a junio para la temperatura máxima, y temporada fría de noviembre a marzo y temporada cálida de abril a octubre para la temperatura mínima. La diferencia entre las temporadas cálida y fría fue del orden de 5 ºC ($P < 0.0001$). No se identificaron diferencias en la temperatura mínima en función de los niveles de cobertura de la vegetación. Sin embargo, la humedad relativa fue mayor en el nivel alto de la cobertura vegetal. La relación entre la intensidad del EIC y la fracción de superficie impermeable fue inversamente proporcional. La intensidad del EIC fue similar para la temporada cálida y fría y varió de 0.1 a 5 ºC. La vegetación con mayor cobertura presentó menor temperatura a las 17:00 horas y mayor de las 9:00 a las 10:00 horas durante la temporada cálida. Al aumentar 50% la cobertura vegetal en la zona urbana se lograría reducir la intensidad del EIC en 2.05 ºC. En conclusión, una mayor cobertura de la vegetación mejora las condiciones ambientales en términos de humedad relativa y regularización de los extremos de temperatura durante la temporada cálida.

ABSTRACT

Alteration of climatic conditions and the urban heat island effect (UHI) are consequences of increased human population and activities in urban zones. Determining the magnitude of the UHI is important to improve urban planning in medium-size cities like Querétaro. Increase and conservation of vegetated areas is a mitigation option for UHI. Here we characterized both the UHI and the role of vegetation cover over temperature regularization in urban zones. Four local climatic zones were defined: three urban and one rural, each with two plots with low and high canopy cover defined by their average leaf area index (0.5 and 2.0, respectively). Air temperature and relative humidity were measured with data loggers at a 30 min time step from June 2012 to May 2013. Climatic data from six weather stations was also analyzed. Daily mean temperature increased at a rate of 0.75 ºC per decade ($r^2 = 0.38$, $P < 0.0001$), and this was related to population dynamics ($r^2 = 0.52$, $P < 0.0001$). Patterns of air temperature defined a cold and a warm season: July to March and April to June for maximum temperature, and November to March and April to October for minimum temperature. The difference between cold and warm seasons was 5 ºC ($P < 0.0001$). The minimum temperature was similar

between canopy cover levels. However, relative humidity was higher in high canopy cover plots. The relationship between UHI and the pervious surface fraction of the city was inversely proportional. The UHI ranged from 0.1 to 5 ºC and this magnitude was similar between the warm and cold seasons. Vegetation with high canopy cover had lower temperature at 17:00 LT and higher at 9:00 to 10:00 LT during the warm season. Increasing the urban zone canopy cover by 50% would reduce the UHI by 2.05 ºC. In conclusion, vegetation with higher canopy cover improved environmental conditions in terms of relative humidity and regularization of extreme temperatures during the warm season.

Keywords: Climate change, urban heat island effect, urban planning, Querétaro, vegetation.

1. Introduction

According to the population report of the United Nations (2014), 54% of human population lives in urban areas and it is increasing at a rate of 1.8% per year. By year 2050 rural population would decrease to one third of its present size. Urban concentration of human population causes deep modifications in the city and its surrounding landscapes, affecting environmental and climatic conditions (Yu and Hien, 2006; Um *et al.*, 2007). The effect and dynamics of the urban heat island (UHI) are well-known and deeply studied climatic processes (García-Cueto *et al*., 2007; Doick and Hutchings, 2013). The UHI effect is described as the difference in environmental temperature between the urban area and its rural periphery (Oke, 1973; Stewart, 2011; Li *et al.*, 2013). The variation of air temperature associated with the UHI intensity depends on factors such as infrastructure and building design and density, among many others (García-Cueto *et al.*, 2009; Li *et al.*, 2013). Compared to the countryside, the low albedo and high heat absorption of city surfaces (Doick and Hutchings, 2013), coupled with the generation of greenhouse gases (GHG) and dust from industrial processes and anthropogenic activities (Wilby, 2003; Hunt *et al.*, 2007), contributes to the increase in air temperature, and modifies surface wind flow and air quality (Blake *et al.*, 2011; Doick and Hutchings, 2013).

The increase of vegetation areas is a main option explored to mitigate UHI (Anyanwu and Kanu, 2006; Li *et al.,* 2013). Urban vegetation regulates climate mainly by shading (Emmanuel, 2005), CO_2 sequestration (Lin e*t al.,* 2011) and evapotranspiration (Yu and Hien, 2006). The mitigation potential of urban vegetation needs additional research because native vegetation and climate are strongly related, and this types of plants should be preferred as a robust mitigation option; nevertheless, exotic trees are common in the urban context.

In this paper, we analyzed the UHI for Querétaro City, Mexico. This study is an effort of the Programa Estatal de Acción ante el Cambio Climático-Querétaro (State of Querétaro Action Program Addressing Climate Change, PEACC-Q) (Suzán-Azpiri *et al.*, 2014). The aims of this study were to evaluate (1) the role of vegetation in urban temperature regularization, and (2) the role of vegetation cover in the adaptation to UHI effects.

2. Methodology

2.1 Study area

The study area is the city of Querétaro (Fig. 1), located in the southwestern portion of the State of Querétaro, Mexico (20º 35’ 34.8’’ N, 100º 23’ 31.6’’ W). It covers an area of 759.9 km^2 with a population of 626 495 (INEGI, 2010). Its predominant climate is semiarid with summer rains, annual precipitation average of 549 mm and annual average temperature of 18 ºC. The landscape comprises plains and small hills (Baltazar *et al.*, 2004).

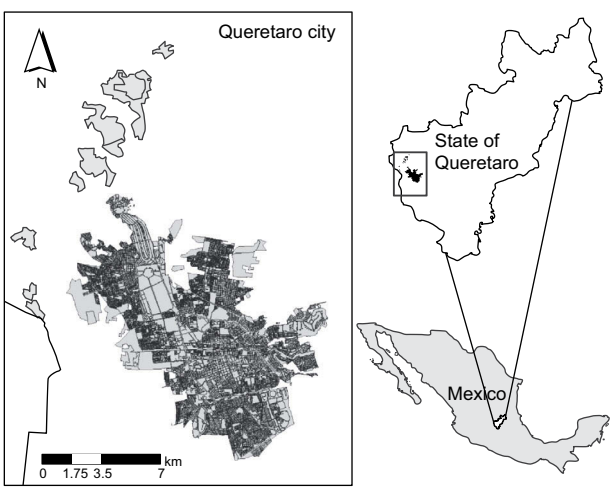

Fig. 1. Geographic location of the study area (Querétaro City).