IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

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To cite this article: Francisco de la Barrera *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **471** 102042

Urban Parks and Social Inequalities in the Access to Ecosystem Services in Santiago, Chile

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Abstract. In emergent economies, severe social inequalities can produce high exposure to deprived environmental conditions, affecting people's wellbeing. Urban parks can greatly help to increase the urban environmental quality by providing fundamental ecosystem services, such as local climate regulation, recreation and sense of place. Urban parks are, therefore, key elements for urban sustainability. This is particularly important in urban settings where investment in green spaces is deficient. In this work, we monitor the relationships between socio-economic features and the provision of local climate regulation. To look at the potential mitigation of air temperatures we analysed a sample of seven parks and their surroundings in Santiago de Chile. Three physical variables were measured: land surface temperature (LST) as a proxy of air temperature, and vegetation cover and soil imperviousness as predictors. These variables were obtained from calculations based on Landsat imagery (2015), using the thermal bands, and estimated through normalised differences of vegetation (NDVI) and built-up (NDBI) indices. We used socio-economic as another predictor variable. Data used classifies households in five groups according to the family income and education level. The socio-economic data was obtained at census track level and served to explore the relationship between physical variables (LST, NDVI and NDBI) relate to socio-economic data. In addition, we measure air temperature using 8 in-situ sensors inside and outside of each park measuring each 150 seconds during two days of high temperatures (over 25°C). Results showed that LST correlated significantly with vegetation cover and imperviousness (r spearman = -0.706 and 0.645, respectively). Socio-economic variables correlated with the same variables, where wealthier neighbourhoods correlated negatively to LST and NDBI but positively to NDVI, while poorer neighbourhoods had higher values of LST and NDBI and correlated negatively to NDVI. Differences between air temperature inside and outside parks were higher in poorer than in wealthier neighbourhoods with an average difference of 2.5°C with a maximum observed difference of 7.1°C. Our results highlight the importance of implementing urban parks in deprived urban settings, to contribute to reduce shortages and inequalities in the access to ecosystem services.

1. Introduction

In emergent economies, severe social inequalities can produce high exposure to deprived environmental conditions, affecting people's wellbeing. Urban parks can greatly help to increase the urban environmental quality by providing fundamental ecosystem services, such as local climate regulation, recreation and sense of place [1,2]. Urban parks are, therefore, key elements for urban sustainability. This is particularly important in urban settings where investment in green space is deficient.

Several variables rule local climate regulation. Vegetation helps by increasing humidity, providing shadows, and increasing albedo [3,4]. On the contrary, areas without vegetation cover such as bare soils, streets or constructions are poor providers of this ecosystem service [5]. In this regard, urban parks increase the vegetation cover, reducing the share of imperviousness inside the parks. But, outside of the parks, the setting and composition of neighbourhoods become relevant and can contribute to the provision of this service by incorporating vegetation in streets and gardens, reducing the share of impervious or bare soils, and facilitating natural air ventilation. These interactions have been already tested in Santiago, at city scale, showing that the higher the vegetation cover or NDVI, the higher the regulation of high air and surface temperatures, while the contrary can be observed with soil imperviousness or NDBI [6,7].

In this work, we monitor the relationships between socio-economic features and the provision of local climate regulation through the analysis of physical variable using remote sensing data and in situ measurements.

2. Methodology

The capacity of parks to regulate local microclimate through the mitigation of extremely high air temperatures was analysed in a sample of seven parks and their surroundings in Santiago de Chile (Figure 1). These parks have similar areas (4-7 ha and only two exceptions) and take place in districts strongly differentiated by family incomes (Table 1). The surroundings analysed for each Park also have similar extensions (90-160 ha) and diversity in the composition of household incomes.

Table 1. Spatial and social characterization of parks and their surroundings. Average percentages represent household incomes, where HIH are high income household, MIH are middle income households and LIH are low income households.

Park name	District	Park area (ha)	Park and surrounding area (ha)	Average household income at neighbourhood level	HIH	MIH	LIH
Carlos Ossandon	La Reina	1.6	86.4	High	75%	23%	1%
Bicentenario Vitacura	Vitacura	22.6	112.9	High	51%	47%	2%
Los Dominicos	Las Condes	6.2	106.6	High	51%	42%	7%
Juan XXIII	Ñuñoa	4.1	150.1	Middle	37%	51%	11%
Santa Rosa	Las Condes	6.5	119.0	Middle	26%	46%	28%
La Castrina	San Joaquin	6.8	126.7	Low	1%	39%	60%
Mapocho Poniente	Cerro Navia	7.3	167.4	Low	0%	25%	75%

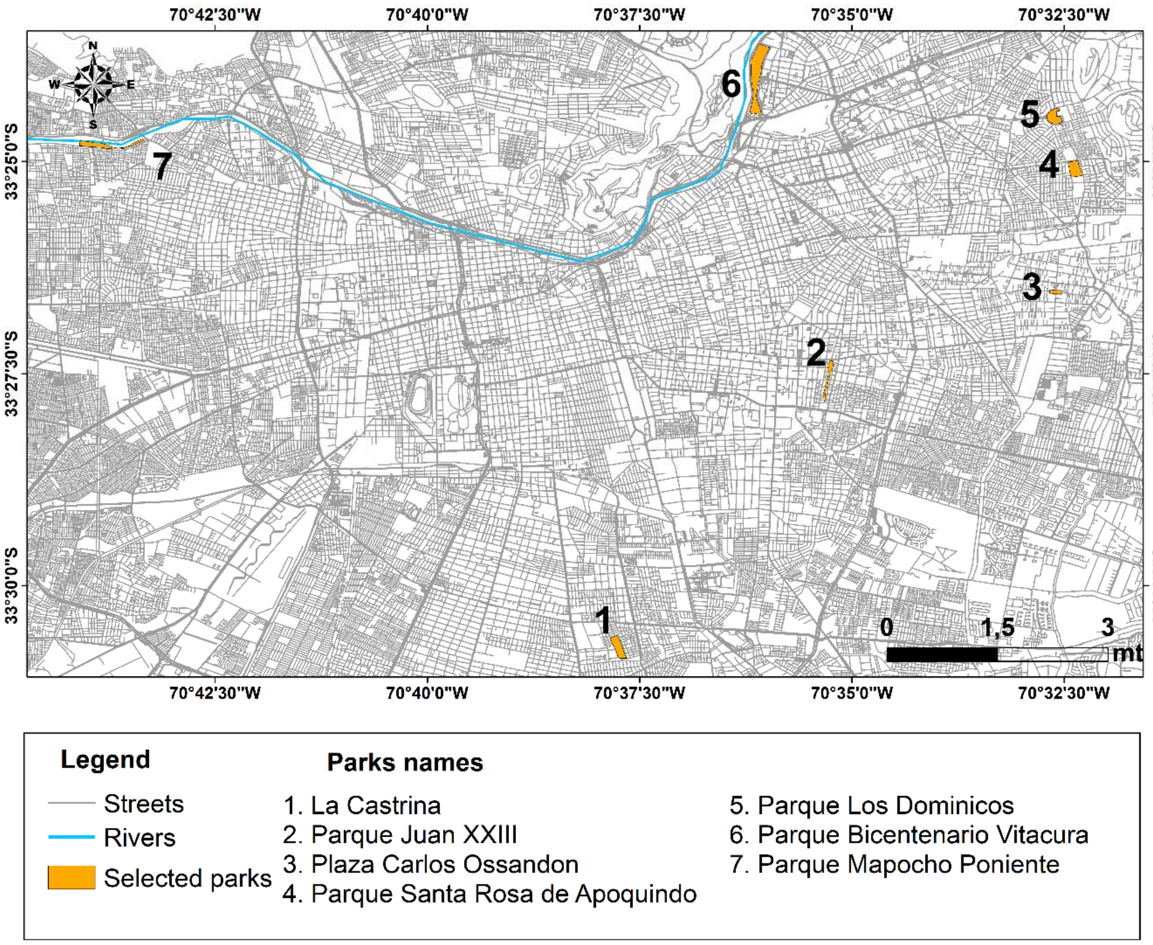

Figure 1. Location of the analysed parks in the Metropolitan Area of Santiago.

Three physical variables were measured on each park and surroundings: land surface temperature (LST), vegetation cover and soil imperviousness. LST was used as a proxy of air temperature. This variable informs about temperature radiated by the land surface. Vegetation cover was estimated through the normalised difference of vegetation index (NDVI). On the other hand, soil imperviousness was estimated through the normalised difference of built-up index (NDBI). NDVI and NDBI vary from -1 to 1. Highest NDVI values means more vegetation vigour or vegetation cover. For NDBI, highest values represent soils entire impervious or paved. Both variables were used as predictors of air and land surface temperature because of their crucial role in local climate regulation as ecosystem service.

LST, NDVI and NDBI were obtained from calculations based on Landsat imagery (2015), using the thermal band (pixel with a re-scaled spatial resolution of 30 m), the red and the infrared bands for NDVI (30 m of spatial resolution), and near infrared and shortwave infrared bands for NDBI (30 m).

To evaluate the associations between the physical variables and potential social inequalities, socio-economic data was considered as another predictor variable. Data analysed is based in a classification of household incomes and education level of each census track. This allowed to perform a detailed spatial analysis of the surroundings of each park and using census track as replicas. Five categories compose the above-mentioned socio-economic data: high (ABC1), middle-high (C2), middle (C3), middle-low (D) and low (E). These five categories were simplified into three categories: 1) high incomes was conserved, 2) middle-high and middle incomes were grouped as middle incomes, and 3) middle-low and low incomes were grouped as low incomes.

In addition, to gain temporal resolution and to validate the association got from LST and the above-mentioned predictor variables, air temperature was measured using 8 in-situ sensors located inside and outside of each park. These sensors measured air temperature each 150 seconds, during two days of high temperatures (over 25°C).

3. Results and discussions

The sample of parks mirrors socioeconomic differences with exposition to heat (LST), access to vegetation (NDVI) and extension of impervious areas (NDBI). Higher temperatures are associated to low income neighbourhoods as well as to scarce vegetation (NDVI) and to higher coverage of impervious soils (NDBI) see table 2.

Table 2. Physical variables by neighbourhood

Park name	Family income at neighbourhood level	LST (average, °C)	NDVI (average)	NDBI (average)
Carlos Ossandon	High	24.5	0.31	0.07
Bicentenario Vitacura	High	23.7	0.26	0.07
Los Dominicos	High	25.4	0.27	0.09
Santa Rosa	Middle	25.0	0.25	0.11
Juan XXIII	Middle	25.4	0.24	0.11
La Castrina	Low	27.0	0.13	0.20
Mapocho Poniente	Low	26.8	0.15	0.20

Regarding the correlations between physical variables, LST correlated significantly with vegetation cover (NDVI) and imperviousness (NDBI; r spearman = -0.706 and 0.645, respectively) see table 3. These correlations prove that vegetation cover has cooling effects, affecting negatively the LST, i.e. vegetation cover has a positive effect in the local climate regulation. On the other hand, a higher NDBI means more surface able to accumulate heat, increasing the LST. Vegetated parks, urban forests and gardens increase the NDVI and decrease the NDBI, i.e. they help to decrease LST.

The exploration of how the above-mentioned variables correlated to socio-economic features of neighbourhoods at household scale showed that socio-economic variables correlated significantly with all of them (LST, NDVI and NDBI). However, they did it in a different way. Wealthier households correlated negatively to LST and NDBI but positively to NDVI, while poorer households did it inversely, having higher values of LST and NDBI and lower values of NDVI.

Table 3. Spearman correlations between physical variables and household incomes. ** significant correlations ($p < 0.01$).

	LST	NDVI	NDBI	HIH	MIH	LIH
LST	1.000	-0.706**	0.645**	-0.531**	-0.143**	0.460**
NDVI	-0.706**	1.000	-0.910**	0.680**	0.264**	-0.614**
NDBI	0.645**	-0.910**	1.000	-0.684**	-0.252**	0.704**

Differences between air temperature see table 4 inside and outside parks were higher in poorer than in wealthier neighbourhoods. A little average difference but a large maximum observed difference was observed in neighbourhoods of high household incomes, whereas that differences were higher for average differences and maximum observed differences in neighbourhoods of low household incomes.

Table 4. Air temperature differences between inside and outside of parks

Park name	Family income at neighbourhood level	Average difference IN-OUT (°C)	Max. diff. IN-OUT (°C)
Carlos Ossandon	High	-0.1	-2.0
Bicentenario Vitacura	High	-0.4	-3.5
Los Dominicos	High	-0.6	-2.5
Juan XXIII	Middle	-2.0	-6.1
Santa Rosa	Middle	-0.9	-2.8
La Castrina	Low	-2.5	-7.1
Mapocho Poniente	Low	-0.6	-6.4

4. Conclusions

Socioeconomic features of neighbourhoods tested in urban parks of Santiago de Chile are strongly associated to the capacity of regulation of local temperatures. Land surface temperature and air temperatures were significantly differentiated by the socioeconomic condition of the households, being explained by differences in vegetation coverage and extensions of impervious soils.

Our results highlight the importance of implementing urban parks in deprived urban settings, to contribute to reduce shortages and inequalities in the access to ecosystem services.

Acknowledgments

Authors thanks the support of FONDAP 15110020.

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