Impact of Urban Parks on the Climatic Pattern of Mendoza's Metropolitan Area, in Argentina.

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ABSTRACT: Mendoza's Metropolitan Area (MMA), in central-western Argentina, is the result of a development model where the man-made environment and the natural one conform an intermingled mosaic, resulting in a strong insertion of green open spaces in the city. In this context, the open spaces: parks, squares and urban forests significantly modify the climatic pattern of the built environment.

In this study the microclimatic effect of the parks have been evaluated by the analysis of different landscaped structures -San Martín, San Vicente and O'Higgins parks- located along the city's main development lines and characterized according to the space and physical components: green lawns, water surfaces and wooded areas.

These green structures were previously monitored during a summer season, in an urban heat island's study, using a less detailed method, showing that the temperature profile decreases between 2 to 5 ºC respect the city's centre, especially during the night. In this work 26 automatic stations, measuring temperature and humidity were placed inside and in the surroundings of the evaluated parks, starting on January 15th, 2006. The aim is to record their effect and environmental features related to the temperature and humidity profiles of MMA.

The results show that, green spaces of smaller areas and contained within the urban tissue, perform as more efficient when compared to the greater extension parks as those placed at the city's edge and that the landscape design decisions of green spaces acquire greater importance as the lesser are their dimensions.

Keywords: green structures, urban configuration, heat urban island.

1. INTRODUCTION

High density land use in many cities has caused an uncomfortable urban environment, due to the modification of energy's budget which directly influences the thermal environment in outdoor spaces around residential buildings. This phenomenon, known as "urban heat island" (UHI); is defined as the increase of air and surface temperatures in urban areas relative to surrounding suburban and rural areas. The increase of the urban temperature has a direct effect on energy consumption, thermal comfort conditions and environmental pollution in urban spaces. [1]

Several (UHI) mitigation strategies have been recently reviewed by researchers [2] to determine their relative effectiveness and cost efficiency. Two basic strategies include reflective surface materials and increased vegetative cover.

It is well known and documented that trees and green spaces contribute significantly to cooling our cities and saving energy [3]. Trees can provide solar protection during the summer period; while in addition, evapotranspiration can reduce urban temperatures. In parallel, trees absorb sound and block erosion-causing rainfall, filter dangerous pollutants, reduce wind speed and prevent erosion.

In other hand, the presence or absence of greenspaces and the special and varying qualities of such spaces are linked with the life quality of the urban dwellers. For this reason it is important to evaluate how a city's Greenspaces might be planned in a spatial sense, and then how they might best be designed, managed and maintained in function of climatic and morphological urban characteristics to obtain the maximum benefit for the local population.

The objective of this paper is to evaluate the cooling effect of green areas and the impact of different green configurations over the climatic features in Mendoza's Metropolitan Area. Starting from this analysis and diagnosis, it is possible to develop a strategic planning of green spaces with the aim of mitigating the effects of the city's existence over the region's climate.

2. THE STUDY'S IMPACT ON THE LOCAL SCALE

Mendoza's city is the most important metropolis of mid-western Argentina, with a population of 973,173 inhabitants; it is located at the foothills of the Andean Range between latitudes -32 and –37 and at an altitude of 790 m.a.s.l. As it is typical for many arid zones, the region's climate features wide daily and seasonal temperature fluctuations, intense solar radiation in all seasons and a regime of low annual precipitation (250 mm.).The winters are dry and cold with predominance of stable weather. The local winds are anabatic-katabatic types with average speed of 2 m/s and NE-SO direction.

This large city concentrates 65 % of the total population of the province occupying only 3% of its territory, it has a high population growth; 14% during the last decade. This important growth rate has led to a practically uncontrolled expansion of the urban area, modifying the city's profile in its horizontal and vertical dimensions, All these conditions have contributed to the heat island formation which reaches values of 8 and 9 ºC; both in summer and winter, during the night and first morning hours, depending on their position related to the direction of predominant breezes, building densities, altitude, forest; etc. [4]

Mendoza's city presents a consolidated urban grid structure, and inserted urban voids. Figure 1. The urban canyons have 20 and 16 m of width average, the building's materials are concrete and brick mainly because the high seismicity of the zone. The "city center" is a central area of the city which is characterized by the highest building densities, with housing and commercial structures of high rise buildings (up to 19 storeys). It also features the higher and denser trees structures and the most intense vehicular traffic over the whole metropolitan area.

The city's configuration is the result of a development model where the man-made environment and the natural one make up an intermingled mosaic, resulting in a strong insertion of green open spaces in the city. In this context, the open spaces: parks, squares and urban forests significantly modify the climatic pattern of the built environment; but whose benefits and disadvantages have not yet been thoroughly analyzed in the province. [5]

3. METHODOLOGY

To evaluate the impact of parks over the temperature profile of Mendoza's Metropolitan Area (MMA), three parks were selected; taking into account their position related to the city's centre (Point 50 figure 1) and the park's landscaping structures because our scope is to compare the environmental performance of different green space configurations and the relative weight on its built environments.

3.1 The cases studied were:

O'Higgins Park: (extension 9 ha.) Green space assigned for public use at the beginning of the XX century, using the surplus lands between the edge of the old city and the main circulation viaduct in the north-south connection of the urban tissue. Although in the past the park defined the eastward limit of the urban fabric, presently the growth of the city has surrounded it. In its space it contains some constructions for recreative and cultural activities (theatre, aquarium, etc).

From the morphologic viewpoint it presents, a longitudinal development with a central axis defined by a vaulted green structure, lateral groups of irregular distribution and discontinuous green hedges that line-up along the park's limits. The abundance of tree individuals that reach their maximum vegetative expression, in relation to green lawns defines the park as a structure featuring predominantly shaded areas.

The park is located at 741 m.a.s.l on flat terrain. The urban configuration that borders the park, present low construction density (1.96 m^3/m^2) mainly, with a mean building height of 3m.

***San Vicente Park*:** (extension 18 ha.). The structure is the result of the revaluation of a former urban void contained in the grid. Therefore, it is a "new" greenspace, without consolidation and unplanned from the viewpoint of landscape design. In its structure an important expanse of lawns is predominant, it includes some young arboreal individuals and bushes scattered with conforming groups. It presents an open, luminous scheme when compared to the O'Higgins Park. Such morphology offers full insolation possibilities. Its limits are defined at the northern edge by a green tunnel of eucalyptus, only specimens of first magnitude and, the southern extreme by a screen of poplars.

The park is located at 833 m.a.s.l on the foothill of the metropolitan area. The mediate context is conformed by low density built-up structures and the irruption in the grid of the new fashion of commercial buildings (hypermarkets), with significant open spaces used for parking.

San Martín Park (extension 358 ha.). Located at 821 m.a.s.l on the foothill of the metropolitan area. This park presents an organic type of structure which harmonizes the English and French traditions from the XIX century landscape design. It establishes the west limit of the city and extends to the first Andean foot hills. It contains, in its structure wide avenues lined-up by fully grown trees, extensive areas of lawns, densely forested area of different extension, an artificial lake and a significant number of small buildings belonging to public and private organizations: clubs, sport infrastructures, educational and administrative.

It contains an important forestal stock, integrated by more than 300 tree species of different origins. 50,000 individual conforming densely wooded masses within a dynamic spatial order. It also presents a great botanic variety mostly conformed by exotic species, which has recently been enriched by the addition of native species. The landscape design presents a balance of wooded areas and open sky lawns.

The location of new housing ensembles on the foot hills defines the northern and southern limits of the park, partially modifying its character at the edges, at the east the urban configuration are composed by low and mean (3 m^3/m^2) density built-up structures. See figure 1, for the spatial distribution of the selected parks into de MMA.

3.2 Monitoring campaigns

With the purpose of monitoring the thermal behaviour of the different parks over the city and the impact of their greenspaces design, for instance, grassland predominant over woodland; two campaigns were performed.

First during February and March 2005, 18 fixed automatic stations measuring temperature and humidity in the urban canyons every 15 minutes, have been installed in coincidence with diverse transects that cover the most noticeable directions of the city's growth. Three of these points (3, 81, and 33) are in concurrence with the studied parks. Figure 1

Secondly, for monitoring and comparing the impacts of different greens conformation, during January and February 2006, 26 fixed stations were installed, covering four types of green spaces conformation, present within the evaluated parks: grassland, woodland, isolated tree and anthropogenized zones such as recreation spaces, theatres or public administration agencies. Also, reference instruments have been placed to monitor the impact of the buildings surroundings parks and in the outskirts of the metropolitan area on the four cardinal points. Figure 1 shows the locations of the measurement points within MMA for the first campaign.

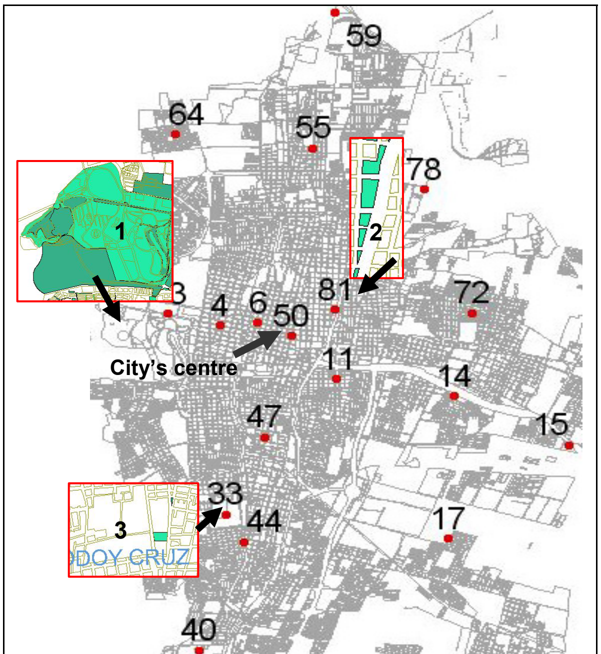

Figure1 Locations of measurement's points and evaluated parks within MMA. (1) San Martín; (2) O'Higgins; (3) San Vicente parks.

The stations installed are of the type: H08-003-02, two channel logger with internal temperature and user-replaceable RH sensors, temperature measurement range: -20 to 70 ºC, temperature accuracy: +/- .7º at 21 ºC, RH measurement range: 25 to 95 % RH (user replaceable RH sensor), RH accuracy: +/- 5% RH. The sensors have been placed at a height of 2.5 m from the street or ground level [6], within perforated PVC white boxes, to avoid irradiation and assure adequate air circulation.

3.3 Cartographic Representation

The recorded data of temperature and humidity, during each campaign of measurements, have been cartographically plotted using GIS software ArcView 3.2. The interpolations have been done using the IDW method (distance's inverse), which, compared to the Krigging Universal and the Spline methods, has demonstrated to be the most adequate, since it minimizes the quadratic error.

4. RESULTS

From the analysis of the data obtained during the first campaign (summer 2005), it can be observed that the evaluated parks are always cooler related to the city center during the night and early morning hours, i.e. during the cooling period (8pm – 7am). During the warming period (8am – 7pm) in general, parks present higher temperatures than the city center, with the exception of San Vicente park (Fig.2).

This behaviour during the warming period can be explained as a result of the dense urban forest present in the studied metropolitan area, mainly conformed by first magnitude arboreal species, whose overlapping of crowns conform a dense tunnel which blocks the intense insolation typical of arid climates and, as consequence, during this period, the city is cooler than its surroundings; which present a large sky view factor and are generally constructed with high absortance and thermal accumulation materials. This climatization derives from the oasis-city concept, which has been predominant in the urban conception of the city.

On the other side, the behaviour of San Vicente park, during the warming can be explained by the joint effect of different factors; among them it can be mentioned: lesser intensity of vehicular traffic, greater altitude and favorable position related to the local breezes direction, during the afternoon hours (SO-NE). At the beginning of the study it was thought that this behaviour was a consequence of an important effect of evapotranspiration, given its configuration which present large exposed areas, but the analysis of the absolute humidity contours does not show a differential behavior from the humidity records in this park, compared to the other two, which could explain the cooling effect. (Table 1).

Table 1: Minimum, maximum and mean absolute humidity for the three parks analyzed

Humidity (gr/kg)	Configuration	SM	O'H	SV
Mín	Grassland	12,40	4,00	4,24
Máx		22,28	22,34	23,15
Mean		4,26	11,30	12,46
Mín	Woodland	4,37	4,24	
Máx		22,25	22,82	
Mean		12,37	11,70	

During the cooling period, San Martin Park is the one that records maximum temperature differences related to the city center, reaching values of 7°C, while San Vicente an O'Higgins parks present maximum differences of 5°C and 4°C, respectively.

During cloudy (> 6/8 cloudiness) and calm days, parks are, at any time, cooler than the city, but their magnitude's differences are much less, reaching maximum values of 2,5°C. From this behaviour it is clear that for equal surrounding conditions, the sky view factor, or the solar access, is responsible for the behaviour of parks during the warming hours of clear days; while in absence or reduction of the radiative component, the anthropogenic component presents in the city, added-on to the thermal capacity of the materials that compose it, results in its higher temperature.

Besides, on Fig. 2 it is observed that the temperature curve of the parks follows their configuration features (extension, park area relationship: forested area, etc.) and to the features of the urban tissue in which they are inserted. For example, O'Higgins park, immersed in strongly consolidated urban tissue, surrounded by circulation viaducts with high level of vehicular traffic and major composition of highly forested areas predominantly shaded (i.e. with a low Sky View Factor) present lesser cooling when compared to San Vicente park, with a similar extension but with a configuration of the "green" mainly conformed by lawns and inserted in an urban tissue with predominant urban voids (i.e. with a high value of SVF).

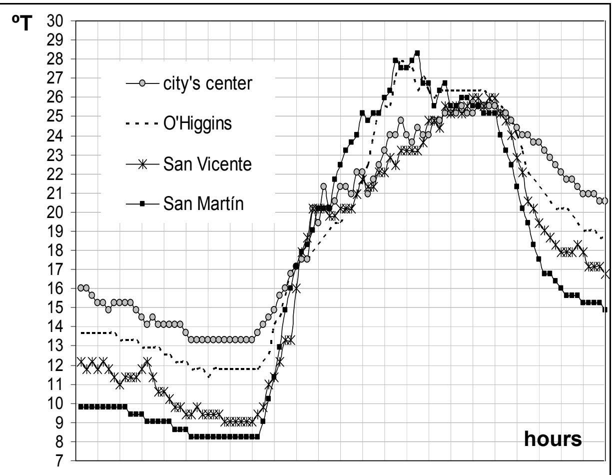

Figure 2: Daily temperature distribution in three evaluated parks and the city's center for a typical summer day (cloudiness < 3/8 wind velocity < 1km/h).

Figures 3, 4 and 5 show the temperature profiles for each transects that contain the analyzed parks and extend from the city center to the reference points in the outskirts of the metropolitan's area, for the winter and summer periods as well.

Therefore, the transect C-W (Center-West) contains San Martin park (Fig.3- station 3 is San Martín park). The transect C-N (Center-North) contains O'Higgins park (Fig. 4- station 81 is O'Higgins park).. The transect N-S contains San Vicente park. (Fig. 5 – station 33 is the San Vicente park).

From the obtained profiles it is possible to analyze the impact of the spatial distribution of the studied parks, i.e. the effect of their place on the thermal behavior of the urban sector in which they are contained.

As an example, it is observed that the high impact of park O'Higgins on the urban fabric during the night as moderator of the temperature profiles reducing their values in a 15%, related to the city center and a 10% related to the suburban areas to the north, while during the warming period the temperature differences only attain a 7% related to he center and only a 3% over the nearby suburban areas. In the same way San Vicente park moderates the temperature profile reducing the air temperature of the suburban area by a 12% toward the center city and a 16% on the suburban area toward south besides, during the warming it muffles the temperature profiles by a 10% related to the suburban area toward the South. While San Martín park which features an extension 20 times larger than San Vicente park and 40 times greater than O'Higgins park, it moderates the temperature of the close suburban area toward the center city by only a 16,5%.

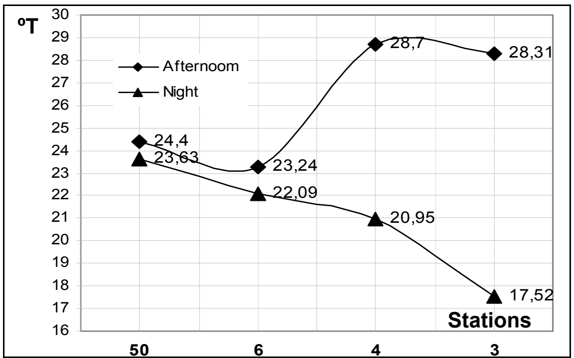

Figure 3: Temperature profile transect C-W San Martín park for a typical summer day.

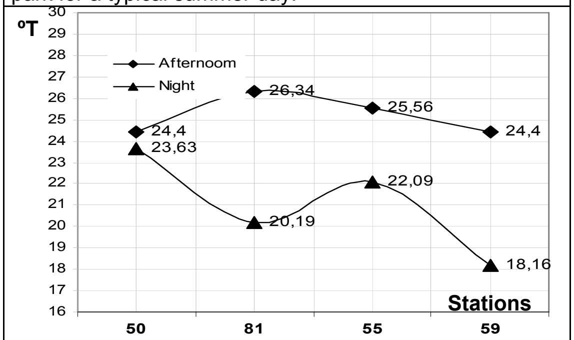

Figure 4: Temperature profile transect C-N O'Higgins park for a typical summer day.

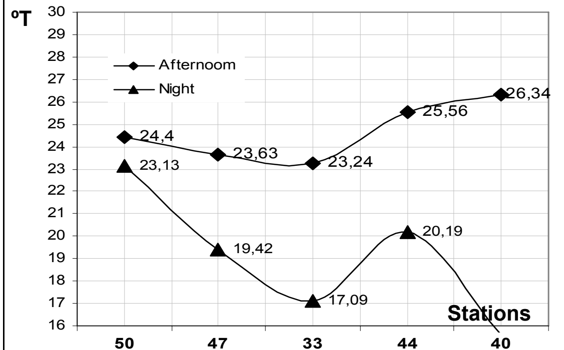

Figure 5: Temperature profile transect C-S San Vicente park for a typical summer day.

In figure 6 and 7 the horizontal distribution of the temperature profiles for MMA, during periods of warming and cooling have been cartographically presented. The thermal behavior of the green spaces evaluated can be observed; besides, it can be emphasized that the representations are in agreement and support what has previously been discussed.

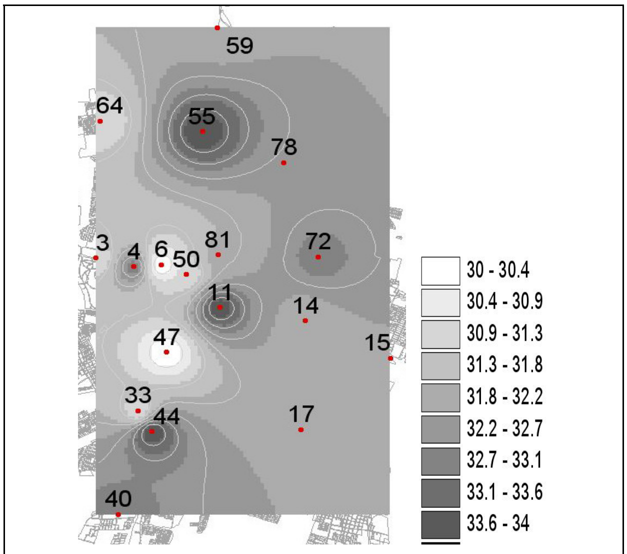

Figure 6: Horizontal temperature profiles within MMA for a summer day during the warming period (4 pm). Station 3, 81 and 3 represent the evaluated parks.

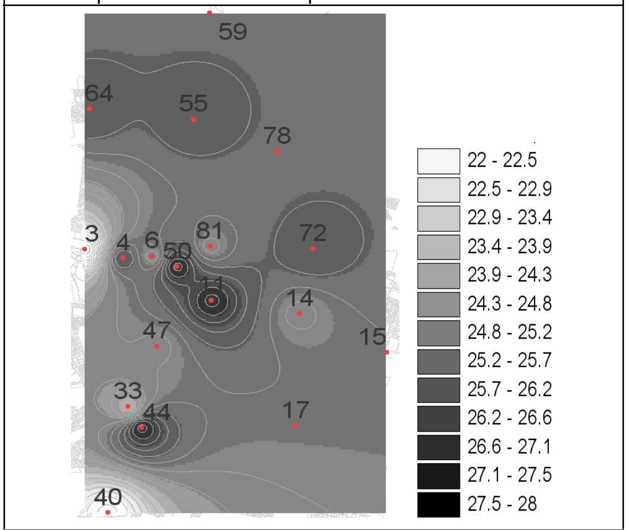

Figure 7: Horizontal temperature profiles within MMA for a summer day during the cooling period (4 pm). Station 3, 81 and 3 represent the evaluated parks.

4.1 Analyses of Greenspaces Configuration

From the analysis of the obtained data during the second campaign (summer 2006), whose objective was to evaluate the impact of the different configurations of green areas on the thermal performance of the urban spaces, an analogous behavior can be observed, resulting the lawn the one that cools the most during the night and warms the most during the afternoon. The forest is the structure that displays the lesser warming during the sunshine hours, as it is logical, given its shaded condition but, during the night, depending on its extension and the design of the park in which it is located, this structure can cool down to the temperature of the lawn or not. The isolated tree behaves in a similar way than the forest and therefore is not a structure that contributes particular benefits to the green space. In Fig.8 the daily temperature distribution of the three considered structures related to the behavior of the city centre, for two of the analyzed parks of well defined features, is shown. The first graphic corresponds to the San Martín Park, the one of the greatest extension that materializes the west limit of MMA, the second displays the O'Higgins park which features a longitudinal development and an extension 40 times smaller and completely inserted within the urban fabric.

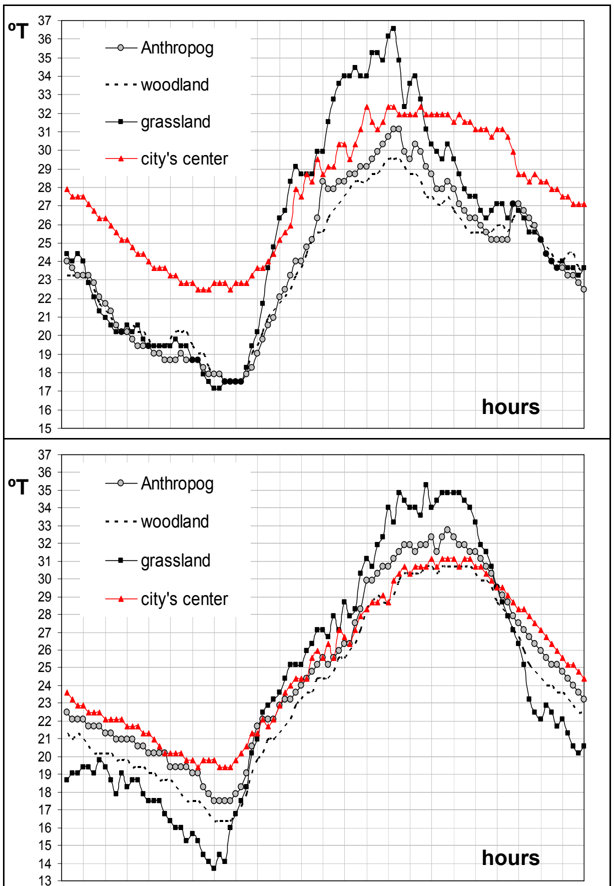

Figure 8 Daily temperature distribution of the three considered structures related to the behaviour of the city centre for a typical summer day.

It is observed that in both parks, during the warming, the green structures analyzed display the same behavior while during the cooling period their behavior is quite different, while in San Martín park all structures converge toward the minimum cooling and separate the most from the temperature contours of city's centre; in the case of O'Higgins parks the cooling of the structures are well differentiated and the temperature contours get closer to those of city's centre. This indicates that the type of green structure acquires greater importance when the lesser is its extension and greater the density of the surroundings urban tissue. Besides, it is observed that the anthropized zone's impact within the parks decreases when related to its area and its location within the urban fabric.

Finally, in Fig 9, 10, and 11 the temperature distribution horizontal profiles for each one of the parks, comparing the incidence of the structures that conforms them, which has been monitored in the second campaign by reference measurements on the four cardinal points that surround the parks.

In the graphics, the relative reach of the cooling gradient due to the impact of each one of the parks on the immediate urban tissue that surrounds them, can be observed. They demonstrate the efficiency of parks of lesser extension than the San Martín settled on the city's edge. The "stack effect" of the cool focus of the parks during the night that exerts its influence draining the heat accumulated in the built environment that surrounds them, can be observed. This is demonstrated by the grouping of the temperature contours in the zones around the parks. In the same images, in spite of the area of San Martín Park, it can be seen that its influence range does not extend more than three blocks from the park's edge.

5. CONCLUSION

The results demonstrate the beneficial effect of parks on the nocturnal cooling of the urban fabric. It is worth to point out that the present thermal conditions in the studied area; this behavior is of particular interest since the heat island phenomenon reaches its maximum expression during the cooling period [7]

In the urbanistic conception of MMA the intense forestation is a part of the bioclimatic strategy of thermal conditioning of the exterior spaces during the sunshine hours. But this has caused a reduction of the sky-view factor which brings, as a consequence, a reduction of the radiative cooling of the city during the night, contributing to the intensity of the urban heat island effect.

In these conditions, the presence of small parks inserted in the urban fabric as a tool for nocturnal thermal conditioning, stands as an interesting proposal which allows to minimize the nocturnal impact of the beneficial effects of the shade during sunshine hours.

The results also show that, green spaces of smaller areas and contained within the urban tissue, perform as more efficient related to the greater extension of parks as these placed at the city's edge.

It is important to stress that the landscape design decisions of green spaces acquire major importance as the lesser are their dimensions.

In future stages, it is planned to deepen the knowledge of the impact of the intense urban forestry at MMA on the humidity profiles, which in the studies performed so far, does not show significant variations, which could be caused by the hydric deficit of the urban forest.

REFERENCES

[1] AKBARI H., DAVIS S., DORSANO S. HUANG J. AND WINERT S. (1992). Cooling our Communities-US Environmental Protection Agency, Office of Policy Analysis, Climate Change Division.

[2] ROSENFELD, A., AKBARI, H., ROMM, J., POMERANTZ, M., (1998). Cool communities: strategies for heat island mitigation and smog reduction. Energy and Buildings 28, 51–62.

[3] SANTAMOURIS, M. (2001).Energy and Climate in the Urban Built Environment. James & James. UK. ISBN 1873936907.

[4] CORREA, et.al. (2005). Isla de Calor Urbana. Monitoreo y análisis del impacto de la configuración de los espacios sobre la temperatura del aire en la ciudad de Mendoza. AVERMA- Avances en Energías Renovables y Medio Ambiente- Vol. 9, 11,49-54. Impreso en la Argentina. ISSN 0329-5184

[5] ENDLICHER, W (1999). Concepción y Metodología del proyecto Mendoclima. Rev. Meridiano ISSN 0328-543X

[6] OKE, T.R (2004). Initial Guidance to Obtain Representative Meteorological Observations at Urban Sites. IOM Report, TD In Press, World Meteorological Organization, Geneva.

[7] CORREA, et.al. (2005). Urban Heat Island Features in the city of Mendoza, Argentina. The Effects of Urban Configuration and the Climatic Conditions. PLEA2005. 22 nd Conference on Passive and Low Energy Architecture. Beirut, Lebanon.

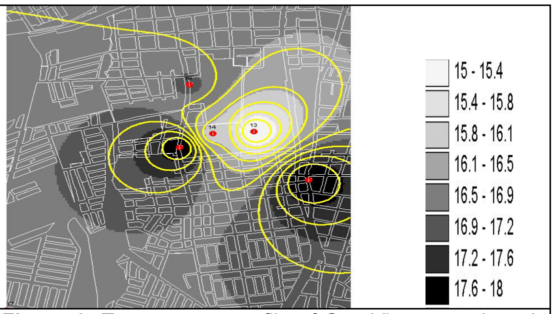

Figure 9. Temperature profile of San Vicente park and surroundings during cooling period.

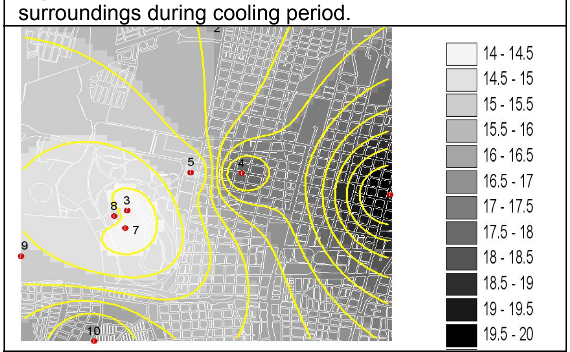

Figure 10. Temperature profile of San Martín park and surroundings during cooling period.

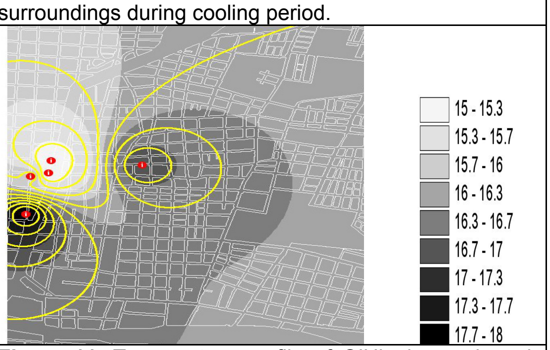

Figure 11. Temperature profile of O'Higgins park and surroundings during cooling period.