

Effect of Urban Forest on Daylight Availability in Built Environments. The case of Metropolitan area in Mendoza.

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ABSTRACT: In the city of Mendoza, Argentina, the urban “green” is a predominant feature of the city structure. Even when trees lined along streets generate a number of benefits on the sustainability of the urban environment, the case of deciduous species included, at the building scale it conditions the access to climatic resources in a measure that is necessary to quantify.

The paper presents the first results of the development of horizontal (E_h) and vertical (E_v) illuminance measurements in summer, in urban canyons of low density built environments, similar morphological variables and forested with the most representative tree species in the city’s capital district: “London Plane” (*Platanus acerifolia*), “Mulberry” (*Morus sp.*) and “European Ash” (*Fraxinus excelsior*).

The results obtained allow to identify behaviour and illuminance ranges associated to the urban tree pattern, its development and its spatial configuration: the discontinuous structures – “Ash”– allowed the greatest access to the resource (E_h : 94,000 lux on causeway; 18,000 to 50,000 lux on sidewalks) when related to “vaulted” structures of a continuous type: “London Plane” and “Mulberry” (E_h : 15,000 to 73,000 lux on causeway; 4,000-10,000 lux on the sidewalk), conditioning the open sky resource in a lesser degree on causeways than on sidewalks

In future stages, the results obtained will be correlated with those yielded by the use of computational models to the effect of identifying the incidence of the sky diffuse and reflected components, from the visible sky vault and the nearby environment respectively, and with those obtained in nocturnal measurements.

Keywords: urban trees, daylight resource availability, built environments.

1. INTRODUCTION

The city of Mendoza, Argentina, on the center-west of the country, lies under the predominantly arid climate, typical of the region’s natural desert. Its population conglomerate reaches almost one million people and it is set on the western edge of the artificial agricultural oasis of the province’s Northern area.

From the urbanistic viewpoint, the structure of Mendoza’s Metropolitan Area (MMA) is laid on a gridiron pattern –as spatial definition and physical support of the complex-. Architectural volumes are articulated by “patios” and a strong presence of “green”, strategically laid along streets, parks, “plazas” and green spaces.

The massive presence of green in the urban tissue (48,000 units in the city) is the result of a city planned a laid in the late XIX century, following the structure of an existing irrigation network and of arboreal rows lined against the limits of urban city blocks, planted at regular intervals and with the aim of

achieving homogeneity of specie’s per city block and nearby the preceding irrigation network. The trees, of deciduous species belong in almost its total numbers on an ensemble of seven species, being the most representative in the capital district: Mulberries (*Morus sp.*) 38.27%, London plane-trees (*Platanus acerifolia*) 21.52% and European ash (*Fraxinus excelsior*) 19,36%[1]. (Fig. 1)



Figure 1: View of Mendoza’s Metropolitan Area.

The urban “forest” consolidated by the full development of these specimens provides benefits to the city such as: attenuation of the urban heat-island effect, the absorption of polluting gases and the reduction of noise levels, among others [2]. These benefits have led in the more advanced countries, to consider the urban green areas as a basic strategy for improving the life quality of the urban dwellers.

However, from the energy sustainability viewpoint of the urban building stock, the utilization of the climatic resources is conditioned by the obstructions derived from the presence of the “urban green” along the urban canyons.

Quantifying this phenomenon will allow to optimize the building design, in order to utilize the solar resource as a strategy to achieve thermal and luminous comfort conditions in interior spaces and to reduce the consumption of polluting fuels.

In the case of MMA, the growth of the street trees along the historical development of the city has been of a spontaneous type, limited by the urban condition and subject to works of pruning, derived among other factors, from the need to harmonize its presence with the building volumes and the service infrastructure network. The sustained growth rate of the city has empowered the condition of the immediate environment and its impact on the “green” causing that some specimens get far from their optimum vegetative development, limiting the above mentioned benefits.

Thus, the morphological features of the trees in the urban milieu is substantially different from that of isolated specimens. This is due to a host of factors, such as the condition of alignment, the effects of unskilled pruning, the incidence of a polluted environment and fundamentally the phenotypical expression of each of the tree species. This differential development of each species is the cause of different situations related to the qualitative and quantitative values of the solar available resource in forested urban canyons.

The study evaluates the behaviour of the three most representative tree species of the trees aligned along the city-blocks of MMA – “London plane”, “Mulberries” and “Ash-trees”- in the circulation channels of low building density and its incidence on the use of the luminous resource, as a function of the tree’s morphology in the urban scene, in summer, when trees reach their maximum vegetative expression and they present the greater limitations to the access to the resource.

2. METHODOLOGY

The scenarios have been selected within the context of the low-density urban tissues and correspond to urban canyons with N-S orientation, where the physical parameters of the urban variables (causeway width: 10m, sidewalks width: 5m and

building height: 3-6m) are similar. The lined-up trees are conformed by the more usual species in MMA, whose variables –quantity of specimens, height, trunk-crown relationship, crowns overlapping and vegetative status- are described for each studied case.

2.1 Description of the study cases

- Scenario 1 (Fig. 2)

Circulation channel forested with Plane-trees (*Platanus acerifolia*), adult forestals of first magnitude over 18m in height, shaping dense and continuous tunnels, conforming a green vault over causeway and sidewalks.

The trees are aligned along both sidewalks with some voids due to eradicated individuals. The vegetative status is good in general, and does not put into evidence interventions by pruning, which is reflected by an adequate trunk-crown relationship, being the latter positioned above 10m of height.

In the longitudinal sense of the vegetated channel 30 individuals at plantation intervals between 5.40 and 6.00m. On both sidewalks the tree specimens conform a dense tunnel, with the greater part of the branches extending towards the causeway and the buildings, conforming a complete and homogeneous vault. However, over some stretches of sidewalks the development is laxer due to the larger amplitude of the environment, derived from the presence of urban voids and at causeway level “windows” or voids in the foliage known as “gaps”.

- Scenario 2 (Fig. 3)

Circulation channel forested with “Mulberries” (*Morus* sp.), adult specimens of second magnitude reaching a height of close to 15m. The plantation distance varies between 5.50 and 6.30m.

The vegetative status is between good and regular. This species conforms a continuous channel in the fashion of a screen with a high proportion of crowns overlapping, which is interrupted over the causeway due to the lesser development of the crowns when compared to the Plane-trees channel and the presence of young individuals from repositions. Also, the “gaps” derived from irregularities in the plantation intervals can be observed.

- Scenario 3 (Fig. 4)

The third case corresponds to an urban canyon with specimens of ashes in its two more common species: “European ash” (*Fraxinus excelsior*) and “American ash” (*Fraxinus americana*). The individuals, although adult correspond to second magnitude species [3], are not yet reached their maximum expression. The vegetative development is regular in average with unbalanced crowns and uneven lateral growth.

The morphologic structure of the canyon is not continuous since the specimens maintain their individuality as a function of their crown's dimensions and long plantation intervals (6.00 – 8.00m).



Figure 2: Circulation channel forested with London Plane trees.



Figure 3: Circulation channel forested with Mulberries.



Figure 4: Circulation channel forested with Ash.

2.2 Measurement method (Fig. 5)

To the effect of assessing the luminous resource availability, illuminance measurements were performed:

- Horizontal illuminance (E_h) at floor level over causeway and sidewalks.
- Vertical illuminance (E_v) measured at 1.50m from floor level, directed towards the street center in order to evaluate the quantity of light impinging on façades.

The measurements were performed during the warm season, at solar noon, under clear sky conditions. The measurement grid extended over the total causeway and sidewalks, along five axes in the longitudinal sense of the circulation channel, three axes corresponding to the causeway and one to each sidewalk. Perpendicular to these longitudinal axis, transverse axis were positioned at 3.00m intervals [4].

The measurements program considers the data acquisition in continuous form for each urban canyon, throughout the day and with a detailed hourly time schedule [5]. This paper presents the results of solar noon measurements only, aiming, in a comparative form, to assess the behaviour of the three arboreal species on each circulation channel.

The instruments used for data acquisition were: luximeter LI-COR 189 with photometric sensor LI-210 and levelling base 200 3S and TENMARS DL 201 luximeter, both with cosine correction.

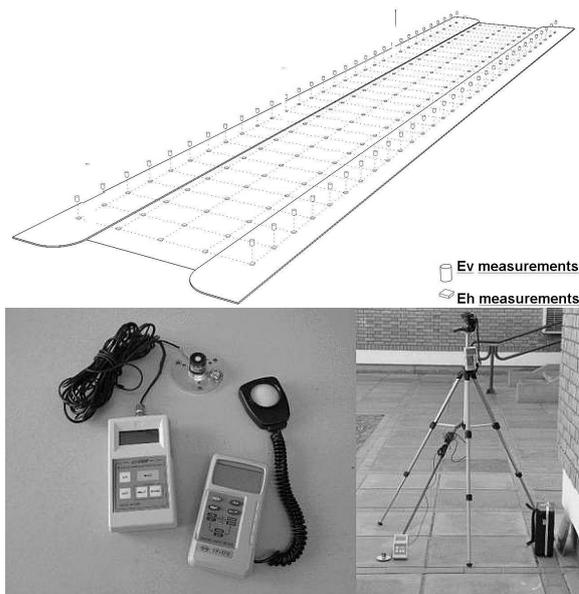


Figure 5: Measurement grid and instruments used.

3. RESULTS

The obtained measurements values have been analysed as to comparatively assess the different structures of aligned trees. To such purpose the results of horizontal (E_h) and vertical (E_v) illuminance, were centered along the causeway and sidewalk's axis from a quantitative and qualitative focus.

3.1 Horizontal Illuminance (E_h)(Fig. 6)

The mean values obtained for E_h along the measurement axis allow to identify a range of the luminous resource availability, varying between 4,500 and 95,000 lux. The large amplitude of the range is

due to the diverse configurations of the green structures analysed.

The continuous structures that conform a vaulted canyon –Plane trees- allow mean availabilities in the order of 15,500 lux at the causeway center and mean minimums on sidewalks varying between 4,300 and 8,200 lux. While in the green structures that conform screens, i. e. more open vaults interrupted at the center of the causeway (73,000 lux) and varies within a range of 45,000 to 69,000 lux on sidewalks.

In this case the value on sidewalks presents subtle differences from the former scenario due, in one case, to the combined effect of the distance between trees and the presence of windows in the foliage and to the crown's density in the other.

The lesser density of the plane-tree's crown related, to the mulberry obstructs in a lesser measure the access to the resource (Plane-tree permeability: 16.39% - Mulberry: 14.5%) [6].

The discontinuous structures conformed by Ash-trees allow a greater access to the resource both on causeways and sidewalks (94,000-17,000 lux respectively) given the lower level of obstruction due to the specie's geometry (crown's diameter), its condition of individual shape and a greater foliage's permeability (19%).

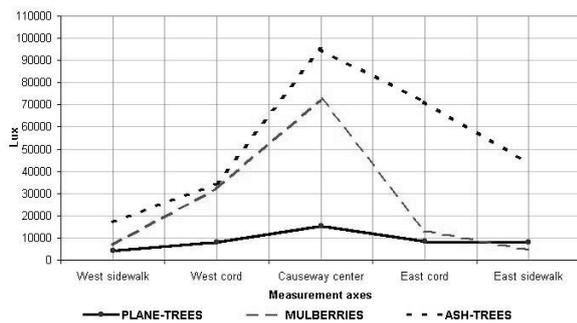


Figure 6: Mean horizontal illuminance values.

In terms of species and their aligned morphology, from the quantitative focus the behaviour of the Plane-tree is similar to that of the Mulberry on sidewalks due to their condition of continuous screen and, at the same configuration of alignment, they are different on the crown's density. On causeways, the Mulberry constitutes an intermediate state, approaching in terms of the resources availability to the behaviour of the canyon conformed by Ash-trees.

From a qualitative viewpoint, the tunnel of Plane-trees offer greater conditions of homogeneity along the longitudinal profile of the canyon: causeways 80% of the measured points is concerted within a range of resource's availability which varies between 1,500 and 10,000 lux. On sidewalks, the quantity of points increases at 95%. This is due, in both cases, to the presence of isolated zones caused by windows or "gaps" inside the crowns, which are placed toward the causeway's center, and to urban voids that expand the public space allowing a greater access to the resource (Fig. 7).

The case of the Mulberries offers greater conditions to solar exposition on causeways: 67% of the measured points is placed in a high illuminance

range (99,000 lux), while on sidewalks the behaviour is more homogeneous, with a low illuminance range (1,400 – 16,000 lux) (Fig. 8). I.e. larger contrasts of sun and shadow between causeways and sidewalks related to the behaviour of the circulation channel conformed by Plane-trees.

On the urban canyon measured with Ash-trees, conditions of full insolation on causeways (106,000 lux) and strong contrasts between points of sun and shadow (2,500 to 93,000 lux) were observed (Fig. 9). They are caused by the incidence on the trees by stretches in their longitudinal development and by specific conditions proper to the species features: asymmetry of crowns due to differential growth and hydric stress made evident by the presence of dry branches that reduce the foliar volume.

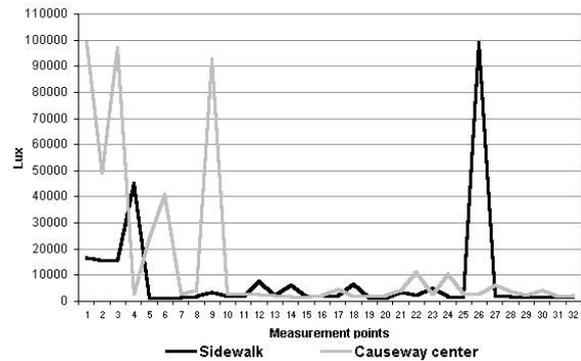


Figure 7: Longitudinal profile of Eh on causeways and sidewalks for Plane-trees.

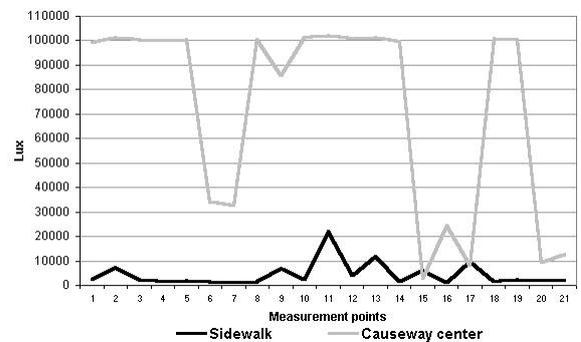


Figure 8: Longitudinal profile of Eh on causeways and sidewalks for Mulberries-trees.

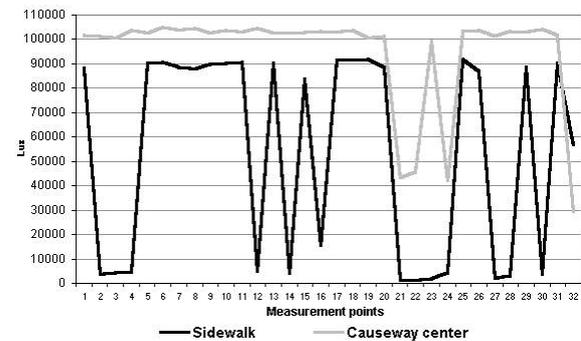


Figure 9: Longitudinal profile of Eh on causeways and sidewalks for Ash-trees.

3.2 Vertical Illuminance (Ev) (Fig. 10)

The vertical illuminance on sidewalks accompanies the behaviour patterns observed when evaluating horizontal illuminance. Even when the availability of the resource on façades is substantially smaller (1,100 – 31,000 lux) it is possible to identify similarities in quantitative and qualitative terms related to the profiles conformed by Plane-trees and Mulberries, and significant differences in the case of Ash-trees.

In the first case the resource's availability is similar for both species (Ev mean: Plane-tree= 2,332 lux; Mulberry= 2,888 lux) resulting from the combined effect of different crown densities and windows in the foliar development of the crown. These windows increase in a pointy fashion the resource availability to maximum values for both cases of 8,200 – 8,400 lux respectively. However in spite of these particular situations, in qualitative terms the condition of homogeneity is dominant over façades.

In the case of the canyon lined-up by Ash trees, where the morphological structure is discontinuous, large luminic contrasts are observed resulting from the minimal vertical illuminances around 2,500 lux and maximum of 31,800 lux. These contrasts reflect façade areas conditioned by the presence of the urban green where the resources main availability is 5,400 lux and areas exposed with mean vertical illuminance of 25,200 lux. These values are supported by the calculation of the standard deviation. Longitudinal profile of Ev on causeways and walkways for (10,500 lux), which confirms the observed contrasts and the large amplitude range of the availability range of the resource.

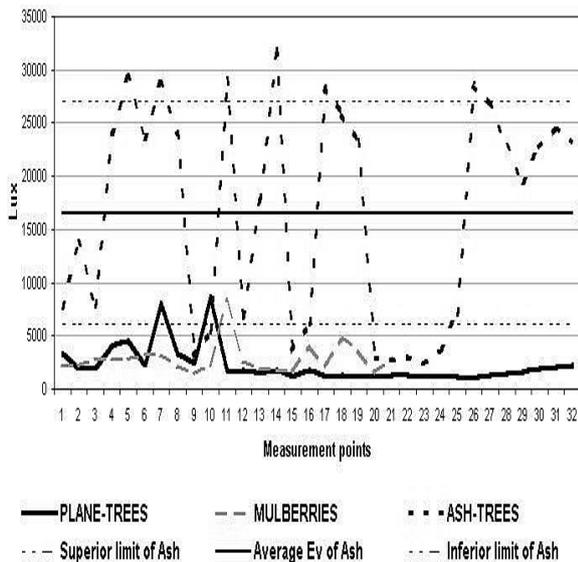


Figure 10: Behaviour of the vertical illuminance (Ev) along the measurement grid for the three species.

4. CONCLUSION

The results obtained demonstrate that the availability of the luminous resource in urban environments is strongly conditioned by the presence of aligned trees in magnitudes that depend on the tree type and the morphological structure resulting from the urban condition.

The continuous structure of the vaulted type – Plane trees- allow in a minimal measure the access to the resource due to that 92% of the grid of measurement points the horizontal illuminance range is low (0-25% Eh at open sky) and only on a 8% of it, the range varies in similar proportions, between 26-50%; 51-75%; 76-100%.

In the more open structures conformed by Mulberries the availability of the resource increases due to a lesser impact of the minimum illuminance range (73%) and to the concentration of the 21% of data in the maximum range (76-100%) given the smaller incidence of trees over causeways

Finally, the discontinuous structures of Ash-trees allow a major access to solar radiation given the balance reached by the illuminance percentages between extreme values of the range: 48% of data between 0-25% of open sky global radiation and 47% of the points between 76-100%, a result of a development of individual profiles (Fig. 11).

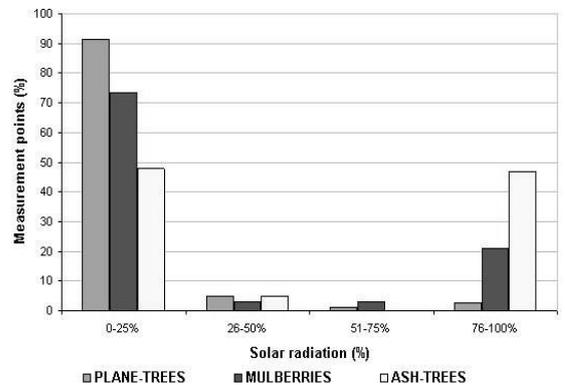


Figure 11: Horizontal Illuminance (Eh) in forested circulation channels.

The discussed values put into evidence that, in qualitative terms, the continuous structures filter the resource in a more homogeneous fashion that the discontinuous ones, in which strong contrasts of isolated and shaded surfaces can be observed.

As to the vertical illuminance, the behaviours are maintained within the framework of a resource availability considerably smaller.

In future stages it is planned to correlate the results obtained with two groups of results: those obtained by computational models to the effect of identifying the contributions of the diffuse and reflected components from the immediate

environment and, the results from nocturnal measurements with the aim of elaborating technical recommendations aimed at optimizing the use of natural and artificial light in vegetated urban environments.

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