Case Study

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Urban trees as sunlight control elements of vertical openings in front façades in sunny climates. Case Study: *Morus alba* on north façade

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Abstract

Benefits of urban trees are evident from the energy and environmental perspective, likewise they reduce glare and control light intensity. Given the hypothesis that trees reduce visible radiation significantly reaching lower level façades, this study is an approach to the analysis of urban forestation as a solar control element. The methodology employed involves measurement of: illuminance – transmittance variation, permeability variation and luminance contrast, by levels along the vertical development of the tree. Vertical illuminance values that exceed 25,000 lx were detected from 5.5 m onwards and values inferior to 3500 lx under that height. Based on the daily analysis of mulberry trees permeability variation in the visible spectrum, it is noted that incident radiation decreases by 90%, with 15% of variability. Natural light analysis must be differentiated by height since daylight scenarios vary accordingly.

Keywords

Daylight, Urban forest, Solar control element, Façade, Visible radiation

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Introduction

Urban trees can provide solar protection to buildings, reducing energy consumption for interior thermal conditioning, due to its shade effect and the phenomena of mass and energy transference to reduce temperature rise (heat island effect) in cities. Likewise, they absorb sound, reduce soil erosion, wind speed and pollution.[1–4]

Although a wide variety of studies analyse the influence of urban forestry in the reduction of solar radiation available indoors,[5–7] there are relatively few studies regarding natural lighting that analyse urban forestry as a solar control element for interior spaces. Urban forestation has the ability to reduce glare; trees help control light scattering, and light intensity as well as they modify the dominant wavelength of their location. Urban trees also block and reflect sunlight and artificial light, thus they diminish ocular tension and frame areas illuminated for architectonic emphasis, security and visibility.[8]

Besides the benefits urban trees can bring in relation to energy savings, the improvement of environmental conditions,[9,10,4] and to the physiological functioning of human beings, there are studies that show people's

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remarkable preference for trees. User preferences studies show that, trees have a considerable significance when choosing a residence, and they could contribute significantly in property value. Their aesthetical attributes are highly considered, among those that make reference to urban trees, followed by shade, the increase of property value and privacy. Scenes with woodlands are categorized as beautiful, interesting, pleasant, stimulating, gratifying, peaceful, warm, clean and relaxing.[11]

Mendoza City (32°52′0″S, 68°49′0″W), located in west central Argentina, presents clear sunny skies 80% of the year, and this is due to the arid climate predominant in the region.[12] Within this context, the urban area of Mendoza City has given an answer different to the traditional compact morphology of desert cities. Based on an urban forest, that modified the natural landscape of the territory, an oasis city model was settled (Figure 1). Within strictness of the city's climate, shade strategy in summer season is embodied by the urban forest that minimizes sun exposure of buildings.[13]

In studies related to the public grove of Mendoza city, performed by the Laboratory of Human Environment and Housing, INCIHUSA-CONICET,[14] the existence of a strong concentration of few tree species is determined. This concentration reaches its maximum in high building density and decreases towards lower densities. Urban woodland consists mainly of deciduous species (loss of foliage in winter), the most representative being the "white mulberry" (*Morus alba*) (38.27%), the "London plane" (*Platanus acerifolia*) (21.52%) and the "European ash" (*Fraxinius excelsior*) (26.3%).[15]

There are many studies addressing the influence exerted by trees, in the solar spectrum range, in urban canyons of Mendoza City.[16] In terms of natural daylight, studies determine that streets located in high density urban areas present a significant reduction of sunlight access.[17] In winter condition, this reduction is due to the characteristics of urban morphology which condition the incidence of natural light. In summer, the decline of radiation is directly linked to the presence of canopy at its maximum leaf development. In this season, urban forest significantly reduces the natural light available as a potential source of luminous energy in interior spaces neighbouring façades (horizontal illuminance is decreased in percentages higher than 85% throughout the day).

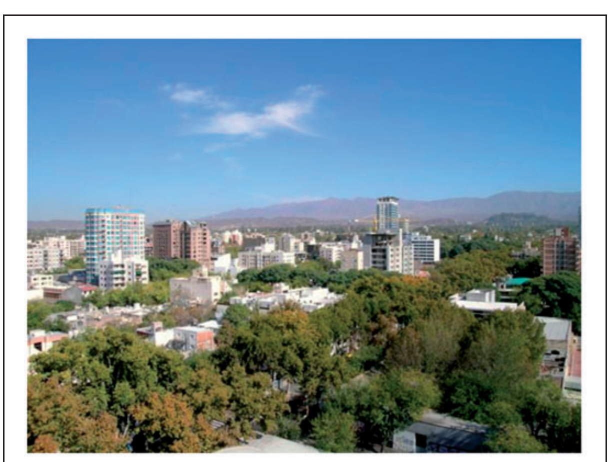

Figure 1. Image of the oasis City of Mendoza.

Furthermore, and in connection to the incidence of light on vertical surfaces, to ensure natural light in indoor spaces, a façade should receive a vertical illuminance of 10,000 lx. Above this threshold, values would give rise to the incorporation of light transport and redirection technologies.[18,19]

Studies were conducted in the city of Mendoza in the summer season,[20] and these determine the availability of vertical illuminance in lower level façade of buildings which should not reach the recommended 10,000 lx in 73% of cases. The mitigating factor is provided by the urban forest, inferring that trees would represent a "solar control element" in indoor spaces lit with side windows.

Benefits of urban trees are evident from the environmental and energy perspective. Likewise, trees could contribute to better conditions for human physiological functioning and present groves spaces that are preferred by urban occupants.

This work is an initial approach to the study of urban trees as solar control elements on lower levels of building façades, in the visible range of the spectrum. With this aim, this article analyses the behaviour of mulberry trees, which is a representative species in the city of Mendoza, with respect to decreased availability of lighting on lower level façades. The study was conducted in summer season, as the trees are at their maximum foliar development, applying various tools to assess natural light.

Case study

The case study was conducted in the Mendoza city which is an oasis city that provides a network of urban forestry to act as a "solar control" on lower level of building façades in high density areas of the town (Figure 2).

Within the plot of the city of Mendoza, a representative urban enclosure was chosen for this case study. The plot is composed of three-storey buildings (Figure 3) with a north facing façade. The urban morphology of the building accords with the restrictions imposed by the Building Code of the City's Zoning and Land Use, [21] and major architectural features include the following:

- Building density: medium
- Street width: 20 m
- Façade orientation: north
- Sidewalk dimension (distance driveway-construction line): 5 m
- Tree distance from the façade: 4 m.

As discussed above, the tree species selected for this study is a *Morus alba* (Figure 4), commonly known as mulberry tree, and this species has a permeability (in the solar spectrum) of 31.4% in summer and 74.1% in winter.[15] In order to select a representative specimen within the urban grove of Mendoza city, the following guidelines were considered, taken from previous studies,[14,22,23] on the state of the trees of Mendoza city:

- Average height: 12.5 m
- Average leaf size: length 14.2 cm, width 9.5 cm
- Average trunk perimeter at 1 m height: 1.30 cm
- Trunk diameter: 0.40 m to 0.50 m
- Development status: good
- Tree canopy width: 10 m average
- Arrangement in the urban enclosure: located at intervals between 6 m and 10 m.

The analysis of the specimen in situ is vital for this type of study since its characteristics can vary strongly according to pruning, car pollution and irrigation.[23]

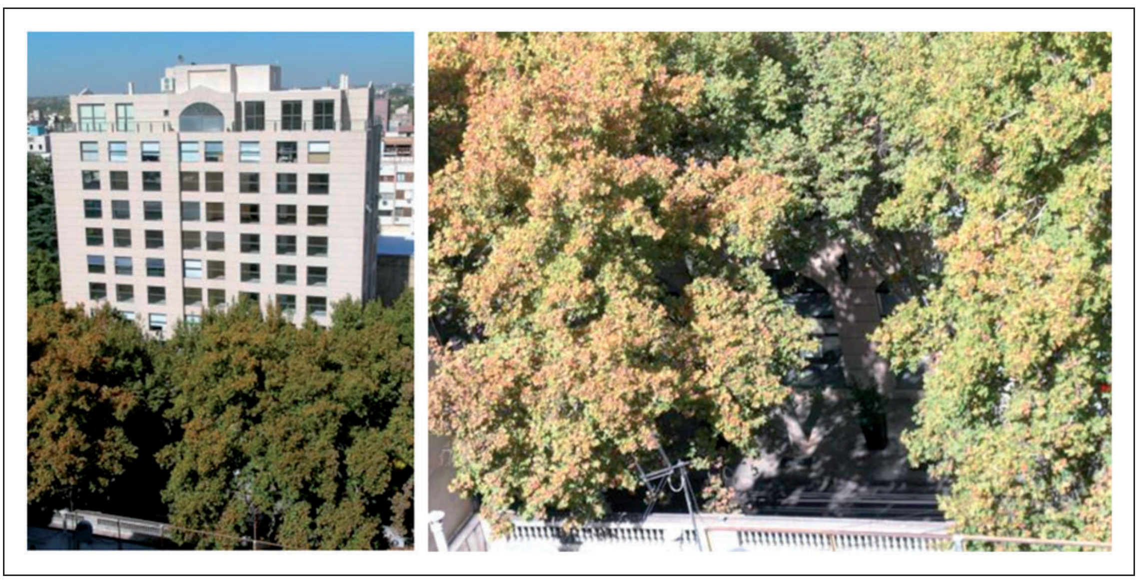

Figure 2. Lower levels receive a clear drop in sun radiation due to the presence of trees. Building of España Square and Montevideo Street, Mendoza city.

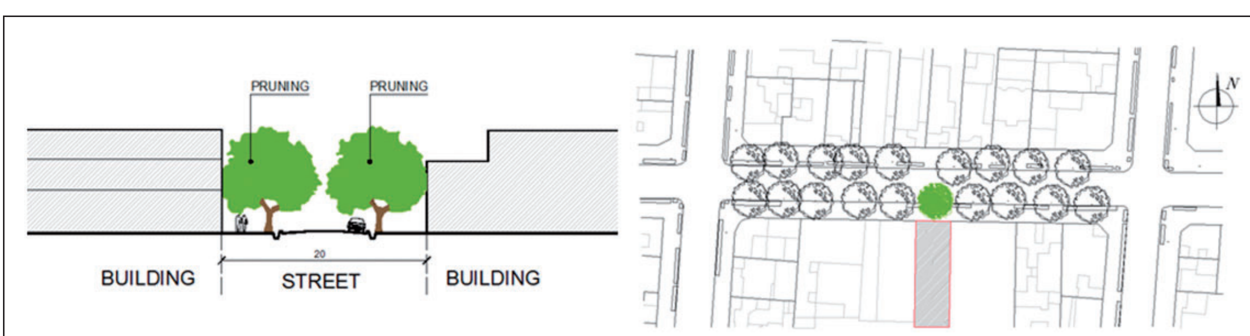

Figure 3. Graphics of the urban enclosure selected for the study.

Figure 4. Images of the selected specimen.

Methodology

Data were collected on 29 November at 13:30 local time (solar midday), and the solar altitude and azimuth on this date and time was 79.30° and 0°, respectively. The sun's position allowed the isolated study of tree's affect, without the interference of the urban volumetry. Also, at this time, the tree specimen presents its complete foliar development and, therefore, its maximum expression as solar control element. This condition is important due to the close relation between the availability of natural lighting and the morphological characteristics of the urban enclosure, depending on the season. Only the summer season was examined, and this was because the mulberry is a deciduous species; thus the absence of foliage in autumn and winter season enabled full investigation of the effects. Previous studies regarding daylight permeability of mulberry in winter, concluded that this tree does not behave as a solar control element in this season, and the morphology of buildings could act as barriers of visible radiation during this season.[16] While in spring the tree would behave like in summer, due to its brief period of phenological development of 15 days,[23] thus presenting similar conditions, regarding foliage, over a period of approximately 170 days.

Measurements were taken on the southern façade (northern visual), as the southern hemisphere would receive the highest annual sun radiation, thus closely reproducing the complete visible spectrum, as well as respecting the seasonal variations.[24]

The methodology employed was divided into three stages:

1. determination of illuminance – transmittance variation along the vertical development of the tree;
2. determination of the permeability variation, by level, along the vertical development of the tree;
3. determination of luminance contrast for each level.

Vertical illuminance measurements as well as images were taken at a 1.5 m distance from the façade line, because the elevator platform could not be located more closely to the façade. For this study, height of the building façade was divided into three ranges, ground floor (0–3 m), first floor (3–6 m) and second floor (6–9 m).

Based on the results achieved by applying the methodology explained above, a more detailed analysis of façade access to visible radiation was performed at 5 m.

Determination of illuminance – transmittance variation, on vertical front façades, along the vertical development of the tree

In order to register vertical illuminance along the façade, a light-meter (545 testo, according to EMC Directive 2004/108/ guidelines[25]) with cosine correction and lambda V filter was placed on the front part of the elevator platform in a vertical position. Through the vertical trajectory of the elevator platform, measurements were taken at every 0.25 m. This stage of analysis allowed determining the variation of the availability of natural lighting along the vertical development of the tree (Figure 5). Under the same conditions, adjusting the sensors position,

Figure 5. Images of data collection and photographs capture.

horizontal illuminance records were conducted for each point. Global vertical illuminance values (without obstruction) were also registered, in order to calculate transmittance (dimensionless) at different heights.

Determination of permeability variation, per level, along the vertical development of the tree

So as to determine the permeability of the tree under study at different heights, digital images were taken with a Nikon Coolpix 5400 camera with Nikon FC-E9 fisheye lens. Images were later processed with Gap Light Analysis software,[26] developed by the Institute of Ecosystem Studies of the Simon Fraser University, Burnaby, British Columbia, Canada. This imaging software analyses canopy structure and gap light transmission indices from true-colour fisheye photographs.

Luminance contrasts assay for each level

So as to determine illuminance contrast of the scene, images of low dynamic range were taken and then processed with Photosphere software,[27] in order to obtain images of high dynamic range.[28] These images were calibrated according to illuminance measurements taken *in situ* with a Minolta LS110 luminance meter (1/3° angle of measurement and measurement range of 0.01 to 999.900 cd/m^2). Through these images, luminance contrast for each of the scenarios can be known and the adjustment revised according to the thresholds established in IRAM AADL J 2005 national regulations.[29] Images were taken outside at façade level, in order to determine the outdoor illuminance contrast.

Sky conditions for the day of measurement were corroborated with global and diffuse horizontal illuminance data from the Measurement Station INCIHUSA CCT-CONICET Mendoza[30] (belonging to the International Network of Natural Lighting Measurement Stations IDMP) (Figure 6).

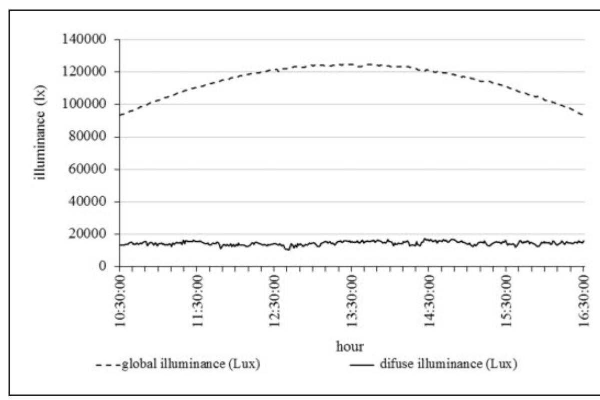

Figure 6. Data of the sky condition for the day of measurement: global and diffuse illuminance (lx) per hour.

Results

Vertical illuminance – transmittance variation, on front façade, along the tree's vertical development

Based on the analysis of registered vertical illuminance data, two situations markedly different were identified in terms of façade daylight access along the tree's vertical development. On one hand, values exceeded 25,000 lx (vertical illuminance) from 5.5 m onwards and, on the other hand, values were less than 3500 lx under that height. In lower levels, canopy blocks access to direct sun radiation, which causes a decrease in vertical illuminance of 23,400 lx, within 25 cm (Figure 7).

This steep variation in illuminance value was due to the high location of the sun (80° altitude), at the date and time of measurement, surpassing the "tree" obstacle at the superior level (Figure 8).

Variation coefficient (VC) was determined based on standard deviation (σ) and mean (μ) values for each of the levels; this determined the relative dispersion of illuminance values for each scenario (Table 1). First, the general variation among the three levels was calculated, the VC observed was high (1.62), showing that illuminance dispersion along the façade was elevated. This proves that each level must be analysed individually, and no overall generalizations can be made. Second level VC was almost insignificant, suggesting a high uniformity of vertical illuminance values (above 25,000 lx). First floor VC (1.65) was the highest, even higher than general VC. This is because, at this height, transition between direct and diffuse sunlight takes place. At the first floor level, mulberry tree would begin to work as a solar control element. Finally, the VC at the ground floor was 0.09, showing low variation (9%) of illuminance values.

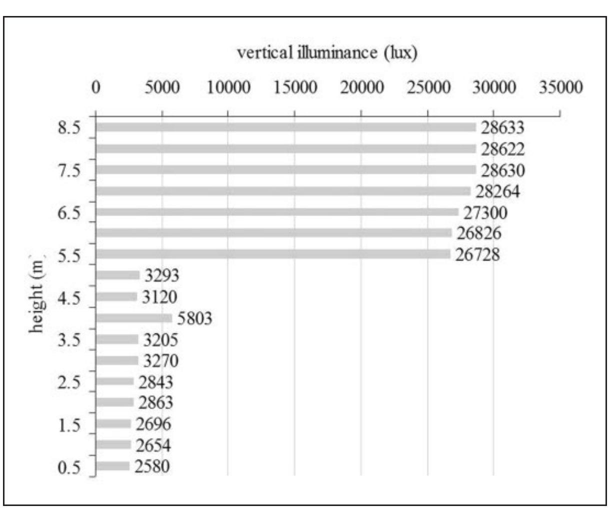

Figure 7. Levels of vertical illuminance detected along the tree's vertical development over façade.

Note that for higher points (from 5.5 m to 8.5 m), mulberry tree transmittance was close to 1 (Figure 9), showing that for these heights the tree canopy was not working as a sun control system, at high summer solar altitudes. However, the average transmittance for heights inferior to 5.5 m was observed as 0.1, 89% of the incident sun light would be absorbed or reflected by the canopy, and thus for heights below 5 m, forestry would behave as a solar control element.

Determination of permeability variation, per level, along the vertical development of the tree

Image processing with GLA software determines the percentages of vertical gap light area (Table 2). From

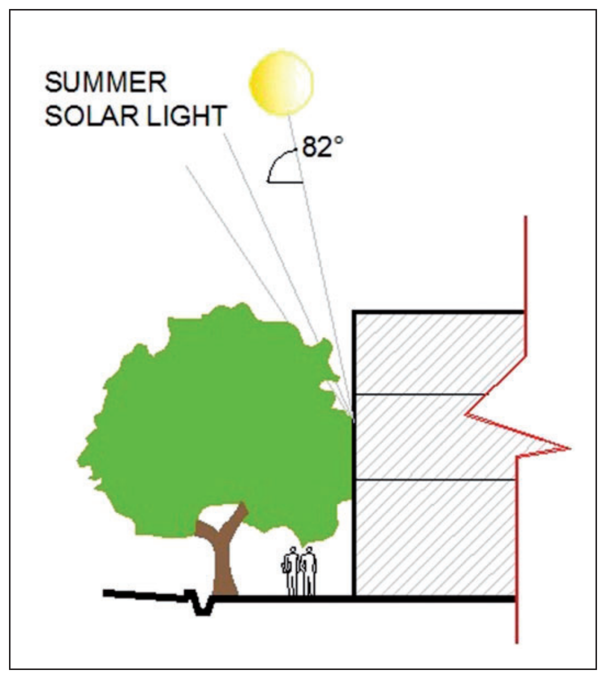

Figure 8. Sketch of sun altitude for the time of measurement and its corresponding variation for previous and later times (dotted line).

Table 1. Illuminance variation coefficient.

	VC
General	1.62
Second floor	0.02
First floor	1.65
Ground floor	0.09

the processed images, the sky-canopy ratio for each of the scenarios was observed (Table 2). Ground floor and first floor presented similar percentages of gap light transmission (about 8%). Second floor gap light transmission was much more significant (41%) due to the existence of a gap area close to 50% of the image, which did not present any obstacles. This analysis corresponds to a high degree of congruence with the illuminance and transmittance values obtained.

Luminance contrast evaluation for each level

Luminance contrast was determined for each level from the luminance values detected in the HDR images (Figure 10(a) to (c)). Images were captured from the same point illuminance were measured.

Detected luminance contrasts do not respond to the established national regulations in any level (Table 3). The most critical situation was located on the first floor. This was due to the fact that, though most parts of the scene present luminance levels below 3900 cd/m^2, the presence of a reduced sector of sunspot (41,200 cd/m^2) greatly changed the luminance contrast, this being a challenge for the visual system. On the highest level, luminance contrast was lower than in the other two scenarios, and this was due to the non-existence of solar control. The adjustments respecting IRAM AADL J20 05 national regulations[27] were verified according to the luminance contrast between visual task and any point of the environment (40:1). Contrast ratios obtained were inappropriate when compared with recommended contrasts in standards for indoor spaces; therefore, more specific studies are necessary to evaluate contrasts in outdoor spaces.[16,18]

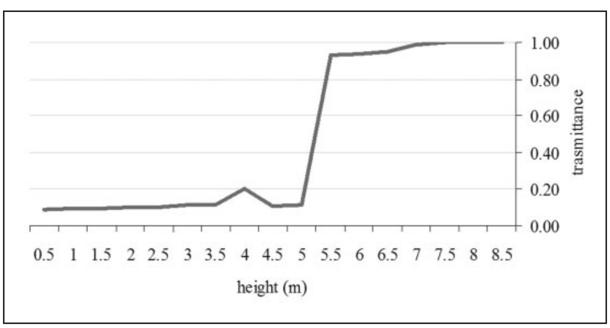

Figure 9. Graphic of the variation of transmittance according to height of measurement.

Moreover, there are studies that analyse visual comfort for outdoor tasks,[31,32] based on other photometric parameters. According to exterior horizontal illuminance values, the following ranges of comfort are proposed: *very comfortable* (up to 8000 lx), *comfortable* (8000–43,000 lx), *uncomfortable* (43,000–80,000 lx) and *very uncomfortable* above 80,000 lx. [31] The case study presented, according to these ranges, has a *very comfortable* visual environment due to the shadow cast by mulberry below 5.5 m. Conversely, above this height, the exterior visual environment would become very uncomfortable attributable to the impact of direct visible radiation (Figure 11).

Variation of vertical illuminance at 5 m height throughout a day

Based on the previous analysis performed in this study, it is detected that mulberry tree canopy would behave as a solar control element on façade beneath 5 m height, for the case under consideration. Proceeding from this and, since this study focuses on mulberry trees as a solar control element on lower level façades, an analysis of vertical illuminance on the façade for the whole day was performed, from 10:30 until 16:30 on 21 December

Table 2. Percentages of gap light area and image of gap light area, per level (GLA).

	Ground floor (0–3 m)	First floor (3–6 m)	Second floor (6–9 m)
Percentage of gap light	8.46	7.96	41.23
Image of gap light			

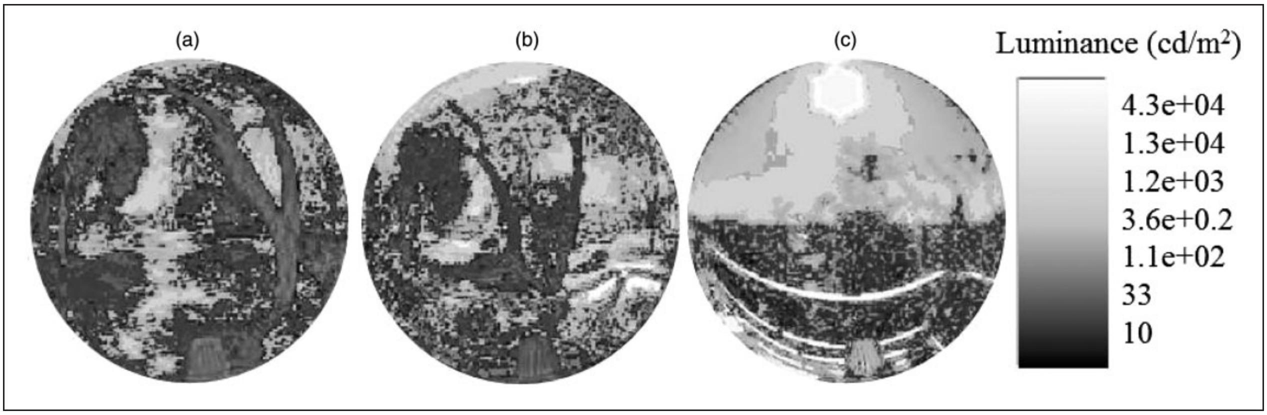

Figure 10. HDR images from (a) ground, (b) first and (c) second floor. The scale is in cd/m^2 (Ward 2009).

Table 3. Maximum and medium luminance and contrast of luminance values for each level.

Luminance	Maximun (cd/m^2)	Medium (cd/m^2)	Luminance contrast
Ground floor	6160	110	56:1
First floor	41200	410	101:1
Second floor	42000	1000	42:1

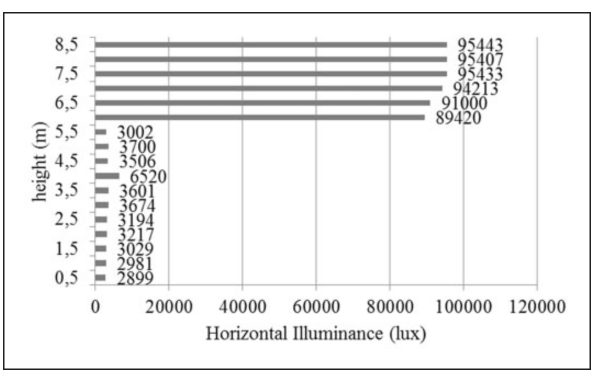

Figure 11. Levels of horizontal illuminance detected along the tree's vertical development over façade.

(solar altitude: 81°), which corresponds to the summer solstice and the highest solar altitude.

Vertical illuminance measurements were carried out over an eight point grid (50 cm diameter), with a radiometer ILT 1700 multiplexer A415 with an eight channel selector for multiple detector input (SCD110 International Light), at first floor façade level (5 m) (Figure 12(a)).

Vertical illuminance values at façade level, for the study case, oscillate between 1440 lx and 3360 lx (Figure 12(b)), the maximum occurred at solar midday and the minimum at the hours when the solar altitude is lower. In this case, the study mulberry tree has reduced the global daily vertical illuminance, between 57,000 lx and 19,000 lx, in a significant way (average permeability 10%) (Figure 13(a)). Permeability was highest (18% between 12:00 and 15:00 hours (higher solar altitudes) and lowest (4%) in the early hours of the morning and late in the afternoon (lower solar altitudes) (Figure 13(b)).

Discussion

Results show that for north-facing buildings located in oasis cities, forested with white mulberry, second floor (6 m to 9 m), would present a transmittance close to 1, high values of vertical illuminance (over 25,000 lx), a percentage of gap light over 40% and a luminance contrast of 42:1, slightly above the value set by national regulations. Although the luminance contrast would present the lowest values of the three scenarios, this was due to the nonexistence of elements blocking the way of visible sun radiation. However, according to visual comfort ranges established through horizontal illuminance values, this scenario would be *very uncomfortable*, due to the high illuminance (over 80,000 lx) caused by the presence of direct sunlight. Furthermore, high illuminance values registered would require intensive sun protection. The previous considerations added to the proposed illuminance threshold would require the application of a natural lighting strategy (10,000 lx) to show that retro-reflection strategies for the second floor could be employed.[33] This would ensure the redistribution of the elevated light flux on the entire interior space adjoining the front façade of the building, avoiding the presence of the sunspot on the visual field.

Although the situation at the highest stage seems easy to solve, what daylight strategy could be applied

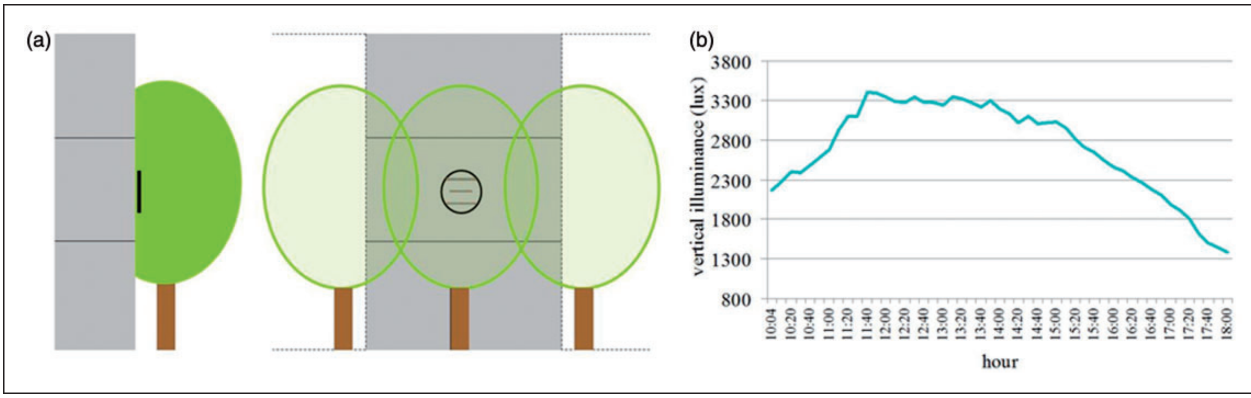

Figure 12. (a) Vertical illuminance at 5 m height throughout a day. Illuminance sensors located on the measurement grid. (b) Graphic of vertical illuminance values over façade on forested street registering each one of the eight sensors in a range from 10:00 to 18:00 h.

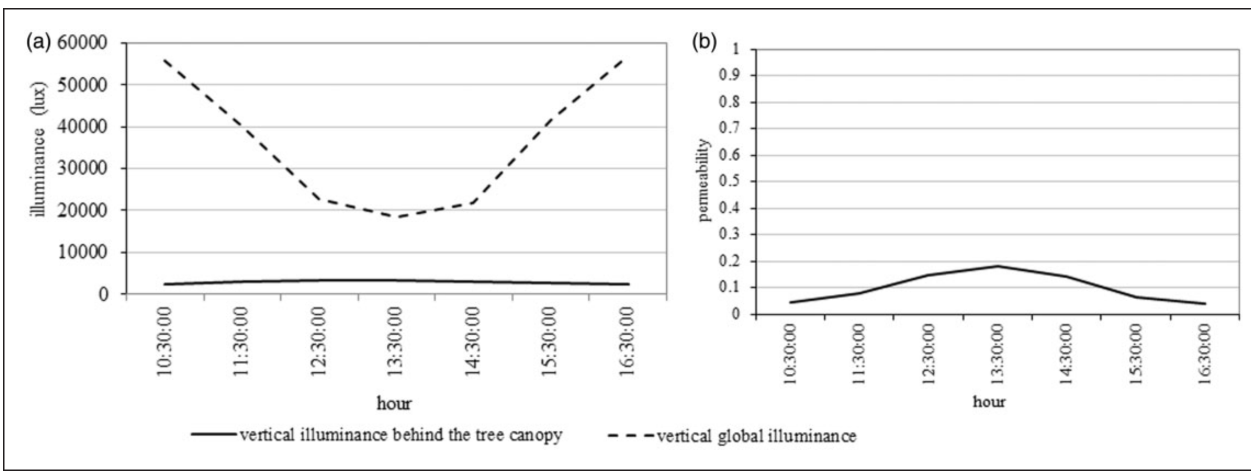

Figure 13. (a) Graph of vertical illuminance values behind the forest and global vertical illuminance values, from 10:30 to 16:30 h. (b) Graph of mulberry trees permeability variation, from 10:30 to 16:30 h.

on the first floor for this case study? Luminance contrast results (101:1) show side by side areas of shadow–sunspots in the scenario under study and this could cause discomfort to users. This was also detected at the high variation (3000–89,000 lx) of horizontal illuminance values. In order to diminish the luminance differences, a diffusion strategy could be employed; however, it must be considered that this can turn the window into a source of glare. This scenario could also lead to asking whether the luminance contrast technique could sufficiently represent the visual comfort or discomfort of occupants.

When analysing the lighting panorama presented on the ground floor, the vertical illuminance values (below 3000 lx) were much lower than those necessary to apply an additional strategy of sun control, with luminance contrast (56:1) significantly lower than the one on the first floor, but still were higher than the established as acceptable given by the national standards. However, analysis of visual comfort for outdoor tasks based on horizontal illuminance indicates that this scenario would lie in the comfort zone, due to the diffuse light produced by tree shading effect. This being the lighting situation, this would thus infer that the sun control element in summer is necessary. Although no solar control is needed in summer because of the tree, there could still be a need for solar control to avoid glare from the lower winter sun through the bare tree.

In previous studies, 40% of the non-residential buildings of Mendoza city present large windows at ground floor level, which are used as showcases for exhibition of objects and not as workspaces.[34] This reaffirms what many authors, among them

Boyce,[35] ascribe each space adjacent to the façade to present adequate lighting to their visual task.

Results obtained in the overall analysis show that beneath 5 m height, the mulberry tree would act as a solar control system on façade openings in visible spectrum, illustrating the mulberry tree behaviour during a day. Based on the daily analysis of permeability variation (visible spectrum) of the tree, the incident radiation would decrease by 90%, with 15% of variability in this value during the measurement session (10:00 to 16:00 h). The previous analysis revealed that, for this height, the tree could act as a dimmer of the wide range of variation of vertical solar radiation throughout the day, resulting in more homogeneous conditions of radiation availability.

Conclusion

This paper has presented the findings of an assessment of luminous performance of urban trees in sunny climates, through the application of various methods and tools, which analyse the mulberry tree as a solar control system on façades in the visible spectrum. This initial study focused on the Morus alba, as this is the predominant species of mulberry tree in the oasis city of Mendoza. From the study, the natural light analysis must be differentiated by height since daylight scenarios could vary significantly accordingly.

Based on the results obtained in this analysis, "*Morus alba*" would behave as a solar control system at lower levels of the façade. Thus in cities with the presence of urban trees, when planning daylight of interior spaces of lower levels, architects must consider the attenuation of solar radiation on façade generated by trees. Therefore, it is of great importance to study trees as solar control systems, using a wide range of tools for its correct evaluation.

Finally, further study is needed to highlight the need to replicate the study on other façades in similar contexts (mulberry, 20 m street width, north orientation) to obtain a pattern of behaviour of this species on façades for natural lighting. There is also a need to determine the solar control behaviour presented by the other two predominant species in the urban environment of Mendoza city, "European ash" and "London plane".

Authors' contribution

All authors contributed equally in the preparation of this manuscript.

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References

1. Mc Pherson EG. Functions of buffer plantings in urban environments. *Agri Ecosyst Environ* 1988; 22/23: 281–298.
2. Nowak DJ. Air pollution removal by Chicago's urban forest. In: McPherson EG, Nowak DJ and Rowntree RA (eds) *Chicago's urban forest ecosystem: results of the chicago urban forest climate project*. USDA Forest Service General Technical Report NE-186. 1994, pp.63–81.
3. Santamouris M and Asimakopoulos DN. *Energy and climate in the urban built environment*. London: James & James, 2001.
4. Correa EN, Ruiz MA and Cantón MA. Morfología forestal y confort térmico en "ciudades oasis" de zonas áridas. *Ambiente construido* 2010; 10: 119–119.
5. Brown RD and Gillespie TJ. *Microclimate landscape design*. New York: Wiley, 1995.
6. Rosenfeld A, Akbari H, Romm J and Pomerantz M. Cool communities: strategies for heat island mitigation and smog reduction. *Energy Build* 1998; 28: 51–62.
7. Von Stulpnagel A, Horbert M and Sukopp H. The importance of vegetation for the urban climate. In: Herbert S and Hejny (eds) *Urban ecology: plants and plant communities in urban environments*. The Hague, the Netherlands: SPB Academic Publishing, 1990, pp.175–193.
8. Coder RD. *Identified benefits of community trees and forests*. Athens, Georgia: University of Georgia, 1996.
9. Sudo Gand Ochoa JM. *Spazi verdi urbani. La vegetazione come strumento di progetto per il comfort ambientale negli spazi abitati*. Napoli: Sistemi Editoriali, 2003.
10. Ruiz MA and Correa EN. Confort térmico en espacios abiertos. Comparación de modelos y su aplicabilidad en ciudades de zonas áridas. *Avances en Energías Renovables y Medio Ambiente* 2009; 13: 01.71–01.78.
11. Getz DA, Karow A and Kielbaso JJ. Inner city preferences for trees and urban forestry programs. *J Arboricultura* 1982; 8: 258–263.
12. Fuerza Aérea Argentina. Servicio Meteorológico Nacional. *Estadísticas Climatológicas 1981–1990*. Serie B- N°37. 1992. Argentina.
13. Correa EN, Martínez CF and Cantón MA. Influencia del uso de distintas magnitudes forestales sobre el comportamiento térmico de los cañones urbanos: el caso de la primera magnitud en ciudades de zonas áridas. *Avances en Energías Renovables y Medio Ambiente* 2008; 12: 155–162.
14. Cantón MA and Martinez CF. Sustentabilidad del bosque urbano en zonasáridas. Análisis y Diagnóstico de la condición de las arboledas en Mendoza – Argentina. In: *PARJAP 6° Congreso Iberoamericano de Parques y Jardines Públicos*. Póvoa de Lanoso, Portugal, 2009.
15. Cantón MA, Mesa A, Cortegoso JL and de Rosa C. Assessing the solar resource in forested urban environments: results from the use of a photographic-computational method. *Architect Sci Rev* 2003; 46: 115–123.
16. Cantón MA, Cortegoso JL and de Rosa C. Solar permeability of urban trees in cities of western Argentina. *Energy Build* 1994; 20: 219–230.
17. CóricaL. *Comportamiento de la Luz Natural en Entornos Urbanos Representativos del Modelo Oasis en Regiones Áridas. Caso de Estudio: Ciudad de Mendoza*. PhD Thesis, Universidad Nacional de Tucumán, San Miguel de Tucumán, 2009.

18. Compagnon R. Solar and daylight availability in the urban fabric. *Energy Build* 2004; 36: 321–328.
19. Tregenza P. Mean daylight illuminance in rooms facing sunlit streets. *Build Environ* 1995; 30: 83–89.
20. Córica L and Pattini A. Study of the potential of natural light in low and high density urban environment in the oasis city of Mendoza, in summer. *J Light Visual Environ* 2009; 33: 101–106.
21. Código Urbano y de Edificación (Indicadores Urbanos). Ordenanza 3788/10, Municipalidad de Mendoza, 2010, Mendoza, Argentina.
22. Martínez CF, Bastías L, Endrizzi M, Córica L, Pattini A and Cantón A. Influencia de las morfologías arbóreas en las condiciones de iluminación en recintos urbanos del área metropolitana de Mendoza. *Avances en Energías Renovables y Medio Ambiente* 2006; 10(1): 7–13.
23. Martínez CF. *Incidencia del déficit hídrico en forestales de ciudades oasis: caso del Área Metropolitana de Mendoza, Argentina*. PhD Thesis, Programa de Posgrado en Biología PROBIOL, Universidad Nacional de Cuyo. Mendoza, Argentina, 2011.
24. Pattini A, Córica L, Correa E, Martínez CF and Cantón MA. Propiedades ópticas del arbolado urbano en el cálculo de la iluminación natural. El caso de la estación otoño en plátanos y moreras. *Avances en Energías Renovables y Medio Ambiente* 2010; 14(5): 113–118.
25. Guide for the EMC (Electro Magnetic Compability) Directive 2004/108/EC, http://ec.europa.eu/enterprise/sectors/electrical/files/emc_guide__updated_20100208_v3_en.pdf (2010, accessed 20 June 2014).
26. Gap Light Analizer V. 2.0. Simon Fraser University, Institute of Ecosystem Studies, 1999. Canadá.
27. Ward G. Photosphere 1.8.4 OS Mac, http://www.anyhere.com/ (2009, accessed 20 June 2014).
28. Reinhart CF, Mardaljevic J and Rogers Z. Dynamic daylight performance metrics for sustainable building design. *Leukos* 2006; 3(1): 1–25.
29. Instituto Argentino de Normalización y Certificación. (1973). Asociación Argentina de Luminotecnia. IRAM-AADL J20-05: Iluminación Artificial en interiores. *Características*. Bahia Blanca, Argentina, 1973.
30. Measurement Station INCIHUSA CCT-CONICET Mendoza International Network of Natural Lighting Measurement Stations IDMP, http://www.cricyt.edu.ar/lahv/atm/ (2002, accessed 20 June 2014).
31. Yilmaz H, Demircioglu Yildiz N and Yilmaz S. Effects of snow-reflected light levels on human visual comfort. *Environ Monit Assess* 2008; 144: 367–375.
32. Córica L and Pattini A. Estudio del confort visual en recintos urbanos de climas soleados. In: *Anais 2013 XII Encontro Nacional de Conforto no Ambiente Construído- VII Encontro Latino Americano de Conforto no Ambiente Construído*. ENCAC ELACAC 2013. Ciudad de Brasilia, Brasil, 25–27 September 2013, pp.1875–1883.
33. Köster H. *Dynamic Daylighting Architecture: Basics, Systems, Projects*. Basel: Birkhäuser, 2004.
34. Villalba A and Pattini A. Análisis morfológico de componentes de paso y elementos de control de luz solar en envolvente edilicia no residencial en climas soleados. El caso de la ciudad de Mendoza. *Avances en Energías Renovables y Ambiente* 2010; 14(1): 65–72.
35. Boyce P, Hunter C and Owen H. *The Benefits of Daylight through Windows*. Lighting Research Center, Rensselaer Polytechnic Institute Troy, New Cork, 2003.