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An approach to urban tree daylight permeability simulation using models based on louvers

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In oasis cities urban forestation shades the lower level facades of buildings. It is thus crucial to analyze the distributional patterns of sun radiation produced by trees on facades. Nevertheless, the complexity of the canopies requires simplified representations for its study through simulation techniques. On the assumption that lighting behavior of trees, as sun control elements, more closely resembles a louver system rather than other frequently used solar control systems (e.g. perforated obstruction), the present study seeks to verify which of these formal simplifications adjusts better to the real case. The methodology used in this study relies on raytrace simulation of solar control system models generated with hemispherical images. Comparisons are made between measured data of vertical illuminance (lux) in situ and those obtained through simulation for each of the models. Louvers model showed a high degree of adjustment (RMSE 9%). This study may be useful to streamline the analysis of urban trees impact in daylight availability on building facades through simulation.

1. Introduction

Urban forestation can bring solar protection to buildings, reducing energy consumption for interior thermal conditioning due to its shade affect and the phenomena of mass and energy transference that produces the diminishing of temperature in cities. Besides, urban trees reduce erosion, control wind speed and mitigate pollution [1–4].

Added to the benefits related to energy saving, the improvement of environmental conditions and the thermal habitability of space [5,4], there are studies that show the remarkable predilection of people for trees. Getz [6] explains in his works of preference that urban trees have a considerable relevance for people when choosing a residence, and informs that trees contribute significantly in the value of the property due to their aesthetical attributes, comfort associated with attenuation of solar radiation and the increase of privacy [7].

Although, a wide variety of studies examine the impact of urban forestry as a reducer of solar radiation available indoors [8–10], regarding daylighting there are relatively few studies that analyze urban trees as sun control elements for interior spaces. Coder [11], explains the ability of urban forestation for reducing glare; he states that, trees help to control light dispersion and light intensity as well as modifying the predominant wavelengths of their location. He also states that they block and reflect sun light and artificial light, thus diminishing ocular tension, and frame areas lit for architectonic emphasis, security and visibility [11].

These benefits are characteristic in the denominated "oasis cities" -wide streets and intense forestation- for the urban development of arid areas. This is the case of Mendoza city, where the urban forestation is one of the most prominent features of the landscape, wherein the ratio tree-inhabitant is 1:1 [14] (Fig. 1). In the city of Mendoza urban forestry is mainly composed by four species: white mulberry (*Morus alba*), London plane (*Platanus acerifolia*), European ash (*Fraxinius excelsior*) and China berry tree (*Melia azedarach*) [12].

Mendoza city presents semi-arid climate, in this context it is important to use shadow as a strategy to decrease solar radiation, without it, it is impossible to achieve a visually comfortable habitat.

In Mendoza city, the shading strategy is carried out by inserting a vegetable plot that minimizes sun exposure of the metropolitan area [13]. There are detailed studies developed in the city of

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Fig. 1. Features of study city.

Mendoza which determine the shading affect exerted by urban trees in horizontal surfaces of streets [12].

Regarding the availability of natural lighting in urban areas of the city of Mendoza, Córica [14] claims that: in the oasis city models access to the global availability of visible solar radiation depends on the built environment during winter and on the presence of trees in summer. Availability of solar radiation in summer is directly related to the sky view factor. In the oasis cities, the SVF is very much affected by the presence of afforestation, that is to say, that natural light conditions of urban canyons, in summer, mainly depend on arboreal morphology [14]. It also states that on south sidewalks (north visual) of 20 m wide roads forested with *M. alba* in urban high density areas of Mendoza city (case study of this work), horizontal illuminance is decreased on average 85% throughout the day in summer (maximum leaf development of trees). In summer the availability of vertical illuminance in lower level facades does not reach 10,000 lx in over 70% of the cases [14]. In order to use a solar control or a retro-reflection system on facades, a vertical illuminance of 10,000 lx is required [15]. Thus, it is concluded that, in summer, trees are a "solar control element" for interior spaces illuminated with side windows.

Due to the mentioned effects, urban forestry needs to be analyzed as an environmental item.

Light passing through trees is difficult to simulate [16]. Most lighting and building energy simulation tools assume no exterior obstructions, but it is unlikely to find actual buildings without exterior obstructions, which typically are adjacent buildings and trees. This affects the amount of indoor daylight provided as well as solar heat gain. Therefore, it is very important to take into account all exterior obstructions in lighting and building energy simulation tools [17]. In oasis cities urban forest shades the lower level facades of buildings in summer [14], it is thus crucial to analyze systematically the distributional patterns of visible solar radiation produced by trees on facades. Furthermore the development of predictive simulation models to be used in the study of interior spaces, so as to achieve energy efficiency and visual comfort, is of primary importance.

In particular, for those approaches in which the use of simulation tools is required, the geometrical and optical representation

Table 1
Classification of solar control systems and optical phenomena that they involve.

Textil courtain	Screen panel	Louvers	**Mulberry tree**
Difuse transmitance	Obstruction Direct transmitance	Reflection-redirección	**Obstruction** **Difuse transmitance** **Direct transmitance** **Reflection-redirección**