The Impact of the Tree in the Patio on the building microclimate and the indoor thermal environment, Case of Study south of ALGERIA

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Abstract:
The purpose of this study was to investigate the effects of building microclimate on the indoor thermal environment of traditional houses in the south of Algeria, focusing especially on the shading effect of the Palm tree in the patios. The indoor thermal environment was found to follow the outdoor conditions due to the open-plan and, eco-friendly material which has a high thermal mass. Moreover, air temperatures of the living rooms in the two case study houses were lower than the corresponding outdoor ones by approximately 3°C and 10°C, respectively. It was found that the semi-outdoor spaces acted as thermal buffers for promoting cross-ventilation as well as pre-cooling to provide “warm but breezy” conditions to the surrounding indoor spaces. The results showed that the surface temperature of semi-outdoor spaces can be reduced by shading, among which shading has prolonged effects and can reduce the surface temperature during peak hours and the following night.

Keywords: Ghardaia, Patios, Trees, indoor cooling, thermal comfort

1 Introduction:

Ghardaia is located in the centre of the northern part of the Algerian desert. It is situated 600 km south of the capital Algiers at latitude 32° North and longitude 2°30’ East. The climate of the Ghardaia city is a hot desert climate characterised by summers with torrid heat reaching 50°C and soft winters with the average minimum just above freezing point. Relative humidity is very low except for the winter months where 60% is common (Tidourt, Mayer,2005). Precipitation is low and less than 25 mm/month throughout the year. The thermal comfort zone (TCZ) for the hot and arid climate of Algeria is according to ASHRAE 55-2015 standards 18°C < T < 30°C . Figure 1 presents the average yearly sum of global horizontal irradiation covering a period of 16 years.

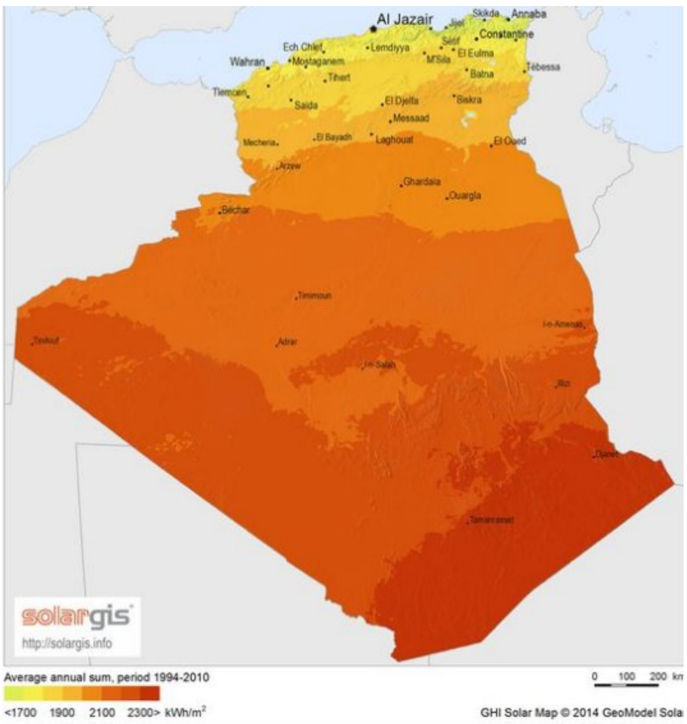

Figure 1. Total annual Irradiance, (1994-2010), kWh/m^2
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In the hot dry climate of Ghardaia, a vernacular building design can be used as a starting point to realise how the environmental stresses and climatic hazards influence the architectural elements of the home and how the buildings can be more responsive. However, in Algeria building regulations did not consider the climatic design issue that conditions should follow. There is also a lack of knowledge between the authority, architects, contractors, and residents to improve indoor thermal performance (Djenane, 1998). Accordingly, the key objective of this study is to consider the influence of climate on the architectural elements and to determine passive strategies that can produce comfortable indoor spaces to enhance people's living standards and future well-being. In brief, the field studies identified these facts which then led to the use of building thermal simulation that focused on how the internal performance of buildings can be enhanced for comfortable living and for providing good satisfaction by passive cooling techniques. Ghardaia was selected because it has traditional, eco-friendly and new concrete-based houses (Nikolopoulou et al, 2001).

This research aimed to investigate the thermal performances of two traditional houses considering the effect of the palm tree in the patio, with contemporary designs, on the indoor temperature of the surrounding rooms in the context of the summer season. Another objective was to assess if these houses required any improvements to be made as a good model for future construction in Algerian desert cities.

2 Research methodology:

To understand the impact of the tree in the patio and the thermal performances of the various houses of the Ksour (settlements built on rocky mountain peaks; see Figure 2), which overhang the valley, the methods undertaken in this study were the buildings' measurement survey and the climatic data monitoring. The building survey was pertinent to this study to get similar physical and climatic parameters for consistency of the collected data and results, at the same time and the same location. Two houses were selected due to their differing house types (designated H1 and H2) as required for this study and from the same location. The first is H1 without a palm tree inside the patio; the second a typical H2 (same location) with a palm tree inside the patio. The two houses were selected, and physical measurements were taken and drawn on ArchiCAD and VI-SUITE. The environmental parameters used for the analysis were indoor air temperature, relative humidity and the outdoor air temperature. The readings were taken during the summer from 6-14th August 2018. Measuring instruments and devices included Onset Hobo data loggers to measure

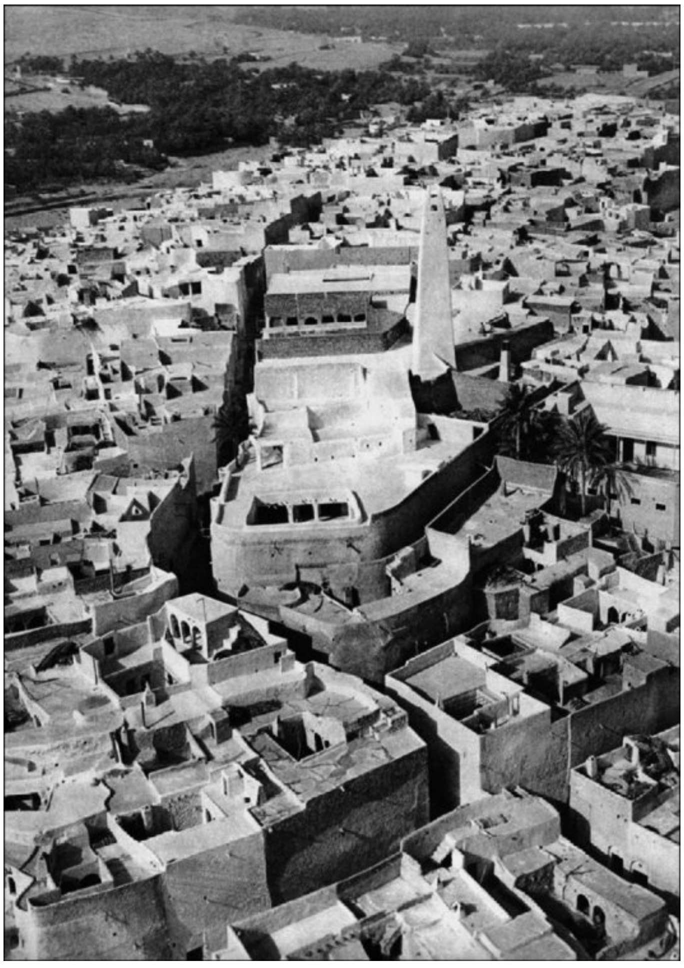

Figure 2. A view of the compact urban fabric of the upper part of the old city of Beni-Izguen (Roche 1973)

relative humidity and air temperature every 15 minutes. The external logger was housed in a radiation shield.

3 Building descriptions:

The urban structure reveals the distinctive influence of the climatic conditions, which are just as important as the cultural dimension. The medium height houses are inward-facing buildings allowing extreme compactness of the urban fabric (Figure 3).

Figure 3. The old city of Beni-Isguen, Mzab valley, Algeria

Figure 4. Timchent

Figure 5. Stone vault with Timchent and trunks of Palm

Only the rooftops and a few façades are exposed to the intense solar radiation. The streets are very narrow and shaded by the neighbouring walls, in some places also covered or further protected from the sun with trellis, cloth and awnings. The placement of the house design further controls radiant heat and glare using the superimposed patios. The patio is the main source of light as the outside façades generally are windowless. At ground level, there is a skylight that can be covered with a lattice screen. This level and underground spaces are refuges during the hottest time of the day. Moreover, the walls made of stone and gypsum together with their whitewashed coloured surfaces further prevent daytime summer overheating. Even if these houses were built to cope primarily with very hot and long summers, the winter conditions are improved with the southern orientation of the semi-outdoor living spaces on the terraces (galleries) and by taking advantage of the heat storage capacity of the buildings (Ravérau, 1981). Air movement occurs through small openings in the walls, and doors are left open most of the time. Thermal differences between the cool street, the house and the warm terrace may promote indoor ventilation. Even though the urban fabric and the building envelope are the main climatic filters, the people of these cities also show adaptation to the severe thermal regime by employing a 'nomadic' way of living in their houses.

3.1 Traditional house (H1): (Patio without tree)

The H1 was constructed in 1870 and located in Ksar Beni Isguen approximately 15 m from the H2. The layout of the building is similar to the closely packed H2. This house has a 120 m^2 plot area and 11 m^2 Patio and was constructed using 500 mm thick stone external walls in the basement level (Figure 6). A hard quick-drying plaster (timchent), local limestone/gypsum which is heated to produce plaster, was used for making the building blocks. The external rendering of buildings is still applied in the traditional way with palm branches, giving an energetic surface texture to the wall. The woodwork was limited to the ingenious use of palm; large planks were sawn from the trunks for doors and shutters, branches cut in two as initial support for vaulted roofs, and the nervure bent and tied to form permanent centring for arches. (Figures 4,5).

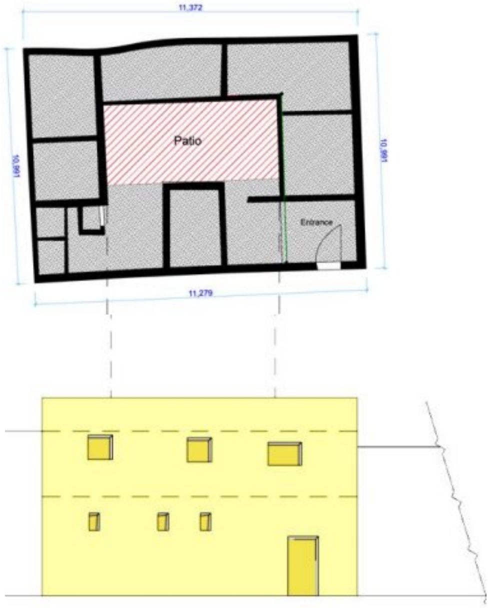

Figure 6. H1 patio without Palm tree

3.2. Traditional house (H2): (Patio with tree)

The H2 was also constructed around 1830 and located in Ksar Beni Isguen with a plot area of 112 m^2 and patio of 12 m^2. The construction materials used were the same as H1: (Figure 7), with stone exterior walls 400 mm thick and constructional details the same for both buildings. In order to protect the walls from direct sunlight, they used a palm tree in this example The tree has a diameter of 3 metres and a height of 7 metres and it covers an area of 30 m² and it occupies 20 % of the house surface, and thus all the patio is covered by the palm tree leaf around the day.

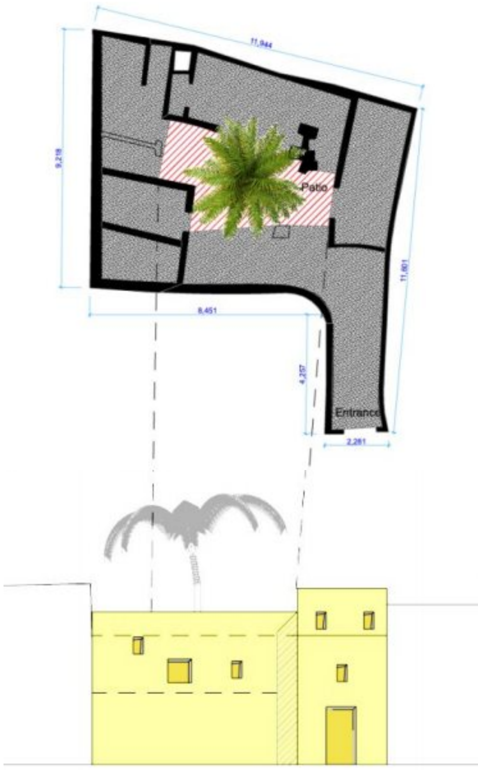

Figure 7. H2 patio with Palm tree

4 Results and Discussion:

Data loggers were located at five different locations in the houses. This paper discusses those situated in the living, kitchen and patio areas only. In both houses, only the kitchen walls were next to the outdoors. The other walls of the houses were attached to neighbouring buildings.

4.1 Physical measurements for H1: Over the one-week monitoring campaign, the recorded measurements from the outdoor data logger show that the mean daily temperatures ranged from 32.2°C to 38.4°C. The Patio's temperature variation was found to be notable; the temperature varied very little (2-3K) through the week (35°C on average). Meanwhile, the data reveal that the relative humidity (RH) ranged from 15% (or even lower as the limit of the sensor had been reached) to 35%.

(see Figure 8).

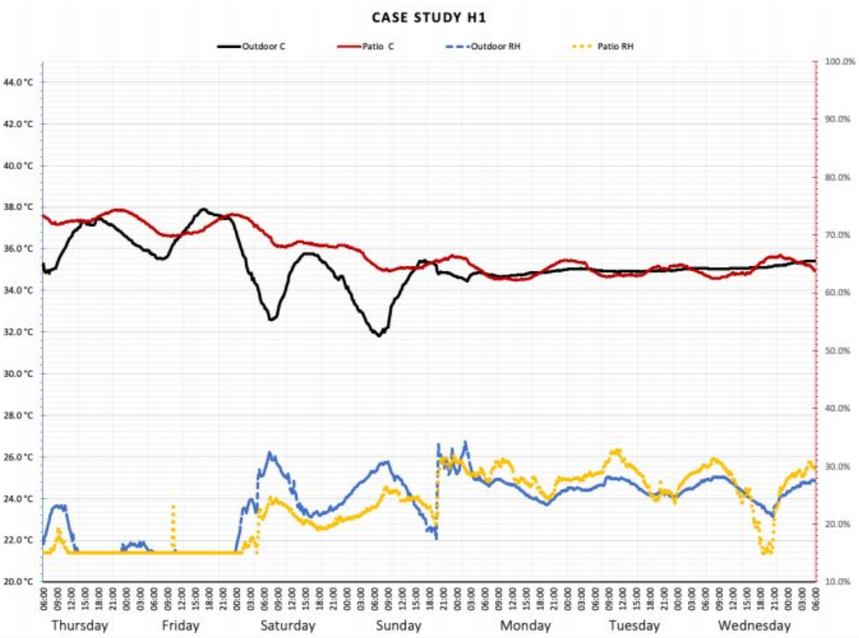

Figure 8. Measured external and Patio dry-bulb temperature and RH for H1.

Looking more closely at Figure 8, the patio air temperature fluctuates much less than the external air temperature in the first three days. After this the external temperature varied little but was generally 1-2°C higher than the patio air temperature. For house H1, the excessive heat gains through the non-insulated exposed roof, together with the unavailability of an air conditioner and/or an evaporative cooler, and the lack of openings facing the street for social reasons and also to avoid dust getting inside the space, all openings are into the patio and result in a hotter and relatively drier, indoor environment there. In particular, the impact of the poor building envelope and its failure in

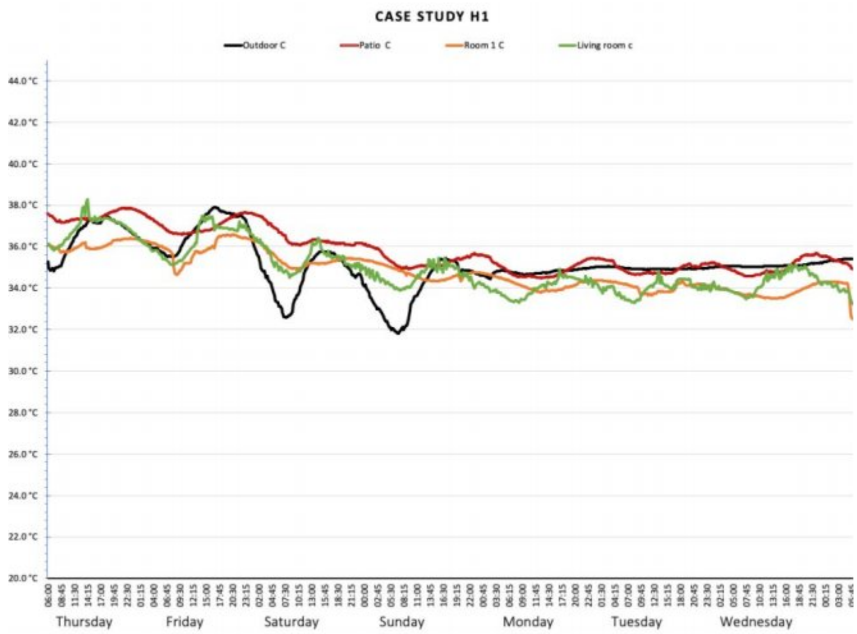

Figure 9. Measured indoor and outdoor dry-bulb temperatures for the period (August 6th to August 14th) for H1

delaying the heat transfer is evident in numerical data analysis showing a notable correlation between internal and external temperatures, particularly in the bedrooms, patio, and the outdoors Interestingly (see Figure 9).

The relative humidity (RH) in the two spaces (Patio and External) was generally between 35% and 15%, i.e. both are very dry environments and uncomfortable because of their effect on the mucous membranes of the residents.

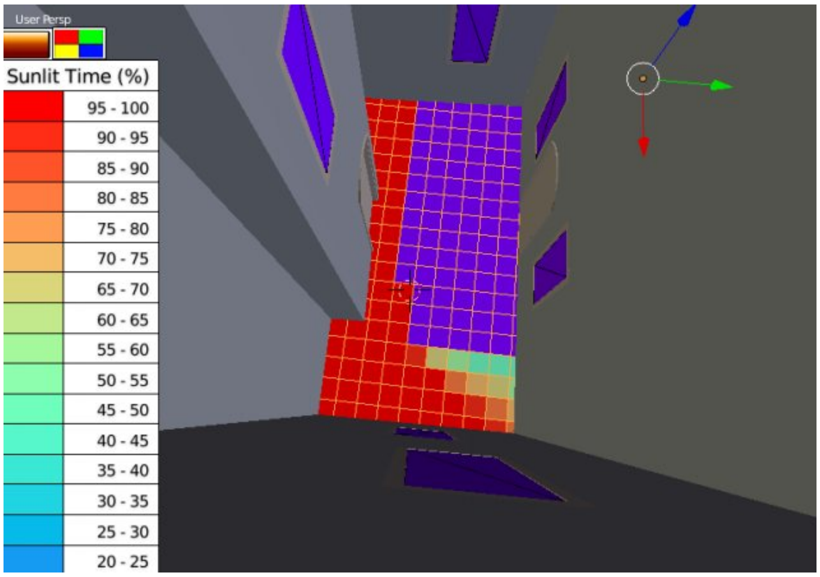

Fig. 10. Shadow Mapping analysis for the patio H1 for one day

Figure 10 shows shadow mapping analysis for the patio of H1. The sun strikes surfaces on the ground and heats them up; 80% of the patio is exposed to the sun during the day. These surfaces start interacting with the air layer above them and exchange heat and energy. The extent of this exchange is dependent on the physical properties of the surface being irradiated. Patio and building roofs become 27-39°C hotter than the ambient temperature. (Asaeda 1996). The fabric heats up during the day but it releases the heat during the night. Desert climates worldwide are known to have a significantly large diurnal temperature range resulting in cold nights even in the summer, as the stored heat in the roofs and floors is all radiated back to the clear desert sky (Olgyay 1963).

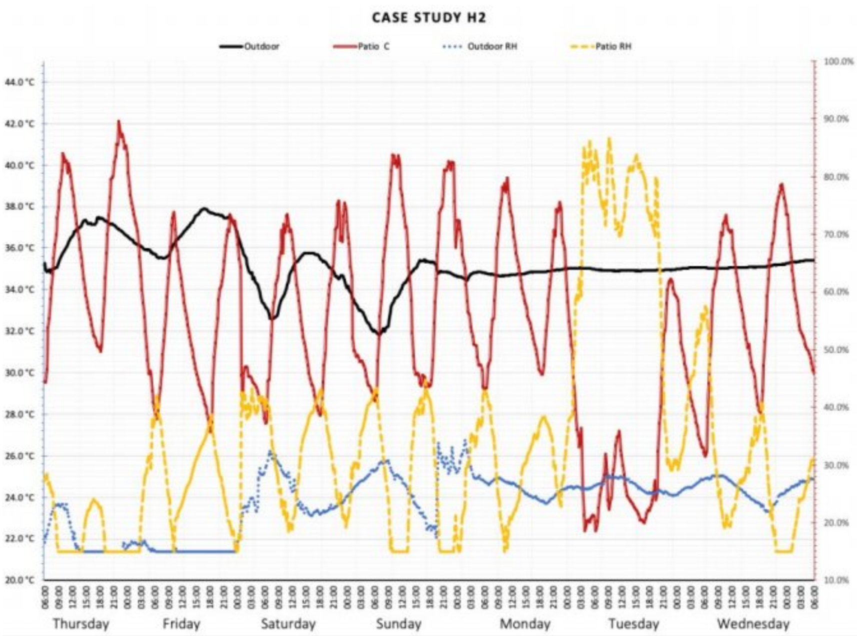

Figure 9. Measured indoor and outdoor dry-bulb temperatures for the period (August 6th to August 14th) for H2

4.2 Physical measurements for H2

Over the one week of monitoring, whilst the outdoor data logger shows that the mean daily temperatures ranged from 32.2°C to 38°C, the diurnal temperature variation in the patio was found to be 15K on average), starting from 25°C early in the day until late at night reaching 42°C. Meanwhile, the data reveal that RH ranged from 15% to 27% outdoors (see Figure 11), compared to the patio which has the RH range from 15% to over 80%

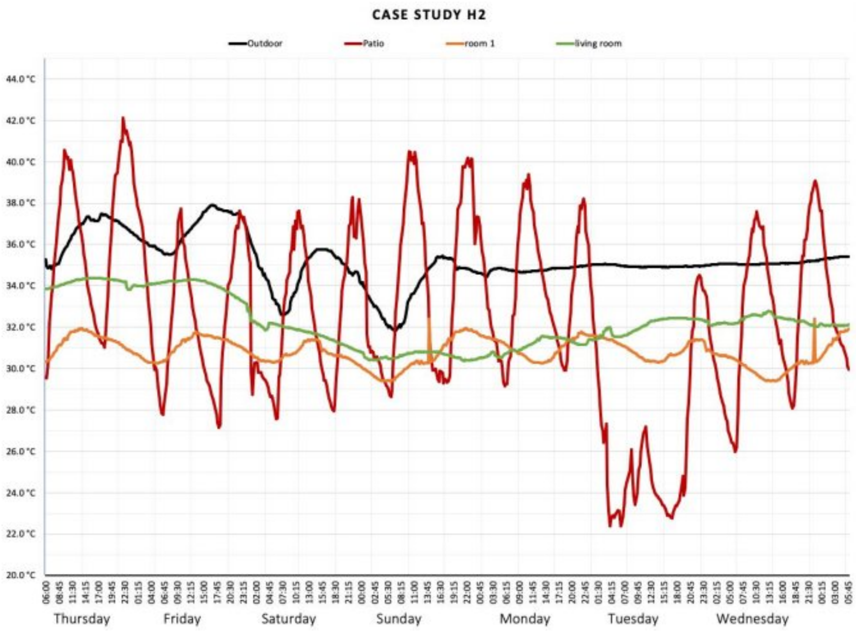

Figure 12. Measured indoor and outdoor dry-bulb temperatures for the period (August 6th to August 14th) for H2

Trees affect our climate, and therefore our weather, in three major ways: they lower temperatures, reduce energy usage and reduce or remove air pollutants. Figure 12 describes the temperature difference in the same house showing the impact of the patio in the house and how it can induce airflow due to a pressure difference from the cool to the hot courtyard. In the hot-dry regions, there is a large diurnal temperature swing and the air temperature drops greatly during the night-time especially in the patio. Consequently, the semi-outdoor spaces act as a cooling source to the adjacent spaces. As spatial strategies of climate integration, the traditional house develops concepts worthy of a referential repertoire for the sustainable architecture which associates comfort and respect of the environment. Figure 13 shows that the patio is 100% shaded during the whole day.

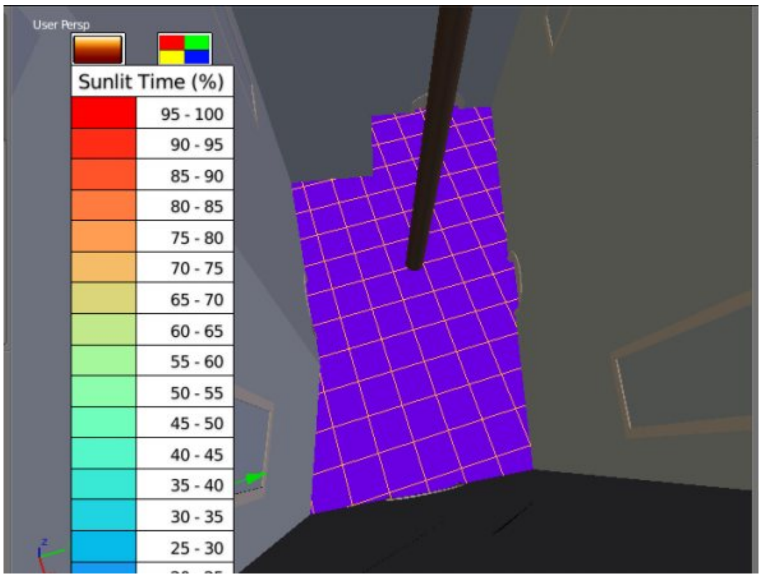

Figure. 13. Shadow Mapping analysis for the patio H2 for one day

The palm tree inside the patio promotes the air temperature reduction because it blocks sunlight, and hence it increases the coolness and reduces the energy consumption. The evaporation of water from the surface of the leaves of the tree helps reduce the air temperature, and so the tree acts as a natural air conditioner. Trees thus help to conserve energy and are to be encouraged as the residents in the south of Algeria usually have issues with the high cost of air conditioners and the intermittency of electricity during the day peak (12:00-16:00) in the summer season.

5.Conclusion:

The effect of the palm tree in the patio was investigated during this study and it was concluded that the urban tree plays a major role in shading the surfaces and decreasing their surface temperature and heat gain compared with the exposed surfaces. As indicated house 2 has a cooling effect compared with house 1. In addition, it has positive effects on the microclimate: it can lower the outdoor temperature and surrounding air which is usually saturated with humidity, and reduce an energy consumption. In these conditions, the tree inside the courtyard owes its survival to its suitability to the climate which in turn reduces fuel use and makes pollution control easier because it reduces energy consumption. Future research might investigate the old building with reference to new buildings which can help the architects and urban designers to learn from the past to develop our future building design.

6.References

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