Conference Proceedings

EuroSun 2016
Palma de Mallorca (Spain), 11 – 14 October 2016

IMPACT OF FORM AND DENSITY ON THE URBAN OUTDOOR SPACE COMFORT IN HOT AND DRY CLIMATE

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Abstract

In recent years, rapid urbanization and a tremendous increase in population have exerted pressure on urban developments in developing countries. The strategy adopted by most governments in the past twenty years in Algeria was that of densification. New and different urban forms have evolved from this strategy, but resulting in a loss of public green spaces and creating new problems in terms of environmental issues.
The present paper examines the relationships between forms and resulting environmental parameters such as temperature, ventilation, relative humidity.
The investigation is carried out by using the three dimensional numerical model « Envi-met 4.0 » which simulates the microclimatic parameters within urban environment and neighborhood. Models calculations are run for typical summer day 'Design Day July 21st ' in Biskra, south East of Algeria (34,48° N, 5,4° E), a region characterized by a hot and dry climate.
The aim of this study is to develop guidelines for architects and urban designers in order to develop new strategies and urban forms for a better and sustainable urban space.

Keywords: *hot and dry climate, outdoor space comfort, urban density, urban form, urban microclimate*

Introduction

Cities' planning and design has been conditioned throughout history by many and diverse factors including political, environmental, cultural, social, etc.
There are two main challenges related to the design of modern cities; the first is linked to global climate change, urban morphology (shape, density, vegetable and mineral volume, atmospheric air pollution, energy consumption ... etc.) is achieved in a context of rapid climate change (Vinet, 2000).
The second issue concerns the specific microclimate of cities. The phenomenon of urban heat island "UHI" is known for decades as a direct consequence of urbanization (Claverie, 2011). A sharp warming in air temperature of city centers, caused mainly by pollution from industries and transport. It has been defined (Oke, 1987) as the temperature difference between the city center and the surrounding countryside.
The urban heat island is the most dramatic manifestation of the global climate change consequences. It can be very drastic and leads to a temperature difference of the order of 10°C to 15°C between urban and surroundings areas (Musy, 2014).
Urban heat island is responsible for an increased mortality during heat waves periods. The elderly are mostly among the worst affected (Campbell, 2009).
It can also cause discomfort, weakness, and disorders of consciousness, cramps, syncope and heat stroke or exacerbate pre-existing chronic diseases such as diabetes, respiratory failure, and cardiovascular disease, cerebrovascular, neurological or renal, to the point of death (Filiatreault, 2015).

doi:10.18086/eurosun.2016.05.04 Available at http://proceedings.ises.org

1-City configuration and heat island risk

The structural and morphological characteristic of the city allows storing and trapping heat from solar radiation. Different parameters can increase or decrease the storage capacity or heat dispersion; several factors contribute to the increase in the appearance of the urban heat island as given in table 1:

Factors	**Parameters**
Climate	Sky state, wind speed and direction
Geographic	City location
Energy	Heat rejection from energy consumption
Morphology	Building density, mineral and vegetal surfaces
Policies	Land management practices
Structural	City size, plot ratio

Table 1: factors favoring the urban heat island.

According to Bozonnet (Bozonnet, 2005) the heat island phenomenon is linked to cities expansive increase of energy consumption see figure 1.

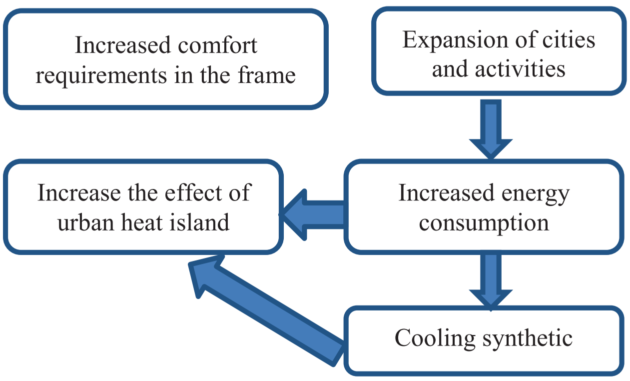


Figure 1: The relationship between the urban heat island and energy consumption (Bozonnet, 2005).

The present research examines the relationships between cities' forms and resulting environmental parameters such as temperature, air speed, and relative humidity.

2- Case study description

The city of Biskra, located in Algeria, is chosen for its hot and arid climate of the country. It has a rigorous climate characterized by very hot, dry summer and mild winter.

Meteorological data of Biskra show that the average temperature ranges from maximum of +44, 9°C and a minimum value of−2.1°C with high insolation exceeding 3500h/year and intense direct sunlight which can reach 900 to 1100 W/m² on a horizontal plane, relative humidity values vary between 25% to 40% with rare and irregular rainfall. This city is characterized by violent seasonal sandstorms (Khelil, 2015).

3-Methodology and approach

In order to assess the effect of urban configuration on the heat island risk in Biskra, a series of simulations has been performed using the Envi-met "*Environment- Meteorology*" version 4.0 code.

ENVI-MET is multidisciplinary simulation consultancy with a core services portfolio including architecture, building physics and microclimate; landscape architecture and garden design; it also includes urban planning and climate change adaption and human comfort and health.(Envi-met, 2014)
A simulation has been performed specially for the 21st July 2011 as it represents the hottest day of the year 2011. At 4 p.m, the air temperature reached almost 53°C.

4 -Urban typologies modelization

Biskra is an urban configuration with a variety of typologies: traditional, colonial and post-colonial. Creating a very diverse urban landscape, see figure 2.

(1)

(2)

(3)

Figure 2: Different typologies of Biskra: (1 traditional, (2) colonial and (3) post-colonial.

In order to assess the risk of heat island in this specific town, we have selected typical typologies (4 cases) representing a general trend form and typology of new urban developments, described in table 2.

Case	Total surface (m²)	Sb (m²)	Nb	Plot ratio	D (m)	Total plant area (m²)
1	12800	400	12	3.75	10	300
2	12800	400	10	3.125	10	300
3	12800	400	8	2.5	10	300
4	12800	400	6	1.875	10	300

kTable 2: Biskra urban typologies characteristics.

In order to assess the natural environment, a specific species of trees has been selected in order to be incorporated in the modelization process. The tree species is widely planted in the region and known as *Abies Alba* see figure 3.

Figure 3: The species of the tree *Abies Alba.* Source (http://www.lesarbres.fr/sapin.html)

This tree is characterized by:

- Height: 30m to 50 m
- Width: 10m to 15 m
- The leaves are needle-like, flattened, 1.8–3 centimetres (0.71–1.18 in) long and 2 millimetres (0.079 in) wide by 0.5 millimetres (0.020 in) thick

4- Simulation process

The four cases selected urban configuration representing Biskra urban landscape as described in table 2, have been used as models for the simulations.

- Case 1 consisting of 12 detached blocs aligned in result grid.
- Case 2 is 10 blocs configuration with a central courtyard.
- Case 3 consisting of 8 blocs aligned in U form.
- The last case, case 4 is 6 blocs urban composition evenly distributed over the surface area.
- Two green belts of *Albies Alba* tree have been added on the models on the East and West orientation as given in figure 4, 5 and 6.Wich a total vegetal density 0.1875 given by: vegetal density **(Vd)** = total plant area / total area
  Vd = [30 x 10 x 8] / 12800 =
  0, 1875

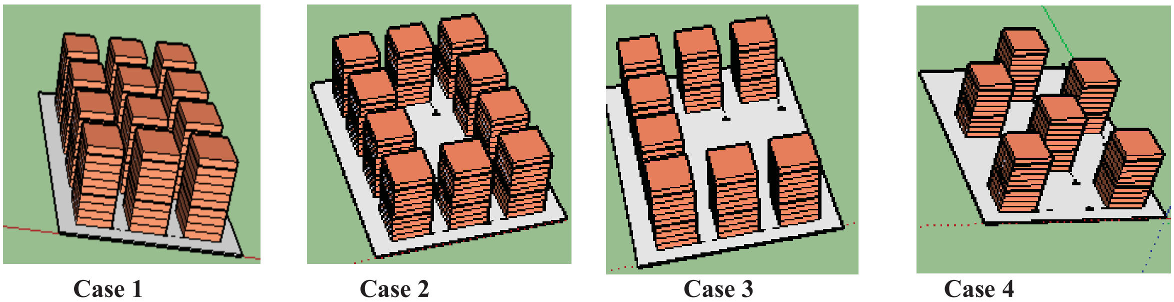


Figure 4: Generics models via Skeutchup.

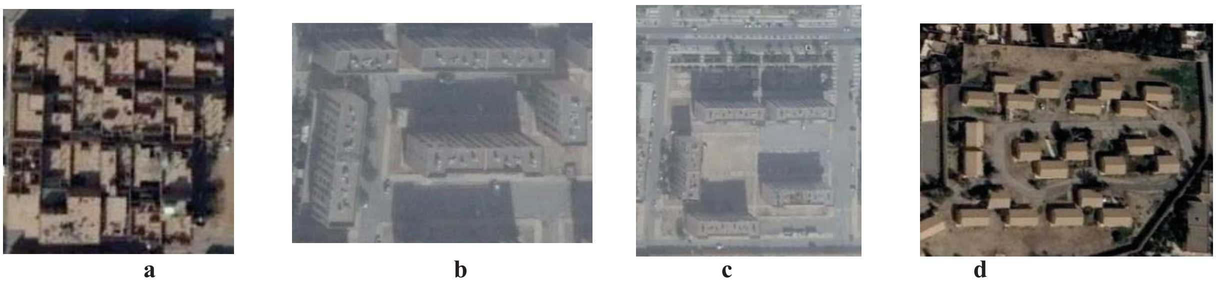


Figure 5: Different urban configuration in Biskra. a: city 1000 lodgements, b: city 500 lodgements, c: city 300 lodgements, d: city Bab Al Dherb.

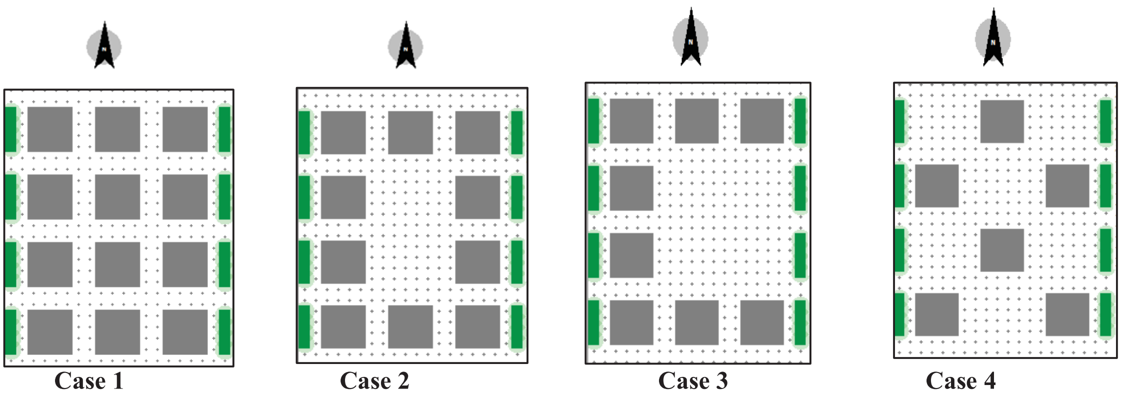


Figure 6: Generics models via Envi-met 4.

5- Results and discussion

From the results shown in figures 7 to 9 and tables 3 to 5 it is clear that, air temperature, air speed and relative humidity varies differently from one urban configuration to another.

3-1- Air temperature

Air temperature inside the models decreases with increasing plot ratio and vice versa.

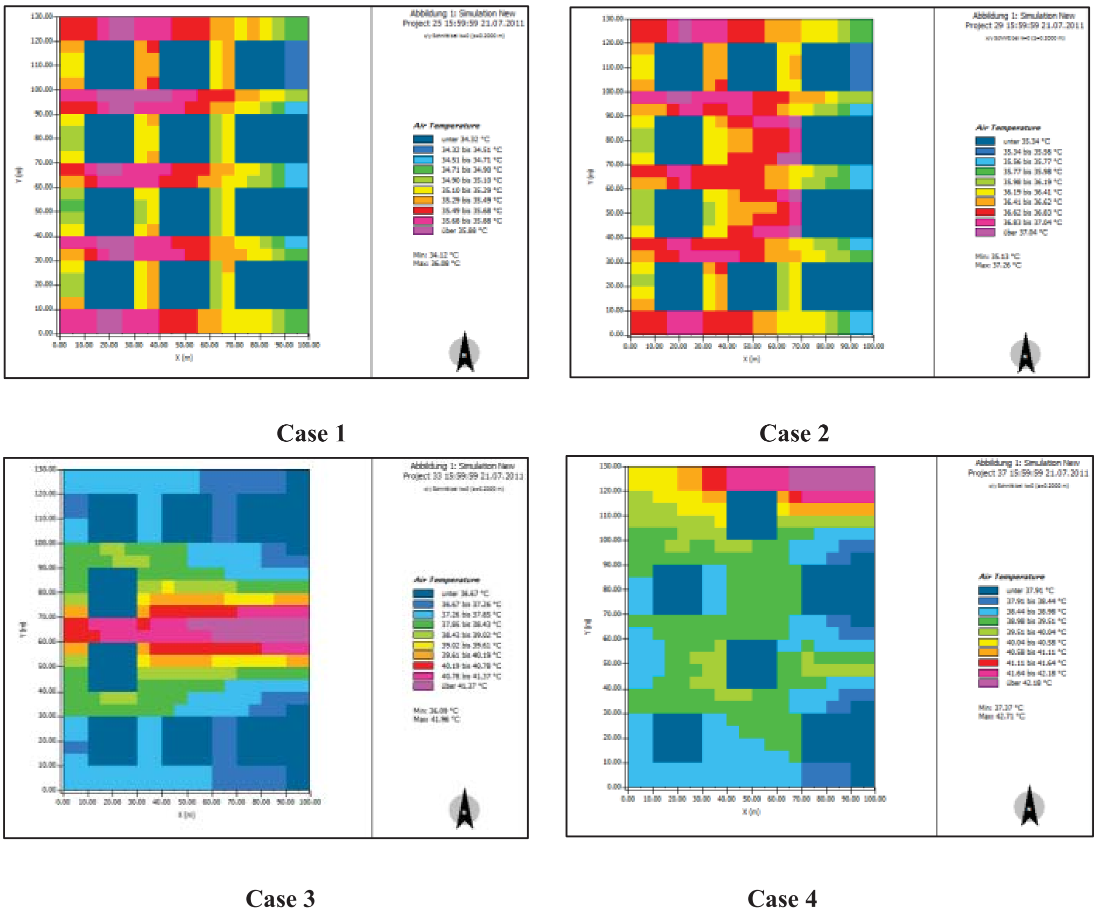


Figure 7: Air temperature variety results for each configuration

T°c	Case 1	Case2	Case3	Case4
Tmin	34.12	35.13	36.09	37.37
Tmax	36.08	37.26	41.96	42.71

Table 3: Max and Min values of air temperature inside each configuration.

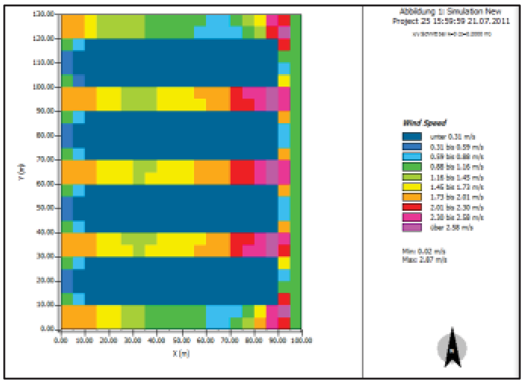
The increase in the number of blocs on the same surface area helps to decrease the outside air temperature.
The effects of shadowing bloc to bloc reduce the blocs surfaces exposed to direct sun heat. The same effect can be seen on case 2 and 3.
The outside air temperature rises as the number of blocs decreases.
However, the orientation and the green belt have different subsequent results as seen in case 2, 3 and 4, see figure 5.

3-2- Air speed

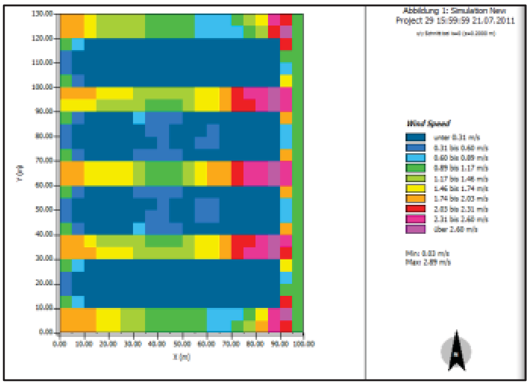
It has been reported that during anticyclonic periods and during the months of July and August reduced wind speed 2 m/s to 3 m/s (APUR, Bigorgne, 2012), combined to a clear sky increases the risk of creation of urban heat island.

Figure 8 and table 4 shows the results of the simulations for the wind speed factor for the four typical urban configurations.

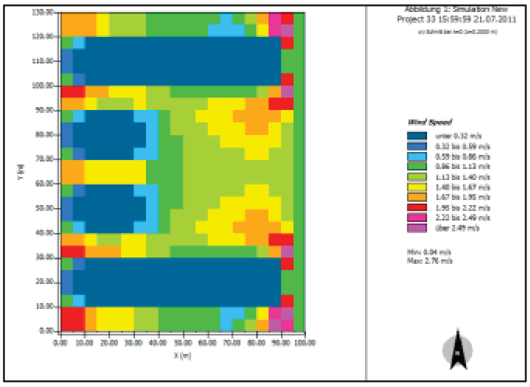
The air speed is quite uniform for all the four configurations with slight differences between the reference case (case 1) and case 4. The risk of heat island is more probable for case 4.



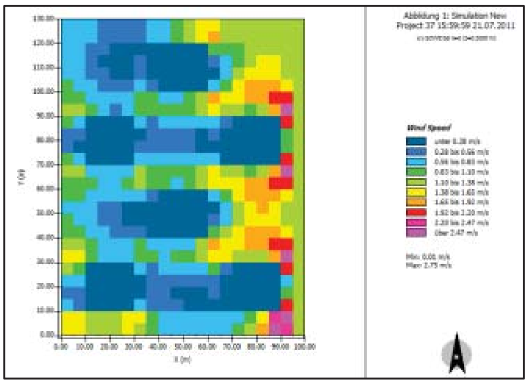
Case 1



Case 2



Case 3



Case 4

Figure 8: Air speed variety results for each configuration.

V (m/s)	Case1	Case2	Case3	Case 4
V min	0.02	0.03	0.04	0.01
V max	2.87	2.89	2.76	2.75

Table 4: Max and Min values of air speed inside each configuration.

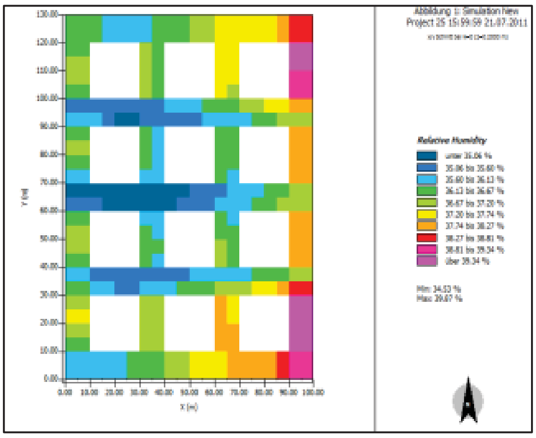
3-3- Relative humidity

Relative humidity values could influence the risk of the urban heat island.

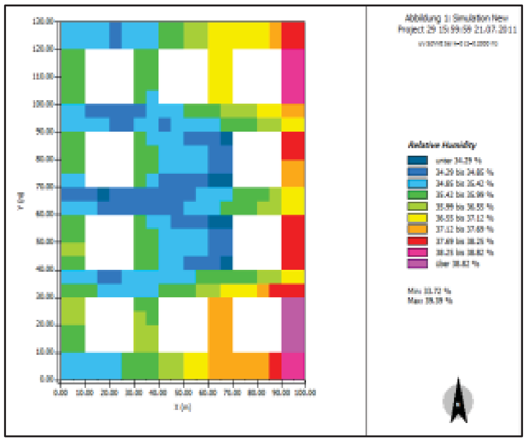
When humidity is low, climate becomes too dry promoting water and energy consumption. The evapo-transpiration phenomenon “green and water spaces” helps to reduce outside air temperature.

However, it could be pointed out that excessive increases in relative humidity reduce comfort temperature.

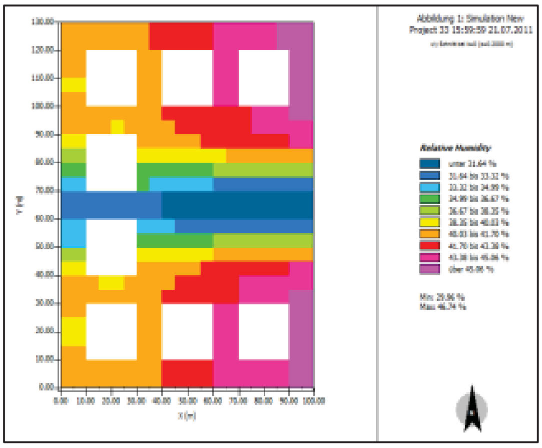
From figure 9 and table 5, we can deduce that relative humidity values are at their highest in cases 3 and 4. On the East orientation in case 4 and evenly distributed all over the urban configuration in case 3.



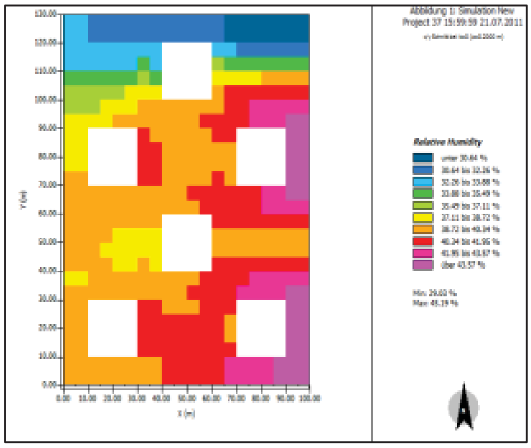
Case 1



Case 2



Case 3



Case 4

Figure 9: Relative humidity variety results for each configuration

RH%	Case1	Case2	Case3	Case4
RH min	34.53	33.72	29.96	29.03
RH max	39.87	39.39	46.74	45.19

Table 5: Max and Min values of relative humidity inside each configuration.

Conclusion

The results show that in hot and dry climate; the urban density creates a microclimate on the urban outdoor spaces by the diminution of air temperature and the urban heat island risk.
Urban typology has a great effect on the urban heat island risk. Designers of new urban development should take into account all the factors influencing urban morphology such as: form, geometry, density and orientation in the design of new towns and districts.
A sustainable architecture or urban design, should take into account all the variables which could influence positively the resulting urban climate.
A holistic approach could constitute a fundamental strategy for resolving nowadays urban issues and problem.

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