

Urban Growth vs Density:

The case of a low – density and hot desert climate city

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ABSTRACT: One characteristic of sustainable urbanization is high density and compact city morphology. The actual global trend in urban growth is taking cities to lower densities. For hot desert climate cities, this form of dispersing growth is not beneficial. This work aims to evaluate urban sprawl and urban density behaviour of a dispersed city and provide solutions that could improve the quality of urban life. To this end, we analysed the case of Hermosillo, a low – density hot desert climate city with extreme temperatures and high solar radiation values (mean of 6,7 kWh/m² per day during the hot season). We evaluated the built density distribution and the distribution of vacant lots using GIS-based maps. The relation between its urban morphology and the incidence of solar radiation at street level was evaluated through simulations with Heliodon2. The results show that an urban policy that encourages the densification of the city centre by the infill of vacant lots, could be a strategy to contain the urban sprawl while improving the public space by providing shade through the own city form. The implementation of “mixed-use lots” and the vertical edificatory density could foster the creation of sub-centres where people enjoy a qualitative urban life.

KEYWORDS: Urban form, Urban density, Hot desert climate city, Disperse city, Urban infill.

1. INTRODUCTION

Urban density is commonly used to measure life quality in a city [1]. High density and a compact urban morphology are often seen as prerequisites for sustainable urbanization and economic growth [2]

Even though high density seems to be the best approach, nowadays actual trend at global scale follows the opposite way, an urban sprawl.

As shown in Figure 1, in almost all the selected cities for this study, the population density has decreased in a lapse of 15 years. This is due to that mean annual growth rate of the urban surface (4,3%) is higher than that of the population (2,8%) [3].

In numerous cases, the extension to metropolitan areas causes this reduction in density, for example, the case of Barcelona. When only the urban core is considered, the density is 159 inhab/ha. If analysing the metropolitan area, its density falls to 59 inhab/ha. The same happens with other cities, such as Paris (203 inhab/ha in Paris Centre – 40 inhab/ha in Grand

Paris) or New York (282 inhab/ha in Manhattan – 20 inhab/ha in New York) [3].

The current pace of urban growth is taking the centre of the cities to lower densities by increasing their suburbs with low – density residential and commercial development, this fractures them and creates great distances to cover increasing traffic [4].

In cities where the climate is one of the main parameters to take into account to achieve a quality urban life, a sprawl development that leads to low densities is not recommended. These cities are located in low medium latitudes (20°-33°) and concentrate a large part of the world population. [5]

Cities such as Phoenix, Tucson, Las Vegas, Hermosillo, Mexicali in America; Riyadh, Mecca, and Baghdad in the Middle East; Khartoum in Africa. In this framework, the study of the urban growth and density in hot desert climate cities (BWh, Köppen climate classification) takes big importance.

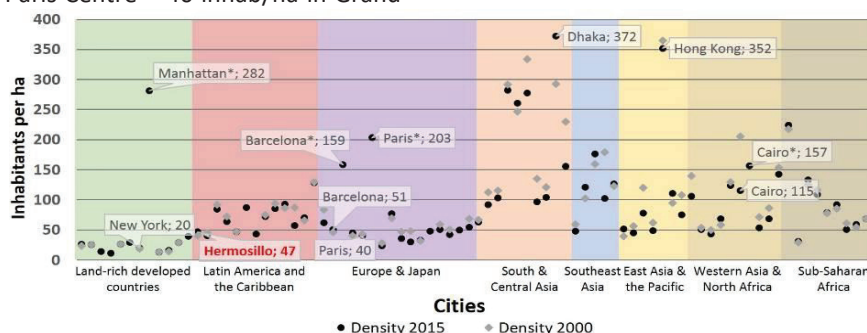


Figure 1: Urban density change 2000-2015. (*): urban core. Author’s elaboration with data of Atlas of Urban Expansion [3].

2. OBJECTIVE

The goal of this work is to evaluate the urban growth and the change in urban density of the city of Hermosillo, Mexico, in the local and global context

This could help to provide urban planning that could improve the quality of life. To achieve this goal, it is also important to take into account the climatic conditions of the city. Given that in hot cities the direct component of solar radiation is one of the main parameters that affect the urban life quality, is analysed here.

3. METHODOLOGY

The methodology followed in this study focuses on different aspects to evaluate the urban growth:

- Urban density distribution
- Distribution of vacant lots within the city
- Urban form and climate

Divided into three phases where the two first phases consist of the data collection and it's processing and the third assesses the solar access at street level in a representative area of the city.

Data collection: the statistical data of 82 cities with more than 500,000 people used is from the Lincoln Institute of Land Policy [3]. The population data of Hermosillo is from the National Institute of Statistic and Geography (INEGI) [6] and the urban data is from the municipality of Hermosillo [7].

The climatological data is from the National Meteorological Service (SMN) [8] and from the Energy, Environment and Architecture Laboratory (LEMA) [9].

Data processing: The creation of GIS-based maps with the information processed is necessary to improve the comprehension of the data collected; this could be a useful tool in urban planning decision-making. The software used was ArcMap.

Solar access assessment: The solar radiation calculation program Heliodon2 [10] helps to assess the solar access at street level in the selected area (in this case, the streets of the city centre). For this assessment, 3D models must be built and simulated.

The solar access assessment takes place during the hot season (May 1st to October 31st). This period presents high temperatures and levels of direct solar radiation, which directly influences the comfort in the urban public space, conditioning its use by pedestrians during the day.

4. CASE STUDY

The city of Hermosillo (29° NL), shown in Figure 2, follows a scattered pattern of urban growth. It has a hot desert climate (BWh, Köppen climate classification) with an annual mean temperature of 25°C and a mean relative humidity of 43%. During the hot season, the city presents extreme temperatures of 40-45°C, sometimes reaching 50°C. It presents an

annual mean solar radiation of 5,85 kWh/m² per day, but during the hot season, the mean solar radiation is 6,7 kWh/m² per day (Table 1).

In the last century, in this region of North America, there has been recorded an increment in the mean temperature. In Hermosillo, this increment is more noticeable during the hot season. In the last 50 years, there has been an increment of around 2°C in the mean temperature of this season (Figure 3).



Figure 2: Satellite image of Hermosillo. Author's elaboration with Google Earth Pro.

Table 1: Monthly data (1980-2010) of average maximum temperature (AMT), mean temperature (MT), average minimum temperature (AmT), relative humidity (%) and global horizontal radiation (kWh/m²) [8, 9]

Month	AMT °C	MT °C	AmT °C	RH %	kWh/m ²
JAN	24,2	17,2	10,2	48	3,88
FEB	25,8	18,5	11,3	44	4,76
MAR	28,7	20,9	13,1	40	6,34
APR	32,3	24,1	15,9	34	7,45
MAY	36,3	27,9	19,4	31	7,73
JUN	39,8	31,8	23,8	34	7,59
JUL	39,3	32,5	25,8	48	7,07
AUG	38,3	31,9	25,6	53	6,88
SEP	37,5	31,0	24,6	48	5,74
OCT	33,9	26,9	19,8	42	5,23
NOV	28,6	21,6	14,0	43	4,11
DEC	24,0	17,1	10,2	49	3,25

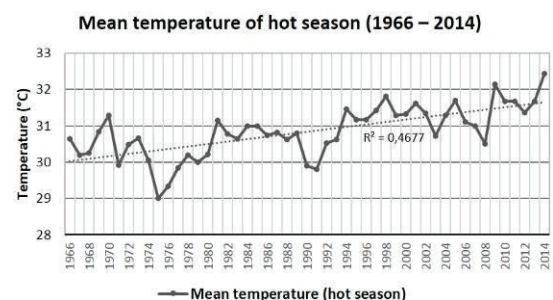


Figure 3: Mean temperature change (1966 to 2014). There is an increase of almost 2°C. Author's elaboration with data of the Municipality of Hermosillo [7].

Since the 20th century, the city has maintained an accelerated rate of urban and population growth. It has followed a housing policy that favours the construction of single-family dwellings in closed neighbourhoods.

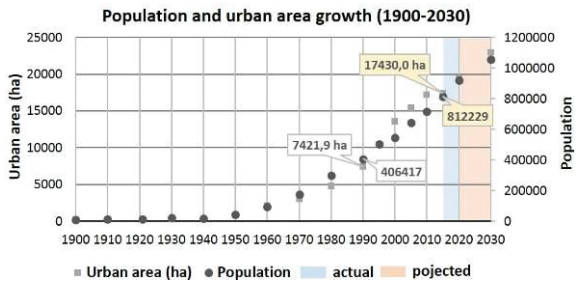


Figure 4: Evolution of the population and urban area of Hermosillo (1900 – 2030). Author's elaboration with data from INEGI [6].

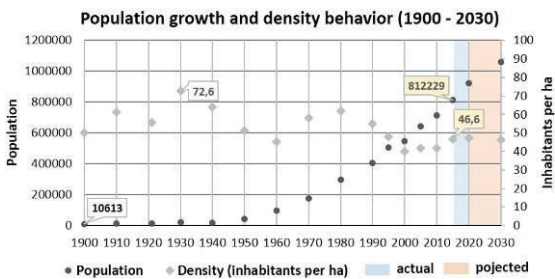


Figure 5: Evolution of the population and the behaviour of the urban density (1900 – 2030). Author's elaboration with data from INEGI [6].

As shown in figures 4 and 5, in 2015, the urban area was close to 17.500 ha with a population of over 800.000 inhabitants. The population and urban area will continue to grow at an accelerated rate maintaining a low urban density (less than 50 inhabitants per hectare).

But, how is Hermosillo located globally when comparing the relationship between its urban density and its climate?

It can be seen, in Figure 6, that the value of the urban density of Hermosillo (47 inhab/ha) is similar to

the one of Riyadh (43 inhab/ha). This value is far from that of historical cities such as Cairo (157 inhab/ha) and Alexandria (143 inhab/ha). In Mexico, this value is also behind recently founded cities, for example, the border city of Mexicali (87 inhab/ha).

5. RESULTS AND DISCUSSION

The behaviour of the last 30 years and the current social housing policy have led the city to present an irregular distribution of the population, displacing it from the city centre to suburban areas. At the same time, and due to its climate, it has transformed Hermosillo into a city that is not walkable and lacks quality public spaces.

5.1 Urban density distribution

The map in figure 7 shows the city's distribution of population density. While in most cities the density starts to decline while increasing the distance from the city centre [3], in Hermosillo, it is quite the opposite.

This low centrality effect is a characteristic of dispersed cities [11]. It means that inhabitants and certain economic activities tend to move from the city centre to the outskirts of the city. This causes the urban centre to lose economic and population weight compared to the suburban areas.

The city centre presents an urban density of 14 inhabitants per hectare, while the mean urban density of the rest of the city is 47 inhab/ha. These low densities remain around the city centre and create a donut effect in the urban area as higher densities surround it.

The growth of Hermosillo has been mainly in the north and south, while to a lesser extent in west directions. That is the reason why these areas present higher levels of urban density. The growth of the city follows this path since the city limits to the east with the Abelardo L. Rodriguez Dam, and to the northeast with the Bachoco hill, which is part of the Espinazo Prieto mountain range.

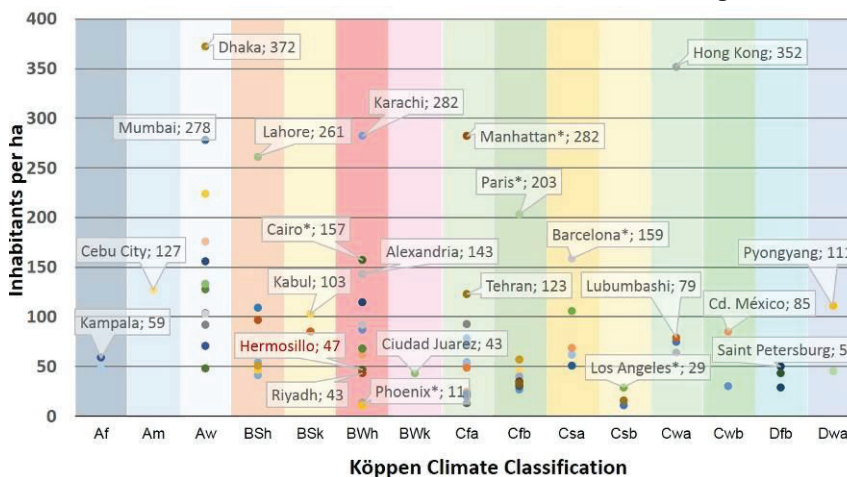


Figure 6: Population density by its climate. Hermosillo is located in the BWh strip. (*): Urban core. Author's elaboration with data from Atlas of Urban Expansion [3].

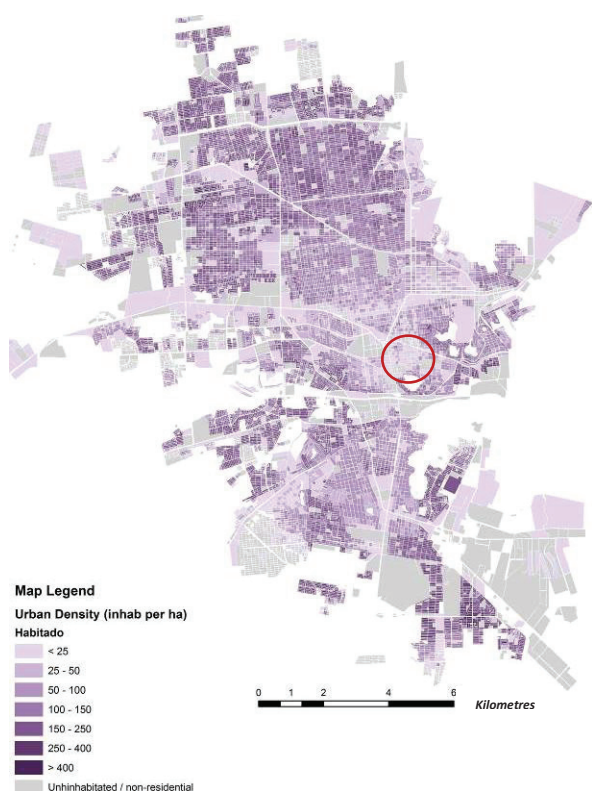


Figure 7: Urban density distribution by city blocks of Hermosillo. The red circle indicates the city centre location. Author's elaboration with data from INEGI [6].

Figure 7 shows that there are some city blocks listed as uninhabited of non-residential, but these city blocks are not necessarily empty. For instance, the industrial zone stands out in the southeast part, while the University is in the downtown area next to the city centre. There are other types of city blocks distributed throughout the city: industrial estates, housing reserves, urban equipment, etc.

5.2 Distribution of vacant lots within the city

Figure 8 shows the distribution of the existing vacant lots. We have considered a vacant lot the one that is within the urbanized area and does not have buildings, this, regardless of the type of land use. However, those listed as green areas by the municipality are not considered.

In Figure 8 we can see how most of the vacant lots are in the west, northwest and southeast areas. However, a strip (black rectangle) of vacant lots divides the city in two. The idea behind the development of this area was to create an urban megaproject that would detonate the area of the old riverbed of the Sonora River, making it the business centre of the city [12]. Currently, it has not been as successful as expected, and now more than being a business centre, it acts as a border between the north and south of the city.



Figure 8: Vacant lots distribution of Hermosillo. The black rectangle indicates the Sonora River Project. Author's elaboration with data from INEGI [6].

There are 34.096 vacant lots in the city. This amount is equivalent to approximately 5.000 ha, that is, if we consider that the urban area is 17.500 ha, about 30% are vacant lots.

In this study, we did not find a single sample of the existence of mixed-use lots (i.e., commercial use on the ground floor and housing above).

5.3 Urban form and climate

Regarding the relationship between urban form and climate, Hermosillo follows the dispersed city model: single-story dwellings, wide streets, and low densities. All this driven by the use of the automobile, creating great distances to travel.

All this, together with a hot – desert climate, characterized by high temperatures and high levels of solar radiation, leads to a deficient public space and a continuous demand for land for housing developments [13, 14].

The area selected for the assessment of solar access at the street level is the city centre. This case study has been selected after considering that it is the area of the city with the highest construction density and the highest average building height. Therefore, this area should present the lowest levels of direct solar radiation on the streets.

The calculation was made considering 184 days (May 1st – October 31st), a grid precision of 15 minutes and a mesh size of 2 meters.

Figure 9 is a map that shows the results of simulating the behaviour of direct solar radiation in the selected area. The amount of energy displayed is that accumulated for square meter (kWh/m^2) throughout the hot season. As the figure shows, most of the streets receive a great amount of direct solar radiation.

As shown in Figure 9 and 10, the high level of penetration of solar radiation at the street level is due to two characteristics of the urban morphology of Hermosillo: the layout of its streets and the low height of its buildings (Figure 10).



Figure 9: Results of the simulation of the direct solar radiation (kWh/m^2) at the street level during the hot season (1st May – October 31st). Author's elaboration with Heliodon2 [10].

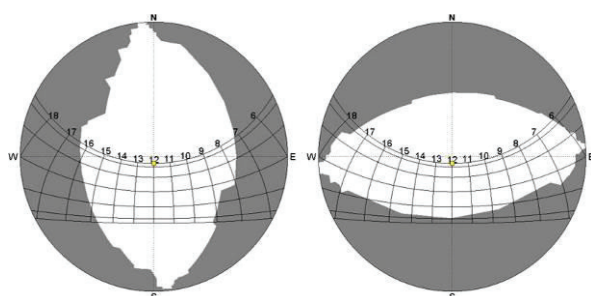


Figure 10: Solar path in stereographic diagrams of two streets with different orientations but similar aspect ratios ($h/w < 1$): the one on the left is the NS.1 point (North – South), on the right is the EW.1 point (East – West). Author's elaboration with Heliodon2 [10].

Figure 11 shows the maximum possible solar irradiance and the actual irradiance received for each day of the hot season. The maximum values range from $6,70 \text{ kWh/m}^2$ on May 1st, $7,29 \text{ kWh/m}^2$ on June 21st and $3,57$ on October 31st. These values are the maximums that a square meter can accumulate

throughout the indicated day. However, the actual values present a reduction occasioned by the obstruction produced by the own city form. On the same days, and order, the values are: $5,49 \text{ kWh/m}^2$ (18% less), $6,13 \text{ kWh/m}^2$ (16% less) and $2,42 \text{ kWh/m}^2$ (32% less).

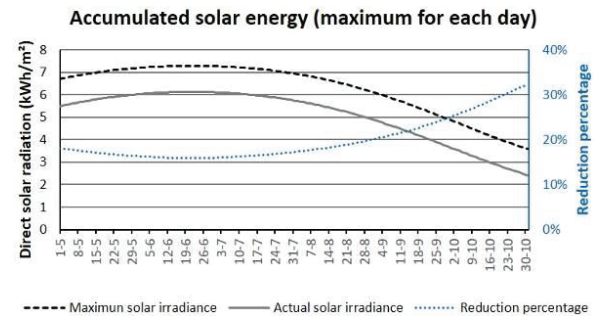


Figure 11: Maximum solar radiation accumulated daily during the hot season and the difference between the maximum possible solar irradiance and the actual solar irradiance. Author's elaboration with Heliodon2 [10]

5.4 Discussion

After observing the distribution of population density and vacant lots, as well as the relationship between urban form and climate, it seems necessary to define some strategies for an urban planning policy that includes these aspects. In this work, we propose two different strategies to help reduce urban distances, hence promoting the proximity in civic, administrative, social and daily life.

The first strategy is the infill of the vacant lots that are within the consolidated urban area. This approach could represent an improvement in terms of a slight increase in urban density. For this approach to work, it is necessary the implementation of mixed-use lots, that is, a lot that combines both commercial and residential use. This type of approach could help to reduce the typical zoning of land uses present in dispersed cities (large areas of a single type of land use).

The second strategy is the creation of urban sub-centres in different areas of the city. This approach attempts to change the current growth dynamics of the city, that is, to move from the dynamics of the typical dispersed city in continuous expansion to a new dynamic in which the creation of several sub-centres is encouraged to limit urban sprawl and thus increase urban density. These new sub-centres need to have a high density, both of construction and population. At the same time, they must have a morphology that allows the creation of shade in public space by the same urban form, protecting the pedestrian from the high incidence of solar radiation, and acting as an urban oases network (Figure 12).

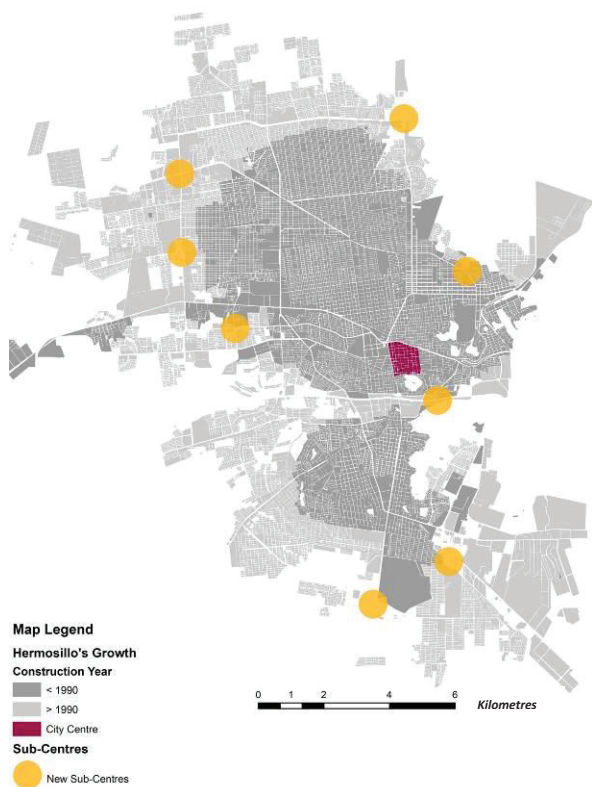


Figure 12: Possible hotspots for the creation of a network of sub-centres. Author's elaboration.

These two strategies, even though they can be used individually, should be considered complementary to each other, since they would be producing a synergy to achieve a common goal. Continuing with the example of the urban centre of Hermosillo, these two strategies could be applied in that area while taking advantage of the fact that it is an active commercial area and counts with all the public services. This can be done by the infill of vacant lots and the stacking of homes on top of current buildings whose construction permits it. This would allow the diversification of land uses and increasing building and population density. These interventions could lead to an improvement in the quality of public space, therefore, of urban life.

6. CONCLUSION

The behaviour of the last 30 years and the current social housing policy have led the city to present an irregular distribution of the population, displacing it from the city centre to suburban areas. At the same time, and due to its climate, it has transformed Hermosillo into a city that is not walkable and lacks quality public spaces.

Some strategies to densify could be applied to the city of Hermosillo to achieve a more regular distribution of the population density and contain urban sprawl while improving the public space by providing shade through the own city form.

These strategies act at two different scales:

- Filling the vacant lots within the city.
- The creation of sub-centres in different areas of the city.

For these strategies, the implementation of mixed-use lots (commerce at ground level and housing in upper levels) is necessary.

The urban mixed-use through the infill and the vertical densification through stacking in the city centre could help to raise the urban density (built and population density) of the area and act as a catalyser for other zones of the city.

A change in the housing policy could help to improve the situation, by favouring the construction of multifamily housing instead of just single-family.

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