Bioclimatic Urban Green Indicators for the Sustainability of Cities in Arid Environments

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Abstract

Within the sustainability of cities located in arid environments, bioclimatic indicators of urban green are proposed, taking as a study case the Metropolitan Area of San Juan, Argentina, city located in the arid strip of South America, which has one of the most rigorous climates of South American arid areas. The state of situation of European and Latin American cities is analyzed, and results of investigations performed in the aforementioned city are considered. It is suggested to adopt as bioclimatic indicators of urban green, two parameters that represent equivalent values: one, which relates the area of green spaces in the city with its population; and the other, which relates it to the area of urban land. The first, called Bioclimatic Indicator of Urban Green Areas Density, results 9%; the second, designated as Bioclimatic Indicator of area of urban green spaces per inhabitant, obtained a value of 25m^2/in hab.

Keywords: Bioclimatic Urbanism Bioclimatic Indicators Urban Green Spaces Urban Sustainability Arid Environment

Introduction

In the Argentina Republic, the arid zones comprise 69% of its territory, the highest percentage of all the countries in Latin America according to the Atlas of arid zones of Latin America and the Caribbean (UNESCO, 2010)[1]. These areas have only 12% of area water resources and its population is approximately 30% of the national total. The province of San Juan is located on the South American arid diagonal[2]in the Central-West region of Argentina. According to the aforementioned Atlas, here can be find the unique Xerica Region of the country, which covers only 1% of the national territory[3] (Figure 1).

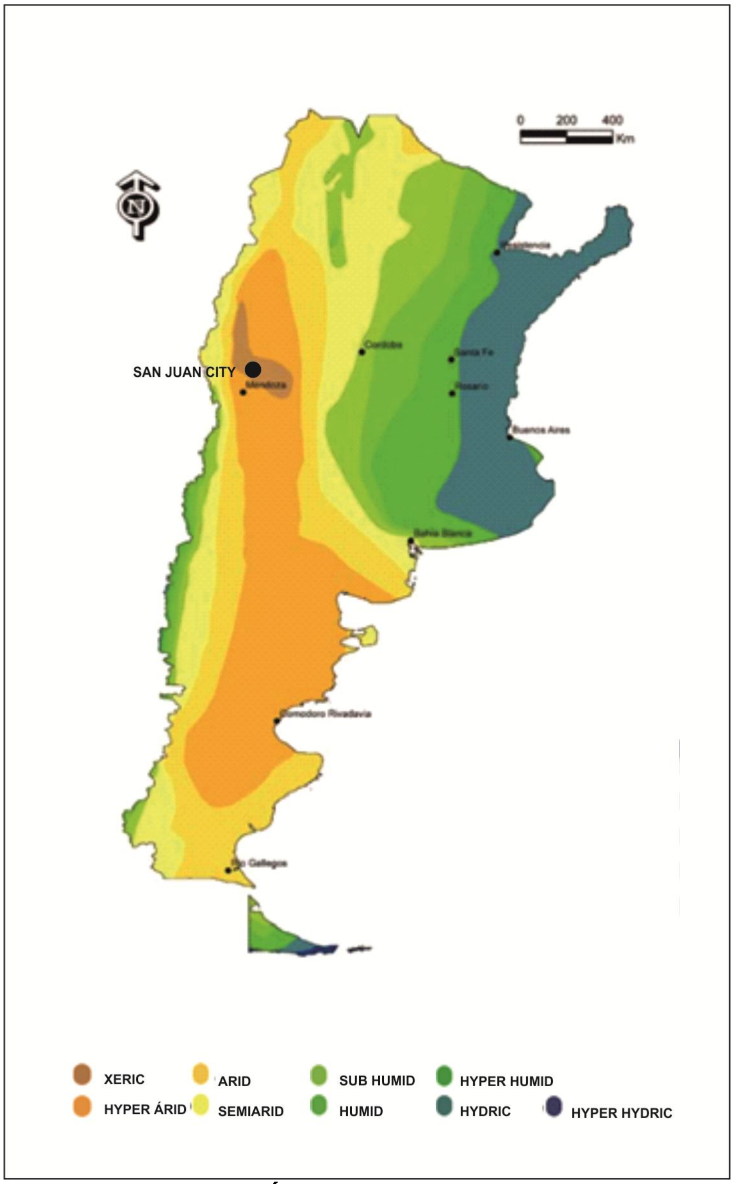
San Juan possesses one of the most rigorous climates of the South American arid zones: occupies the first place by of the Gorzinsky continentality index (40.5), for its annual maximum average temperatures (26.2°C) and its minimum annual (10.2°C). The second place by the relative heliophany percentages (71.8%) and the third place by their water and aridity rates (- 53.8 and 0,102, respectively) and by rainfall (annual 96 mm) and solar radiation (annual: 456.3 calxcm-2xdia-1) (Papparelli *et al*., 2001).Depending on these parameters, the climate of San Juan can be characterized as: arid continental geothermal with high annual and diurnal temperature oscillations; strong solar radiation in summer and moderate cloudiness spread evenly throughout the year. It presents hot summers, relatively dehydrated air and cold winter with more humid air. It shows summer rainfall regime. Prevalent wind from the southern sector with intense gusts associated with storms of dust after the Zonda local wind (Papparelli *et al*., 2001).

[1] The order of the first three countries in percentage of aridity is: Argentina with 69%; Mexico with 65% and Chile with 58%. The Atlas is a project carried out in the framework of UNESCO - PHI and the Flemish Government, Department of Science and Innovations.

[2] In South America extends a large arid region encompassing, from the Peru coast, part of Bolivia, the Puna, the Argentinean Northwest and crosses to the Atlantic Patagonia. Other South American semi-arid areas are the Brazilian Northeast and the shores of the sea of the Caribbean, which have lesser territorial extension.

[3]Xerica classification, which joins the four initials of UNESCO (1977), is obtained by the application of the indicator System of Aridity (supplementing the aridity index), and calculated on the basis of the extension of the dry period. This indicator considers the distribution of the monthly evapotranspiration and precipitation, incorporating the effect of seasonality.

Figure 1: Zoning of Aridity Regimes in the Republic Argentina



Source: ATLAS de Zonas Áridas de América Latina y el Caribe (2010)

Characteristics of the San Juan Metropolitan Área Urban-space distribution

The Metropolitan Area of San Juan is located on the Tulum Valley, Southeast of the province of San Juan, at 31° 30' south latitude; 68° 31' west longitude and an altitude of 645mosl. It consists of six departmental jurisdictions. Occupies an area of 126558129m^2 and has a population of 458230 inhabitants (Papparelli *et al.*, 2015). Its population density is 36.21 inhabitants per hectare, and has a medium-low building density. Attending the urban rates of Land Occupation Factor and Volumetric Building Density, homogenous areas called Urban Characteristic Bands - BUC[4] (Papparelli *et al.*, 2009) are identified. The eminently urban BUC presents the highest urban rates; urban BUC, media rates; the suburban BUC, low rates and the not urban BUC surrounds the city forming its boundary. For the 2010, the values that represent each BUC and the population distributed according them, are presented in Table 1. The specialization of such BUCs is shown in Figure 2.

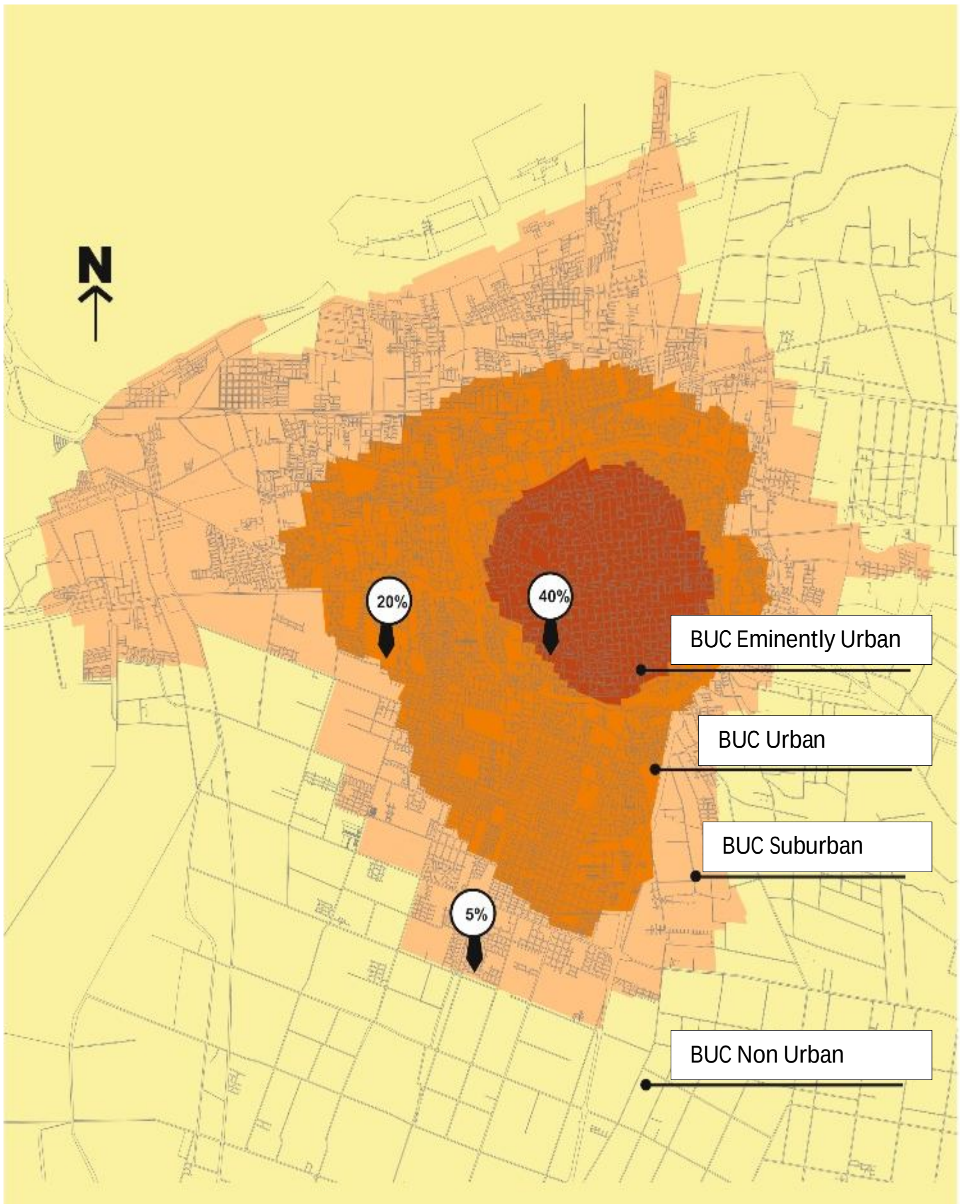
[4] Urban Characteristic Bands (BUC): Homogeneous and continuous areas of the urban frame, with urban indices of similar value that Identify its territorial condition and its state of spatial situation, between two representative limits of Land Occupation Factor, that determine another o-ring surface concentric to the main center of the city.

Table 1: FOS y DV Boundary values of the Urban Characteristic Bands in the Metropolitan Area of San Juan (AMSJ). Area and population for each BUC. Source: Kurbán, *et al.* (2013); Papparelli, *et al*., (2015).

Urban characteristic bands	Land occupation Factor (FOS)	Volumetric building Density (DV)	Area (m^2)	Population
Eminently urban band.	FOS≥40%	DV≥ 15000m^3/Ha	12324721	42366
Urban band	40%> FOS ≥ 20%	15000m^3/Ha >DV≥ 8000m^3/Ha	57159230	253415
Suburban band	20% >FOS≥ 5%	8000m^3/Ha >DV≥ 1000m^3/Ha	57074178	162445
Non urban band	5% >FOS	1000m^3/Ha >DV	Total AMSJ 126558129	Total AMSJ 458230

This spatial distribution in the AMSJ of medium scale is similar to in several Latin American cities on the arid strip of South America, and these singularities are also common to other cities located in arid environments.

Figure2: Urban Characteristic Bands in AMSJ. Source: Kurbán *et al*., (2013) and Papparelli*et al*., (2015).



Urban Climate of the AMSJ

The process of enthronization in urban areas due to the increasing changes in the conditions of the original support, involve an alteration of the small-scale climate produced by the building volumes, the characteristics of the road infrastructure, the urban a forestation and the anthropogenic heat (produced by population, air pollution by cars, emission of heat into the atmosphere by use of environmental conditioning systems).This effect is produced by the alteration of four physical mechanisms: radiation balance, natural flow and turbulence of the air, water vapor balance; increased emission of water vapor and contaminants. There are also interactions between these mechanisms: for example, air pollution affects the radiation balance and the thermal regime (Mazzeo, 1984). Overcoming certain levels of urban density, these changes are more marked and influence the hydrothermal conditions, both in open spaces and in building interiors. This final state of the modified microscaleclimate is called urban climate and its scientific knowledge constitutes the starting point to be incorporated as real data to the bioclimatic design, to obtain conditions of hydrothermal comfort for the population. In this way, the urban climate is an essential tool for urban-architectural planning and design. The main phenomenon of the urban climatology is the heat island, due to its direct impact on the life quality of its inhabitants, mainly those located in arid zones (Oke, 2006).

Some authors define the heat island as the relative heating of the city compared with the pre-urban conditions (Mazzeo, 1984); or as the differences between the temperature of the urban area and the non-urban area (Papparelli, *et al*., 1997 and 1998); or an 'inverted oasis', where air and area temperatures are warmer than those in their rural environments (Garland, L., 2011). Stewart and Oke (2012) identify it as the difference in temperature between two different climatic zones (LCZ)[5], characterized each by its uniformity in soil coverage, urban structure and human activities. The urban climate of the metropolitan area of San Juan studied by processing satellite images (Cúnsulo *et al*., 2013) showed an urban heat island of 5.0ºC and 4.5ºC for summer and winter respectively. This demonstrates the incidence of the urban occupation, particularly in its area distribution (land occupation factor) and volume (volumetric building density).The mentioned urban-spatial-microclimatic peculiarities are similar to those that characterize other cities of medium scale located in arid zones.

This requires the decision-making of bioclimatic urbanism in order to incorporate them into the city planning of arid environments, to generate comfort conditions to the population in order to allow to counteract the thermal effect and the pollution generated by the heat island (Alchapar, *et al*., 2016 and 2015; Arellano Ramos, *et al*., 2015; Correa; *et al*., 2010; Pulliafito, *et al*., 2013; Sosa, *et al*., 2016; Tumini 2010; Villanueva-Solis, *et al*., 2013).

Environmental Sustainability and Urban Bioclimatic Planning in arid environments

Tending to urban environmental sustainability requires, among other actions, the implementation of policies aimed on: making full use of renewable energies, utilizing responsibly non-renewable natural resources, designing and producing energy-efficient and low-polluting transport systems, encouraging the creation of food sources as close as possible to reduce the energy used in its transport, reusing and recycling the waste, minimizing the urban area and thereby optimizing the services (compact city), increasing the green spaces for the generation of oxygen, absorption of CO_2 and part of the rainwater, and reduction of the effect of the heat island. In short, a city subjected to control ofits ecosystemic entropy increasing. The planning of the cities must consider the characteristics and modality of growth, among other factors that contribute to the public welfare, not only the development of activities in dimensional, spatial and technological appropriate spaces, but having the best hydrothermal conditions to allow their use with an adequate standard of urban life. The urban bioclimatic planning is framed in this concept and takes advantage of the climatic offer, in this case of the arid and its resources, to respond to the requirements of hydrothermal comfort of the population, attending to the continuous interrelation existing between the man, its environment and the impact that its action exerts on it. In this sense, the urban bioclimatic planning, understood as the set of strategies to procure the conditioning of the open spaces in the city which benefit in the decrease of the climatic load on the interiors building, serves the regulation of the urban space through multiple aspects. They are:

- Urban index: Land Occupation Factor; Total Occupation Factor; Free Area Index; Volumetric Building Density; Area of green spaces per inhabitant; Percentage of green area in relation to the urbanized land.
- Geometry of urban road channels: To ensure access to the sun and breezes.

[5]Stewart y Oke, definieron zonas urbanas homogéneas a las que denominaron Local Climate Zones, en relación al uso del suelo y las características edilicias y arbóreas.

- Orientation of the urban plot in relation to the prevailing winds and the sunning.
- Geometry, orientation and sizing of apples and lots
- Street technology: roadways and sidewalks, to reduce the albedo
- Distribution, systematization, area, sizing and tree imprint of green spaces.
- Tree species appropriate to the arid and the conditions of winter sunning and summer blockade.
- Location, distances between specimens and characteristics of the alignment woodland.

The use of urban forestry to mitigate the conditions of rigor of the climate in the open spaces implies a strategy that contributes to the decrease of the thermal load building. In this way each building will be subjected to lower climatic pressures and therefore the control of the interior temperature and humidity will be more accessible. In other words, urban forestry contributes to the mitigation of the heat island and the humidical depression effects (Goward, S.N., 1981; Oke, T.R., 2006; Kurbán *et al*., 2004; Kurbán *et al*., 2007 a and b; Garland, L., 2011).Among the complementary ecological roles of green spaces together with bioclimatic one, we can highlight the increase in the absorption of greenhouse gases, mainly CO_2, the release of oxygen, the filtering of suspended particles and the absorption of noise by the foliage of the trees. The socio-economic implications are not left out of the analysis, since any strategy propending to the decrease in the energy consumption of fossil resources is of priority importance as a contribution to the environmental sustainability referred to urban poverty. This is because the low-income population suffers hydrothermal discomfort by not possessing the economic resources that allow them to access conventional sources of energy for the conditioning of their homes. Furthermore, the green areas and their trees are one of the components of the urban space of simple intervention in existing urban areas, particularly in those with urban index of low or medium density.

Urban Green Indicators: General and Bioclimatic

The need to provide useful and simple tools that collaborate with the urban bioclimatic planning of cities of arid environments, leads to the decision to obtain indicators of the Urban Bioclimatic Green. Considered as empirical interpretation of reality, the indicators have three main functions (OECD, 1997): simplification, quantification and communication.

The indicators used in urban green planning in cities are generally related to the amount of population in cities and/or with their area. In the first case the relationship arises from the quotient between the area of the urban green spaces and the population that inhabits in the considered urban sector (m^2/inhab). In the second case, the relationship responds to the quotient between the area of urban green spaces and the total area of the considered urban sector (%). Then, it is an indicator of the Urban Green Space (EVU) density.

For the purposes of this article, it is understood by Urban Green Space (EVU) those areas of public use, predominately occupied with trees, shrubs, plants and grass, usually used for recreation, urban, social, cultural, ecological, ornamentation, protection, recovery and rehabilitation of the environment, or similar purposes. In the case of urban bioclimatic planning, the green that intervenes in the mitigation of the urban heat island is not only the one that conforms the EVU but also the forestation planted along the streets, that is to say, the alignment trees. For this reason, the terms used in the calculation of the indicators, vary as they are focused or not to the role of bioclimatic urban green. In one case, they will be referred to the General Urban Green and on the other to the indicator of the Bioclimatic Urban Green.

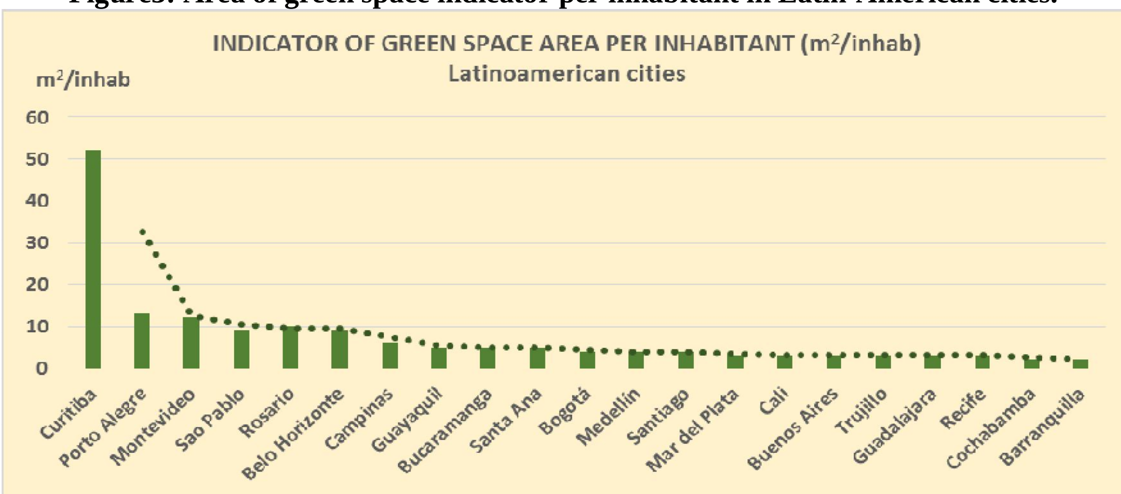
Indicator of the General Urban Green

EVU area per inhabitant indicator

According to recommendations of the World Health Organization (OMS), cities must have a minimum of 10-15 m^2 of green area per inhabitant, distributed equitably in relation to the population density (CAD-MED, 2016; Rojas, 2007). Reyes y Figueroa (2010), argue that the stipulated amount is 9m^2 per inhabitant. Terrace (2012) matches that value, but called as "mythical" area recommended by the OMS in the early 90's, since it is considered that it has not been possible to find the source document; in some cases it is 10m^2/inhab and in other 12m^2/inhab always quoting the same institution as the source of the data. PNUMA (2010) indicates that OMS recommends between 9 and 11m^2 of green area/inhabitant. But it recognizes that the criterion for adopting a particular quantity is complex since the distribution of green spaces is usually not a product of the application of environmental criteria, but as a result of the disordered growth of cities. According to Herrera (1995), the Organization of the United Nations estimated the proportion of green area as optimal in 16m^2 per inhabitant.

However Rendón Gutiérrez (2010) indicates that the United Nations considers that it shall have one area not less than 12m^2 of green areas per capita, to guarantee the life quality of the inhabitants in the cities. Terraza (2012), cites studies made for cities in Europe which can be reference for cities of comparable population density with Latinamerican one. One of them, (Fuller and Gaston, 2009), performed on 386 cities, the indicator has a range between 4m^2/inhab in Cádiz (Spain) or Reggio Calabria (Italy), up to 300m^2/inhab in Liega (Belgium). This study concludes that countries of the South and Eastern Europe, such as Spain, Italy, Portugal, Greece, Poland, Czech Republic, Bulgaria, etc., are closer to an average around 10 - 15m^2/inhab, while in the North, eg. Scandinavia, Germany, Netherlands, Belgium, etc., are above 50m^2/inhab. Also cites another study (Levent, Vreeker and Nijkamp, 2004), conducted in 25 cities, in which the range is very wide, ranging from 2.6m^2/inhab in Istanbul, 11.8m^2/inhab in Sarajevo and 144m^2/inhab in Edinburgh, with an average close to 49m^2/inhab.The aforementioned study of Terraza for Latinamerica, carried out with the group of the ICES (emerging, sustainable cities initiative), threw as result the indicator values presented in Figure 3. It shows that for the 96% of the Latinamerican cities studied this indicator ranges between 2 and 12m^2/inhab, constituting the exception Curitiba, with 52m^2/inhab. The variance of the sample is 109.

Figure3: Area of green space indicator per inhabitant in Latin-American cities.



Source: own elaboration on Terraza (2012).

EVU Density Indicator

Another way of sizing up urban green spaces is the density indicator of EVU, which relates the green space area and recreational area to the total area of the urbanized area. This percentage also represents an indicator of urban sustainability. In the work "Indicators of Green Zones and recreation areas " (CAT-MED, 2009), carried out in 11 European cities members of the CAT-MED foundation, Platform for Sustainable Urban Models, the values resulted as shown in Figure 4. In this case, the sample variances 22.

Figure 4: Indicators of green areas and areas of recreation in European cities.

Source: own elaboration on CAT-MED, 2009.

Analysis of indicators for a city of arid zone Regulations on Urban Green Areas in San Juan - Argentina

In the province of San Juan, in the early '80, the Urban Planning and Development Directorate made a proposal on the green spaces in the city, based on the stipulated by FONAVI (National Housing Fund). This organism adopted in this matter the criteria of the Decree-Law 8912/77 "Law of land and land use" of the Province of Buenos Aires, norm that in chapter III article N° 13 delimitation and dimensioning, stipulated: "The green or free public spaces in an urban nucleus will be dimensioned based on the maximum potential population established by the Management Plan for it, adopting a minimum of ten square meters ($10m^2$) of free or green area per capita. Within that area, small squares, squares and public parks either communal or regional, shall be computed. Green spaces will be conveniently distributed and located in each area or zone, at the rate of three and half square meters per capita ($3.50m^2$/inhab) for small squares, squares or neighborhood open spaces; two and half square meters per capita ($2.50m^2$/inhab.), urban parks and four square metres per capita ($4m^2$/inhab.) for local or regional parks. "For the purposes of computing the four square meters ($4m^2$) corresponding to trade or regional parks may include the parks located within a radius of 60Km."

The above mentioned proposal of the Directorate of Urban Planning and Development, which is an internal document, redistributed the $10m^2$/inhab (meeting according to the source[6], to the stipulated by the OMS) due to the condition of oasis of the city and the existence of alignment trees in most of its streets. That distribution was: neighborhood green spaces, $2.5m^2$/inhab; alignment trees $2.0m^2$/inhab; urban parks $2.5m^2$/inhaband regional parks $3.0m^2$/inhab (radius 50 km = 130Ha).Also in the of edification code of the San Juan province (Res. No. 5580 - 1951), booklet III: General Building Requirements for the Planning in General, article 4.1.2.3. (a) Formation of new urban centers, standard to be "not less than 4% of the total area for the formation of squares and parks. Squares in general should have a similar area to the fractionation square type, unless otherwise specified by the Competent Authority."Therefore, the province of San Juan has two types of indicators of green spaces which are detailed above: one related with the amount of population (not possessing character of norm) and the other related to the amount of urban area, regulated in the Building Code. From them, the studies of the most appropriate indicators from the bioclimatic point of view are developed below.

Strictly from the urban planning, the inclusion of the alignment trees on the area of green spaces would not correspond, since the EVU are those areas of public use, predominantly occupied with trees, shrubs, plants and grass, usually used for purposes of recreation, urban, social, cultural, ecological, ornamentation, protection, recovery and rehabilitation of the environment, or similar. This criteria is supported also by other definitions such as "all that spaces and corners of the different districts of the city even the small ones, that allow the development of tree or shrub vegetation on them (squares, small squares, boulevard, gardens and parks)"[7] or "public buildings predominantly occupied (or used to be), with trees, shrubs or plants and allow recreation of people in them" (Housing and Urbanism Ministry, Chile, 2007).

However the above, from the bioclimatic urban planning point of view, alignment woodland should be included in the green area of cities, as their contribution is effective, particularly when the tops of the trees row make up a significant coverage of sidewalks and driveways. In that case, this area will assimilate to the horizontal tree projection at 90º, given that it is assumed that its hydrothermal effect is reduced to his own imprint (Kurban *et al.*, 2004).Therefore, two ways to define an indicator of urban green are possible: a) a general one, that considers the green spaces equipped with multiple roles; and b) a bioclimatic one, that covers only those areas that demonstrably provide bioclimatic coverage. In the latter case, the road woodland would be incorporated.

Indicators of the Urban Green in the Metropolitan Area of San Juan

To calculate the urban green indicators, different parameters are considered: both of area per inhabitant as density in relation to the urban area. In the first case, referred to here as *General*, two variables are involved: population and area of urban green (without considering the alignment trees). In the second case, called *Bioclimatic*, there are involved three variables: population, urban green area, and alignment trees.

[6] Urban Development Division of the Planning Department of the Planning and Urban Development Directorate - DPDU.San Juan Province. 2001.

[7] Law Nº7874 "Preservation and Control of the Public Trees ", Mendoza, Argentina. 2008.

EVU area per-capitaindicator

→ *General Indicator*

The parameters involved in its calculation are: population 458230 inhabitants; Total area of urban green: 130.76Ha (Kurbán, *et al*., 2010) (111.15Ha of neighborhood green areas; 19. 61Ha of urban parks; the alignment trees is not considered); there is no Regional Park.

-The Global Indicator results equal to 2.86m^2/inhab, composed by:

- Neighborhood EVU = 2.43m^2/inhab
- UrbanPark = 0.43m^2/inhab
- Regional Park = 0.00m^2/inhab

→ *Bioclimátic Indicator*

The parameters involved in its calculation are: population 458230 inhabitants; Total area of urban green: 522.79Ha (Kurbán, *et al*., 2010) (22.84Ha of neighborhood green spaces; 19.61Ha of urban parks and 480.34Ha of alignment trees); there is no Regional Park.

- The Global Indicator resultsequal to 11.41m^2/inhab, composed by:
- Neighborhood EVU = 0.50m^2/inhab
- UrbanPark = 0.43m^2/inhab
- Alignementtrees =10.48m^2/inhab
- Regional Park = 0.00m^2/inhab

In a priori way, the preceding values demonstrate:

- General Indicator: very deficitary Global and Neighborhood index; highly deficitary index in urban park; zero value index in regional park index.
- Bioclimatic Indicator: suitable Global index; very deficitary Neighborhood index; highly deficitary urban park index; surplus in Alignement trees index; zero value index in regional park index.

Bioclimatic planning studies (Kurbán, *et al.*, 2009) concluded that the bioclimatic coverage of the San Juan Metropolitan Area, considered as the area covered by thermal and homicidal effects of the EVU, resulted in 6.92% of the urban area in the case of the thermal and 5.55% in the homicidal one. If the thermal and homicidal effect of the alignment trees is added, the cover increases to 10.7% of the urban area for the thermal effect and to 9.3% for the homicidal one. Calculating these percentages as area per inhabitant values resulted a thermal and humidical coverage of 30m^2 and 26m^2per inhabitant respectively. It can be concluded then that 10 m^2/inhab of the provincial proposal is a quantity globally dedicatory, resulting in 1/3 of the existing bioclimatic coverage, already on its highly deficient.

EVU Density Indicator as related with the urban area

The parameters that intervene in this indicator are:

- General Indicator: urban area; Provincial Building Code regulations; urban green area (without considering the alignment trees); total green area according to the provincial planning proposal.
- Bioclimatic Indicator: urban area; urban green area including the alignment trees; Total green area according to the provincial planning proposal.

→ *General Indicator*

Intervening parameters: urban area 12656Ha; Building Provincial Code 4% of the area; urban green area (without considering the alignment trees) 130.76Ha; Total green area according to the provincial planning proposal 506.24Ha.

- General Resulting Indicator: 0.01%

→ *Bioclimatic Indicator*

Intervening parameters: urban area 12656Ha;Building Provincial Code 4% of the area; urban green area 522.79Ha; Total green area according to the provincial planning proposal 506.24Ha.

- General Resulting Indicator: 4.13%

The General indicator is very low, even if referenced with European cities with more compact urban imprints (Figure 4). This indicates that the city of San Juan is very far from having the minimum quantity of required green areas to get urban sustainability. The bioclimatic indicator conforms to the proposal of the Provincial Planning Directorate.

Alignment trees

In accordance with the edification code of the San Juan province, in the pre-projects of fractionation of any kind, it must be provided at least 18% of the fractionation total area for the formation of avenues and streets, and must incorporate the chamfers to this area (Art. 4.1.2.1 a).Therefore, if the alignment tree coverage in the AMSJ is related with reglamentary road area, it can be estimated that this area covers 22780463m^2. If the tree imprint is 480.34Ha (Kurbán*et al.*, 2010), the coverage of streets (roads and sidewalks), is 21%.Kurbán*et al.* (2004) estimated that the horizontal projection area of the alignment trees considered as optimum in cities of arid climate characterized by a Land Occupation Factor of around 50% and a Volumetric Building Density about of 35000m^3/Ha, is in the order of 70 to 75%.For the Eminently Urban characteristic urban band (BUC) which minimum FOS is 40% and the minimum volumetric building density is15000m^3/Ha the suggested minimum value could be reduced in the same proportion, which results 43%.

Analysis of indicators of the Urban Green in the AMSJ

Both from the consideration of green spaces in their multiple roles for the society as from the bioclimatic point of view, the presence of the green in the AMSJ is undersized. The EVU General Global Indicator of green area per inhabitant (2.86m^2/inhab) is 28% of the regulated; the neighborhood one (2.43m^2/inhab), is adequate; Urban Park (0.43m^2/inhab), represents only 17% of what was needed. In addition, thereis no a Regional Park. The EVU Bioclimatic Global indicator of green area per inhabitant (11.41m^2/inhab) is adequate, but when analized one by one, the neighborhood (0.50m^2/inhab)represents 20% of the regulated; Urban Park (0.43 m^2/inhab) represents 17% of the regulated; the alignment trees (10.46m^2/inhab) is surplus, and there is no Regional Park.In accordance with the parameters that quantify the harshness of the arid urban climate in the AMSJ, such as: spatial distribution of temperature and humidity, high values of heat island, high comfort index calculated for each EVU and their environments; both indicators calculated with the existing values and the regulated ones, are undersized. This arises because while the global values are adequate, being the thermal coverage in the AMSJ, as said above 10.7% and the humidical one 9.3% (Kurbán*et al.*, 2009), the parameters used in the proposal of the Provincial Planning Directorate are not appropriate to our bioclimatic zone. This situation is more evident when analyzing the partial indicators, due to high neighborhood and urban park deficits, and the absence of a regional park. According to the bioclimatic area per inhabitant indicator, in all cases, the area of alignment trees is oversized. But if it is related with the imprint of shadow that actually generates the road grove, it shades only 21% of the streets (Kurb án *et al.*, 2004). Regarding the 70 to 75% optimal, its actual thermal efficiency is far from ideal. However, to arrive at this amount, the proportion should be 37m^2 per in hab, which added to neighborhood and parks areas, would lead to the Global Indicator values well above to the possible to pretend in arid areas.

Proposal for Bioclimatic Urban Green Indicators

Due to the preceding analysis and as a situation that can improve the city bioclimatic considering the logical restrictions on urban green characteristic of arid environments, it is intended to take a bioclimatic road coverage indicator corresponding to the coverage percentage as a function of the urban densification and the Land Occupation Factor range. This road bioclimatic coverage indicator is obtained with the following procedure: provides 70% of coverage that would correspond to a volumetric building density of 35000m^3/Ha (Kurbán, *et al.*, 2004), to the density 15000m^3/Ha that characterizes the minimum value in the predominantly urban band. The same procedure applies to the FOS: 70% of the coverage corresponds to 40% FOS. The first value is 30% and the second 56%. It is adopted an average of both, equal to 43%. In the same way it is processed with FOS and DV boundary values of each characteristic urban band.

The resulting road coverage values are: BUC EU=43%, BUC UR=22%,BUC SU=3%.To obtain the Bioclimatic Road Indicator, the weighted value of the area of each BUC/total area of the AMSJ percentage is adopted[8].The Bioclimatic Road Coverage Indicator for the AMSJ is 16%.As the road area represents 18% of the total urban area, 16% of coverage corresponds to 3% of the urban area. In relation to the population of the AMSJ, this indicator would be equivalent to 8m^2/inhab. Preserving the proportion suggested by the DPDU, values by neighborhood EVU and City Park would be 10m^2/inhab each. This would give a Global EVU area indicator of 28m^2/inhab.

[8]The percentages of area occupied by each BUC with respect to the total of the AMSJ are: EU 10%; UR 45% and SU 45%. Kurbán, *et al.* (2013), Papparelli, *et al.* (2015).

Regarding the density indicator of global EVU in the city, the average value of European cities is 7.7%. If adopted for the AMSJ 8%, it would correspond to a green area in the AMSJ 10124650m^2. This percentage would be equivalent to 22m^2/inhab. Since the relationship between the result of both indicators (28m^2/inhab and 8%), converted to green area per capita is similar, the following parameters, which represent equivalent values: EVU density indicator: 9% of urban area; EVU area indicator per capita: 25m^2/inhab., are proposed. This latter index is broken down according to the criteria suggested by the DPDU (but excluding the regional parks whose area for their multiple roles should exceed 20Ha considered as the maximum bioclimatic coverage limit[9])

Results

According to the three main functions of the indicators already mentioned, i.e. the simplification, quantification and communication, properties are assigned to every urban green bioclimatic indicator. These have been adapted from the criteria and conditions proposed for Ecological Urbanism (S. Rueda *et al.*, 2012). These are:

- Indicator Objective: defines the indicator bioclimatic role.
- Calculation: explicit the formula in units of the decimal metric system.
- Value: Specifies the minimum or maximum parameter, as the case may be.

The detail for each of the obtained indicators is the following:

a) Bioclimatic Indicator of EVU Density
  - Indicator Objective:
    Achieve adequate bioclimatic coverage in relation to the urbanized area.
  - Calculation:
    (ΣEVU Area / Total city area) x 100 = %
  - Value:
    Minimun: 9%

b) Bioclimatic Indicator of EVU area/ inhabitant
  - Indicator Objetive:
    Achieve adequate bioclimatic coverage in relation to the amount of urban population
  - Calculation:
    Σ EVUárea/ City Population(m^2/inhab)
  - Value:
    Global Area Indicator: 25m^2/inhab
  - Neighborhood EVU Indicator: 9m^2/inhab
  - Urban Park Indicator: 9m^2/inhab
  - Alignement Tres Indicator: 7m^2/inhab

Conclusions

The thoroughness of the arid urban climate requires concrete actions of bioclimatic urban planning that reduce the climatic load of the city in open spaces, in order to reduce its influence on the building. The need to provide useful and simple tools that can work together with the bioclimatic urban planning of cities in arid environments, lead to the decision to obtain Green Urban Bioclimatic Indicators. Indicators relating the number of inhabitants and the area of the city are proposed. These are calculated on the basis of international standards, study cases and research findings of the urban climate in a city of arid zone. While the application of a bioclimatic legislation that take into account the proposed urban green indicators requires to be the political actor the first who intervenes, changes in the physical plant of a city, together with a proper management in communication, will certainly contribute with valuing by the society of the role of bioclimatic green areas, in arid urban environments.

[9]According to the spatial distribution of the thermal and humidical effects (Kurbán, *et al*., 2007).

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