Planning tool for the transformation to low density cities in more sustainable urban models

Jimena GOMEZ PIOVANO; Alejandro MESA, INCIHUSA CONICET CCT- Mendoza, Mendoza Argentina

1. Introduction

South America is one of the regions where the phenomenon of urbanization has a big proportion overcoming Europe and USA. This phenomenon increases in Argentina considering that 70% of the population lives in cities (ONU Habitad 2012). Most of the developments are concentrated in fertile and productive areas, while there are large desert areas without occupation or explotation. Therefore the accelerated urbanization processes constitute a loss of agricultural production. There is a great need to preserve natural soil in the environment and is more complex in arid land where the expansion is limited to a certain area.

Salvador Rueda (1998) sustains that there are currently two antagonist models of urbanism, compact city and urban sprawl. Urban sprawl is the one that is dissipated in large areas, that has everything and much but with low population density, with functionally separate areas: university, industry, residence, commercial areas, and offices. (Rueda, 1998). These functional cores bind through a dense network of roads and private transport. Hence, urban sprawl is characterized by the increase in urbanized areas, consuming excessive amounts of energy and other natural resources such as soil.

The combination of the dispersion of activities that the diffuse city imposes, and the need of man to be in touch personally give as a results in a massive use of motorized means of locomotion, mostly private vehicles. This is due to the low population density makes that public transport becomes economically inefficient and unprofitable (Rueda, 1998; Mesa, 2005; Papparelli, 2009). Thus the urban sprawl model is considered unsustainable because the urban land track cover and horizontal mobility network is expands invading high-value land both ecological and agricultural (Rueda, 1998; Papparelli, 2009).

In contrast, compact cities, the highest population density promotes greater diversity of uses, that is to say, the coincidence in the same sector of the residence, services, economic activities and equipment. In this way provides the proper context for increased exchanges of information (Rueda, S. 1998; de Schiller, S. 2000). The confluence of activities on the ground floors meets the necessary urban services and facilities to the people, thus increasing the number of trips on foot or by bike and reducing the need to use motor transport (de Schiller, S. 2000). In turn, the highest population density favors public transport which produces fewer cars on the road, thus freeing up mobility pathways saturated today by private transit. The densification, in relation to infrastructure, resulting in lower energy consumption, as well as feasibility of implementing them (Burgess, 2000; Rueda, S. 1998; de Schiller, S. 2000).

The benefits resulting from the reduction in the rate of urban expansion, through the promotion of higher density settlements are particularly important where the urban growth rate is high, the cultivated land per capita and growth rates agricultural production are low (Mathey, 2000).

An example of this problem occurs in Metropolitan Area of Mendoza (MAM). The City is inserted into an oasis irrigated by the Mendoza River, forming a "green island" in a large space semidesert. The conglomerate urbanized area has increased by 129% between 1986 and 2011, while population growth was only 41%. In this process invade soil areas with high agricultural potential and the piedmont-extremely fragile ecosystem, while in the central areas the population decreases. This phenomenon is the result of internal migration, associated with the inhabitants of the central districts moves their place of residence to the periphery looking to improve their quality of life. Thus, it accelerates the process of territorial fragmentation, increasing demand for services and equipment, and unbridled competition for land use. Without considering the energy costs associated with new developments and isolated dwellings models that it promotes.

This is a very common trend in Latin America and corresponds begin planning the population growth in already developed areas. Consequently, this paper develops a simple simulation tool to visualize urban growth

2. Methodology

This paper consists of a description and application of a calculation methodology that allows to evaluate the different levels of sustainability indicators associated with land use of urban growth in low density cities (<80 inhabitants/hectare)**. The** second step aims to verify theoretical application in a case. To this end, the different variables of urban growth for the MAM are studied.

The simulation tool designed develops a digital projection system in order to estimate levels of urban scale sustainability of cities. The instrument designed is structured as a strategy of continuous improvement (Deming PDCA Cycle), consists of four stages, which are called: know, estimate, test and act. For each one of the stages will establish the specific procedures that make up the tool.

2.1. Know

This first step aims to understand the characteristics of the study area: the historical, geographical, morphological and social place. In this study we obtained the data needed to perform the numerical estimation, which are described below:

- Population Data
    - Total Population Year A
    - Total Population Year B
    - Number of years between A-B
- Urban Data
    - Urban area (m^2)
    - Surface mitigating public spaces[i] (m^2)
    - Total floor area (m^2)
    - Urban parcels surface (m^2)
    - Area of undeveloped urban parcels (m^2)
    - Surface circulation (m^2)
    - Relationship between the built footprint and the surface of building land (F.O.S.)
    - Relationship between the floor area and the area of land (F.O.T.)

Where A= prior to the current period with data and B= current year

2.2. Estimate

In this second stage is performed the simulation for growth. For this, it is necessary to set the time period under study, it is denominated "year C", subsequently it projected population growth in the study area, based on population data recorded in the previous point.

- Estimation of population growth [(ii)]

$$\textbf{Population C} = \left\{ \left[\left(\frac{\frac{\text{Population B}}{\text{Population A}} - 1}{\text{Year A- Year B}} \right) . \text{ Year A- C} \right] + 1 \right\} . \text{ Population A}$$

- Public spaces stipulated

$$\textbf{New public spaces} = (\text{Population C - Population B}) . \left(\frac{\text{Mitigating public spaces}}{\text{Population B}} \right)$$

- New area built

$$\textbf{New area built} = (\text{Population C - Population B}) . \left(\frac{\text{Area built}}{\text{Population B}} \right)$$

- Area of new urban parcels

$$\textbf{Area of new urban parcels} = \frac{\text{New area built}}{\left(\frac{\text{Area built}}{\text{Area urban parcels}} \right)}$$

- Area of new urban parcels without building

$$\textbf{Area of new urban parcels without building} = \text{Area of new urban parcels} . \left(\frac{\text{Area of urban parcels without building}}{\text{Area of urban parcels}} \right)$$

- Area of new circulations

$$\textbf{New circulations area} = \frac{\text{Circulation Area . (New parcels area + Area of new urban parcels without building+ New public space area)}}{\text{(Parcels areas + Public space area)}}$$

2.3. Test

In this instance, assesses sustainability levels of the estimated simulations during the time period studied. To this end, we compare the simulation results obtained in relation to the ideal values established by Salvador Rueda (s/f) as optimal, of the following urban indicators:

- Density Housing

$$\frac{\text{Estimated number of inhabitants}}{\text{Total urban area}} \rightarrow \text{Desirable value 220-350 inhabitant / ha}$$

- Absolute Compactness (Ca):

$$\frac{\text{(Area built + New area built)*3}}{\text{Total built-up area}} \rightarrow \text{Desirable value 5}$$

- Corrected Compactness (Cc):

$$\frac{\text{(Area built + New area built)*3}}{\text{Public space area + New public space}} \rightarrow \text{Desirable value 10 a 50 m}$$

- Public space mitigating (EPA):

$$\frac{\text{(Public space area + New public space)}}{\text{Estimated number of inhabitants}} \rightarrow \text{Desirable value } 10\text{m}^2\text{/inhabitant}$$

2.4. Act

At this stage the results are evaluated in the previous point. If the values found far from the reference values shall be proposed generating growth options and the cycle begins again.

3. Development

3.1. CASE A: Estimation of growth of the Metropolitan Area of Mendoza in a period of 30 years according to current growth parameters.

3.1.1. Know

The AMM consists of six political-administrative regions City of Mendoza, Godoy Cruz, Guaymallén, Las Heras, Luján y Maipú. The urban area that comprise have approximately 18,000 ha, inserted into the oasis watered by the Rio Mendoza of 158,000 ha. Historically, the formation of the AMM was developed as an extension of the urban area of the City of Mendoza to the neighboring departments. In a first stage, the growth was around the foundation area, but from an earthquake happened in 1861 built a new town on land adjoining. The continued growth of the urban area was including small urban centers, independent in its formation, as the departmental centers. This development process that began in the late nineteenth century and is maintained to the present , resulting in extensive low density urban area, which invades the neighboring agricultural areas of high ecological value, and piedmont areas (at west), extremely fragile ecosystem (Figure 1).

Figure 1: Growth of MAM. Mosaics built on cadastral base

In recent years, the AMM has increased the urban area with an annual rate of 4.5%. Between 1983 and 2011 the area grew by 129%. For example, from 2003 to 2011, the urban spot went from having an area of 14,026 ha to 17,732 ha. However, this model of rapid increase of the urbanized area contrasts with the population increase which has a slower pace (Figure 2).

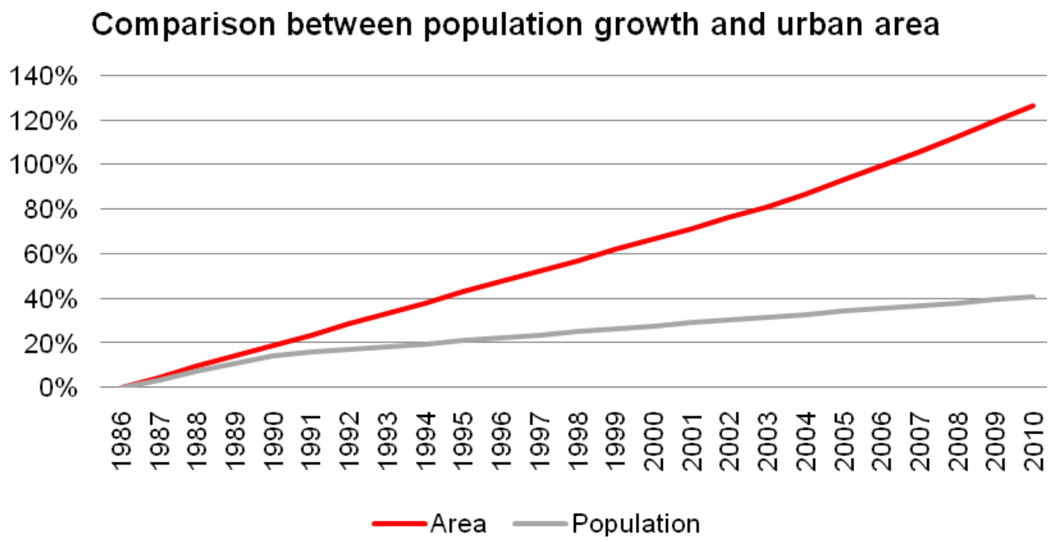

Figure 2: Comparison between population growth and urban area

On the one hand, this is because new projects are of lower density than the consolidated areas. While on the other hand there is a intra-urban migration process where the families living in the center leave their former homes and move their residences to new areas on the periphery. Thus, when comparing the 1991 census data and 2001 in 46% of consolidated urban areas were declines in the number of inhabitants, while in the periphery increased the population (Figure 3).

Today the MMA is the fourth largest city in Argentina with a population of 1,086,633 inhabitants and an urban area of about 18,000 ha. It is formed by 60% of urban parcels, 36% of circulations and 4% of public recreational spaces (squares, parks and pedestrian) (Figure 3). The relationship built between the tread surface and ground (FOS) of MMA is 0.37, with variations depending on the department. The one with greatest levels is the City department who reaches a 0.5, while the lower value 0.17 corresponds to Lujan. The relationship between the floor area and the area of land (FOT) on average is 0.66, taking the most range in City department and lowest in Maipú department (Figure 2).

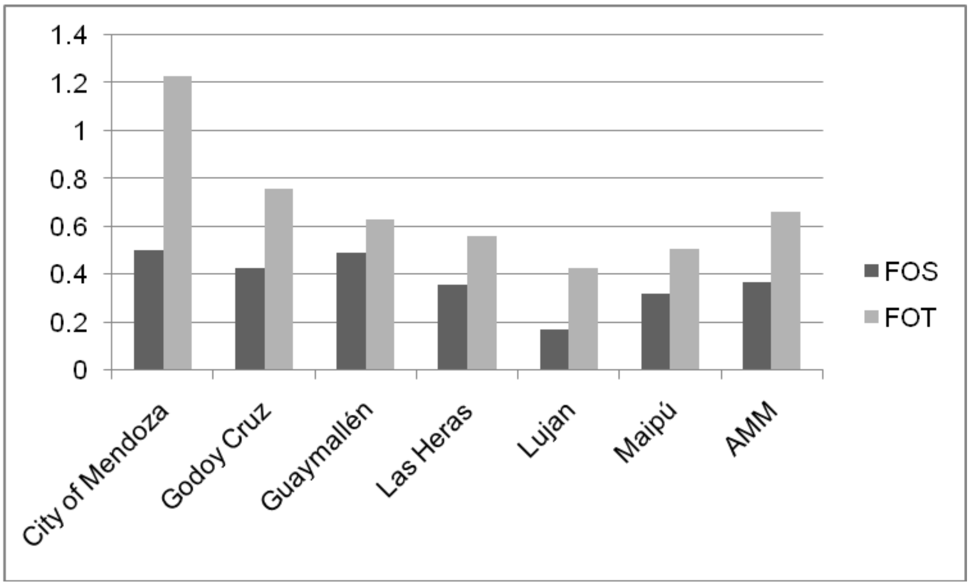

Figure3: Urban indicators FOS FOT by department

On the other hand, within the consolidated urban area are available 30,608,775 m2 of parcels unoccupied, representing 24% of the area devoted to such use (Figure 4). The relationship between floor area and number of inhabitants is 39.35m2/hab.

Population density **Population evolution beating 1991 and 2001**

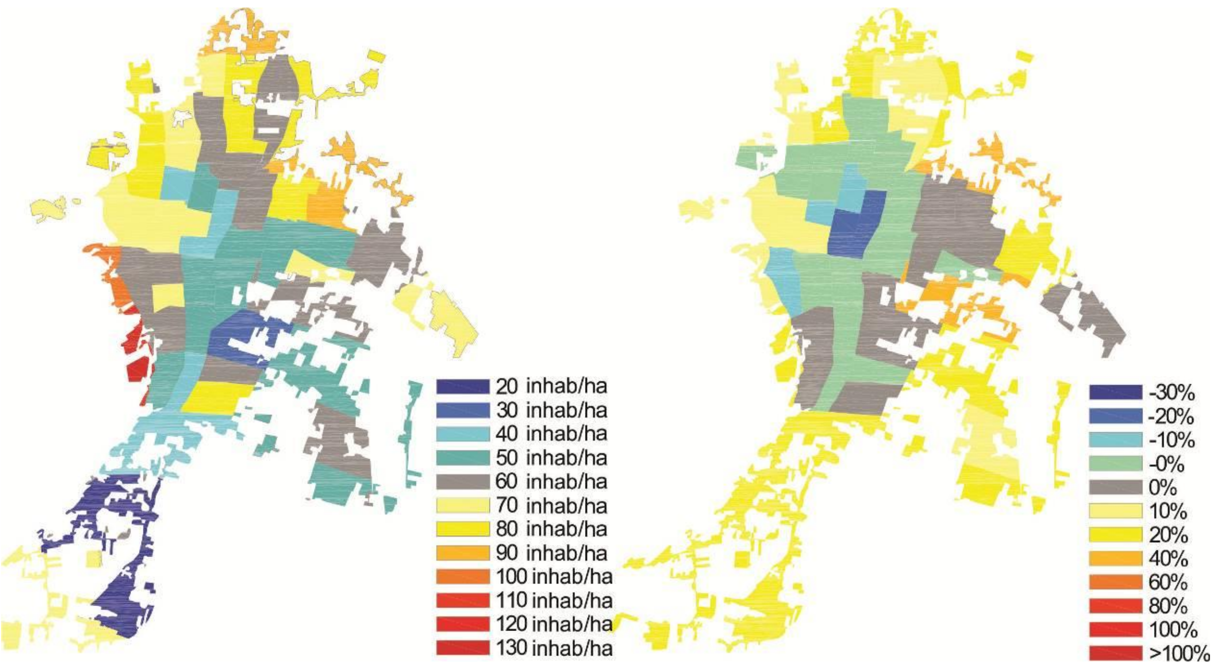

Figure 4: Population density and Population evolution

The AMM has 8,097,088 m2 of public spaces attenuating, which correspond to 7.45 m^2/inhab. The distribution of the same in the territory is uneven: in the district of City lies the most (50.15m2/inhab.), While the Department of Las Heras is the one that has fewer (0.62 m2/inhab.) (Figure 5).

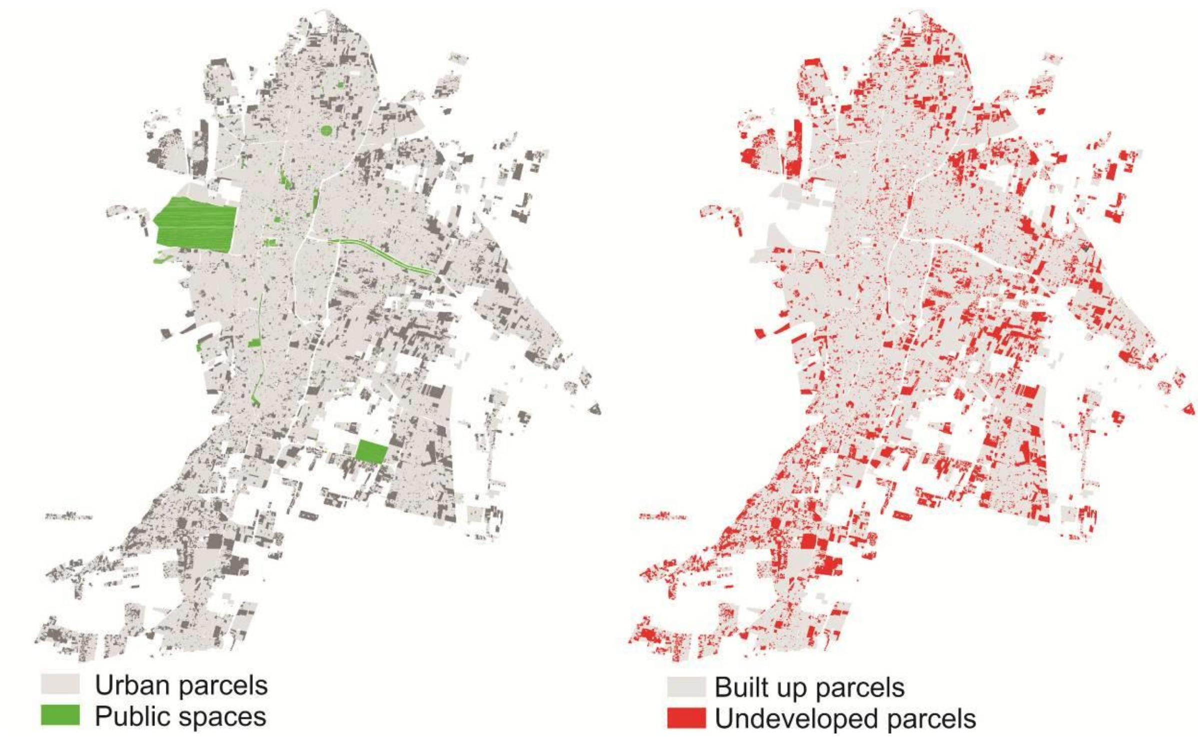

Figure 5: Composition of the urbanized surface of the Metropolitan Area of Mendoza.

3.2. Estimate:

The growth simulation raised here covers the period of 30 years, 2,013 [iii] and 2,043 [iv]. Following the current growth trend, by the year 2043 the number of inhabitants of the AMM would amount to 1,407,567 inhabitants, which would mean an increase of 320 934 people (28%), accompanied by an expansion of the urban area of 7,318 ha, composed as follows:

Siguiendo las tendencia actuales de crecimiento, para el año 2.043 la cantidad de habitantes del AMM ascendería a 1.407.567 habitantes, lo que significaría un aumento de 320.934 personas (28%), acompañado por una expansión de la mancha urbana de 7.318 ha, compuesta de la siguiente manera:

- New public spaces: 2,391,455.15 m^2
- New built-up areas: 12,630,639.77 m^2
- New surface plots: 37,259,064.31 m^2
- New areas of undeveloped parcels: 9,040,226.87 m^2
- New surface circulation: 26,851,075.91 m^2

3.2.1. Test:

In this third stage, we will evaluate the levels of sustainability of the urban to 2,043.

· Density Residential: 49 inhab. / Ha →desirable value 220-350 inhabitant / ha
· Compactness Absolute (Ca) 0.59 →desirable value 5 m
· Corrected Compactness (Cc): 15.84 →desirable value 10-50 m
· Public space mitigation (EPA) = 7.37 → desirable value 10 m2/habitante

3.2.2. Act

The values of sustainability indicators, evaluated in the previous section, not found within the optimum parameters, so that there is proposed a new growth strategy. This new project aims to meet the demand of building area, on the current consolidated structure, completing the current undeveloped parcels.

3.3. CASE B: Estimation of growth of the Metropolitan Area of Mendoza in a period of 30 years without increasing urbanization surface.

3.3.1. Know:

As in the previous simulation, at this stage is performed a growth forecast for a time period 30, which will compare the results of the two proposals. Consequently, population growth would be identical to the previous inhabitants 320,934.40, but contrary to the previous model this will not increase the urbanized area.

3.3.2. Stimate:

Posed simulation corresponds to the period between 2,013 and 2,043. According to the statistical estimation of the urban population would 1,407,567.40 inhabitants. This population increase would not be accompanied by the expansion of the urban area, but for the use of parcels without buildings, the available surface is 30,608,775 m2. It involves the construction of:

- New public spaces: 2,391,455.15 m^2
- New built-up areas: 12,630,639.77 m^2

Here we see that the current urban area can host for 30 years the growth population following the current urban construction rates and including mitigating public spaces, all of this using only 80% of vacant land. For this reason, we conclude that the developed area of the AMM can be maintained without increases for more than 30 years.

3.3.3. Test:

As in the previous case, in this stage are evaluated sustainable levels of new urban structure.

- Density Residential: 67 inhab. / Ha → desirable value 220-350 inhabitant / ha
- Compactness Absolute (Ca): 0.80 → desirable value 5 m
- Corrected Compactness (Cc): 15.84 = → desirable value 10-50 m
- Public space mitigation (EPA) = 7.37 →desirable value 10 m2/habitante

3.3.4. Act:

The values of urban indicators of this proposal have better performance than the previous simulation, but are far from the desired parameters. For this reason, we propose a new strategy for growth. This new project proposes, as above, limit growth to the current area. It also proposes to work with the population level necessary for stocking density is within the ideal values involving sustainable development. This new calculation implies the renewal of the building industry.

3.4. CASE C: Estimated population growth necessary to reach desirable urban density values posed by Rueda.

3.4.1. Know

To carry out this simulation proceeded to calculate the necessary population to urban sprawl current density reached 220 inhabitants / ha. The calculation indicates that this requires 4,596,853 people. Following the statistical estimations this level of population would be reached in 360 years.

3.4.2. Estimate

Referred simulation corresponds to the period between 2,013 and 2,373. According to the statistical estimation of population growth will be 3.51022 million people, reaching the 4,596,853 inhabitants. It involves the construction of:

- New public spaces: 26,156,540.65 m^2
- New built-up areas: 138,147,622.54 m^2

The parcels surface unbuilt, today, is 30,608,775 m 2, that to leading to the 85% of them would be destined to public spaces. While newly built surfaces correspond to the renewal of current buildings.

3.4.3. Test:

As in the previous case, at this stage assess sustainability levels the urban sprawl of 2043.

- Density Residential: 220 inhab. / Ha → desirable value 220-350 inhabitant / ha
- Compactness Absolute (Ca): 2.61 →desirable value 5 m
- Corrected Compactness (Cc): 15.84 = →desirable value 10-50 m
- Mitigation Public Space (EPA) = 7.37 →desirable value 10 m2/habitante

3.4.4. Act

Two of urban indicators evaluated in this proposal are within parameters of sustainability, while the amount of public space is slightly smaller than that established. Consequently, future simulations should increase public spaces surfaces.

This is a theoretical exercise, since we do not know what can happen in 360 years.

4. Conclution

The work done, on the one hand, presents a simple simulation tool for the visualization of the evolution patterns associated with urban growth of cities, and also assess the levels of sustainability of land use. Studies denote that for the urban area reached sustainable levels established for other regions, it should quadruple its population.

On the other hand, analyzes the current characteristics of AMM and its future projection, showing that the current low density urban model is far from the standards of sustainable development. Therefore, urban planning must develop strategies that reverse sprawl.

In short, the introduction of simulation tools in urban planning allows to evaluate the current models, and redirect unsustainable growth processes in more sustainable models.

References:

Bunge, V. (2010). La capacidad de carga en la planeación territorial: una propuesta para su análisis [versión electrónica]. *Documento de Trabajo de la Dirección General de Ordenamiento Ecológico y Conservación de Ecosistemas, Instituto Nacional de Ecología, México*. Recuperado el 3 de diciembre de 2011 en: http://www.ine.gob.mx/descargas/ord_ecol/2010_doc_trabajo_capacidad_carga.pdf

Burgees, Rod. (2000) The Compact Cities Debate: A Global perspective. *Compact Cities. Sustainable Urban Forms for Developing Countries*, London: Spon Press

de Schiller, S., Bentley, I. & Butina Watson, G. (2000). Sustainable urban form: environment and climate responsive design. En Zetter, R. & Butina Watson, G *Sustainable cities, sustainable development: the urban agenda in developing countries*. Oxford: Oxford Brookes University.

Mathey, K. (2000) Urban Agriculture Trialog 65: *A Journal for Planning and Building in the Third Word* Special Issue, Vol. 2, pp3-43,

Mesa, Alejandro. y de Rosa, Carlos. (2005) Estudio de los Patrones de Apropiación del Suelo Urbano por la Expansión de las Áreas Residenciales. Análisis del Área Metropolitana de Mendoza. Salta: AVERMA.

ONU-Habitad (2012) Programa de las Naciones Unidas para los Asentamientos Humanos. Recife: ONU-Habitad

Papparelli A., Kurbán A. y Cúnsulo M. (2009) *Planificación sustentable del espacio urbano*. San Juan: Nobuko

Rueda S. (1998). *Modelos e indicadores para ciudades más sostenibles.* Catalunya: Ed. Agencia Europea de Medio Ambiente Generalitat de Catalunya.

---

[i] Mitigating public spaces: are all public spaces not destined for circulation, but rather to stay at the meeting and recreation of the inhabitants, such as parks, plazas, parks, footpaths, etc. (Rueda, s/f)

[ii] The estimated population growth is geometric

[iii] Año B

[iv] Año C