Energetic and Environmental Impacts of the Urban Sprawl on Productive Oasis Land around Cities in Arid Zones. The Case of Mendoza's Metropolitan Area, in Argentina.

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ABSTRACT: Mendoza's Province northern oasis, in central–western Argentina, presents environmental features that are the result of long period of investment and labour. Nowadays they are menaced by the uncontrolled sprawl of the urban area.
The present expansion of the urban area, following the demand's requirements, is the cause of major problems due to disperse growth and are already present in the area: excessive soil use, growing requirements for service networks, larger consumption of energy used in transportation and the segregation or functional zoning, all contributing to social disintegration.
To modify the city's tendency to grow in an anarchic mode, irrationally exploiting resources and generally occupying valuable productive fields would be a fundamental step towards establishing urban development guidelines that would progressively correct the present trends, establishing the necessary theoretical basis, in order to consolidate a model of sustainable city.
The present study evaluates the different present configurations of soil appropriation and their incidence, direct or indirect, within the universe of intervening variables, (dimensions and orientation of the gridiron, building morphology, green spaces and public urban forest, soil's sealing, the features of urban edges and the environmental degradation produced at the interface of the natural and the man-made environment, among others) on the energy efficiency of the building stock and the availability of renewable energy resources in each urban environment.

Keywords: urban expansion, residential areas, renewable energies.

1. INTRODUCTION

1.1 Geographic features

Mendoza's Metropolitan Area (MMA) is laid on the alluvial plains east of the Andean massif; its western edge is laid on the natural desert lands of the region and the rest of its perimeter on the man-made agricultural oasis.

The close presence of the Andean range has a direct influence on the region's climate which features temperate-cold winters, hot dry summers and a generous solar resource. The low values of wind, rain and relative humidity and the high heliophany contribute to class the zone within the so called "South American Arid Diagonal".

1.2 Urban development of MMA

By mid XIX century the urban area of the city already covered approximately 100 ha, being its population around 12,000 inhabitants. It was then (1861) when a strong earthquake totally destroyed the foundational city leaving a toll of several thousand dead.

A new city was laid in 1862, located toward the southeast of the former site. The gridiron pattern was maintained, incorporating the European urban trends of the times.

The new urban scheme is laid around large central green square and 4 minor squares on the layout diagonals. Between 1850 and 1870, three surrounding villages: Las Heras, Guaymallén and Godoy Cruz were designated as "head-towns" of the corresponding departments (counties) each one featuring gridiron layouts. They were linked with the capital city and between then by road and rail. Simultaneously, the rural oasis area expanded toward east and south, overtaking the area around the capital. (Fig. 1)

From 1940 on, the city goes through a process of accelerated expansion; the original gridiron pattern is maintained only around the capital and departments head towns, the original orderly scheme begins to get lost.

This vertiginous process leads to the urban agglomeration of MMA which includes by conurbation the closer head towns; and the cities of Maipu, eastward and Lujan southward as satellite centers. According to the 1947 population census [1], MMA

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had reached 320,000 souls in a continuously urbanized area.

During the 70´s, the capital city increased its functions and this process was accompanied by the densification of the –downtown area by the construction of multistory buildings, under a new seismic-resisting legislation. Besides, in further stages, suburban spaces for subdivisions and housing complexes were incorporated.

This growth was not the result of any consistent plan or policy for the use of urban voids and allowed for the invasion of the productive oasis land to the east and the natural dry ecosystem to the west.

Presently, the situation features a predominant low-density structure, with the exception of the downtown area and a few small high density "islands" in planned housing ensembles. This is the cause of important limitations of the existing infrastructure net-works and the constant demand for their extension.

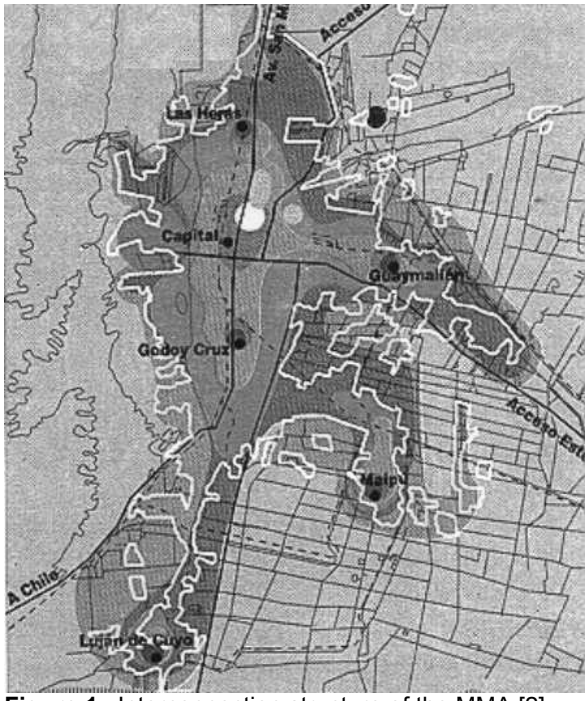


Figure 1: Interconnection structure of the MMA [2].

1.3 Evolution and spatial distribution of MMA´s population.

According to the provisional data of the 2001 Population and Housing National Census [1], the population of MMA had reached 984,753 inhabitants, for the 6 municipalities of the conglomerate. The largest percentage of these (95%) lives in the urban area, and stands for 62.46% of the total provincial population. Presently, the city features a population density between 50 and 150 inhabitants per hectare. These values show a homogeneous distribution of buildings, with a notorious preference of people to live in individual houses and low rise buildings. (Fig. 2)

The high density zone is located on the central area of Mendoza's Capital department, with other foci dispersed along the urban fabric.

The data referring the rate of population growth of the MMA, indicate that the area presents an increase over the 2001 census figures, over the former census (1991), of 12.6%. From the six municipalities, the one featuring the largest increase is Lujan (30.7%) followed by Maipu (22.4%).

An important aspect to be considered is that the population's evolution of the Capital's area, presents a negative value (-9%) related to the former census data.

Even when the Capital's zone is expanding westward, the downtown area is being progressively depopulated, this "population's abandonment" is due to structural changes in different zones which evolved from residential to commercial uses.

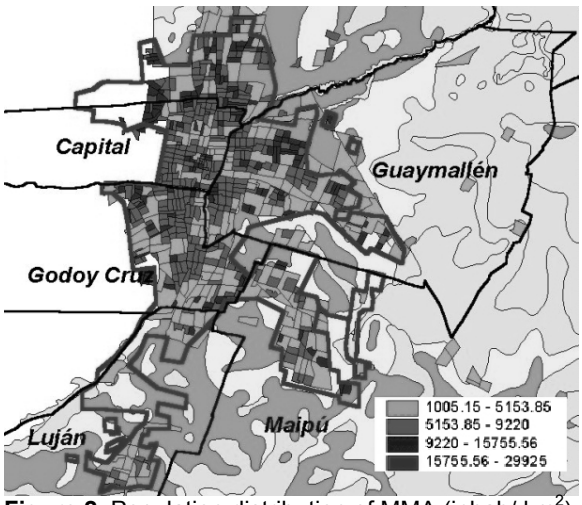


Figure 2: Population distribution of MMA (inhab/ km^2).

Another aspect with influence on the emigration from the central area is the environmental degradation at the center (urban microclimate, excessive soil coverage, atmospheric and acoustic pollution), due to the concentration of administrative and commercial uses, which is not observed in other departmental centers [3], [4], [5], [6].

The negative growth-rate featured by the Capital city is due to the preference of a population's sector which seeks a better life quality in areas protected from crime and without pollution. Recent studies show that only 14% of the population surveyed, would prefer the dense center neighborhoods, the 20% prefers periphery neighborhoods, while more that 45% would prefer personalized solutions, on the suburban area [2]. The inhabitant's preference is extending the urban area southwardly and in a lesser degree eastwardly. The 32% of the surveyed wishes to live in the southern districts (Godoy Cruz, Chacras de Coria and Vistalba), only a 2% chooses the Las Heras department on the northern edge of MMA.

This expansion lines of low density residential areas built, by individuals or housing ensembles, brings wits it the destruction of agricultural productive solid.

In order to grasp the magnitude of the area occupied by urbanized lands in the MMA, it is compared to that of the Ciudad Autónoma of Buenos Aires [1]:

	MMA	Buenos Aires
Area (km^2)	190	200
Population (hab)	820,000	2,900,000
Density (hab/ km^2)	4,315	14,500

All the rural area limiting the urbanized area has had along decades, a clearly defined agricultural will benefiting from the favorable conditions of site and position. It is characterized as a rural zone, covered almost totally by vineyards, fruit-trees and orchards. However, in recent years the area has begun to suffer from the urban sprawl of MMA, a process that has already devoured other rural districts closer to the downtown area.

The emergence and adoption of newer cultural patterns produced by globalization: as the emergent gated neighborhoods, yield as a result heterogeneous and fragmented territories on which contrasting situations are juxtaposed: residential lots, aging vineyards, high technology wineries, etc. share the landscape, resources and communications ways.

The direct foreign investment becomes one of the principal impulses of the territorial transformations (for example: the construction of new wineries and the refurbishing of others, vineyards with advanced technologies, etc). The large demand of land for residential uses generates a differential value of the soil for new subdivisions, i.e. a constant pressure for the selling of agricultural land, enhanced by the cultural patterns of the new generations.

2. UNCONTROLED GROWTH OR SUSTAINABLE DEVELOPMENT?

Aiming at sustainable development, it is necessary to check the city's trends to occupy and expand irrationally, exploiting natural resources and valuable productive soil. A way toward this achievement is to update the present normative and legal bases that rule property and use of the urban soil, in order to counteract the social, productive and environmental costs due to the incorporation of new productive land to the urban tissue.

The principle is not to oppose the inevitable growth of cities, but to improve the conditions where it takes place, revising the development guidelines to contain the urban expansion within tracks that allow in reasonable time terms, to achieve acceptable ranges of environmental sustainability.

Presently, MMA´s periphery following the current trends, has taken the characteristic featured by the so called disperse cities. Even though growth is favored, its consequences are being studied. The economic and environmental costs of the sub utilization of the existing infrastructure in the consolidated zones of the cities are not absorbed the new suburban areas.

The tendency to build in open spaces and on fertile agricultural land, thus destroying the environment at the periphery and the problems of transit, the increasing need of automobile use to reach commercial or administrative centers are aspects that society is beginning to recognize.

2.1 The problematic derived from disperse urban growth.

The disperse urbanization of the agricultural land or open with the development of new establishments has negative effects by itself: loss of the high quality agricultural soils and of open space, destruction of biotopes, fragmentation of ecosystems and change of soil sealment coefficients.

The irregular urbanization also generates higher costs in infrastructure and public services. The spatial pattern resulting from this type of growth is characterized by low demographic density and excessive soil use, inducing a high use level of private mobility means, coupled with longer trips, congestion of the radial roads which provide access to the city center, increase of fuel consumption, more emissions and air pollution.

3. IMPACTS OF THE NEW PATTERNS OF URBAN SOIL APPROPRIATION IN MMA.

The above described features are present in today's MMA. They bring along a noticeable degradation of life's quality of several sectors, due to climate change, air cleanliness, urban noise, and all aspects related to the almost anarchic urban sprawl.

The population increase, contributes to the uncontrolled expansion of the urban area. Comparing Mendoza's case with other cities of similar size, this growth has mainly been produced in the horizontal scale, situation that in Mendoza generates large problems when the lands invaded by the city are those of the productive agricultural oasis. Considering the physical and environmental restrictions of the oasis zones of MMA, this is of vital importance.

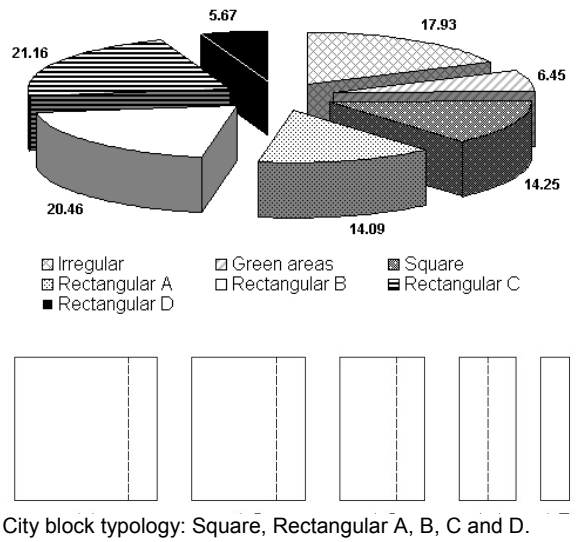
3.1 Analysis of urban configurations of the consolidated periphery.

In spite that the city in its origins was laid on a gridiron pattern, with time this trend began to weaken leading to the present configuration, even when the present orthogonal forms are predominant, the proportions between the block's sides are varied, existing also cases of irregular layouts.

Over a total of 114,000 ha of urbanized area, 5 typologies of orthogonal city blocks can be identified, they represent a 75% of the total, and the remaining 25% corresponds to irregular shapes and green areas. Also, each one of these shapes has a differential representation when considering the orientation of their main axis related to the north, increasing even more typological diversity. (Fig. 3)

The selection of urban configurations on the consolidated periphery, aimed at identifying the different zones, corresponding to former lands of agricultural production, now invaded by the new residential uses, all of then distant from MMA´s city center.

The results presented illustrate the situation of 9 zones of residential neighborhoods, with city blocks and parcels of variable shapes and sizes, 8 of them are located on the consolidated periphery and one (0101se14) on an area close to the city center, which is used as reference for comparison.



City block typology: Square, Rectangular A, B, C and D.

Figure 3: Percentages of each city block shape over the total urbanized area.

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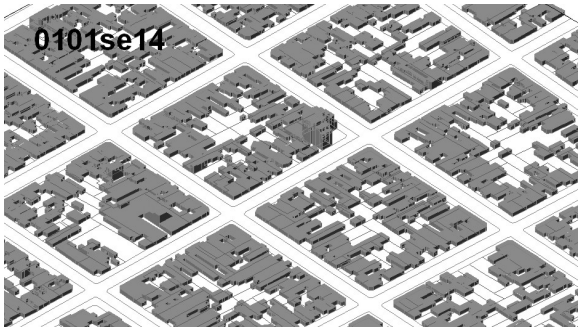
The configuration of the streets and the proportions of parcel sides impair the possibilities of access to the available climatic resources: solar radiation and night ventilation, demanding in each case different requirements of parcel area. When analyzing the growth trends of the peripheral, a predominance of rectangular (Rect B, C and D) and irregular typologies is observed. A 250 m radius area was considered as analysis unit for the study. (Fig. 4)



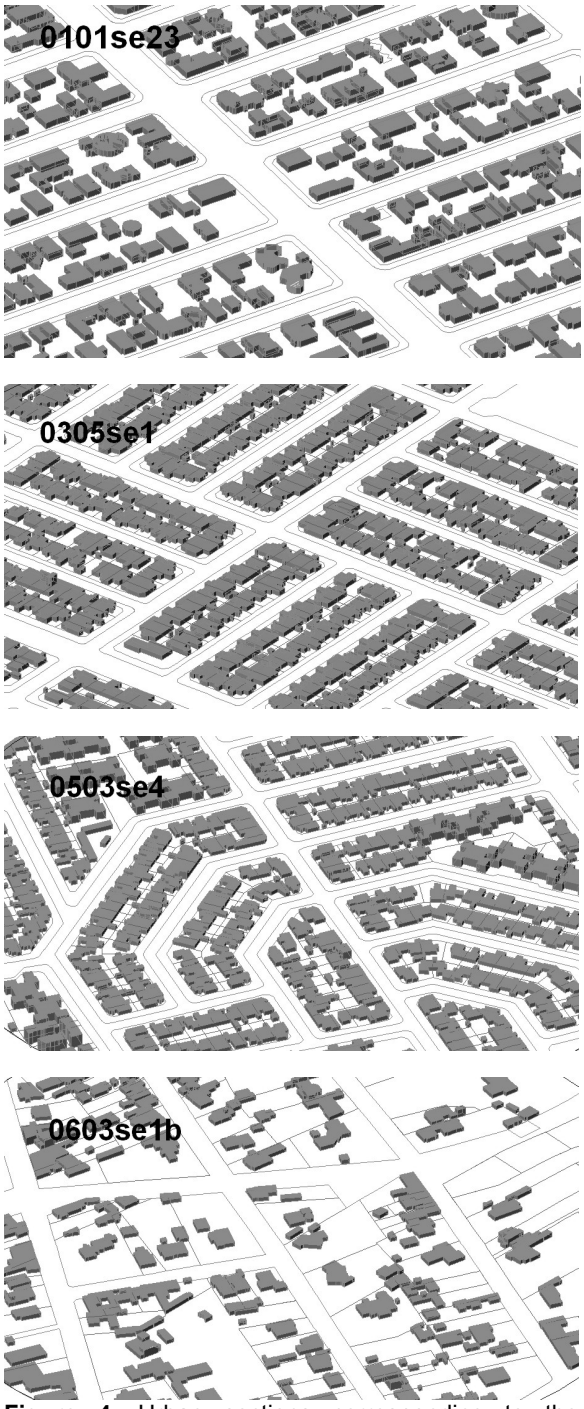


Figure 4: Urban sections corresponding to the departments of MMA.

The variables considered in the first stage as of greater incidence on soil use and energy performance of existing construction are: Total Occupation Factor (FOT), Soil Occupation Factor (FOS), FAEP (exposed built area/built-up area), Form Factor (exposed area/built volume), building density, green spaces, quality and size of parcels, urban voids, sealed soils by buildings and road infrastructure.

Even when the urban transportation analysis is a part of the problematic under consideration, its relevance and environmental incidence did not justify its inclusion in this study. Urban transportation

presents itself as an issue of top importance, impossible to be dealt with the limits of this research.

3.2 Energetic and environmental impact to f the new appropriation patterns of urban soil in MMA.

The different selected urban sectors were evaluated taking into account the incidence of the variables on aspects related to soil-use and the energy performance of buildings.

Comparatively analyzing the result obtained for the different urbanization typologies, it is observed that the constructions inserted in the most recent subdivisions (0602se1a, 0602se1b, 0603se1a, 0603se1b), maintain a similar relationship of the indicators used to quantify the energy efficiency in the more consolidated zones. The Form Factor (FF) and the FAEP, present, among all the analyzed cases, variations lower than 10%, which indicates that, in spite of being isolated units (not coupled), their morphological development causes them to have a similar thermal behavior.

The relationship of values of potential solar use (potential collecting roof area per built volume), presents the same behaviors. In every case the potential collecting area is significant: higher than 0.30 m^2 per unit built volume (Fig. 5).

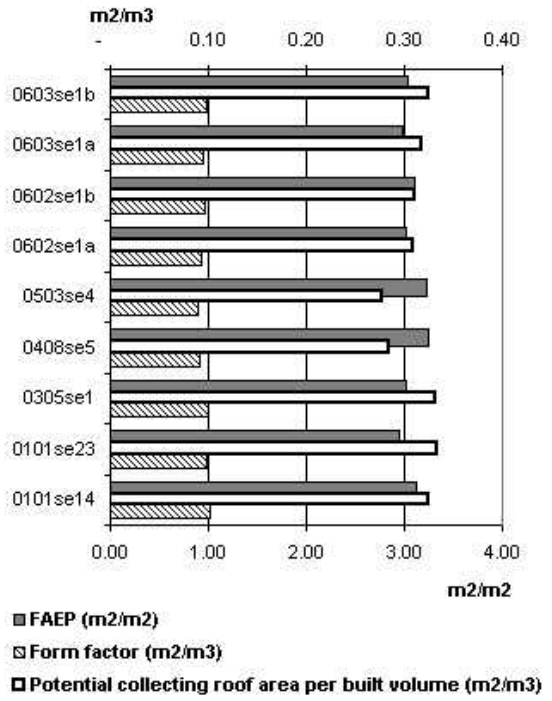


Figure 5: Relationship of variables related to the energy efficiency of constructions.

Even if the results referred to the energetic efficiency of constructions, in all the analyzed zones, present similar values, the indicators which assess the soil-use in the analyzed zones present significant differences.

The zone corresponding to the urban core (0101se14), and the more consolidated peripheral zones as well (0101se23, 0305se1, 0408se5, 0503se4), do not present perceptual variations higher then 20%. The percentage of soil occupied by constructions, the circulation network and the private green space is within the range of 30% of each category. This relationship changes for the cases of more distant zones, where the private green space reaches values higher than 50% of the total urbanized area, maintaining the area occupied by construction and circulation network percentages close to 20 and 30% respectively. When these values are related to the population density of each area, the disproportioned soil appropriation becomes evident (Fig. 6). From values between 20 and 50 m^2 per inhabitant of private green space, it jumps to 130 to 200 m^2 per inhabitant in the new settlements.

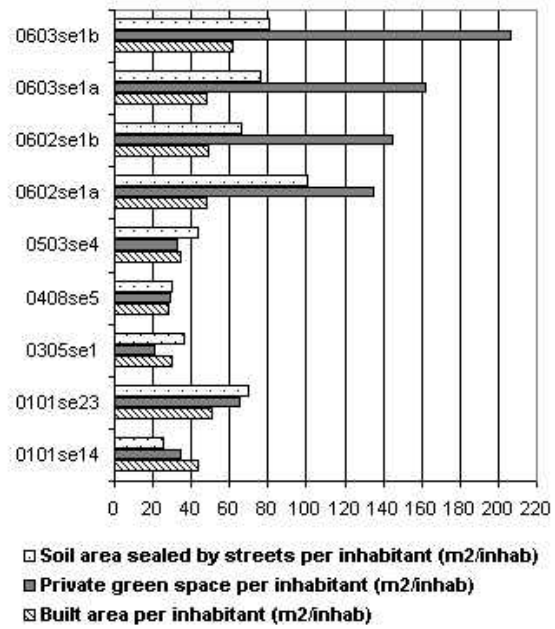


Figure 6: Relationship of variables related to soil use.

The environmental impact of these new configurations was quantified considering the following variables: soil sealment, water use and fertile soil loss. The incidence of the increase of vehicular traffic, the development of complementary infrastructure, and of the dispersion on consolidated central zones, are related aspects that are to be assessed in following stages.

MMA is close to the Andean foothills, which makes it susceptible to suffer the incidence of torrential floods during the summer rainy season. The sealment of large urban surfaces not only reduces the possibility of recharging the acquifers, but also increase noticeably the speed and flow of rain-water along the drainage ditches, thus increasing the danger of disasters. Even when the sealment percentage is lower in the evaluated areas than in the more consolidated ones, it is useful to make clear that these new settlement are occupying former zones of high productive value where sealment was null.

When the water volume consumed by the new uses is analyzed, the yearly irrigation need for a hectare of park or garden is the equivalent that is needed by a hectare of vines or fruit trees (from 8 to

10 x 10^3 /ha. year). Considering besides that the cultivated areas are irrigated by water from the Mendoza river, while the newer settlement use tap water for garden irrigation.

Although the quantity of available green areas in urbanized zones is important, the results obtained clearly indicate that some urban configurations make an unsustainable use of the soil, considering that the utilized lands are vital in their belonging to the irrigated, productive oasis.

5. CONCLUSIONS

The analysis performed assessed the features of the new urban configurations of MMA´s building stock, related to solar access, and optimum soil use, allowing for the characterization of each studied zone.

In all zones the potential collecting areas is large, allowing for important savings in the consumption required for solar space heating and domestic water heating; this considering always the maximum use of all potentially collecting areas, situation that in reality can be termed as utopian.

The assessment of the variables that affect soil-use, demonstrate that there are zones in which, pursuing higher life standards, ignoring the needs of the urban society al large, make an unsustainable use of the fragile environment of the region. The present growth trends of MMA give a sing of alert on the existing "freedom" of territorial management, considering the high vulnerability of the analyzed area.

To quantify the energetic and environmental consequences on the existing resources, derived by the present growth tendencies of the residential sector, is a possible starting point to correct and establish guidelines of the future urban development, thus consolidating a model for a more sustainable city.

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