This Version: February, 2012

"Zoning and Land Cover Metrics for Municipalities in Argentina (1990-2001)"[1]

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We present descriptive statistics of the geographic extent of zoning regulation -as extracted from zoning maps- and of land cover indicators -obtained from satellite images-based measurements- for a large sample of municipalities (local governments) in Argentina. Zoning maps, which in Argentina do not generally follow a standard for their creation, were collected from planning directors and then categorized according to a common criterion to allow the analysis. A total of 111 municipal jurisdictions were included in the analysis. In the case of land cover metrics, we follow Angel, Civco and Parent (2010) in their methodology for the classification of satellite images pixels and in their construction of land cover metrics. Images for 30 agglomerates -comprising 140 municipal jurisdictions- circa 1990 and 2001 were collected and processed, allowing the analysis of developments occurring during that period.

In the case of zoning images, we find that zoning for residential use accounts for an average of approximately 60% of the non-rural zoned area. There is also great degree of dispersion in zoning uses across municipalities. Our preliminary analysis shows that residential areas are higher in those jurisdictions with most of their territory in process of urbanization. The zoning for gated communities is on average only 3% and also the highest across these municipalities. No clear correlation with other characteristics of the municipalities such as the jurisdiction population or its extent of vacant land was found in the descriptive analysis.

In the case of land cover metrics, and between other findings, we quantify the negative relationship between fragmentation and population across all the scales of fragmentation considered. We also find largest fragmentation in those jurisdictions in process of urbanization. Notably, we document a homogeneous tendency towards less fragmentation for the period 1990-2001.

[1] We specially thank Anna Chabaeva, who selected, classified and prepared all the satellite images for this research. Alejandra Gambino provided excellent research assistance with the GIS processing of zoning data. Natalia Arbelo, Nidia Beltrán, Silvana Gonzalez and Macarena Saenz provided excellent research assistance processing the resulting images. Jonathan Cohen provided excellent research assistance in the statistical analysis. We also special thanks Raquel Kismer de Olmos and Thomas Hagedorn from Secretaria de Asuntos Municipales, Ministerio del Interior de la Nación, for the support of this project. We would also like to thank Jason Parent for his assistance with scripts and GIS software problems, and Angel Shlomo for his help and suggestions. We gratefully acknowledge the financial support of the Lincoln Institute of Land Policy for this research.

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I. Introduction

In this paper we present descriptive statistics of zoning geographical data and land cover metrics for a large sample of municipalities (local governments) in Argentina. This descriptive work is part of a research agenda which is compiling and producing new data with the aim of making possible the empirical study of significant questions to the economic study of cities, such as the causes and effects of land regulation, the effects of regulation on household's tenure condition, and the relationship between regulation and urban fragmentation. In particular, this data supplements land regulation information -also compiled at the municipal level- by the 2011 Land Use Regulation Survey (See Goytia, Hagedorn, and Pasquini, 2012).

The collection of zoning geographic maps was carried out in collaboration with the Secretaría de Asuntos Municipales (Municipal Affairs Secretariat – SAM) at the Ministerio del Interior de la Nación Argentina. Maps collected from Planning Directors or similar officials in each of the municipalities. Zoning uses, which in Argentina do not generally follow a standard for their creation, were categorized and GIS-measured according to a common criterion that allowed the analysis. A total of 111 municipal jurisdictions were included in the analysis.

This zoning information is intended to improve the knowledge on the stringency of uses and building parameters across jurisdictions. Building parameters usually take different values according to the respective zoning category (might even differ within a same category), so in order to understand the overall degree of parameters buildable stringency in a given municipality we need to take into account both the values of the parameters in each zoning category and the extension of the municipality jurisdiction area covered by each of them. In this paper we only present descriptive statistics on the extension of zoning categories, and let for a future study a joint analysis of parameters values and the areas covered. Nonetheless, this preliminary analysis is interesting on itself. It allows us to measure the extent in which patterns of zoning areas are similar or not across jurisdictions.

Our results provide a general pattern of zoning uses in Argentinean municipalities. Particularly important to our research objectives, we find that zoning for residential use accounts for an average of approximately 60% of the non-rural zoned area. There is also great degree of dispersion in zoning uses across municipalities. Our preliminary analysis shows that residential areas are higher in those jurisdictions with most of their territory in process of urbanization. The zoning for gated communities is on average only 3% and also the highest across these municipalities. No clear correlation with other characteristics of the municipalities such as the jurisdiction population or its extent of vacant land was found in the descriptive analysis

The second part of this study is related to analysis of land cover. There are many motivations to collect and analyse this information. Just to mention some of them, in a country such as Argentina there is necessity to properly account for the density of cities, which is a central variable in any urban economics analysis. The density measures that are available might not be proper for many analysis since jurisdiction limits (needed for the calculation of the areas in the density denominator) are not always available (we discuss more of this below). The measurement of vacant land is another significant issue in order to understand many urban processes and regulations. In this case, although the definition of vacant land is not as precise as we would like -in our measurements we associate as vacant land those 30 by 30 meters pixels that are mostly completely open space or vegetation, without discriminating ownership or regulatory restrictions such as reserves-, the resulting measures are still useful for many analysis. A third significant motivation is to obtain measures of urban fragmentation, which constitutes a key issue in the understanding of infrastructure provision costs, and many other determinants of formal and informal land ownership.

Our work with land cover consisted in the collection of satellite images, and, to follow Angel, Civco and Parent (2010) in their methodology for the classification of satellite images pixels and construction of land cover metrics. Images for 30 agglomerates -comprising 140 municipal jurisdictions- circa 1990 and 2001 were collected and processed, allowing the analysis of developments occurring during that period. The process allowed us to obtain metrics of, for example, the extent of built-up surfaces and its composition (distinguishing between urban, suburban and rural built-up), the extent of new developments and its composition (distinguishing between infill, extension and leapfrog developments) as well as a number of built-up fragmentation indicators (i.e., the fragmentation of built-up regions by open space under different scales of analysis). These measures allow rigorous quantitative assessment of urban spatial structure –and its changes over time.

In the case of land cover metrics, and between other findings, we quantify -an expected- negative relationship between fragmentation and population across all the scales of fragmentation considered. We also find largest fragmentation in those jurisdictions in process of urbanization. Notably, we document a homogeneous tendency of reduction in fragmentation across almost all jurisdictions and all the scales of analysis considered for the period 1990-2001.

This document is organized as follows: Section II presents a motivation and brief literature review for the use of GIS and satellite image's data in empirical studies; Section III introduces the methodology followed for both the zoning use maps and land cover analysis; Section IV presents the resulting descriptive statistics; and the final section concludes.

II. Zoning Use Regulation and Land Cover Analysis in Empirical Studies

It is important to remark how data from satellite imagery -and geo-referenced spatial data- are now providing additional sources of information to complement the analysis of spatial issues. The vast amount of new sources and types data (i.e., on land cover, use, and topography), that is released are helping to increase our understanding of diverse spatial issues , and will certainly help in advancing our understanding and testing new hypothesis related to the determinants and effects of land policies, and land use regulation in particular. Basically, we are now becoming even more familiar with using GIS to integrate data from different sources and these highly original data sources are increasingly been adopted as standard in every economic analysis of space.[2]

In particular, one of the most promising developments is the rapid increase in the availability of, and ability to process, remote sensing data on land use; and the parallel ability to integrate such physical data with socio-economic or other data. Until recent years, these tools have been little used outside of a relatively small, technically-proficient group of users. The increasing accessibility of GIS software and growing interest in spatial issues is starting to change this. For example, the 30 meters by 30 meters land use raster images which categorizes into land cover classes[3], has allowed researchers to ask new questions, for example, examine the amount of developed land in each jurisdiction and the characteristics of such land development, which can be matched with population and other database sources.

The first precedent study that allows multiple forms of land use regulatory measures to be observed simultaneously -and do so over an area as extended as a state- is the one by Evenson and Wheaton (2003). Their paper includes a description of land use facts and land use rules (from this single state).

While a few other studies have amassed (geographical) data on a specific type of land use control, Evenson and Wheaton (2003) provide a data set of remarkable detail about land uses, the rules governing them, and permissible future development in Massachusetts. They show how very detailed data on the physical use of land can be integrated with jurisdictional and socio-economic data. In particular, a rich set of data on land use controls for Massachusetts is matched with information on (GIS) geo-referenced zoning ordinances across a large number of local towns and counties, and data based on a satellite-based measurement of all open land, which is done by relying on digitized maps of open space and their regulation. Finally, town-level data on land use -and its regulation -were matched to information on the maximum potential development that could take place under current regulatory laws. The exercise is based on the idea of assessing "potential development," where the amount of build-out permitted under existing land use regulations is computed.[4]

Sprawl studies (e.g., Burchfield et al. 2006) and land-cover studies (e.g., Angel et al., 2005, 2010, 2011) have significantly been benefited by the availability of these new types of data. These studies estimate urban land cover metrics in large samples of towns or cities[5]. Econometric models are then used, to explain several facts, such as the sources of variation in urban land cover among them, as

[2] One of the most powerful aspects of GIS is arguably its ability to quickly analyze spatial data matched from different sources (Gibbons and Overman, 2009).

[3] These group of studies includes land cover data classification which identified land use in each 30-by-30-meter pixel in the study area. Every pixel was classified as either built-up, open (that is, not built-up), or water. For example, following Angel et al, 2010, indicators for the built-up area, the urbanized area, and the city footprint, for each city for two time periods are here included.

[4] Their effort has been celebrated (Quigley, 2003; Guyrko, 2003). The ability to merge and intersect these data spatially means that they are incredibly precise relative to all those previously available.

[5] Measured with ArcGIS software.

well as to make (future) projections for the considered countries and regions (i.e., for 2000 to 2050 in Angel et al., 2010)6

Urban-sprawl, the fragmentation of the built-up area of cities by the open spaces interpenetrating them (distinct from sprawl understood as lower-density development), is analysed using satellite images and census data for 1990 and 2000 for a global sample of 120 cities in Angel, et al., 2010. Variations in fragmentation -defined at various spatial scales as the relative share of open space in the urban footprint - among cities and regional groups, are further explained by the use of econometric models. Larger cities are found to be less fragmented; and those cities that do not permit development in large areas around are slightly, yet significantly, less fragmented.

Future urban expansion is estimated in Angel et al, 2011, by assembling four complementary data sets which include Landsat satellite images for the universe of over 3,600 metropolitan agglomerates and cities over 100,000 inhabitants (in the year 2000), a geo-coded census tract data, as well as data drawn from digitized historic maps, and a sample of 120 of these cities with data from 1990 and 2000. They found that on average, built-up area densities in developing countries double those in Europe and Japan and that such average built-up area densities declined by 2 percent per annum between 1990 and 2000. The fragmented open spaces in and around cities are found to be equivalent in size to their built-up areas, but the share of fragmented open space within city footprints has declined slowly yet significantly in the 1990s. Finally, considering average annual growth rate of urban land cover between 1990 and 2000, it doubled that of the urban population. As conclusion, they point to the importance of acknowledging that the rate of grow of urban land cover is being greater than that of the world's urban population (it is expected to double in 43 years while urban land cover will double in only 19 years). They point to the need of policies to prepare for the sustainable growth and expansion of cities in rapidly urbanizing places -rather than containment planning policies which are seen to be non-effective and harmful-.

Another study, Burchfield et al, 2006, use remote-sensing data to track the evolution of land use on a U.S. grid of (8.7 billion) 30 x 30 meter cells, to provide basic facts about the extent of urban residential land development, in particular, whether residential development is sprawling or compact. The paper is devoted to describe this variation and to investigate the ability of the various theories of urban economics to explain it.

Another example of the uses of land cover metrics is the amount of developable land, which has been introduced as a key explanatory variable in recent studies in different ways. For example, developable land might be used to construct instrumental variables that help in the identification of causal effects (see Burchfield, 2006, and Hilber and Nicoud, 2010, who use topography and other set of metrics for their estimations).

Hilber and Nicoud (2010) matched data from various sources and geographical levels of aggregation to the MSA level using GIS (i.e., the National Land Cover Data 1992 derived from satellite images) to create a measure of developed land (SDL) and use the two US regulatory indices -these are the

[6] The metrics of urban spatial structure based on these data sets, measure a city's built-up area (containing buildings and impervious surfaces) and the city footprint (the built-up area plus open spaces surrounded by or within 100 meters of built-up area). Population densities for these areas are calculated by using available population data. Both population and area measures produce comparable urban built-up area average densities for year 2000.

WRLURI and Saks (2008) regulation index- as the counterpart in the data to a regulatory tax. Emphasizing political economy mechanisms, this data is used to understand how the fraction of land actually developed influences regulation.

Another study, Saiz (2010), builds a measure of developable land based on metrics obtained from satellite images for each large metropolitan area (MSA), to regresses the Wharton Residential Land Use Regulatory Index (WRLURI) on this measure. His findings characterize land supply elasticity as function of both physical and regulatory constraints.

Concluding, the literature reviewed here provides a strong motivation for our study since, given the scarcity of empirical studies that combined spatial and regulatory data, our efforts to assemble such database are certainly warranted.

III. Methodology

i. Zoning Metrics

In order to understand the regulation of land use, and in particular its degree of stringency/flexibility, an empirical analysis needs to considerate those parameters that determine the intensity of land use. Some of these are: the minimum area and minimum front length of a lot, as well as building parameters, such as the floor to area ratio, (Factor de Ocupación Total, FOT in Spanish) or the maximum building height. Goytia, Hagedorn and Pasquini (2012) survey many of these variables for the municipalities in Argentina. Moreover, in order to understand the degree of stringency or flexibility of the regulation, the spatial dimension needs to be added to the analysis -we need to incorporate the spatial extent in which those regulatory variables constrain the total buildable area-. In order to fulfil this second objective, we develop zoning maps metrics which will serve the purpose of providing a spatial dimension to those variables in a subsequent work.

The collection of zoning geographic maps was done by contacting the local planning authorities (i.e., the Planning Director or a similar authority), and through the Ministry of Government of the Buenos Aires Province. We then proceed to geo-refer and delimit zoning uses by creating shape files in GIS software (We use ArcGIS 9.3). Since the names provided to the zoning categories and the characteristics differ across many jurisdictions, we also proceed to categorize them using those which follow similar uses. A simplification of categories in 10 major uses allows our analysis. Table 1 provides an example of the uses that were taken into consideration and our grouping by categories: i) Residential (including different categories for High, Medium and Low Density), ii) Commercial (or Mixed when the category incorporates residential uses), iii) Industrial, iv) Gated urbanizations or communities, v) Other Uses: Equipment / Specific uses and Green Space, and Rural (including Reserved Areas and to be developed).

Table 1: Categories for GIS Analysis of Zoning (in Spanish)

Proposed Categorization	Zona según SIOUT

Rural	Agropecuario extensive Agropecuario intensive Corredor de servicio rural
Urbanización privada	Barrio cerrado Club de campo
Residencial de alta densidad	Centralidad de primer rango Centralidad de segundo rango Centralidad de tercer rango
Residencial de media densidad / mixto	Corredor comercial principal Corredor comercial secundario
Equipamiento	Equipamiento Uso específico
Espacio verde	Esparcimiento / espacio verde
Industrial	Industrial exclusive Industrial mixta
Residencial de media densidad	Residencial de media densidad
Residencial de baja densidad	Residencial de baja densidad
Residencial mixto	Residencial mixto
Otros	Zona de protección Zona de recuperación Zona con regulación especial / urbanizable Zona de reserve
S/D (sin datos)	S/D (sin datos)
Otros	Servicio de ruta

Data Sources: Interactive System for Urban Planning and Land - SIOUT, Ministry of Government, Province of Buenos Aires, official websites of the municipalities: Malvinas Argentinas, Moreno, Moron, San Fernando and San Miguel.

Results obtained based on image georeferencing (zoning plans of each municipality) in ArcMap 9.3.

Gauss-Krüger projection, coordinates POSGAR 1998 Strip 5.

On the basis of this categorization and the geo-referenced maps, GIS thematic layers were created for the adjusted zoning districts, and the respective areas were computed.

When computing zoning uses as percentage of total zoned area, it is required to note that in Argentina, the territorial jurisdiction for local governments (municipalities) are differently assigned by each province. In other words, there is not a unique territorial definition for municipal jurisdictions. As an example, in few provinces, such as Buenos Aires, Mendoza, La Rioja, and San Juan the entire provincial territory appears territorialized –in each of them the second level administrative boundary, or *departamento*, matches the municipal jurisdiction limit- and each jurisdiction incorporates urban areas and also a significant amount of rural land. In other provinces (such as Catamarca, Córdoba, Chaco, or Santa Cruz, among others) a municipality has administrative jurisdiction only over the main urban area (or "Ejido" in Spanish) –in these provinces a multiplicity of municipal jurisdictions might exist within the first administrative boundaries-. In other provinces the limits of municipalities might be more complex (e.g., containing no contiguous territories) or simply not clearly defined.

It follows that our zoning uses metrics, calculated as percentage of total zoned area, will therefore be biased in relation to the jurisdiction limit, and in particular to the amount of rural territory that is included. We therefore proceed to recalculate those percentages on the basis of the non-rural total zoned area. Also, for our purpose of understanding the allocation of zoning to residential uses vis a vis other land uses –particularly in relation to the use of land with some degree of infrastructure provision-, this measure results more appropiate.

ii. Land-Cover Metrics

We follow Angel, Parent, and Civco (2010), in their use of satellite images to measure the extent of urban footprints, built-up areas, fragmentation indicators, and the extent of developable land (using topographic imagery) in each jurisdiction.

By using satellite images we can detect and distinguish surfaces that characterize built-up areas from those non-built open spaces in and around them. The images were initially coded into maps of pixels, where each pixel is classified as built-up, open space, or water. We used Landsat 5-satellite images with a 30-meter pixel resolution. We classified images covering a sample of 30 biggest agglomerates in Argentina for two time periods, one circa 1990 and the second circa 2000[7].

Once the images were classified, we obtained the metrics by closely following the methodology of Angel, Parent, and Civco (2010)[8]. To ease the reading of this paper, we replicate the definition of the main indicators that were analyzed. For more details, the reader should consult the referenced paper.

The main input for the all measurements is the grid of classified pixels covering all the analysis area. Then all the indicators are calculated on the basis of their relative location.

A brief description is the following:

Built-up Area Components

The area that is occupied by all built up pixels is calculated. Moreover the methodology allows the definition of a further classification of built-up areas into urban, suburban and rural areas:

An *Urban* pixel was defined as a built-up pixel that had a majority of built-up pixels in its immediate neighborhood, that neighborhood defined as a circle 1 km^2 in area about the center of that pixel. A *Suburban* built-up pixel was defined earlier as a built-up pixel had more than 10 and less than 50 percent of its immediate neighborhood occupied by built-up pixels; and a rural built-up pixel was defined as a built-up pixel had less than 10 percent of its immediate neighborhood occupied by built-

[7] The appendix provides a description of the methodology used for the classification and images acquisition, which was carried out by Anna Chabaeva.
[8] We used the Python's scripts coded for the Angel, Parent, and Civco (2010) research.

up pixels. All open space pixels that were more than 100 meters away from urban or suburban built-up pixels were considered to be *Rural Open Space*.

Fragmentation Indicators

Fragmentation indicators, refer both to the way in which open spaces fragment the built-up areas of cities and the manner in which the built-up areas of cities fragment the open spaces in and around them. More specifically, these indicators will seek to understand the extent to which open spaces break up built-up areas of cities and make them non-contiguous. The fragmentation indicators were defined at different scales, which go from micro-scale (a 30 by 30 pixel scale unit analysis) to the largest city scale.

i) The Edge Index

The Edge Index measures the frequency that built-up area pixels are found to be immediately adjacent to open space or water pixels The index varies between 0 and 1, and the higher the value for this index, the larger the frequency that built-up pixels are found to be adjacent to open space pixels. Since pixels in the satellite images we used are 30-by-30 meters in size, the Edge Index is thus a good measure of the fragmentation of built-up areas at the scale of individual buildings, namely of the fragmentation of the open space in an around cities at the *micro* level. (Angel, Parent and Civco 2010)

ii) The Openness Index

The Openness Index measures the share of open space in a circle of 1 km^2 around each built-up pixel. The radius of this circle, 586 meters, corresponds to a distance covered by a leisurely 10-minute walk. The Openness Index is thus an indicator of the amount of open space within walking distance of every urban location, or the amount of open space "in the neighborhood". In fact, it measures the average share of the area of that 1 km^2 circle that is open and not built-up.

iii) Core Open Space Ratio

The Core Open Space Ratio is a ratio of open space at the core to the built-up area at the urban core. It focuses attention on the urban core as a whole while leaving aside for the time being the fragmentation of open space in suburban areas.

iv) City Footprint Ratio

The City Footprint Ratio measures the relative amount of open space in and around the entire built-up area of the city that is fragmented or disturbed by it.

A *Fringe Open Space* pixel was defined as an open space pixel that is less than 100 meters away from an *Urban* or *Suburban* built-up pixel. The *City Footprint* was then defined as the area including the city's built-up area, its fringe open space pixels and the open spaces entirely surrounded and thus captured by both types of pixels.

New Developments (2001-1990)

Total new developments (which are obtained by comparison of built-up pixels between the two mentioned periods) are decomposed into three measures: infill, extension, and leapfrog developments:

Infill was defined as consisting of all new development that occurred within *interior open space*, defined earlier as the set of all fringe open space pixels that were more than 100 meters away from rural open space in 1990.

Extension was defined as consisting of all new development that occurred in contiguous clusters that occupied *exterior open space* in full or in part, and were not infill. Exterior open space was defined earlier as the set of all fringe open space pixels that were less than 100 meters away from rural open space in 1990.

Leapfrog was defined as consisting of all new development that occurred entirely within *rural open space*, defined earlier as the set of all open space pixels that were more than 100 meters away from urban or suburban built-up pixels in 1990.

IV. Results

i. Zoning Metrics

On the basis of the zoning maps collection, a total of 111 jurisdictions were analyzed. 47 (42%) belong to Big Urban Agglomerates (B.U.A.) and the remaining 64 are located outside B.U.A (18 of those have more than 20,000 inhabitants). Most of the jurisdictions that were analyzed 77 come from the Pampa Region (representing 69% of the universe of jurisdictions), 8 jurisdictions were analyzed belonging to the region of Cuyo, 16 to the North East Region (NEA in spanish), 2 to north-west (NOA), and about 8 to Patagonia Region.

The first issue to be mentioned about the zoning data is the high percentage of total zoned area that is allocated to rural use. Table 2 shows that a jurisdiction has on average 66% of land allocated to rural use. The median is slightly higher (73%,) indicating the center of the distribution is slightly higher and the existence of some left-skewed values. We therefore conclude that our sample has majority of jurisdictions with significant amount of rural area. Second, this measurement presents a significant standard deviation of about 33%, which accounts for the fact that our sample is also both comprised of jurisdictions that are nearly completely urbanized (the minimum in in this variable is 0%), and also by jurisdictions that are completely rural (the maximum 99.85%). Those that are nearly completely urbanized, might even be surrounded by others in similar conditions, such as for example, jurisdictions in the agglomerate of Buenos Aires which is the largest in the country.

As result of the high participation of rural use zoning, the rest of the categories seem quite low in percentage terms. On average, only 17% of the land is allocated to residential use (with 1.2% high, 12% medium and mixed , and 8.24% low densities respectively). When considering the median values for residential use participation, these measurements become even lower: 0.4% for high, 3,2% for medium and mixed and 4.43 for low density residential zoning. Also, on average, the industrial zoning use occupies 4.7% and the land allocated to green spaces and to equipment is around 2% in each case.

How much informative are these percentages? Given the fact that jurisdictions limits in Argentina are not uniformly defined -some of them comprise rural areas and others not depending on a great extent of a provincial-level legislation[9]-, the answer seems to be: not too much. Jurisdiction limits change significantly across provinces and total zoned areas change accordingly. It therefore becomes important to exclude the rural component from percentages and analyze the new resulting distribution. In particular, for our purpose of understanding the allocation of zoning to residential uses vis a vis other land uses –particularly in relation to the use of land with some degree of infrastructure provision-, it seems more appropiated to focus our analysis on the zoning allocation of the non-rural jurisdiction territory.

Table 3 displays zoning percentages were each zoning use category was calculated on the basis of total zoning area with the exception of rural use. Now, on average, residential uses accounts for approximately 62% of total zoned area. Nearly half of it corresponds to low density residential zoning (30%), a similar percentage goes to medium and mixed (29%), and only 3% is allocated, on average, for high density residential areas. The industrial use follows in terms of percentage use, with 15% of the total zoned area. 8% is allocated to green spaces, 6.8% to urban equipment and 2.6% to gated urbanizations.

Here is also worth noting the high level of deviation between jurisdictions in most of the zoning categories considered. Low and medium, and mixed densities residential zoning display standard deviations of more than 20%, and both categories range from 0 up to nearly 100% in some jurisdictions. Some jurisdictions, such as Lanús and Granadero Baigorria, are an example of how extreme these measurements might be: Lanús, a municipality in the Buenos Aires region, displays a mixed use zoning of 93% of their total (non-rural) zoned area. No low density zoning or industrial uses areas are allocated in these municipalities. Granadero Baigorria reaches 100% of total zoning in medium and mixed residetial zoning use.

When examining the percentages across population-based jurisdiction quintiles (Figure I, also Table 4), we notice that the zoning categories remain quite stable across them (coeficcients of variation are below 30% with the exception of gated communities and other categories) and that these variations do not suggest any clear correlation pattern between zoning uses and all the population based jurisdiction quintiles.

A similar figure for jurisdictions grouped according to its surface coverage (Figure II, also Table 4) shows that residential zoning (all densities considered) is nearly 10% higher in jurisdictions in process or urbanization than in mostly rural jurisdictions. The total residential area remains close to 70% in mostly completely urbanized jurisdictions. The increase in residential areas in jurisdictions is process of urbanization is driven by a significant increase in the medium and mixed zoning category, nearly duplicating the average percentage of those jurisditions with largest share of their territory still rural (medium and mixed zoning category climbs from 27 to 48% of total zoned area, Table 4), and there

[9] See the Methodology Section for a discussion of this point.

is also a decrease of 10% in the low density residential zoning. The gated urbanizations percentage is also significantly high in the case of jurisdictions in process of urbanizaton. Since this percentage can also be added to the other residential density categories for an overall measure of residential zoning, we can conclude that jurisdictions in process of urbanization display a significantly higher percentage of zoning for residential use.

Figure I: By population-based jurisdictions' quintiles

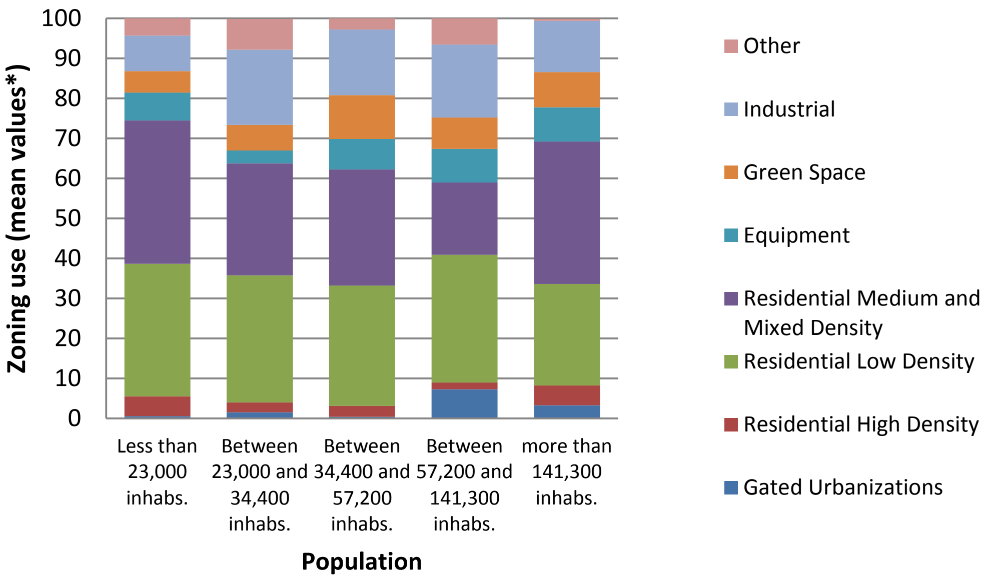
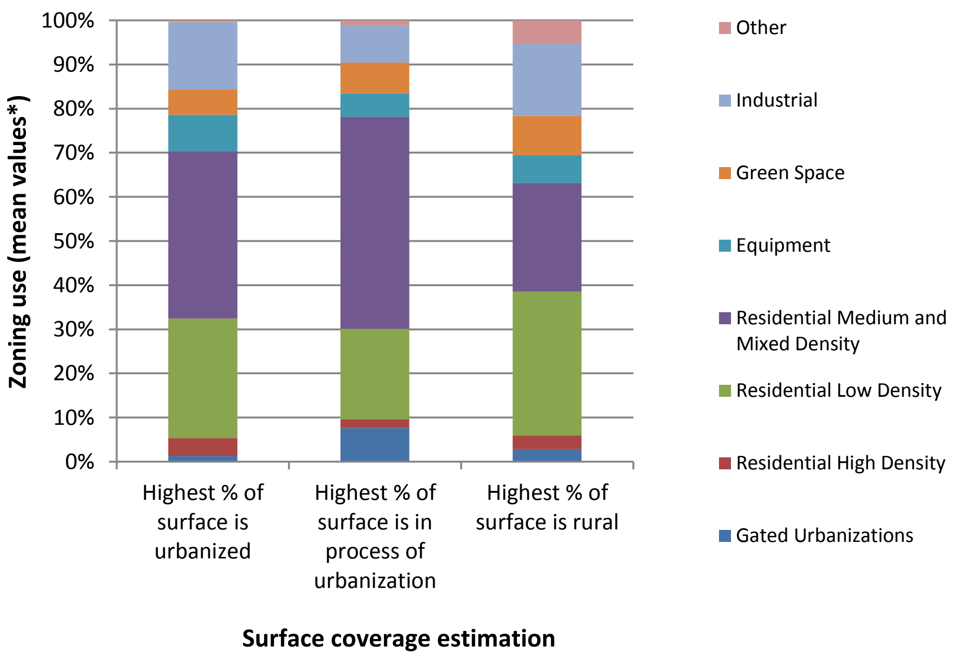


Figure II: Zoning uses by surface coverage



ii. Land-Cover Descriptive Statistics

Satellite images collected for this research project allowed to calculate a series of metrics that will be used in a subsequent research to test specific hypothesis. Images were obtained for 29 urban agglomerates in the years circa 1990 and 2001. The images allowed us to cover more than 140 governmental jurisdictions (municipalities), which are all those belonging to the big urban agglomerates as well as others, medium size ones (20.000 to 50.000 inhabitants and over 50.000 inhabitants), located outside the big metropolitan areas. Land cover images were processed and several metrics and indicators computed. This allows us to analyze the characteristics of the municipalities' areas and some of the dynamics occurring during the period 1990-2001.

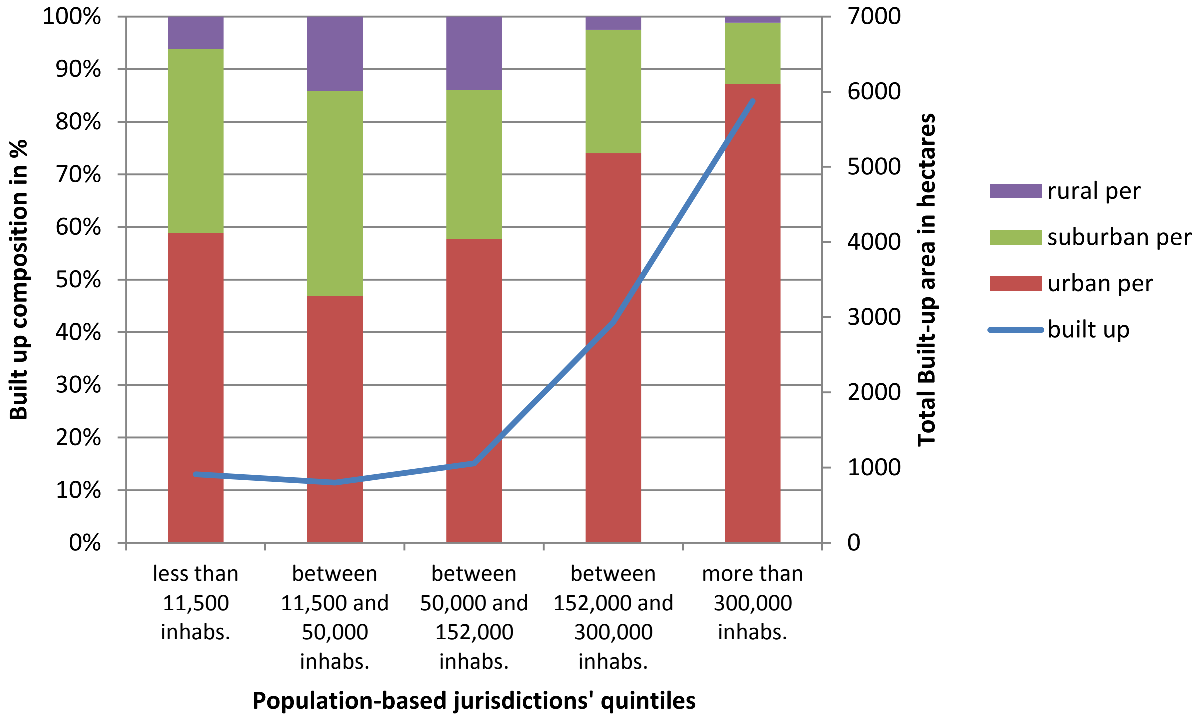
Total Built-up Area Components

Total built-up area metrics and its main components: the urban, sub-urban and rural built-up areas were computed for a total of 139 jurisdictions. Table 5 provides the descriptive results. The average jurisdiction in the sample has a total built-up area of about 1,948 hectares, and the median jurisdiction of approximately 656 hectares, showing that the distribution of this variable is strongly right-skewed due to a relatively small number of jurisdictions with high total built-up areas. In terms of the composition, the average (components of a) jurisdiction has more than half of its built-up area (59%) in the urban core, 38.5% in the sub-urban area and 10.5% in the rural area[10]. The median components of a jurisdiction display values of 68.2% urban, 31.9% sub-urban and 3.7% rural.

As expected, we find that jurisdictions with more population display higher total built-up areas, and a higher percentage of built-up area in the urban core (e.g., jurisdictions in the highest quintile of population display an average urban core percentage of 87.3%, Figure III). Higher percentages of built-up area in the urban core are also found for those jurisdictions with less reported available vacant land (67.2%), those which report their highest percentage of their jurisdiction is urbanized (78.7%), and when the jurisdiction is one of the big agglomerates (66.5%,Table 5).

[10] Notice that these are average values of a distribution of percentages; the numbers might not necessarily sum up to 100%. This is because the average jurisdiction is here taken in terms of the three component variables. A scaling of these values, computed for illustrative purposes, results in 55% urban, 35% suburban and 10% rural.

Figure III: Built-up area and its components



Buildable Areas

Table 6 reports a measure of the total buildable land. These measures were computed on the basis of topographic images, taking into account two alternative maximum slopes of 15° and 30°. The measures are calculated as percentages of the total footprint area.

Results show a scarce degree of variability in these measurements. They range from 95.3 to 100% (of total the total footprint area), with means of 99.4 and 99.6 (for 15 degrees and 30 degrees respectively) and a standard deviation of 1 percentage point. These measures somehow reflect the fact that of the jurisdictions under study are located in plain areas. Both variables share a median of 100 percent buildable area.

Fragmentation Indicators (2001)

We follow Angel, Parent, and Civco (2010) for measuring the fragmentation of the built-up surfaces of our jurisdictions (and the open space in and around them) according to different metrics, each of them measuring fragmentation at a different spatial scale

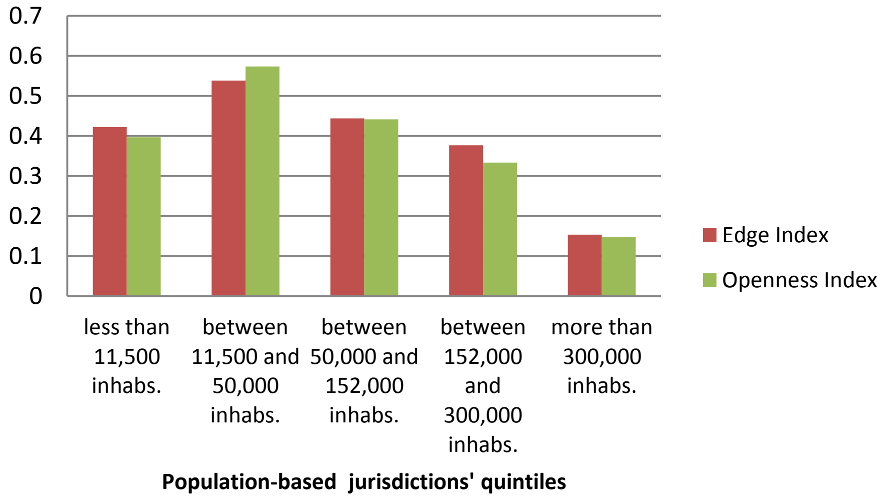
The Edge Index was used to measure fragmentation at the scale of individual buildings; the Openness Index to measure fragmentation at the neighborhood scale; the Core Open Space Ratio at the urban core; and the City Footprint Ratio in the entire jurisdiction surface, including its suburbs.

The Edge and Openness Indices display similar results; both with means of nearly 0.5 (recall that these indicators are defined to be ranged between 0 and 1) and medians of 0.45 and 0.46

respectively (Table 7)[11]. There is a significant degree of dispersion with a standard deviation of 0.23 in both cases. Both measures are strongly correlated (0.97), and maintain a positive and high degree of correlation with the Core Open Space ratio and the City Footprint Ratio (ranging from 0.61 to 0.69, See more below). The Openness index suggests that close to one half of the one-square-kilometer area in the immediate vicinity of a randomly selected built-up place in a given city is likely to consist of open space. In other words, a typical urban neighborhood consists of approximately equal areas of built surfaces and open fields. This gives us a sense of the fragmentation of the typical city at the neighborhood level.

These fragmentation indicators at the smallest scale level are found to display maximum values (highest probability of adjacency with open space) in the second population-based jurisdiction quintile (between 11,500 and 50,000 inhabitants) and then (as expected) decrease in more populated jurisdictions (Figure IV). Seems to be quite surprising the fact that that the least populated jurisdictions are not the jurisdictions with more open space (or more fragmentation at the micro or lowest scale levels)[12]. Also as expected, jurisdictions with largest percentage of their surface in process of urbanization or with rural use show more open space (shown in Figure V).

Figure IV: Edge and Openness Index



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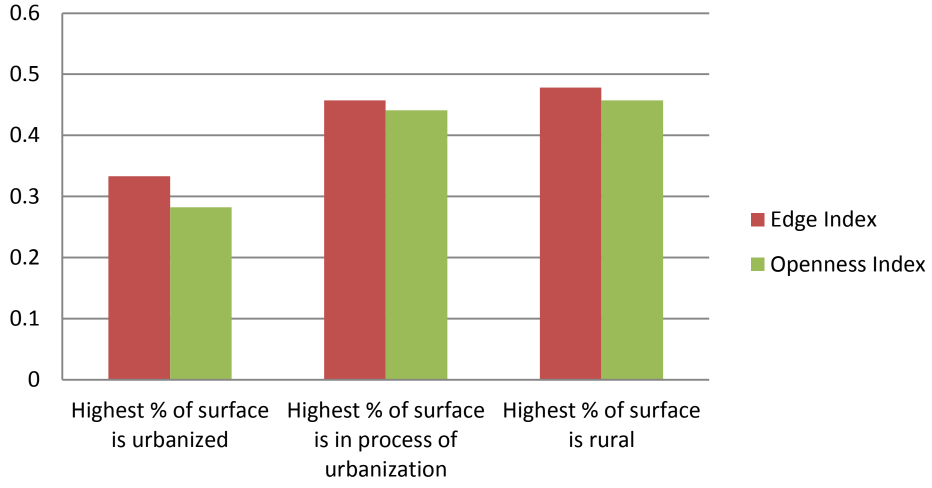
[11] This values are quite similar to those mean values of the Edge Index obtained by Shlomo et al, 2010 for their whole sample of 120 cities, which was 0.494±0.027 (sig. 2-tailed 0.000) in 1990 and 0.445±0.025 (sig. 2-tailed 0.000) in 2000 . However, for their sample, the standard deviation from the mean was 0.15 in 1990 and 0.14 in 2000. In the case of the case of Openness Index, in their sample, the mean value for a typical city was 0.47±0.02 in 1990 and 0.42±0.02 in 2000 (sig. 2-tailed 0.000) and those findings for cities in the global sample in 1990 and 2000 were quite similar in value to the earlier findings of Burchfield *et al* (2005) for the United States in 1976 and 1992. In this case as well, standard deviations from the mean are higher than those obtained in the cited studies (0.14 in 1990 and 0.13 in 2000)

[12] Recall that in these case, least populated jurisdictions are not necessarily isolated cities, but might be jurisdictions that are part of a larger urban agglomerate with low density. This result might also be due to the jurisdiction limits problem we have mentioned in the Methodology Section: In the resulting sample, the lowest populated jurisdictions are located in those provinces allowing the existence of smaller -urban area restricted (i.e., Ejidos)- jurisdictions.

Figure V: Openness and Edge Index



When next examine fragmentation at the urban core and at the city using the Core Open Space Ratio and Urban Footprint ratios. We find that the average (jurisdiction) Core Open Space Ratio is 1.4, with a standard deviation 0.3 (the median ratio is 1.3) (Table 8). In the case of the City Footprint Ratio the mean is 4.8 (the median is 2.5), the degree of dispersion is relatively higher with standard deviation of 6.7. Both distributions are similarly skewed to the right, although in the case of the Footprint Ratio this appears to be more evident due to the larger standard deviation. Both ratios are highly correlated, displaying a correlation coefficient of 0.85 (significant at 1% level).

Similarly to what is shown in the case of the Edge and Openness indicators, the fragmentation is highest in the second population-based quintile, and then tends to decrease as total population increases (this is clearly the case for the Footprint Ratio and is less clear in the Core Open Space Ratio, Figure V).

Differently from fragmentation at the smallest scale, the largest fragmentation is now found in those jurisdictions in process of urbanization (1.43 and 3.23 respectively) with lower level of fragmentation in mostly rural jurisdictions. The largest fragmentation indices are also found in those jurisdictions with relatively more vacant land (1.39 and 2.87) (Table 11).

Figure VI: Core Open Space Ratio and Footprint Ratios by population-based jurisdictions' quintiles

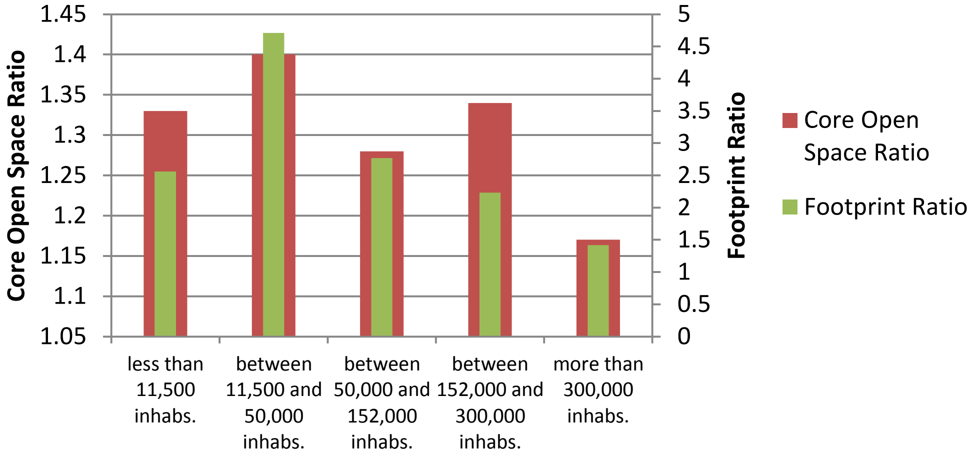
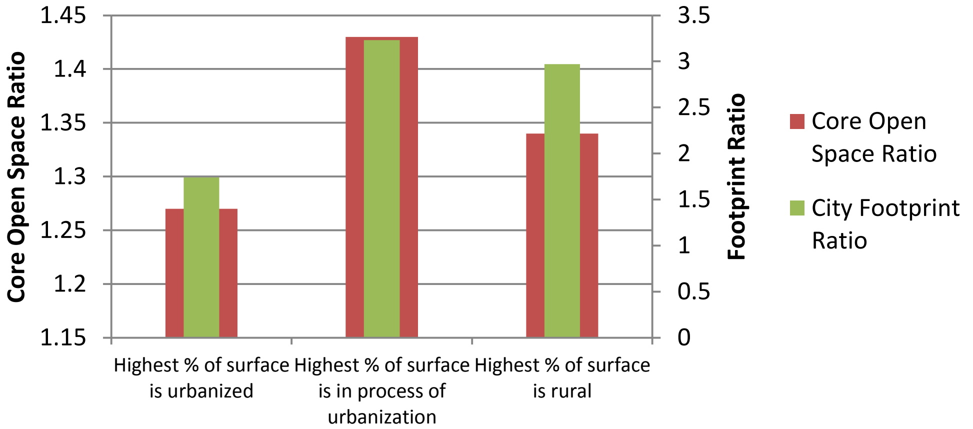


Figure VII: Core Open Space Ratio and Footprint Ratios by population-based jurisdictions' quintiles



New Developments (1990-2001)

Table 9 displays the metrics related to the developments of the jurisdictions during the period 1990-2001. Following Angel et al. (2010), total new developments (which are obtained by comparison of built-up pixels between the two mentioned periods) can be decomposed into three measures: infill, extension, and leapfrog developments (See discussion in the Methodology Section above). We present these measures as percentage of total new developments.

The mean of the total development is 415.90 hectares, with a lower median value of 158.60 (i.e., a right skewed distribution with a number of significant high observations).

According to the new developments metrics decomposition, most of it is related to *extension*. The average extension percentage accounts for 61% of total new developments. Another 29% is computed as *infill* and the average leapfrog area is 10%. Median percentages attribute a slightly higher participation to extension 65%, and lower to infill 25% and to 8% leapfrog.

As expected Extension and Infill percentages are strongly negatively correlated across jurisdictions, with a negative and significant correlation coefficient of -0.9 (significant at 1% confidence level, Table 9b). Interestingly, the *leapfrog* percentage is not correlated with extension, but it is negatively correlated with the *infill* percentage. The correlation coefficient is -0.54 (significant at 1%).

The largest jurisdictions (in terms of population) display the lowest composition of extension (49.4% for jurisdictions with more than 300,000 inhabitants) and leapfrog (4.7 %) developments, or in other words, the largest infill (47.6%). However, the table does not suggest a homogeneous tendency between population and development composition across all categories. We can also find the lowest *extension* for the jurisdictions that report the highest percentages of their surface under complete urbanization (50.7%) and less vacant land (58.7%). Jurisdictions with more vacant land also display more extension and more leapfrog development.

Less Fragmentation across all jurisdictions: Fragmentation Evolution (1990-2001)

We examine the evolution of fragmentation in relation to the variation of indicators that were presented above for the period 1990-2001: The Edge and Openness Indices, and the Core Open Space and Footprint Ratios.

Our results suggest a homogeneous tendency towards less fragmentation across all the indicators considered and across all jurisdictions. In other words, fragmentation indicators for the year 2011 suggest less fragmentation than in 1990 across all the scales of analysis that were considered and in most jurisdictions.

For example, Edge and Openness indices –measuring fragmentation at the individual buildings and neighborhood level respectively- exhibit average reductions of -0.1 and -0.07 (Table 10). Recall that on average these indicators take average values of nearly 0.5, which implies average reductions of 20% and 14% respectively. These reductions are also illustrated in Figure III, where each point represents a jurisdiction, and which also shows another expected result: those jurisdictions which have decreased more their fragmentation at the individual building scale also tend to have also decreased more their fragmentation at the neighborhood scale, as the strong correlation in the differences suggests.

Also for the case of these indicators, the reduction in fragmentation is slighter in more populated jurisdictions, as it is displayed in Figure IV. This is an expected result which shows how the infill process in more populated jurisdictions –in general these are more urbanized jurisdictions- is reasonably lower than less populated jurisdictions – which in general tend to be in process of urbanization-.

Figure III: Edge and Openness Index. 2001-1990 Differences. Cross plot of jurisdictions

Figure IV: Edge and Openness Index. 2001-1990 Differences

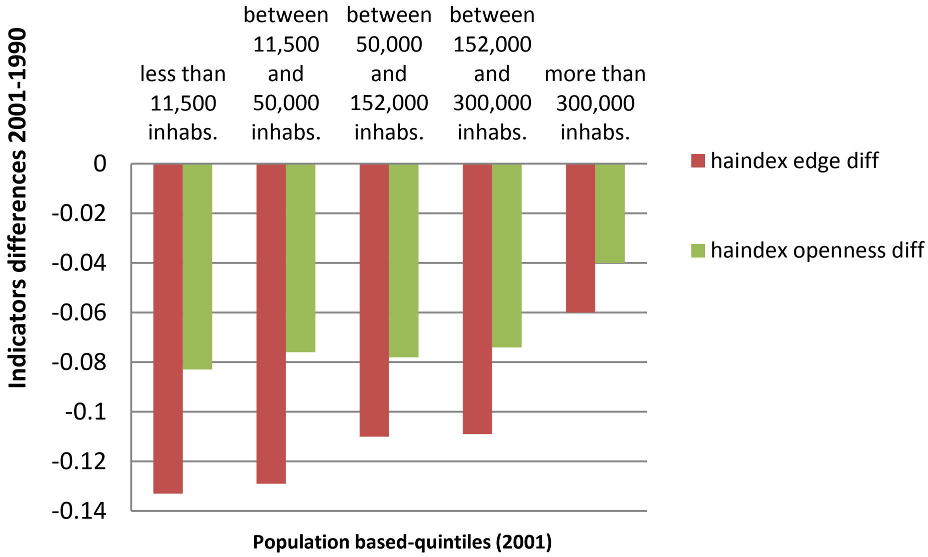
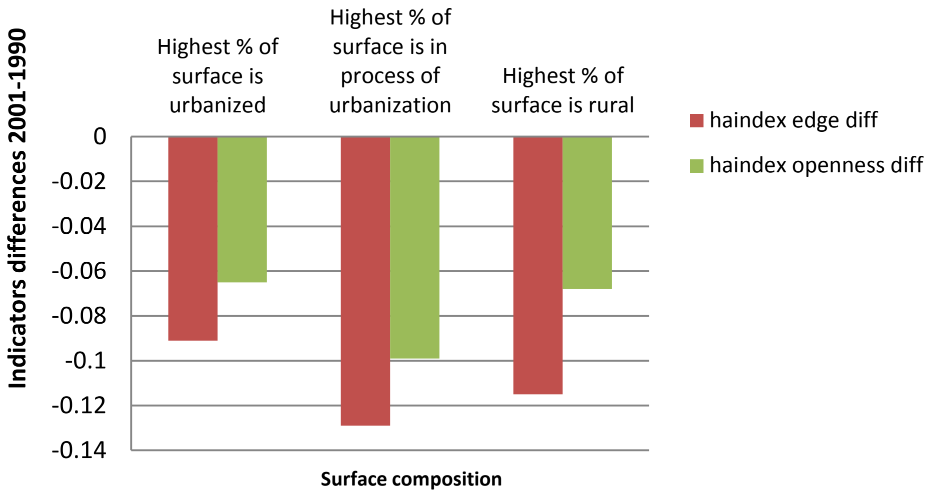


Figure V shows that jurisdictions with their highest percentage of its surface completely urbanized (by 2001) present a reduction in the fragmentation that is lower than those in process of urbanization. Those jurisdictions with most of their surface with rural use also display lower reduction than those in process of urbanization. Unfortunately in this analysis it is not clear whether this reflects a lower growth rate in those jurisdictions, since our surface composition variable is a 2001 variable.

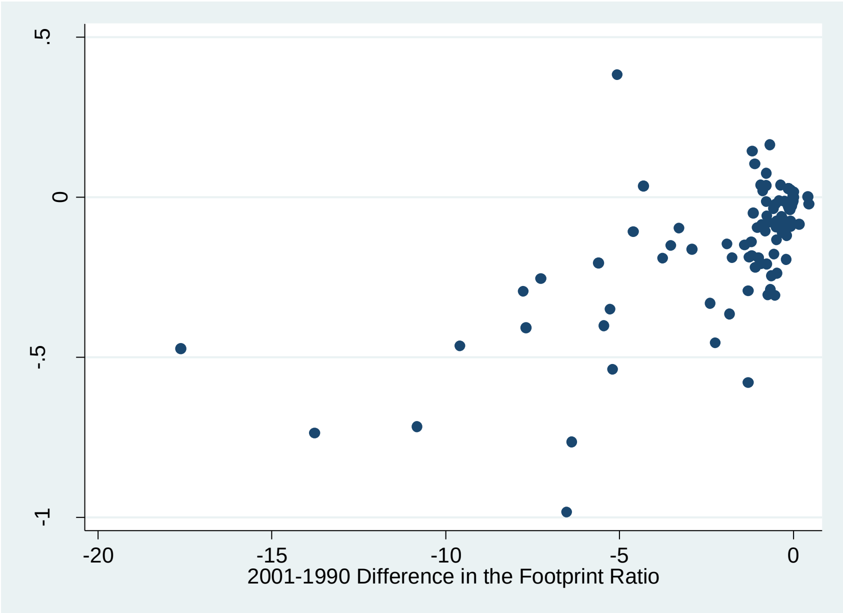
Figure V: Edge and Openness Index. 2001-1990 Differences



Reductions in fragmentation are also found for the case of the Core Open Space Ratio and the City Footprint Ratio –measuring fragmentation at the urban core; and at the entire jurisdiction surface including its suburbs respectively- exhibiting average reductions of -0.13, -1.85 (Table 11). These indicators imply average reductions of 9% and 36% respectively.

These reductions are once again illustrated in Figure V. All jurisdictions display negative values for the Footprint Ratio difference and the majority of jurisdictions do also display negative values for the Core Open Space Ratio. The figure also shows that those jurisdictions which have decreased more their fragmentation at the urban core has also tend to have also decreased their fragmentation at the entire jurisdiction scale, however, here the correlation is less clear than in the previous figure, in part caused by many jurisdictions grouped in the lowest values of both indicators. We neither find clear correlations with the other variables under consideration (See Table 11) such as with population based quintiles, where the relationship is less clear than with the former indicators.

Figure V: Core Open Space and Footprint Ratios 2001-1990 Differences



Conclusions

This paper explores a new set of metrics that allow us to better understand regulation, in particular in relation to zoning determination and to the characteristics and evolution of fragmentation in built-up surfaces across the municipal jurisdictions´ in Argentina. Our aim has been to answer simple questions: How much do zoning uses differ across municipalities? How is the built-up surface composed in a given municipality? How are these municipalities in terms of the fragmentation of their surfaces? How did fragmentation evolve in the period 1990-2001?

We acknowledge that this paper only presents a preliminary analysis of the resulting metrics. Nevertheless, it has provided some suggestive insights that will motivate the future research. For example, in relation to zoning uses we now know that the zoning for residential use accounts for nearly 60% of the non-rural zoned area, with a high standard deviation of nearly 20%. To understand this variability will be an important focus of future studies. These metrics will also allow, in a future study, to weight the regulation uses and building parameters according to the uses and to empirically test hypothesis related to the causes and consequences of land use regulation.

In the case of land cover metrics, we have described several indicators including characteristics of fragmentation and patterns between fragmentation and population and surface coverage. We have presented preliminary evidence on how much fragmentation declines with population and also find that largest fragmentation occurs in in jurisdictions that are in process of urbanization. Notably, we document a homogeneous tendency towards less fragmentation for the period 1990-2001, a finding that is consistent to the available evidence in the cited literature, but in our case we think that still deserves further examination.

In terms of the zoning exercise, we should stress that the collection of zoning images faced the problem of many jurisdictions which simply do not have or do not have recently updated zoning maps. Of course, this is a problem which is more prevalent in smaller jurisdictions so we might need to consider this issue in the future analysis (for example, by correcting a possible bias in the related estimations). A second problem is the heterogeneity in the zoning categories which, even though they display some degree of similarity, they do not follow a standard which would favour the comparative analysis and aggregate understanding. Moreover, in relation to the stringency-flexibility of land use and building parameters within each zoning use –we do not show in this paper but we are aware of-, we take into account that these might differ across municipalities. In other words, a same zoning category might reflect different parameter values in different jurisdictions. Therefore, the construction of flexibility/stringency indicators will have to take these issues into account. Nonetheless we do reach the conclusion that, in order to ease the general understanding of land use regulation, a careful collection and update by a national agency or related central agency is a priority thing to do.

In terms of the land cover metrics, we acknowledge that the availability of (low cost) satellite images and the technology for the classification of pixels is powerful in terms of the analysis possibilities of urban phenomena that they open. Still we are in the point where it is worth to discuss the construction of indicators, and will be good to check their elasticity to some changes. We find some metrics to be simple and appealing, such as for example, regarding the appropriate measurement of the total built-up surface, and the composition of new developments into infill, extension and leapfrog.

In terms of the analysis undertaken in this exercise, there are many issues which are not addressed in this descriptive paper, such as the geographic representation of jurisdictions across the agglomerate which will allow a better understanding the spatial dimension (necessary to control for the relative position of jurisdiction in urban agglomerate), the existence of regulation or related externalities. Also, an appropriate econometric test of many relationships that are only superficially explored here is needed, which we kept for a next step in our study. All these improvements should be included in future studies.

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Appendix

Classification and Images Acquisition Methodology

The Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper-Plus (ETM) data were used as the base maps for image analysis and land cover classification. Cloud-free scenes for both T1 and T2 periods covering applicable metropolitan area were selected and downloaded from the Global Land Cover facility (GLCF) archives (http://glcf.umiacs.umd.edu/index.shtml).

Each scene was geo-referenced to the Universal Transverse Mercator (UTM) projection and the WGS-84 datum. Image pixels were re-sampled to 28.5 meters. Some of the scenes were orthographically corrected to remove geometric distortions and displacements.

Each selected Landsat scene was subset to cover only the extent of the metropolitan area to facilitate further analysis and increase the quality of produced land cover maps. Each subset map was then subjected to the Iterative Self-Organizing Data Analysis (ISODATA) algorithm available as part of the Leica Geosystems ERDAS Imagine 9.3 image processing and pattern recognition software suite.

The ISODATA clustering algorithm was used to partition the T1 subset scenes into 50 spectrally separable classes. Using the Landsat data themselves, along with independent reference data when available, each of the 50 clusters was placed into one of three pre-defined cover classes: water, urban, and non-urban. Because per-pixel, spectral data-alone classification methods often encounter difficulty in discriminating between urban vs. barren and urban vs. water cover types the classification maps were carefully scrutinized to detect obvious misclassifications by comparing results with the source image, through a careful, section-by-section examination of the Landsat imagery. On-screen editing of regions of pixels obviously misclassified was performed through heads-up digitizing. This analyst intervention and application of her expert knowledge increased both the thematic and spatial accuracies of the classifications.

The resulting land cover classifications were recoded into three classes: water, non-urban, and urban. This dataset was then used to mask out pixels classified as urban from the T2 Landsat image subset to simplify the process of further image analysis and increase the quality of resulting base maps. The same ISODATA clustering algorithm was then applied to the T2 Landsat subset to produce three class land cover map for the T2 time period. As this map would be missing urban pixels from the T1 period, it is then combined with the T1 resulting map to fill in the omitted data.

Geographic Coordinates and Dates of Satellite Images

	Big Urban Agglomerates	LAT	LONG	Path	Row	Date T1	Date T2
1	Gran Buenos Aires (p2)	-34.6084	-58.3732	225	84	28-May-89	23-Dec-01
	Gran Buenos Aires (p1)			225	85	28-May-89	23-Dec-01
2	Gran Rosario	-32.9507	-60.6665	227	83	27-Jul-91	13-Nov-01
3	Gran Santa Fe	-31.6324	-60.6995	227	82	02-Dec-91	03-Nov-01
4	Gran Córdoba	-31.3989	-64.1821	229	82	16-Dec-91	17-Nov-01
5	Gran Resistencia	-27.4517	-58.9863	226	79	22-Nov-87	11-Oct-01
6	Gran Tucumán – Tafí Viejo (p1)	-26.7325	-65.267	230	79	25-Sep-91	01-Dec-01
	Gran Tucumán – Tafí Viejo (p2)			231	79	18-Jul-89	11-Jan-02
7	Gran Mendoza (p1)	-32.8902	-68.8441	232	83	28-Jun-91	08-Dec-01
	Gran Mendoza (p2)			232	82	28-Jun-91	08-Dec-01
8	Gran La Plata	-34.9173	-57.9501	224	84	29-Dec-91	11-Sep-01
9	Gran Paraná (p1)	-31.7413	-60.5115	227	82	02-Dec-91	03-Nov-01
	Gran Paraná (p2)			226	82	06-Jul-89	12-Nov-01
10	Mar del Plata – Batán	-37.9799	-57.5898	224	86	01-Aug-89	14-Nov-01
11	Salta	-24.7829	-65.4122	231	77	25-Jul-92	01-Dec-01
12	Gran San Juan	-31.5273	-68.5214	232	82	28-Jun-91	08-Dec-01
13	Stgo. del Estero – la Banda	-27.7844	-64.2673	230	79	18-Jul-89	11-Jan-02
14	San Luis -El Chorrillo (p1)	-33.2996	-66.3492	230	83	20-Mar-89	24-Nov-01
	San Luis -El Chorrillo (p2)			230	84	20-Mar-89	24-Nov-01
15	Corrientes (p1)	-27.4712	-58.8396	226	79	22-Nov-87	11-Oct-01
16	Jujuy – Palpalá	-24.2648	-65.2118	231	77	25-Jul-92	01-Dec-01
17	Bahia Blanca-Cerri	-38.7117	-62.2681	226	87	27-Dec-91	15-Feb-02
18	Posadas	-27.3621	-55.9009	224	79	29-Dec-91	17-Jan-02
19	Neuquén – Plottier	-38.9493	-68.0658	230	87	23-Dec-91	24-Nov-01
20	Formosa	-26.1852	-58.1754	226	78	06-Jul-89	08-Aug-01
21	Gran Catamarca	-28.469	-65.779	231	80	25-Sep-91	01-Dec-01
22	Entre Rios	-32.5176	-59.1042	226	82	06-Jul-89	12-Nov-01
23	Río Cuarto	-33.132	-64.3497	229	83	17-Jan-92	17-Nov-01
24	Comodoro Rivadavia – Rada Tilly	-45.8679	-67.5	228	92	20-Jul-86	07-Sep-01
25	La Rioja	-29.4128	-66.856	231	80	25-Sep-91	01-Dec-01
26	Rawson - Trelew	-43.2999	-65.0995	227	90	19-Jan-92	21-Dec-01
27	Santa Rosa – Toay	-36.6693	-64.3787	228	85	10-Jan-92	10-Nov-01
28	Viedma - Carmen de Patagones	-40.8119	-62.9962	227	88	03-Jan-92	16-Sep-01

Zoning Uses and Land Cover Metrics Tables

Tables' Notes

The population of each of the jurisdiction is obtained from the 2001 Argentine Census. Jurisdictions were then sorted and grouped according to the five quintiles of the resulting distribution of jurisdictions.

The variables *surface, vacant land,* and *survey samples* were obtained from the survey Land Use Regulation and Practices in Argentina, 2011 edition (See details in Goytia, C., Pasquini, R. A., and T. Hagedorn, (2012). The categorical variable *surface* was constructed using the composition of the surface coverage (in percentage terms) as estimated by the planning director of each jurisdiction (see Section i). The jurisdictions were grouped according to: if the highest percentage of its surface is completely urbanized, if the highest percentage is in process of urbanization, or if the highest percentage is rural.

The categorical variable *vacant land* was constructed using the estimation of vacant land as percentage of the total urbanized area and as a total of the area in process of urbanization (see Section i). The percentiles 50 and 75 were used to group the jurisdictions. As a result, the first group of jurisdictions is comprised by those jurisdictions with approximately less than 4.3% of estimated vacant land in the completely urbanized and less than 13% in the area in process of urbanization. The third group is comprised by those jurisdictions with more than 37% of estimated vacant land in the completely urbanized and less than 83% in the area in process of urbanization. The rest of the jurisdictions are comprised by the second group.

The *survey samples* comprise the three groups of jurisdictions as sampled for the cited survey. The first sample consists of all the jurisdictions that are comprised in the big urban agglomerates (B.U.A.) of Argentina[13]. The second comprises those jurisdictions with a population above 50,000 inhabitants. The third comprised smaller jurisdictions with a population above 20,000. According to the 2001 Census our targeted sample accounts for nearly 80% of the total population in Argentina (approximately 60% in the B.U.A and additional 20% in the two samples).

As explained in the methodology of the document, a total of 140 jurisdictions were separately analysed for the land cover study. These resulting data was matched with 2001 Census information (latest available Census information source) and with survey data. Due to mismatch between existent governmental jurisdictions available at the 2001 population census, some of the analysed jurisdictions were not matched. In the case of the survey, the match rate was even lower due to non-response of the survey, which explains the lower number of available observations in most of the group-based statistics.

[13] The definition of big urban agglomerates is given by the National Institute of Statistics and Census (INDEC) of Argentina.

Table 2: Zoning as % of total jurisdiction zoned area

Variable	N	Mean	Median	Sd	Min	Max
Rural	111	66.13	73.22	32.49	0	99.85
Gated Urbanizations	111	1.13	0	4.34	0	34.81
Residential: High Density	111	1.43	0.13	2.83	0	15.32
Residential: Low Density	111	8.24	4.43	11.37	0	58.06
Residential: Medium and Mixed Density	111	11.89	3.28	18.34	0	95.26
Urban equipment	111	2.49	0.16	6.08	0	43.67
Green spaces	111	2.63	0.22	5.6	0	31.19
Industrial	111	4.73	1.37	7.65	0	40.21
Other	111	1.29	0	6.52	0	53.61

Table 3: Zoning uses as percentage of total zoned area, and having excluded the rural use

Variable	N	Mean	Median	Sd	Min	Max
Gated Urbanizations	111	2.64	0	10.53	0	81.79
Residential: High Density	111	3.32	1.78	5.12	0	28.59
Residential: Low Density	111	30.2	27	19.29	0	85.96
Residential: Medium and Mixed Density	111	29.28	25.73	23.32	0	100
Urban equipment	111	6.89	2.69	10.13	0	54.14
Green spaces	111	7.95	3.91	11.86	0	81.13
Industrial	111	15.35	11.61	16.53	0	89.16
Other	111	4.33	0	13.81	0	99.8

Table 4: Zoning uses as percentage of total zoned area, and having excluded the rural use

		Mean			
	N	Gated Urbanizations	Residential High Density	Residential Low Density	Residential Medium and Mixed Density
Population					
Less than 23,000 inhabs.	17	0.6	4.9	33.2	35.8
Between 23,000 and 34,400 inhabs.	25	1.5	2.5	31.8	28
Between 34,400 and 57,200 inhabs.	23	0.4	2.7	30.1	29.1
Between 57,200 and 141,300 inhabs.	21	7.3	1.7	31.9	18.1
more than 141,300 inhabs.	25	3.3	5	25.3	35.6
Total	111	2.6	3.3	30.2	29.3
Surface					
Highest % of surface is urbanized	21	1	4.2	26.7	38.6
Highest % of surface is in process of urbanization	6	7.6	2.1	20.5	48.1
Highest % of surface is rural	81	2.8	3.1	32.5	24.6
Total	108	2.7	3.3	30.7	28.6
Vacant Land					
Vacant Land up to percentile 50	52	0.7	2.5	32.3	29.5
Vacant Land between percentile 50 and 75	51	4.3	4	28.4	29.7
Vacant Land above percentile 75	7	5.5	3.4	31.2	23.3
Total	110	2.7	3.3	30.5	29.2
Survey Samples					
Belongs to a big urban agglomerate	47	3.3	4.9	23.7	34.4
Not in a big U. A. and more than 50k inhabs.	18	5.5	1.6	34.6	16.7
Not in a big U. A. and between 20k-50k inhabs.	46	0.8	2.4	35.1	28.9
Total	111	2.6	3.3	30.2	29.3
Region					
Cuyo	8	0.1	3.6	21.3	45.7
NEA	16	2.3	6.5	27.9	28.9
NOA	2	4.2	1.2	24	61.9
Pampeana	77	3.2	2.4	32.9	26.3
Patagonia	8	0	5.9	19.6	34.4
Total	111	2.6	3.3	30.2	29.3

Table 4 (Cont): Zoning uses as percentage of total zoned area, and having excluded the rural use

	Mean			
	Equipment	Green Space	Industrial	Other
Population				
Less than 23,000 inhabs.	7	5.3	8.9	4.3
Between 23,000 and 34,400 inhabs.	3.2	6.4	18.8	7.7
Between 34,400 and 57,200 inhabs.	7.6	10.9	16.4	2.8
Between 57,200 and 141,300 inhabs.	8.4	7.8	18.3	6.5
more than 141,300 inhabs.	8.6	8.8	12.8	0.5
Total	6.9	8	15.3	4.3
Surface				
Highest % of surface is urbanized	8.1	5.9	15	0.5
Highest % of surface is in process of urbanization	5.3	7	8.5	1.1
Highest % of surface is rural	6.4	8.9	16.3	5.4
Total	6.7	8.2	15.6	4.2
Vacant Land				
Vacant Land up to percentile 50	7.1	7.1	17.4	3.3
Vacant Land between percentile 50 and 75	6.4	8.5	13.3	5.2
Vacant Land above percentile 75	7.9	7.3	15.6	5.8
Total	6.8	7.8	15.4	4.3
Survey Samples				
Belongs to a big urban agglomerate	9.1	7.1	14.9	2.4
Not in a big U. A. and more than 50k inhabs.	6.7	9.8	17.5	7.6
Not in a big U. A. and between 20k-50k inhabs.	4.7	8.1	15	5
Total	6.9	8	15.3	4.3
Region				
Cuyo	4.8	5	18.6	0.9
NEA	7.8	16.2	7.6	2.7
NOA	0	4.5	4.1	0
Pampeana	7	6.2	17.3	4.8
Patagonia	8.2	12.5	11.7	7.7
Total	6.9	8	15.3	4.3

Table 5: Built-up Area Components

Variable	N	Mean	Median	Sd	Min	Max
Total built-up area (hectares)	139	1948.10	656.60	3040.40	3.20	18906.10
Urban (Percentage)	121	58.90	68.20	29.80	0.00	100.00
Sub-Urban (Percentage)	139	38.50	31.90	27.60	0.00	100.00
Rural (Percentage)	135	10.50	3.70	17.80	0.00	100.00

By categories	N	Category Average Value			
		Total built-up area (hectares)	Urban (%)	Sub-Urban (%)	Rural (%)
Population					
Less than 11,477 inhabs.	16	909.5	61.10	36.30	6.40
Between 11,477 and 49,621 inhabs.	16	802	48.30	40.10	14.60
Between 49,621 and 152,226 inhabs.	16	1057.2	62.80	30.80	15.20
Between 152,226 and 300,400 inhabs.	16	2936.6	74.10	23.50	2.50
More than 300,400 inhabs.	16	5875.5	87.30	11.60	1.20
Total	**80**	**2316.2**	**67.20**	**28.50**	**8.00**
Surface					
Highest % of surface is urbanized	19	2991.2	78.70	23.00	2.60
Highest % of surface is in process of urbanization	4	2431.8	58.90	36.10	5.00
Highest % of surface is rural	33	1812.2	54.20	36.40	12.60
Total	**56**	**2256.5**	**62.90**	**31.90**	**8.80**
Vacant Land					
Vacant Land up to percentile 50	21	2979.7	67.20	26.20	6.50
Vacant Land between percentile 50 and 75	33	1913	62.90	31.80	9.50
Vacant Land above percentile 75	6	1784.7	55.60	46.10	7.60
Total	**60**	**2273.5**	**63.80**	**31.30**	**8.20**
Survey Samples					
Belongs to a big urban agglomerate	58	2399.9	66.50	31.00	6.10
Not in a big U. A. and more than 50k inhabs.	1	62.7	0.00	62.40	37.60
Not in a big U. A. and between 20k-50k inhabs.	2	107.4	30.50	18.30	51.20
Total	**61**	**2286.4**	**64.10**	**31.10**	**8.10**
Region					
Cuyo	12	1550.5	64.10	34.10	7.80
NEA	10	1353.3	45.60	48.20	15.20
NOA	20	1014.2	61.50	39.20	17.70

Pampeana	75	2552.9	61.20	36.30	10.10
Patagonia	6	1158.3	63.80	33.50	2.70
Total	**123**	**2039.3**	**60.50**	**37.40**	**11.20**

Table 6: Buildable Area Metrics. As % of Total Footprint Area

Variable	N	Mean	Median	Sd	Min	Max
Buildable Area with 15°	120	99.4	100	1	95.3	100
Buildable Area with 30°	120	99.6	100	0.9	95.3	100

By categories	N	Median	
		Buildable Area with 15°	Buildable Area with 30°
Population			
Less than 11,477 inhabs.	16	99.774	99.781
Between 11,477 and 49,600 inhabs.	13	99.979	99.994
Between 49,600 and 152,200 inhabs.	14	99.996	99.996
Between 152,200 and 300,400 inhabs.	16	99.942	99.974
More than 300,400 inhabs.	15	99.979	99.979
Total	**74**	**99.951**	**99.972**
Surface			
Highest % of surface is urbanized	19	99.91	99.91
Highest % of surface is in process of urbanization	4	99.886	99.955
Highest % of surface is rural	29	99.969	99.979
Total	**52**	**99.918**	**99.946**
Vacant Land			
Vacant Land up to percentile 50	19	99.996	99.996
Vacant Land between percentile 50 and 75	31	99.914	99.914
Vacant Land above percentile 75	6	99.963	99.996
Total	**56**	**99.942**	**99.962**
Survey Samples			
Belongs to a big urban agglomerate	56	99.942	99.966
Not in a big U. A. and more than 50k inhabs.	0		
Not in a big U. A. and between 20k-50k inhabs.	1	98.175	99.12
Total	**57**	**99.934**	**99.966**
Region			
Cuyo	11	99.999	99.999
NEA	10	99.796	99.796
NOA	16	99.944	99.944
Pampeana	66	99.943	99.966
Patagonia	6	99.372	99.46
Total	**109**	**99.952**	**99.978**

Table 7: Openness and Edge Index

Variable	N	Mean	Median	Sd	Min	Max
Edge Index	126	0.5	0.4	0.2	0	1
Openness Index	128	0.5	0.5	0.2	0	1

By categories	N	Median	
		Edge Index	Openness Index
Population			
Less than 11,477 inhabs.	14	0.423	0.397
Between 11,477 and 49,600 inhabs.	16	0.539	0.574
Between 49,600 and 152,200 inhabs.	15	0.444	0.442
Between 152,200 and 300,400 inhabs.	16	0.377	0.334
More than 300,400 inhabs.	14	0.154	0.148
Total	**75**	**0.38**	**0.363**
Surface			
Highest % of surface is urbanized	19	0.333	0.282
Highest % of surface is in process of urbanization	4	0.457	0.441
Highest % of surface is rural	30	0.478	0.457
Total	**53**	**0.424**	**0.38**
Vacant Land			
Vacant Land up to percentile 50	21	0.375	0.328
Vacant Land between percentile 50 and 75	30	0.417	0.383
Vacant Land above percentile 75	6	0.532	0.493
Total	**57**	**0.422**	**0.376**
Survey Samples			
Belongs to a big urban agglomerate	55	0.392	0.366
Not in a big U. A. and more than 50k inhabs.	1	0.79	0.866
Not in a big U. A. and between 20k-50k inhabs.	2	0.721	0.714
Total	**58**	**0.416**	**0.376**
Region			
Cuyo	11	0.5	0.457
NEA	7	0.64	0.626
NOA	19	0.498	0.506
Pampeana	72	0.434	0.432
Patagonia	6	0.395	0.358
Total	**115**	**0.444**	**0.457**

Table 8: Core Open Space and Footprint Ratios

Variable	N	Mean	Median	Sd	Min	Max
ratio_urbanized_built_up	111	1.4	1.33	0.29	1.04	2.99
ratio_footprint_built_up	111	4.76	2.45	6.74	1.04	44.78

	N	Median	
		ratio urbanized built up	ratio footprint built up
Population			
less than 11,477 inhabs.	15	1.33	2.56
between 11,477 and 49,600 inhabs.	14	1.4	4.71
between 49,600 and 152,200 inhabs.	13	1.28	2.77
between 152,200 and 300,400 inhabs.	16	1.34	2.23
more than 300,400 inhabs.	16	1.17	1.42
Total	74	1.3	2.29
Surface			
Highest % of surface is urbanized	18	1.27	1.74
Highest % of surface is in process of urbanization	4	1.43	3.23
Highest % of surface is rural	29	1.34	2.97
Total	51	1.32	2.45
Vacant Land			
Vacant Land up to percentile 50	20	1.33	2.14
Vacant Land between percentile 50 and 75	30	1.3	2.58
Vacant Land above percentile 75	5	1.39	2.87
Total	55	1.32	2.43
Survey Samples			
Belongs to a big urban agglomerate	55	1.32	2.39
Not in a big U. A. and more than 50k inhabs.	0		
Not in a big U. A. and between 20k-50k inhabs.	1	1.28	3.2
Total	56	1.32	2.41
Region			
Cuyo	11	1.42	3.04
NEA	7	1.48	2.96
NOA	13	1.32	2.97
Pampeana	62	1.3	2.29
Patagonia	6	1.27	2.27
Total	99	1.32	2.45

Table 8b: Fragmentation Metrics. Correlation Matrix

	Core Open Space to Total Built-up ratio	Footprint to Total Built-up ratio	Openness Index	Edge Index
Core Open Space Ratio	1			
	111			
Footprint to Total Built-up ratio	0.8504*	1		
	0.000			
	111	111		
Openness Index	0.6295*	0.6143*	1	
	0.000	0.000		
	104	104	128	
Edge Index	0.6984*	0.6355*	0.9659*	1
	0.000	0.000	0.000	
	102	102	126	126

Notes: First row displays correlation coefficient. (*) Significant at 1%. Second row displays significant level, Third row reports the number of observations.

Table 9: New Developments and Its' Composition Metrics

Variable	N	Mean	Median	Sd	Min	Max
Total development	139.0	415.90	158.60	641.40	0.00	3728.30
Extension (%)	131.0	60.50	65.20	21.30	0.30	100.00
Infill (%)	124.0	29.30	25.40	24.20	0.30	99.70
Leapfrog (%)	120.0	12.80	7.90	15.40	0.10	97.80

By categories	N	Median			
		Total development	Extension (%)	Infill (%)	Leapfrog (%)
Population					
Less than 11,477 inhabs.	16.0	219.00	65.30	27.10	11.60
Between 11,477 and 49,600 inhabs.	16.0	192.00	68.00	23.60	9.10
Between 49,600 and 152,200 inhabs.	16.0	256.00	60.50	20.90	7.60
Between 152,200 and 300,400 inhabs.	16.0	716.00	57.20	38.90	3.90
More than 300,400 inhabs.	16.0	980.00	49.40	47.60	4.70
Total	**80.0**	**268.00**	**61.90**	**32.60**	**5.50**
Surface					
Highest % of surface is urbanized	19.0	271.00	50.70	45.20	5.50
Highest % of surface is in process of urbanization	4.0	982.00	71.60	24.00	5.20
Highest % of surface is rural	33.0	399.00	66.50	20.90	9.00
Total	**56.0**	**405.00**	**63.90**	**28.00**	**8.00**
Vacant Land					
Vacant Land up to percentile 50	21.0	411.00	58.90	37.60	4.50
Vacant Land between percentile 50 and 75	33.0	310.00	63.20	29.30	8.60
Vacant Land above percentile 75	6.0	453.00	70.50	18.90	9.10
Total	**60.0**	**333.00**	**63.20**	**28.40**	**8.00**
Survey Samples					
Belongs to a big urban agglomerate	58.0	405.00	62.60	28.60	7.30
Not in a big U. A. and more than 50k inhabs.	1.0	19.00	90.80	0.40	8.80
Not in a big U. A. and between 20k-50k inhabs.	2.0	23.00	64.20	32.10	19.70
Total	**61.0**	**356.00**	**63.20**	**28.60**	**8.00**
Region					
Cuyo	12.0	370.00	66.50	19.80	9.50
NEA	10.0	177.00	66.50	18.90	13.20
NOA	20.0	72.00	69.20	21.30	5.20
Pampeana	75.0	197.00	61.90	28.40	7.80
Patagonia	6.0	281.00	64.30	30.00	9.90
Total	**123.0**	**197.00**	**64.60**	**26.10**	**8.00**

Table 9b: New Development and It's Composition. Correlation Matrix

	Extension (percentage)	Infill (percentage)	Leapfrog (percentage)
Extension (percentage)	1		
	0.0000		
	131		
Infill (percentage)	-0.9003*	1	
	0.0000		
	124	124	
Leapfrog (percentage)	-0.2073	-0.5425*	1
	0.0231	0.0000	
	120	114	120

Table 10: Edge and Openness Index. 2001-1990 Differences

Variable	N	Mean	Median	Sd	Min	Max
haindex_edge_diff	125	-0.1	-0.1	0.1	-0.4	0
haindex_openness_diff	128	-0.1	-0.1	0	-0.3	0

	N	Mean	
		Edge diff	Openness diff
Population			
less than 11,477 inhabs.	14	-0.133	-0.083
between 11,477 and 49,600 inhabs.	15	-0.129	-0.076
between 49,600 and 152,200 inhabs.	15	-0.11	-0.078
between 152,200 and 300,400 inhabs.	16	-0.109	-0.074
more than 300,400 inhabs.	14	-0.06	-0.04
Total	**74**	**-0.109**	**-0.07**
Surface			
Highest % of surface is urbanized	19	-0.091	-0.065
Highest % of surface is in process of urbanization	4	-0.129	-0.099
Highest % of surface is rural	30	-0.115	-0.068
Total	**53**	**-0.107**	**-0.069**
Vacant Land			
Vacant Land up to percentile 50	21	-0.082	-0.056
Vacant Land between percentile 50 and 75	30	-0.127	-0.075
Vacant Land above percentile 75	6	-0.075	-0.068
Total	**57**	**-0.105**	**-0.068**
Survey Samples			
Belongs to a big urban agglomerate	55	-0.108	-0.069
Not in a big U. A. and more than 50k inhabs.	1	-0.084	-0.056
Not in a big U. A. and between 20k-50k inhabs.	2	-0.038	-0.037
Total	**58**	**-0.106**	**-0.068**
Region			
Cuyo	10	-0.182	-0.107
NEA	7	-0.045	-0.051
NOA	19	-0.07	-0.045
Pampeana	72	-0.091	-0.069
Patagonia	6	-0.176	-0.114
Total	**114**	**-0.097**	**-0.07**

Table 11: Urbanized and Footprint Ratios. 2001-1990 Differences

Variable	N	Mean	Median	Sd	Min	Max
ratio_urbanized_built_up_diff	96	-0.1	-0.1	0.2	-1	0.4
ratio_footprint_built_up_diff	97	-2	-0.7	3.4	-17.6	0.4

	N	Mean	
	ratio urbanized built up diff	ratio urbanized built up diff	ratio footprint built up diff
Population			
less than 11,477 inhabs.	13	-0.106	-0.968
between 11,477 and 49,600 inhabs.	12	-0.18	-3.184
between 49,600 and 152,200 inhabs.	12	-0.133	-1
between 152,200 and 300,400 inhabs.	16	-0.114	-1.32
more than 300,400 inhabs.	16	-0.056	-0.409
Total	**69**	**-0.114**	**-1.311**
Surface			
Highest % of surface is urbanized	17	-0.113	-1.319
Highest % of surface is in process of urbanization	4	-0.089	-2.746
Highest % of surface is rural	26	-0.118	-1.484
Total	**47**	**-0.114**	**-1.531**
Vacant Land			
Vacant Land up to percentile 50	19	-0.098	-1.049
Vacant Land between percentile 50 and 75	27	-0.112	-1.205
Vacant Land above percentile 75	5	-0.231	-5.064
Total	**51**	**-0.119**	**-1.525**
Survey Samples			
Belongs to a big urban agglomerate	51	-0.118	-1.51
Not in a big U. A. and more than 50k inhabs.	0		
Not in a big U. A. and between 20k-50k inhabs.	1	-0.187	-1.272
Total	**52**	**-0.119**	**-1.505**
Region			
Cuyo	10	-0.316	-3.344
NEA	6	0.052	-1.355
NOA	12	-0.066	-1.157
Pampeana	56	-0.115	-1.794
Patagonia	5	-0.267	-1.743
Total	**89**	**-0.129**	**-1.85**