Fronteiras: Journal of Social, Technological and Environmental Science
http://periodicos.unievangelica.edu.br/fronteiras/
ISSN 2238-8869

Article

Link between Urban Forests and Poverty: A Case of Study in a City of Argentina

Juan Pablo Celemin[1]

[1] Doctor en Geografía. Consejo Nacional de Investigaciones Científicas y Técnicas. Instituto de Geografía, Historia y Ciencias Sociales (CONICET/IGEHCS). ORCID: 0000-0002-8917-8061. E-mail: jpcelemin@conicet.gov.ar

ABSTRACT
Urban forestry is considered a positive indicator of a city´s environment as it supplies many positive services to local communities. However not all the residents can benefit from it, especially in areas where trees are not native vegetation, such is the case of Mar del Plata (Argentina). In this research an integrated approach combining census data and satellite images shows that the residents of a forested residential area in Mar del Plata with good socioeconomic conditions benefit with a higher Normalized Difference Vegetation Index (NDVI) and lower temperature than most parts of the city.
Keywords: urban forestry; socioeconomic status; normalized difference vegetation index; temperature.

RESUMO
A silvicultura urbana é considerada um indicador positivo do meio ambiente de uma cidade, pois fornece muitos serviços positivos para as comunidades locais. Porém, nem todos os moradores podem se beneficiar, principalmente em áreas onde as árvores não são de vegetação nativa, como é o caso de Mar del Plata (Argentina). Nesta pesquisa, uma abordagem integrada combinando dados do censo e imagens de satélite mostra que os residentes de uma área residencial arborizada em Mar del Plata com boas condições socioeconômicas se beneficiam com um Índice de Vegetação por Diferença Normalizada (NDVI) mais alto e temperatura mais baixa do que a maioria das partes da cidade.
Palavras-chave: silvicultura urbana; status socioeconômico; índice de vegetação de diferença normalizada; temperatura.

1. Introduction

Urban forests can be regarded as an explicit indicator of the local environment of an urban area as it contributes with many aesthetic and environmental benefits to the community (Dwyer et al. 1992). Particularly, urban forestry is acknowledged for ecological, economic and social reasons, therefore it is useful to study the spatial distribution of urban forests within cities. In a local community, forestry can play a significant part in the foundation of physical and social linkages (Nichol 2009). Moreover, its presence can be viewed as a feature that enhances quality of life and individual well being (Dwyer et al. 1992, Jensen et al. 2004, Stathopoulou et al. 2015).

The impact of urban parks and greenspaces as cooling elements is well documented, especially regarding the urban heat island phenomenon as urban vegetation tempers neighboring temperature (Buyantuye and Wu 2010). For instance, urban heat island impact is affected by tree canopy cover that can change fluxes of energy and water, thereby altering air temperatures, wind flows, and air pollution accumulation (McPherson et al. 1997). However not all citizens have access to these environmental advantages, particularly in areas where trees are

Submissão: 12/07/2021 Aceite: 20/12/2022 Publicação: 30/12/2022

v.11, n.4, 67-84. 2022 • p. 67-84. • DOI http://dx.doi.org/10.21664/2238-8869.2022v11i4.p 67-84.

not native plants. Also, residents of lower socioeconomic status are less qualified to enjoy diverse plant presence in their neighborhoods (Kingzig et al. 2005) since wealthy zones have higher tree cover while poor regions have lower. In other words, people in neighbourhoods with important tree coverage have the resources to pay for the cost of conserving high vegetation density (Mennis, 2006) and, consequently, it can be presumed that household earning is strongly related to tree cover (Iverson & Cook 2000). Also, there is a correlation between social and demographic fragmentation and tree cover (Szantoi et al. 2013) as richer neighborhoods have both the highest tree biodiversity and number of trees (Steenberg 2015), resulting in urban forests that are unevenly allocated throughout census radius (Fan et al. 2019).

Social and economic spatial differences have always existed, but today they are more clearly seen in urban areas of the developing world, with territorial distinctions between the richer sectors of the population and the low-income areas, mostly located in the peripheral part of the city. Thus emerges an urban configuration where polarization predominate where tmore affluents residents are the same ones that benefit with a better environmental quality, given that access to environmental benefits and services, and the possibility of avoiding environmental problems (i.e floodings, pollution, noise, among others) are essentially determined by income level, where the costs invariably fall on the weakest and poorest sections of the population. These polarization processes are maintained and reproduced over time, hindering the social progress of marginalized sectors, mainly in parts of the developing world such as Argentina (Celemín & Velázquez, 2018).

A clear example of the link between environment and income occurs with what is known as the "tragedy of the commons", when supposedly free environmental services - resources such as air, water or green spaces, among others - are appropriate for private uses by the more affluent sectors of the urban population. The consequence is a type of city that, in general, appears polarized: there is a city for those who can afford it, that includes a surrounding space with benefits for its residents.

Polarization is closely related to spatial segregation which has been mostly defined as the existence of a differentiation or unequal distribution of social groups within the urban space. It is a notion of a spatial essence, that distinguishes occupations patterns associated with some feature of population groups (i.e. poverty), therefore causing the segmentation of the urban space (Caves, 2004). Socioeconomic segregation leads to less interlinkage between social groups, eventually leading to socio-territorial stigmatization and the generation of conditions for the reproduction of poverty.

There is a longstanding literature on poverty analysis in Latin American cities, however more limited is the research that focuses on the connection between the spatial distribution of environmental variables and the urban socioeconomic context, especially at intra-urban scales. Some exceptions are Escobedo et al. (2006) who analyzes the socioeconomic strata of the communes of Santiago de Chile; Pedlowski, et al. (2006) looking into the environmental inequity of Campos dos Goytacazes (Brazil). Another interesting work is that of Santana Rodríguez et al. (2010) that integrates satellite data with socioeconomic information for the city of Cali (Colombia). Beside these, we can also mention that of Celemín (2012) using spatial correlation between socioeconomic and environmental variables for the city of Mar del Plata. Notwithstanding, more studies of this type are needed for cities of Latin America, particularly the combination of social and ecological data at intra-urban that can be of use for city planners (Barona et al. 2020).

The importance of forests is a relevant issue for sustainable development, and so much so that it is mentioned in global proposals such as Agenda 21 and in the sustainable Development Goals. The Food and Agriculture Organization of the United Nations (2016) describes how urban forests might help achieve the SDGs, including making cities more sustainable, decreasing poverty and hunger, improving natural habitat, and supporting long-term economic growth. Other important topics covered include biodiversity and landscapes, green economy, risk management, land and soil degradation mitigation, and water and watershed management, wood security; and sociocultural values. Although forests are mentioned in several SGD´s, the SDG 3 is the one that explicitly highlights the importance of urban trees, with aims to reduce population pressures on forests at local, regional, and global levels while also improving human well-being. Thus greater exposure to green space, particularly urban forests, has been linked to several mental, social, and physical health advantages for the world's growing urban population.

Following this requirement, and according to the conceptual framework previously mentioned, we integrate census data and satellite images to show how the residents with good socioeconomic status of a forested area in the city of Mar del Plata (Argentina) receive the environmental benefits associated with a high tree cover -higher Normalized Difference Vegetation Index (NDVI) and lower temperature- than most areas of city in the year 2010; hence supporting the hypothesis that socioeconomic status is closely coupled with the access to urban forests environmental services. To do so, first, we analyze the evolution of poverty in the area with the Unsatisfied Basic Needs index of the last two censuses (2001-2010). Then, satellite images from the last year of the census -2010- are transformed and converted from the raster format to vector data to fit the census radius structure of the city, with the objective to observe and compare NDVI and temperature values of the forested area with the rest of Mar del Plata.

The combination of census information and remote sensing data provides an interesting bodywork for urban studies, since both types of data information are complementary. Generally, the information acquired through satellite images stays at the pixel scale, and is rarely transferred to another format compatible with socioeconomic data, such as census radius or tracts, so that the use of remote sensing, conjointly with geographic information systems (GIS), has been recognized as a significant and successful tool for evaluating the changing patterns of cities (Weng 2001).

2.Methodology

2.1.Study Area

Mar del Plata is located in the Pampas Region of Argentina where the weather pattern is that of an oceanic climate with humid and moderate summers and relatively cool winters. As a coastal city facing the Atlantic Ocean, both the sea and the usual strong winds play a major role in keeping mild temperatures. Mar del Plata has a lower temperature record than other cities placed at the same latitude in the Pampas Region. At the time of the last census -2010- it had 614.350 inhabitants. It is a town with several natural features, mainly beaches, which attract hundreds of thousands of national tourists (Velazquez and Celemín 2011). Inside the city there are several forested residential areas, however one at the southern edge of the urbanization stands out due to its size and degree of conservation: the Bosque de Peralta Ramos (BPR). It has a surface of 450ha, and a population of 3193 inhabitants distributed in six census radius, and it can be easily recognized from a satellite image (Figure 1).

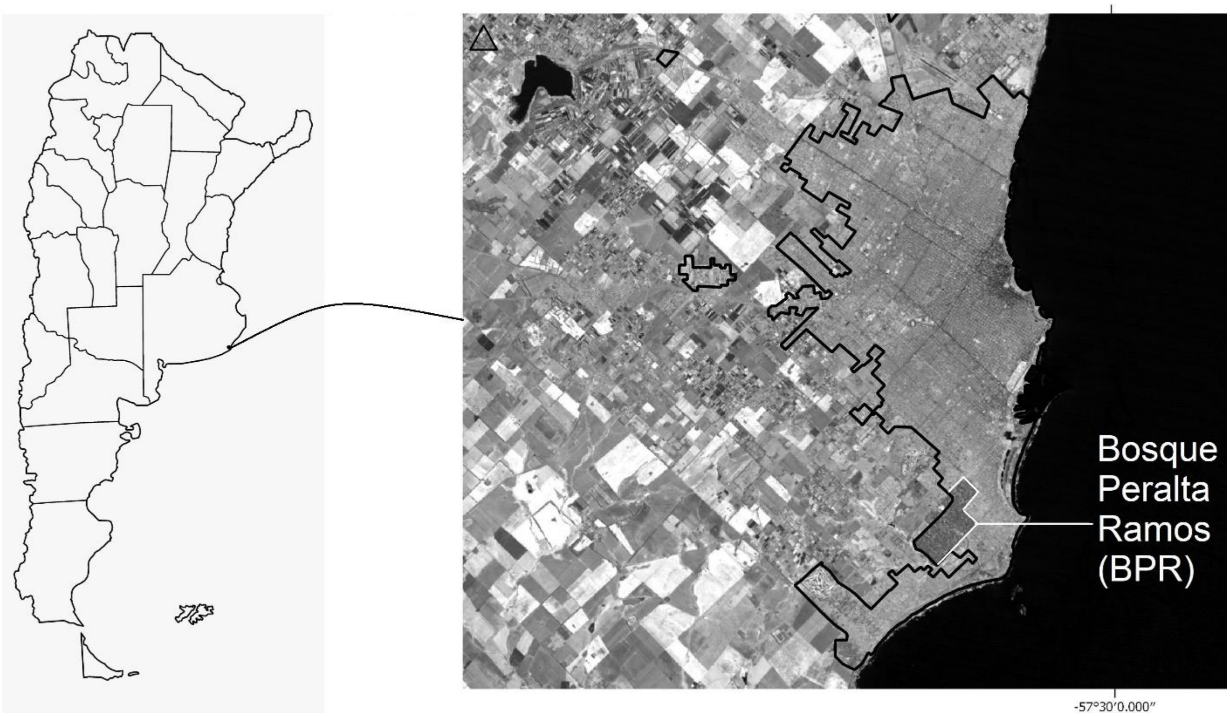

Figure 1. Location of the Bosque Peralta Ramos in the city of Mar del Plata, (Argentina)

Originally, this was an area of wheat and potato crops until in 1952 emerged the idea of creating a forest urbanization -a totally different approach to the existing plots that lacked trees since they are not autochthonous in the region. In the Pampas native trees were originally absent in the vegetation, except for Celtis ehrenbergiana, a deciduous tree known as tala (Stutz et al. 2014). The afforestation work took ten years and in the year 1962 began the commercialization of the forested plots (Montagu 2005). In the region the modern landscape and the introduction of trees is strongly associated with the establishment of European settlements starting in the XVI century. The forest has a variety of trees such as Araucaria angustifolia, Pinus lambertiana, eucalyptus, Tamarindus indica, Juglans, Quercus, Araucaria araucana, Magnolia grandiflora, among many others.

According to the Municipality of General Pueyrredón (where the city of Mar del Plata is located), the "forest reserve" is the land where there are tree species that, due to the quantity and quality of their specimens, form a forest whose natural value justifies conservation and preservation. Based on the changes that were taking place, and that directly affected the ecology of the BPR, the Municipality decided to declare it a Forest Reserve in the year 1994 with the Ordinance No. 9717. In these areas of conservation, for each tree that is extracted from private lots, two species recommended by the municipality must be planted within the limits of the reserve. This is the way they found to control the disappearance and extinction of species.However the reality shows a lack of urban planning and urban environmental knowledge in the integration of the BPR in the urban space of Mar del Plata as it contains species such as the eucalyptus, which is not recommended for residential areas.

The absence of trees in the entire area of the Pampas led to the appearance of these patches of artificial forests that, even today, are a source of attraction for the local population and tourists. The residents with higher economic income want to live on streets and in neighborhoods with abundant trees, while the tourists visit the BPR as it emerges as a rarity in the local environmental landscape. The BPR has developed an infrastructure for receiving visitors with several hostels, cabins, cafes, and tours for those interested in knowing its natural features. This is why the BPR appears as an appropriate study case to show how an area, despite being located far away from the center of the city, began to attract people from higher socioeconomic sectors, resulting in an enclave of wealth in a mostly poor peripheral area of Mar del Plata.

Man-made afforestation is not something unique to Mar del Plata since along the Atlantic coast of the province of Buenos Aires (where the city is located), there are several minor urbanizations that have planted trees decades ago to fix the dunes of the beaches. This is how many seaside resorts have appeared in the last decades such as Pinamar or Cariló -the most well known resorts of this kind - where the integration of forest, dunes and spacious beaches has shaped a unique landscape. These types of resorts, with this particular combination of the natural resources, attract high income visitors from all over the country as well as second-home tourism.

2.3. Poverty Index - Unsatisfied Basic Needs

A procedure to understand the socioeconomic status of the population is with a complex index of poverty, regarded as Unsatisfied Basic Needs. While its definition may change, this index is considered as an suitable measure of national and international poverty by national governments and international institutions such as the World Bank. In this research we analyzed its evolution for the city of Mar del Plata according to the results provided by the last two censuses carried out in the years 2001 and 2010, respectively. The UBN specifies the basic needs of a given population and calculates the type and amount of social and physical infrastructure and services desired to satisfy these needs. With some changes, it is used in many countries of Latin America, including Argentina, and it was introduced by the Economic Commission for Latin America and the Caribbean in the early eighties to distinguish poverty features of the population. The most pertinent basic need indicators are those that detect systemic issues, such as deficiencies in the access to public services (i.e. education and health infrastructure), as well as the condition of housing (Feres & Mancero 2001). One of its advantages is that the data can be disaggregated to large scales that allows the elaboration of well-detailed poverty maps.

In Argentina, the UBN includes the following variables:

• Indicators that calculate subsistence capacity, linked to the household's potential ability to generate the income needed for its sustenance.

• Indicators that calculate housing situations and sanitation services; related to adequate living space or adequate sanitation facilities.

• Indicators referred to education and school enrollment according to different age groups, as it is acknowledged that education enhances the household's prospective capacity to create income and enables social growth (Abaleron 1995).

A household is considered poor if it has a deficiency in at least one of the above indicators.

The values for the UBN index were obtained from the National Institute of Statistics and Censuses and are available at census radius scale. The 2001 values at census radius scale are available only in CD-ROM format, while the 2010 records can be downloaded from the Institute´s web page. In our research we considered the percentage of households with UBN. Poverty is not the only measurement for the living conditions of the population, but nevertheless it is highly correlated with other indicators such as the Human Development Index, which unfortunately, is not available at such a disaggregated scale (Celemín & Velázquez, 2018).

To delimit the urban sector, a vector file elaborated by the National Geographic Institute was used, while the vector files with the census radius were adapted with slight modifications to fit the urban area. Each census radius has 300 houses, approximately. All maps were elaborated with QGIS and classified into quintile categories.

2.4. Temperature and NDVI

For this part we chose Landsat 5 TM images acquired the same year of the last census (2010-01-15) and downloaded through the USGS Global Visualization Viewer (GloVis) (Path 224/Row 86). An image corresponding to the summer time was selected, where tree benefits are more necessary for the population (coverage and cooling effect).

The images are Level 1T (Terrain corrected) and the multispectral bands have 30 meters pixel size while the thermal band has 120 meters (resampled to 30 meters to match multispectral bands). The Semi-Automatic Classification Plug-in (Congedo 2016) incorporated in QGIS was used to atmospherically correct the images following the cost model (Chavez, 1996) and to automatically obtain brightness temperature from the satellite. The thermal infrared sensors measure radiances at the top of the atmosphere, from which brightness temperatures (also known as blackbody temperatures -T_B-) can be derived:

$$T_B = \frac{K_2}{\ln\left(\left(\frac{K_1}{L_\lambda}\right) + 1\right)}$$

where T_B is the effective at-satellite temperature in Kelvin, K_1 (watts/m2 *ster*μm) and K_2 (Kelvin) are the calibration constants. Later, using QGIS's band calculator, Blackbody Temperature was converted manually to Land Surface Temperature, using the following equation:

$$L_{ST} = \frac{T_B}{1 + \left(\frac{\lambda * T_B}{\rho}\right) \ln e}$$

where λ = wavelength of emitted radiance (λ = 11.5μm), α = hc/σ (1.438 × 10–2 m K), σ = Boltzmann constant (1.38 × 10–23 J/K), h = Planck's constant (6.626 × 10–34Js), c = velocity of light (2.998 × 108 m/s) and e is the surface with a constant value of 0,95 (Gangopadhyay et al. 2012)[1].

Lastly, Kelvin degrees ar convert to Celsius by subtracting 273.15 to the L_{ST} image.

Next, the Normalized Difference Vegetation Index was obtained:

$$NDVI = \frac{NIR - R}{NIR + R}$$

Where:
NIR = Near-Infrared Band (Band 4 of Landsat 5 TM)
R = Red Band (Band 3 of Landsat 5 TM)

[1]The emissivity values can be obtained from the reclassification of land uses or as a constant (*e* = ~0,95) to simplify the process (Malek et al., 1997, Gangopadhyay et al. 2012, Hassan et al. 2019, Oshio et al. 2020).

Both the NDVI and the temperature values were also aggregated and averaged at census radius scale in order to compare them with the socioeconomic data (households with UBN). For that, we resorted to the zone statistics function of QGIS. The conversion from the raster format to the vector format of the NDVI and temperature values shows a clear improvement in the visualization of the results, since they can be more easily associated with the urban structure (streets, radius and neighborhoods), thus facilitating urban management.

Finally, an integrated exploratory analysis for these three variables (households with UBN, NDVI, temperature) was carried out with the GeoDa program.

3. Results and Discussion

3.1.Spatial distribution of Households with Unsatisfied Basic Needs

In the year 2001, 1826 persons lived in the three census radius that constituted the BPR, with a percentage of households with Unsatisfied Basic Needs of 2.85%, while the city had 7.27%. Meanwhile, for the year 2010, there is an increase in the number of inhabitants of the BPR -3193- which are then contained in six census radius. The percentage of households with Unsatisfied Basic Needs at the BPR had a mean value of 1.88% for the six census radius, while for the entire city the percentage of households with Unsatisfied Basic Needs was 3.82%.

The spatial distribution of this variable for both years has a similar pattern as it decreases from the downtown to the periphery (Figure 2, Figure 3) of the city, describing the typical urban spatial configuration of Latin American cities where central areas have better socioeconomic indicators. This feature is known as "peripheralization" (Barros & Alves Jr 2003), a growth process marked by the growth of the borders of the city through the emergence of peripheral settlements, which are, primarily, low-income residential areas, shaped by the high costs of transport, social stigmatization, and a deficit in urban infrastructure and facilities (Hidalgo 2008), ultimately resulting in the spatial segregation of the poor (Valladares & Cohelo 1995).

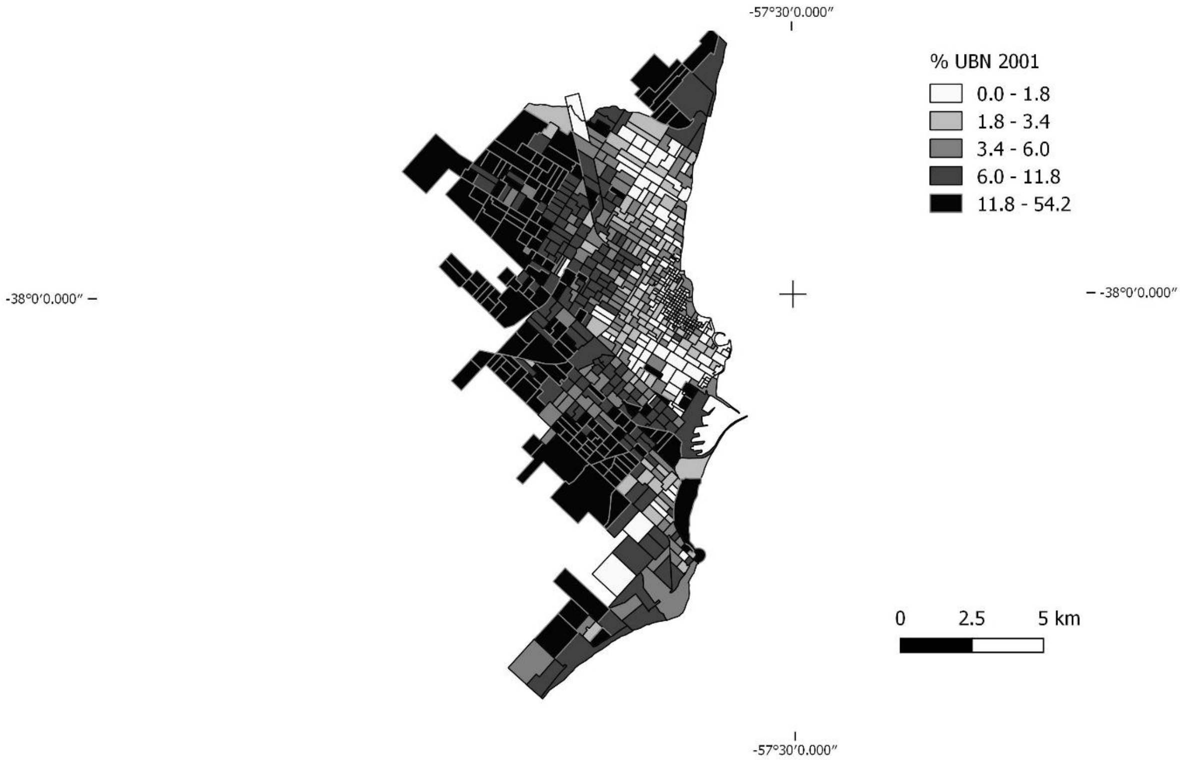

Figure 2. Percentage of households with Unsatisfied Basic Needs (UBN) in the city of Mar del Plata (Argentina). 2001

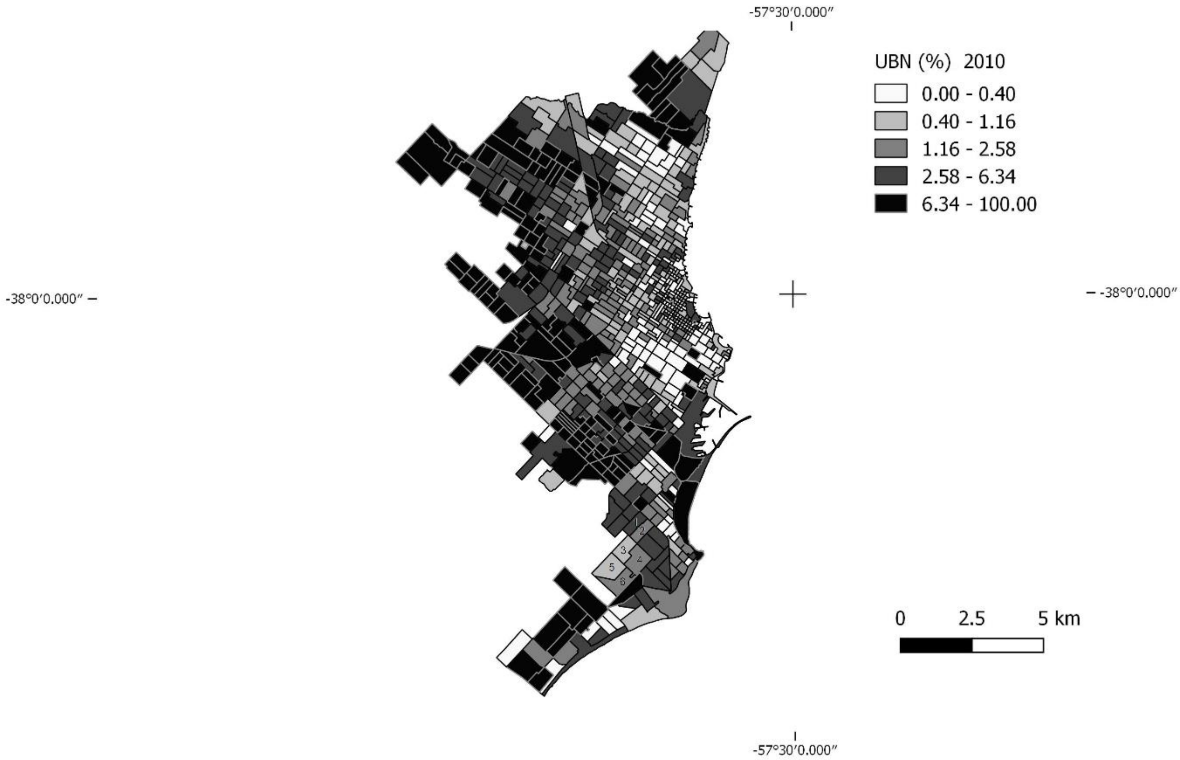

Figure 3. Percentage of households with Unsatisfied Basic Needs (UBN) in the city of Mar del Plata (Argentina). 2010.

Although the BPR is very close to the border, it has a better performance than other peripherals census radius with values of poverty lower than 6% for 2001 and 4 % for 2010. Most of the UBN scores at the BPR are associated with the lack of a sewer system. This is because the expansion of urban services requires time - and money-, to reach peripheral areas, nonetheless, this deficiency should no longer be present as the municipality has been expanding the sewer coverage in recent years.

3.2.Spatial distribution of NDVI values

As expected, lower values in the NDVI can be found in the places of the city where impervious surfaces are present (i.e. downtown area) and rises towards the border where open spaces and pervious surfaces are usual (Figure 4). The aggregated NDVI (Figure 5) shows that the higher values for the year 2010 are found in the BPR. These six census radius register a mean NDVI of 0.432 while the global NDVI for Mar del Plata is 0.153.

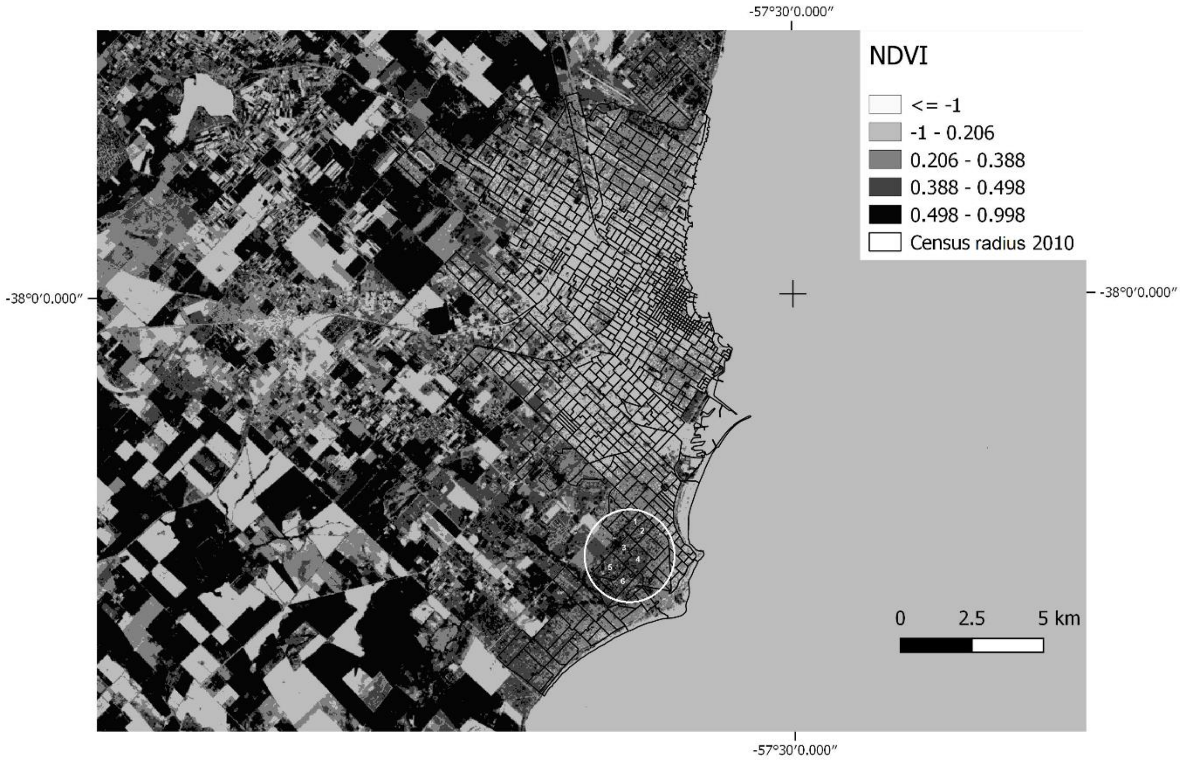

Figure 4. NDVI values for the city of Mar del Plata (Argentina)

Figure 5. Aggregated NDVI values at census radius scale for the city of Mar del Plata (Argentina)

In peripheral areas, where there is a lower building density, NDVI is also higher than in most parts of the city due to the presence of vacant lots. In them, spaces with pastures abound, but the presence of trees is scarce. These are areas in which the fuzzy transition between city and countryside begins to be observed, although from a regulatory point of view they are considered urban areas. The peripheral census radius is usually larger because in order to create one, it is necessary to register 300 houses, something easier to achieve in the central parts of the city with higher building density.

3.3.Spatial distribution of temperature

At first glance, the satellite image shows lower temperature values in the central zone of the city and in the BPR. While this is to be expected in forested areas, it is not in sectors with high building density (Figure 6). This particularity is known as "inverse heat islands" (Camilloni & Barrucand, 2012; Yang et al., 2019) meaning that the rural areas have a higher temperature than urban areas, more specifically, the downtotown of the city. Figuerola and Mazzeo (1998) provide possible interpretations for this phenomenon, however in the scientific literature, it has not been much addressed and it is barely noted (Kamma et al, 2020). This type of occurrence is common when the temperature is recorded from satellite images in areas of the province of Buenos Aires at certain times of the year.

The BPR area registers a lower temperature than the rest of the census radius of the Mar del Plata (Figure 7) except in the downtown area. The six census radius of the BPR have a combined mean temperature of

24,93 C while the global temperature for the city is 27,99 C. It should be mentioned that the recorded temperature is that of the treetops and not the interior of the forest reserve.

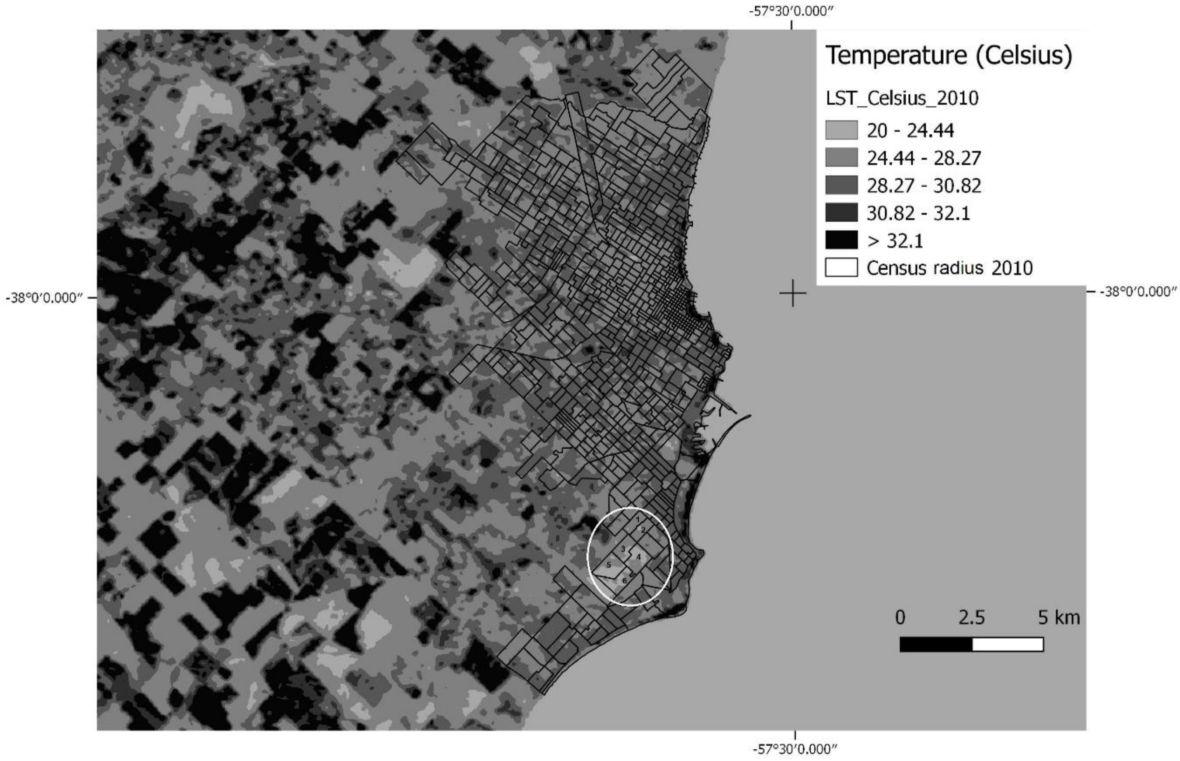

Figure 6. Temperature values in the city of Mar del Plata

Figure 7. Aggregated temperature values at census radius scale for the city of Mar del Plata (Argentina)

3.4.Exploratory analysis of Households with Unsatisfied Basic Needs, NDVI and temperature

Finally, an integrated exploratory analysis using a 3D plot of the three variables shows that six census radius are outliers in the distribution (Figure 8). They are located at one of the corners of the cube, indicating a particular performance as they are the first to be selected in the 3D plot when following this criteria: low percentage of UBN, very high NDVI and low temperature.

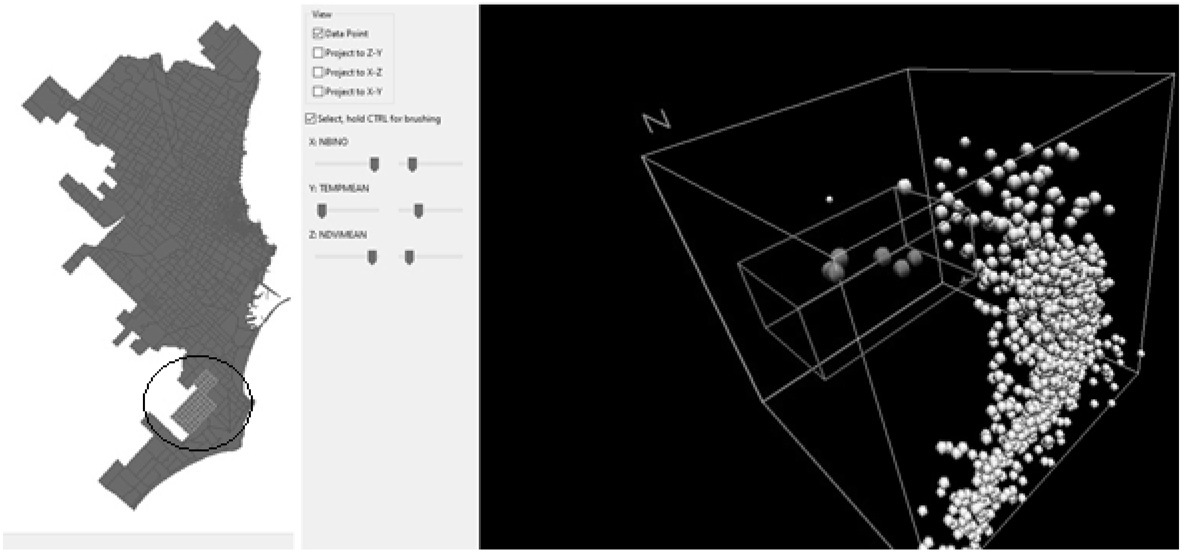

Figure 8. 3D plot with the three variables: UBN, NDVI and Temperature

The outcome of this study is a clear example of spatial and environmental polarization where the BPR appears as a place with abundant tree cover and environmental services that attracts people with good socioeconomic status looking for better living conditions, and where poverty values are below the city average. In a period of nine years (2001-2010) the Bosque Peralta Ramos has increased its population by 75%, creating, then, new questions about the environmental sustainability of the forest reserve that needs to be addressed in future works: how much tree cover has been lost in that period? What is the state of the area's biodiversity? What is the building density nowadays? Moreover, this forest has become a place for tourism, with various services and infrastructure designed for this purpose. While in other latitudes a forest like this may seem normal or trivial, in a place where tree cover is scarce, trees are sources of attraction for both residents and tourists.

That there are forest reserves that, in turn, are residential areas is still a contradiction for a region where trees are not native. The lack of urban planning, the lack of knowledge of the importance of the urban environment by the local population and decision-makers, and real estate speculation have caused the deterioration of urban forest reserves, with the consequent loss of three cover and abundance of species. At present, several of them exist more on paper than in the real urban landscape of Mar del Plata.

To avoid a further deterioration of the BPR, the municipality should apply a concrete management plan for its better functioning. Among several possible measures, two appear as the most urgent:

- The BPR cannot continue to grow at a rate like that observed in the 2001-2010 period, so it would be necessary to limit the number of new residents and dwellings according to the load capacity of the reserve.

- Replacement of not recommended species by others more appropriate for urban areas.

Lastly, nowadays, the city does not escape from another phenomenon that transforms polarization into a more complex urban mosaic: the appearance of gated communities located mainly in the periphery of the city. This has begun to emerge in Mar del Plata, but it is relatively recent, so new data is necessary -specially from the next census which has been delayed due to the Covid-19 pandemic- to assess its territorial impact.

4. Concluding Remarks

Urban sustainability has become a major concern for city planners, decision-makers, and residents where green and forested areas within a city have played a major role in improving the urban environmental quality.

The complexity of urban research requires an integrative approach: Although census data and remote sensing information are collected for different purposes and in divergent formats they can be successfully integrated for urban research. In this context, our study analyzes the situation of a forested residential area in Mar del Plata (Argentina), a mid-sized city that like many others in Latin America has socioeconomic and territorial contrasts and where trees are not native plants.

The study serves to demonstrate the initial hypothesis, where in an area where trees are not indigenous, sectors of the population with better socioeconomic status have the resources to access the environmental services provided by abundant tree cover. The city has the typical distribution of poverty of a Latin American urbanization, with increasing values from the center to the periphery - where the census radius of the BPR are located -, but nevertheless, these do not have poverty values similar to the rest of the periphery of the city, on the contrary the percentage of households with UBN are very close to those registered in the central area.

Due to its unique characteristic of having an abundance of trees, the BPR makes up an enclave that alters the polarization of the city in which trees constitute a center of attraction for residents and tourists in search of their benefits. The results show that the environmental and socioeconomic dimensions are interrelated. This is due to the fact that the environment, at present, is considered in a functional way to the prevailing socioeconomic context and, therefore, subject to its guidelines, whose basic features reproduce the socioeconomic spatial pattern of the city. In this framework environmental problems are mostly limited to those peripheral sectors of the city where people with fewer resources live.

This research also shows that there is a progressive deterioration of the socioeconomic status of the population from the center to the periphery of the city, which is the normal pattern in cities of Argentina. Consequently, towards these border areas it is where the government should implement policies that increase their economic level, as well as the environmental context. For that, it would be necessary to establish new environmental information systems that are compatible with socioeconomic data, allowing a comprehensive view of the social, economic and environmental phenomena at different territorial scales.

The information created in this study (in particular the maps) will help local city planners and decision-makers to understand problems and to find solutions to the socioeconomic and environmental issues that the city requires. Presenting the data at census radius scale appears as a more efficient way of transferring the data, given that decision-makers can recognize the limits of the neighborhoods and streets -a more difficult task at pixel scale. Moreover, an effective urban planning and management must consider the wide range of important benefits that trees and forests provide to local residents. This is also particularly relevant in cities such as Mar del Plata where the trees are not native vegetation, therefore more plans for urban forestation and tree conservation should be implemented, as well as environmental education plans to instruct the local population on the importance of having trees cohabiting with the rest of the urban elements.

References

Abaleron C 1995. Marginal urban space and unsatisfied basic needs: the case of San Carlos de Bariloche, Argentina. *Environment and Urbanization* 7 (1): 97–116. https://doi.org/10.1177/095624789500700101

Barona C, Devisscher T, Dobbs, C, Aguilar L, Baptista M, Navarro N, et al 2020. Trends in urban forestry research in Latin America & the Caribbean: a systematic literature review and synthesis. *Urban Forestry & Urban Greening* 47: 126544. https://doi.org/10.1016/j.ufug.2019.126544

Barros J, Alves Jr S 2003. Simulating Rapid Urbanisation in Latin American Cities. In: Longley P, Batty M. *Advanced Spatial Analysis: The Case Book of GIS*. London, ESRI Press, London, p. 129-14.

Camilloni I, Barrucand M 2012. Temporal variability of the Buenos Aires, Argentina, urban heat island. *Theoretical and Applied Climatology* 107(1-2):47-58. https://doi.org/10.1007/s00704-011-0459-z

Caves R 2004. *Encyclopedia of the City*. Routledge, London, 594 p.

Chavez P. (1996). Image-Based Atmospheric Corrections – Revisited and Improved. *Photogrammetric Engineering and Remote Sensing,* 62, 1025-1036.

Celemin J, Velazquez , G 2018. Spatial analysis of the relationship between a life quality index, HDI and poverty in the province of Buenos Aires and the autonomous city of Buenos Aires. Argentina, *Social Indicators Research* 140(1): 57-77. https://doi.org/10.1007/s11205-017-1777-z

Congedo, L. (2016). Semi-Automatic Classification Plugin Documentation, DOI: http://dx.doi.org/10.13140/RG.2.2.29474.02242/1

Dwyer J, MC Pherson E, Schroeder H, Rowntree, R 1992. Assessing the benefits and costs of the urban forest. *Journal of Arboriculture* 18:227-234.

Escobedo F, Nowak D, Wagner J, De La Maza C, Rodríguez M, Crane D, Hernández J 2006. The socioeconomics and management of Santiago de Chile's public urban forests. *Urban Forestry and Urban Greening* 4:105-114. https://doi.org/10.1016/j.ufug.2005.12.002

Fan C, Johnston M, Darling L, Scott L, Liao F 2019. Land use and socio-economic determinants of urban forest structure and diversity. *Landscape and urban planning* 181(10-21)

https://doi.org/10.1016/j.landurbplan.2018.09.012

Feres J, Mancero X 2001. *El método de las necesidades básicas insatisfechas (NBI) y sus aplicaciones a América Latina, Series Estudios Estadísticos y Prospectivos*. CEPAL Santiago de Chile, 54 p.

Figuerola P, Mazzeo N 1998. Urban-rural temperature differences in Buenos Aires. *International Journal of Climatology* 18(15): 1709–1723. https://doi.org/10.1002/(SICI)1097-0088(199812)18:15<1709::AID-JOC338>3.0.CO;2-I

Gangopadhyay P, Van Der Meer F, Van Dijk P, Saha, K 2012. Use of satellite-derived emissivity to detect coalfire-related surface temperature anomalies in Jharia coalfield, India. *International Journal of Remote Sensing* 33(21):6942-6955. https://doi.org/10.1080/01431161.2012.695093

Hassan A, Belal A, Hassan M, Farag F, Mohamed, E. 2019. Potential of thermal remote sensing techniques in monitoring waterlogged area based on surface soil moisture retrieval. *Journal of African Earth Sciences* 155: 64-74. https://doi.org/10.1016/j.jafrearsci.2019.04.005

Hidalgo R, Borsdorf A, Zunino H 2008. Las dos caras de la expansión residencial en la periferia metropolitana de Santiago de Chile: precariópolis estatal y privatópolis inmobiliaria. In Pereira P, Hidalgo R. *Producción inmobiliaria y reestructuración metropolitana en América Latina*, FAUSP-USP-PUC: Santiago de Chile, pp. 167–195.

Instituto Nacional De Estadística Y Censos (2012). *Censo nacional de población, hogares y viviendas 2010*. Censo del Bicentenario (Serie B No. 2. Resultados definitivos). INDEC Buenos Aires, 378 p. https://www.indec.gob.ar/ftp/cuadros/poblacion/censo2010_tomo1.pdf.

Iverson L , Cook, E 2000. Urban forest cover of the Chicago region and its relation to household density and income. *Urban Ecosystems* 4:105–124. https://doi.org/10.1023/A:1011307327314

Jensen R, Gatrell J, Boulton J, Harper B 2004. Using remote sensing and geographic information systems to study urban quality of life and urban forest amenities. *Ecology and Society*, 9(5) [online] URL: http://www.ecologyandsociety.org/vol9/iss5/art5/

Kamma J, Manomaiphiboon K, Aman N, Thongkamdee T, Chuangchote S, Bonnet, S 2020. Urban heat island analysis for Bangkok: multi-scale temporal variation, associated factors, directional dependence, and cool island condition. *Science Asia* 46:213-223. htpp:// 10.2306/scienceasia1513-1874.2020.024

Kinzig A, Warren P, Martin C, Hope D, Katti M 2005. The effects of human socioeconomic status and cultural characteristics on urban patterns of biodiversity. *Ecology and Society*, 10(1) https://doi.org/10.5751/ES-01264-100123

Malek E, Bingham G 1997. Partitioning of radiation and energy balance components in an inhomogeneous desert valley. *Journal of Arid Environments* 37:193-207. https://doi.org/10.1006/jare.1997.0279

Mc Pherson E, Nowak D, Heisler G, Grimmond S, Souch C, Grant R, Rowntree, R 1997. Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project. *Urban ecosystems* 1(1):49-61. https://doi.org/10.1023/A:1014350822458

Menni, J 2006. Socioeconomic-Vegetation Relationships in Urban, Residential Land: The Case of Denver, Colorado. *Photogrammetric Engineering & Remote Sensing* 72: 911–921. https://doi.org/10.14358/PERS.72.8.911

Montagu C 2005. *Una propuesta para el desarrollo turístico del Bosque de Peralta Ramos*. Universidad Abierta Interamericana, Buenos Aires, 96 p. http://imgbiblio.vaneduc.edu.ar/fulltext/files/TC059958.pdf

Nichol P 2009. Constructing connections: urban forestry and Toronto´s west don lands revitalization. *Environnement urbain/ Urban environment* 3: 83-93. https://doi.org/10.7202/037602ar

Nichol J, Wong M 2005. Modeling urban environmental quality in a tropical city. Landscape and *Urban Planning* 73:49–58. https://doi.org/10.1016/j.landurbplan.2004.08.004

Oshio H, Chen K, Asawa T 2020, Airborne and Terrestrial Observations of the Thermal Environment of Urban Areas Surrounding a High-Rise Building during the Japanese Winter. *Sensors*, 20(2):517. https://doi.org/10.3390/s20020517

Pedlowski M, Carneiro Dasilva V, Adell J, Heynen N 2002. Urban forest and environmental inequality in Campos dos Goytacazes, Rio De Janeiro, Brazil. *Urban Ecosystems* 6:9–20. https://doi.org/10.1023/A:1025910528583

Salbitano F, Borelli S, Conigliaro M, Chen Y 2016. *Guidelines on urban and peri-urban forestry*. Food and Agriculture Organization, Rome, 172 p.

Santana Rodríguez L, Escobar Jaramillo L, Capote P 2010. Estimación de un índice de calidad ambiental urbano, a partir de imágenes de satélite. *Revista de Geografía Norte Grande* 45:77-95. http://dx.doi.org/10.4067/S0718-34022010000100006

Steenberg J, Millward A, Duinker P, Nowak D, Robinson P 2015. Neighbourhood-scale urban forest ecosystem classification. *Journal of environmental management* 163:134-145. https://doi.org/10.1016/j.jenvman.2015.08.008

Stutz S, Tonello, M, González Sagrario, M, Navarro D, Fontana S 2014. Historia ambiental de los lagos someros de la llanura Pampeana (Argentina) desde el Holoceno medio: inferencias paleoclimáticas. *Latin American Journal of Sedimentology and Basin Analysis* 21(2):119-138.

Szantoi Z, Escobedo F, Wagner J, Rodriguez J, Smith S 2012. Socioeconomic factors and urban tree cover policies in a subtropical urban forest. *GIScience & Remote Sensing* 49(3): 428-449. https://doi.org/10.2747/1548-1603.49.3.428

Valladares L, Coelho, M 1995. Urban Research in Latin America. Management of Social Transformations, Discussion Paper Series – 4, UNESCO, [online] URL: http://digital-library.unesco.org/shs/most/gsdl/cgi-bin/library?e=d-000-00---0most--00-0-0--0prompt-10---4------0-1l--1-en-50---20-about---00031-001-1-0utfZz-8-00&a=d&c=most&cl=CL4.1&d=HASH01d153a04aa116d24ee25897

Velázquez G., Celemín, J. (2011), Aplicación de un índice de calidad ambiental a la región Pampeana Argentina (2010). *Finisterra - Revista Portuguesa de Geografia,* 91, 47-64. https://doi.org/10.18055/Finis1324

Yang, C., Wang, R., Zhang, S., Ji, C., & Fu, X. (2019). Characterizing the hourly variation of urban heat islands in a snowy climate city during summer. *International journal of environmental research and public health*, *16*(14), 2467. https://doi.org/10.3390/ijerph16142467

Weng, Q. (2001). A remote sensing-GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. *International Journal of Remote Sensing*, 22(10),1999-2014. https://doi.org/10.1080/713860788