

Research Article

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Periurbanization and conservation pressures over remnants of native vegetation: impact on ecosystem services for a Latin-American capital city

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Abstract: Urban expansion in Latin-American cities is faster than urban planning. In order to implement sustainable planning the capacity of peri-urban areas to provide ecosystem services must be evaluated in the context of competing urbanization and conservation pressures. In this study we analyzed the effect of urban expansion on peri-urban vegetation of the Metropolitan Area of Santiago and what ecosystem services are provided by El Panul, land rich in biodiversity embedded in the fringe of the city. The city has lost vegetation while urbanized areas grow. Under this context, we evaluated the multi-functionality of El Panul through the quantification of three ecosystem services (ES): sense of place through the interviews of 60 residents, recreation via GIS analyses, and local climate regulation determined with air temperature measurements. El Panul increased the provision of urban green spaces, where inhabitants recognize and appreciate ES, and it plays a significant role in mitigating the urban heat island on summer nights. ES have emerged as a concept and framework for evaluating competing urban development alternatives.

Keywords: periurban areas, mediterranean ecosystems, Santiago de Chile, Latin-America

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1 Introduction

Urbanization, population growth and land use changes have increased the pressure on remnants of native vegetation surrounding cities and towns. This trend is not likely to decrease in the coming decades [1]. Increasing urban expansion pressures over periurban areas have led to the establishment of residential and industrial areas without proper planning, having negative impacts on natural elements within the landscape and disturbing environmental and social benefits provided by the surrounding natural and rural areas [2-8].

One of the most urbanized regions in the world Latin America serves as an excellent lab to test the impact of these pressures. Nearly 80% of the population live in cities and many of their cities, including Asunción, Bogotá, Brasilia, Buenos Aires, La Paz, Lima, Mexico City and Santiago de Chile, have been and are currently subject to uncontrolled urban expansion and diffuse growth, causing the replacement of peri-urban remnants of native vegetation by urban land uses [6,9,10]. In recent decades, Latin American cities have not only become highly fragmented and diffuse, there is also a significant level of socio-spatial segregation and critical loss of agricultural lands and native vegetation. They are also increasingly at risk of landslides and flooding, and severely impacted by air and water pollution and periods of heat stress [9,11-15]. These urbanization patterns occur in the absence of public participation in the planning process, largely due to the consolidation of neoliberal policies, promoting the development of private initiatives over public preferences [2,11,12,16]. Thus, the lack of urban sustainable planning has contributed to poverty, inequality, the degradation of the land and the loss of valuable ecosystem services [17].

Despite the level of land degradation, there are remnants of native vegetation that are still able to support important benefits to the health of urban inhabitants, improving quality of life by providing spaces for daily

contact with higher quality environments (e.g., areas with milder air temperatures or lower concentrations of air pollutants [18]). These areas also offer relevant recreational opportunities and cultural ecosystem services not only for people living close to these native vegetation remnants but also for visitors from other parts of the city [19,20]. These areas may also act as water filters and run-off buffers, reduce natural hazards, serve as a green lung and provide habitat to multiple species [7,21,22].

Urban planning and design efforts currently incorporate new approaches to address the challenges of fostering the change to sustainable land use [23], identifying how future landscapes can simultaneously support and integrate ecological, economic and cultural functions [24]. In this sense the concept of ecosystem services is defined as the functions and processes of ecosystems that benefit human beings [25]. While the utility of incorporating an ecosystem services (ES) framework into urban planning has been recognized [26], urban planners need to know the effects of land use changes on the supply of ES [21] and the loss of native and perturbed vegetation in urban areas as part of a tradeoff analysis to promote sustainability. An ES framework could lead to more efficient conservation efforts in biodiversity, and better environmental management planning tools [27-28]. Remnants of native vegetation are capable of providing multiple ES; planning and design professionals, decision makers and stakeholders must ensure their protection. Planning that incorporates ES can improve the quality of life within cities while supporting the conservation of native vegetation remnants around urban areas; this process is fundamental to the promotion of sustainable cities [29].

To understand the importance of peri-urban remnants of native vegetation to sustainable planning in Latin America, we first analyzed how urban peripheries change, defining peripheries as newly developed areas on the border of a consolidated city over a period of time. We assessed the value of vegetated areas along those peripheries in relation to urban planning and then evaluated the trajectory of urban expansion in the capital city of Chile, the Metropolitan Area of Santiago (MAS) along its Andean piedmont, distinguishing the effects of the current growth model on the natural environment. Second, we assessed a set of ES provided by an original vegetation remnant along the periphery of the MAS. We evaluated their multi-functionality by quantifying three ES—sense of place, recreational opportunities and local climate regulation—relevant to the city’s social, economic and ecological sustainability respectively, combining data from interviews, a GIS analysis and temperature

measurements to obtain the results. This research demonstrates the appropriateness of incorporating ES into urban planning and thus conserving valuable native vegetation remnants along the peripheries of large, dynamic cities.

The present study addressed the following research questions: (i) How does urban expansion affect the multi-functionality of peri-urban ecosystems?, (ii) What is the value of conserving peri-urban remnants of native vegetation within areas of new urban development?

2 Methodology

2.1 Case study

The Metropolitan Area of Santiago (MAS) had a population of 5.0 million inhabitants in 1992 which has increased to 6.8 million inhabitants today (39% of the country’s population [30]) and its built-up area covers 616 km²; it is the capital of Chile and the center of the country’s economic activities. To the north, south and west the MAS borders on agricultural land, and to the east the Andean piedmont (650-1,200 m.a.s.l.). Prior to the area’s urbanization, dense shrub, scattered forests, native grasslands and small shrubs characterized the region arising in the wake of abandoned agricultural practices and vineyards [31-32].

The MAS represents a neoliberal model for cities in developing countries and follows similar patterns present in other Latin American cities such as Sao Paulo or Buenos Aires, where urbanization of the periphery has occurred at a rate faster than expected, leading to high levels of social and residential segregation [9,33,34]. In fact, Santiago is one of the cities with the highest levels of social inequality in the OECD [35]. The MAS’s urban growth has resulted in the fragmentation of the region’s native vegetation and agricultural communities, leading to the loss of habitat, climate regulation, and water-related ecosystem services [15,31]. The city also faces a variety of environmental issues such as air pollution, the urban heat island effect and the uneven distribution of vegetation and green spaces for recreation, a pattern similar to that found in other large Latin American metropolises [14,15,36].

The case study focuses on the MAS, in particular ‘El Panul’, one of the remnants of native forest located within the Andean piedmont that has been exposed to urbanization pressures in recent decades. It is located in a privately owned area of a suburban municipality within the MAS (La Florida, 366,376 inhabitants) and is comprised of 520 ha of evergreen sclerophyllous forest

and scrublands, including unique, native species of trees and shrubs such as *Lithraea caustica*, *Quillaja saponaria*, *Colliguaja odorifera* and *Retamilla trinervia*, all of which are adapted to the region's semi-arid conditions. A private developer purchased the land from the government in 1989; however, the developer has not been able to obtain the required building license. An special characteristic of this land is that the community adjacent to it has exerted their public right to oppose development projects within El Panul, citing the importance of the area's ecological values and the ecosystem services provided by the native forest. This conflict has received extensive media coverage as a result of successful social resistance and citizen participation and has highlighted the lack of robust planning policies, formal mechanisms for public participation, leadership of public authorities and the government's commitment to maintaining native green areas close to the city.

2.2 Data and analyses

In this study, we analyzed a city's new periphery (defined in this case as the additions made to a contiguous urban area from 1989 to 2015) as a provider of ecosystem services. First urban expansion and the changes in a vegetation index were calculated, and secondly the study quantifies three ecosystem services provided by the El Panul property, a remnant of native vegetation. Accessibility to recreation in the area was evaluated by calculating the population in the vicinity of El Panul. Then, sense of place was assessed through an eight-question survey. These two services were selected due to the lack of green spaces in the suburban area of the city [37]. Finally we tested the extent of the forest's ability to regulate climate in adjacent urban settings. We selected this third service because the urban heat island effect has been described as an important environmental problem in the MAS [15,38].

2.2.1 Urban growth and new peripheries

To calculate the MAS's urban expansion and consequently its new peripheries, we used Landsat 5 TM satellite images at a 30-m resolution (<http://earthexplorer.usgs.gov/>) to identify the size of the urban area in 1989, 2002, 2009 and 2015 (Fig. 2). These years have similar time-separability, capture different decades with different rates of urbanization (1990s, 2000s) and are limited by the lack of available data. We manually delimited the continuous built-up area using true color compositions and calculated

the Normalized Difference Built-up Index (NDBI) for each image. The NDBI is based on the near-infrared (NIR) and mid-infrared (MIR) bands and can be used to identify developed urban areas [39].

Vegetation data were extracted from MODIS-derived data (<http://modis.gsfc.nasa.gov>) using the Normalized Difference Vegetation Index (NDVI), which is based on red and near infrared (NIR) bands, a methodology commonly used in urban analyses [40]. This multispectral satellite has a moderate resolution of 250 m for NDVI data collected every 16 days since 2000, as a result, it can inform the trajectories of vegetative change, accounting for both seasonal and climatic changes [41]. We used the 'urban and built-up areas' data layer to extract information from the NDVI pixels within this category (Fig. 2), analyzing 365 images to examine annual changes between the year 2000 and 2015. We assessed the data using the annual means, figures from the end of the dry season (March) and figures from the end of the wet season (September). The selection of these months followed criteria suggested by Potter & Brooks [42] and was based on geographic location and climatic conditions.

2.2.2 Quantification of ecosystem services provided by El Panul

Three ecosystem services were quantified for El Panul, two cultural services (i.e. recreation and sense of place) and the other a regulating service (i.e. climate regulation). Recreation was chosen because of its importance to the physical and mental wellbeing of urban dwellers and lack of green spaces in MAS [37,43]. Unlike traditional green spaces, El Panul provides recreational opportunities that meet the needs of multiple users, including people who enjoy outdoors activities, bird watching or scenic views [43]. Sense of place allowed us to evaluate how community members valued the land [44]; and climate regulation was selected because of the importance of air temperature buffers to environmental health under different climate change scenarios [14].

To assess the recreational accessibility of El Panul, we followed the protocol outlined in English Nature, which establishes maximum distances within which every resident should have access to a natural park based on the size of the park (now Natural England [45]). In the present study, all parks (area>2ha) located at a Euclidean distance of 5,000 m inside the border of the municipality where El Panul is located (La Florida) were digitized using satellite imagery provided by Google Earth Pro © to identify recreational options available to the public. Using

the standards described by Handley *et al.* [45] an area of influence was established according to the park's size for all the parks in the study area. Parks between 2 and 20 ha were assigned a 300 m area of influence (i.e. the region around a park from which people could easily access that park); parks between 20 and 100 ha had a 2,000 m area of influence; and parks between 100 and 500 ha a 5,000 m area of influence. The area of influence increased with the size of the park based on the willingness of people to travel (by walking or in a vehicle) longer distances to visit larger parks [45]. We then calculated the proportion of the municipal territory covered by parks by analyzing the total area of those parks compared to the total area of the municipality.

60 semi-structured interviews of people between 30 to 64 years old were conducted in five different neighborhoods in La Florida (i.e. agglomeration of city blocks) to understand the public's sense of place; their understanding of El Panul as a cultural ecosystem service that synthesizes how community members value the land. These neighborhoods were selected from a total of 37 with different socioeconomic characteristics and Euclidean distances from El Panul. Socioeconomic characteristics were determined by reviewing housing conditions using Google Street View, the experiences of the authors in the area and visits to 10 sample neighborhoods. The goal was to maximize the diversity of socioeconomic characteristics and distances to El Panul represented by communities included in the study. The interviews evaluated connections to El Panul, including the interviewees' knowledge of the forest, the conflicts associated with the area and the management options available. To start, we asked whether they knew where El Panul was, if they had visited the area before and the reasons for their visit (questions (Q) Q1,Q2,Q3). This last piece of information was used as a proxy to identify their motivation for visiting the land. A second set of questions addressed individuals' participation in and awareness of the conflict surrounding the area (Q4,Q5). The interviews also explored people's preferences for enhancing and maintaining El Panul in the future, if it were to be officially decreed a park (Q6,Q7). All these questions are presented in Table 2. Finally, to determine the interviewees' willingness to pay for access to the area, we asked, "How much would you be willing to pay to enter El Panul Park?" (Q8) We posed this question based on a hypothetical situation in which the park is well maintained as an official public park, rather than in its current condition, which is characterized by poorly maintained native vegetation and few amenities. This analysis allowed us to evaluate how people value the park compared to other spaces used for recreational purposes.

All interviewees were given a very short description of the land and conflict as part of the interview.

To assess the park's ability to regulate the local climate, we measured changes in air temperature at various distances from El Panul. We collected temperature data hourly using three accurate mid-term stations (data loggers) from December 2010 to February 2011. These stations followed an urban-rural gradient from a central area of development (601 m.a.s.l.) to the core of El Panul (1,095 m.a.s.l.) crossing through an urbanized area located near El Panul (653 m.a.s.l.). The figures were adjusted for altitude.

3 Results

3.1 Urban expansion and the new peripheries of the MAS

3.1.1 Urban expansion

Between 1989 and 2015, the urban periphery expanded by 30,458 ha (73.2%; Table 1, Fig. 2), approximately 1,000 ha/year. This expansion represents 76.2% of the area that is officially designated for urban development according to the current planning instruments. At the current growth rate (Business as usual scenario), the city's development would reach its maximum permissible extent in approximately 20 years (Table 1).

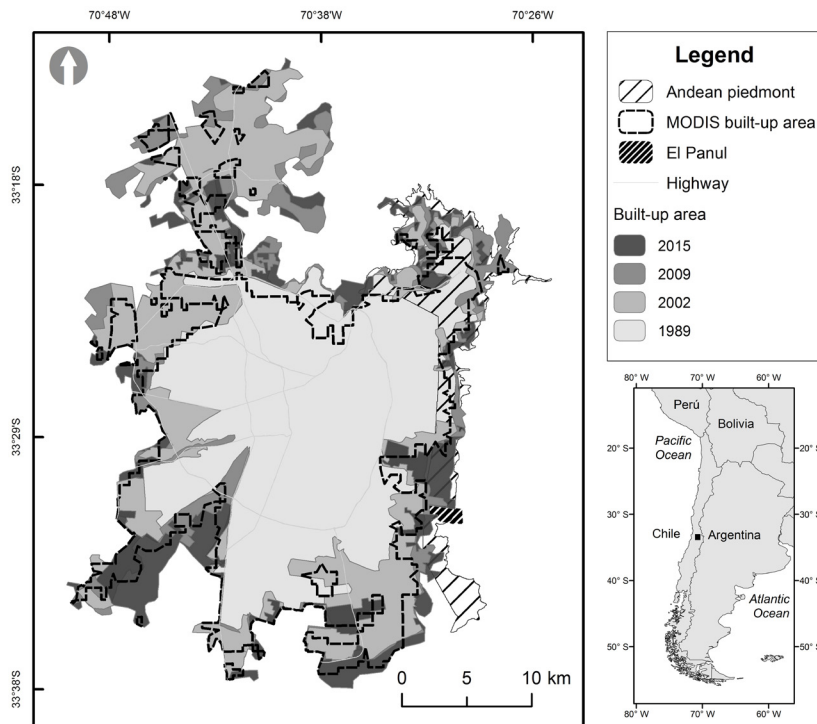
Figure 1. New peripheries of the Metropolitan Area of Santiago, Andean piedmont and El Panul; illustrating the urban and built-up areas data layer from MODIS land use classification.

Figure 1 shows that the growth of Santiago's periphery was most extensive in the 90's and primarily occurred along the city's northern, western and southeastern boundaries. In the 90's, the metropolitan area's northern edge was quickly and extensively urbanized using urban planning mechanisms for the conversion of agricultural land to large lot residential developments affordable to medium-high and high-income families. According to the ADIMARK classification [46] of socio-economic groups in Chile, such families earned income greater than 500 and 1,000 USD per capita, respectively. Following time periods were characterized by a similar but less extensive trend, with more intensive development, the appearance of skyscrapers and the rapid densification of previously low-density residential areas.

The extent of the Andean piedmont designated for urban development has been gradually urbanized following a north-south trajectory. The urbanization

Table 1. Urban growth of the Metropolitan Area of Santiago

Year	Area of urban expansion (ha)	Cumulative expansion since 1989 (ha)	Cumulative percentage of expansion since 1989	Percentage of expansion in relation to the planned urban growth boundary
1989	41,582	-	-	-
2002	57,225	15,643	37.6%	60.6%
2009	61,156	19,574	47.1%	64.7%
2015	72,040	30,458	73.2%	76.2%

**Figure 1.** New peripheries of the Metropolitan Area of Santiago, Andean piedmont and El Panul land. The urban and built-up areas data layer from MODIS land use classification is showed.

pattern is intensive and diverse, with the northern area colonized by medium-high to high-income families and the southern area frequented by medium-income families (according to ADIMARK [46]). The heart of the developable Andean piedmont area has recently been urbanized. El Panul is in the path of this trajectory and represents the northern limit of the southern piedmont where properties are still available for development.

3.1.2 Vegetation changes

The analysis based on MODIS imagery, including all the built-up area of Santiago, exposed the decrease in vegetation cover, revealing a 9% decline in urban vegetation cover within the MAS from 2000 to 2015. The average NDVI value was 0.30 between 2000 and 2005 but

decreased to 0.26 between 2011 and 2015. Additionally, the data show that these figures were lower at the end of the dry season and the end of the wet season (Figure 2).

3.2 Quantification of ecosystem services provided by El Panul

3.2.1 Accessibility for recreation

El Panul has 190 ha of usable space within the urban growth boundary. Using Handley et al.'s [45] criteria, the park's area of influence extends 5000 m beyond its border. The nearest similar recreational area is located in another municipality (Peñalolen) approximately 9 km away. No parks between 20 and 100 ha exist nearby, but there are 7 urban parks between 2 and 20 ha, two within La Florida

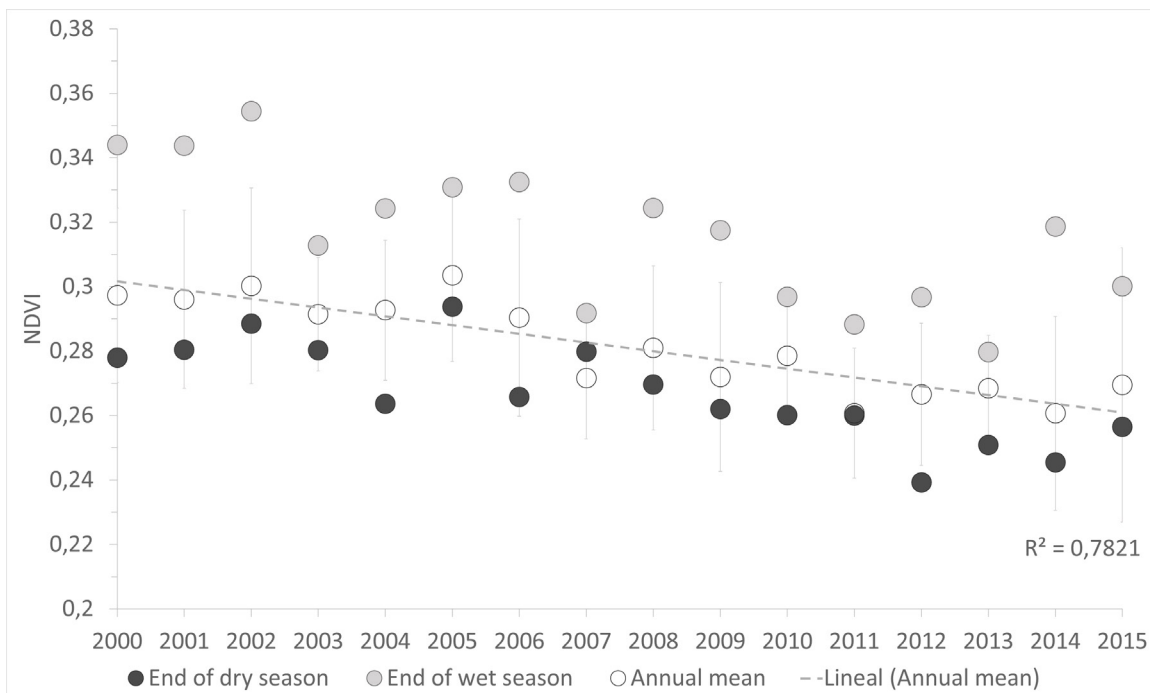


Figure 2. NDVI values for the built-up area of the Metropolitan Area of Santiago (spatial resolution 250m, temporal resolution 16-days).

and 5 in the vicinity of the municipality. These last parks have a 300-meter area of influence according to Handley et al. [45]. This information allowed us to determine that, without El Panul, individuals within 82.7% of the La Florida territory would not have access to green spaces, 315,812 inhabitants (86% of the population in La Florida). On the other hand, should El Panul officially become a park, only 20.9% of the territory would lack green space and the population that would have access to a green space near their households, according Handley et al.'s [45] criteria, would rise from 50,545 to 131,075 inhabitants.

3.2.2 Evaluation of sense of place

We found that 40% of the interviewees had visited El Panul for recreational purposes; they were aware of the conflict and had participated in the plebiscite designed to change the urban planning instrument related to the site. Most of the individuals we interviewed also valued the effect of the forest on their health and greatly appreciated its native biodiversity. The most valued motivation to visit the land was to satisfy recreational needs, particularly sports (31%) and activities with family and friends (48%; Table 2). People defined conservation as crucial to Panul's future and were interested in the development of facilities for public use and the restoration of its unique forest vegetation. In terms of maintenance, respondents'

priorities focused on improving security and signage regarding potentially damaging activities, cleanup efforts, and vegetation conservation, particularly through irrigation (Table 2).

Table 2. Attributes for 'Sense of place': knowledge, use of and motivation for visiting El Panul; people's awareness of and participation in the conflict and the urban planning tool; and preferences regarding what the park should be like and how it should be maintained, preference categories correspond to a synthesis of the most spontaneous answers. Survey questions are indicated with a "Q".

Responses to questions 3, 6 and 7 indicate that the 'sense of place' associated with El Panul was the perception that it is a natural area for recreational activities. However, low awareness of and participation in the conflict (questions 4 and 5) contrasted with the number of people that knew of its existence (questions 1 and 2), showing that 'sense of place' was limited.

Stratification of the survey made it possible to detect significant differences between middle to high income groups and low income groups. The latter knew less about the existence of El Panul and about its conflict.

In terms of the respondents' willingness to pay an admission fee for the park [Q8], people generally felt it was unfair to have to pay to enter a green space or park. Nevertheless, they declared that if they had to pay, they would give approximately \$ 2.5 USD per person. Those

Table 2. Sense of place attributes: knowledge, use and motivation for visiting El Panul; people awareness and participation about the conflict and the urban planning tool; and preferences regarding how should be the park and its maintenance, the preferences categories correspond to a synthesis of the most spontaneous answers. Questions of the survey are indicated with “Q”.

Sense of place attributes	Positive answers or spontaneous mentions	Share of total interviews (N=60)
Knowledge and use of El Panul land and its ecosystem services		
[Q1] Do you know about El Panul land? (yes/no)	49	0.82
[Q2] Have you visited El Panul land? (yes/no)	40	0.67
[Q3] Why did you visit El Panul? (open question: most frequent spontaneous mentions)		
Recreation with friends and family	29	0.48
Contact with nature	24	0.40
Play sports	19	0.31
Get information about El Panul	6	0.10
Health	4	0.07
People's awareness and participation		
[Q4] Do you know about the El Panul conflict? (yes/no)	29	0.48
[Q5] Did you participate in the plebiscite to modify the urban planning instrument to prohibit the urbanization of El Panul? (yes/no)	14	0.23
[Q6] What actions to improve El Panul should be taken if become a peri-urban park? (open question: most frequent spontaneous mentions)		
Conserve it in its current natural state	15	0.25
Build facilities (benches, picnic, kiosk)	13	0.21
Increase tree density and diversity, plant lawns	11	0.18
Build sport facilities	8	0.14
Open footpaths and cycle paths	7	0.11
Improve accessibility (public transport and cycle paths)	4	0.06
Offer information about the conflict and environmental education	3	0.05
[Q7] What actions of maintenance El Panul should be done if become a peri-urban park? (open question: most frequent spontaneous mentions)		
Security and signage about prohibit activities	22	0.37
Cleanliness	21	0.35
Vegetation maintenance (irrigation)	13	0.21
Facilities conservation	42	0.70

who were comfortable paying for admission mentioned an amount close to \$ 3.6 USD. These costs were greater than the price of admission to a nearby park, but lower than a cinema or theatre ticket in the MAS. Low income groups were significantly less willing to pay (-50%).

3.2.3 Air temperature regulation

Summer night air temperatures in El Panul were 1.5°C lower than those in the urban area near El Panul and 3.5°C lower than the core urban area (10pm). On the other hand, afternoon temperatures (2pm) reflected an opposing trend: El Panul was 2.6°C warmer than the nearby urban

area and 2.9°C warmer than the central urban area (2pm: P-value<0.01; 10pm: P-value<0.01). The data is somewhat contradictory but is likely explained by topographical features. Solar radiation hits the piedmont area directly during the afternoon, while local winds move from the valley to the piedmont. The data confirmed the nighttime island cooling effect evidenced in Sarricolea and Martin-Vides [15].

4 Discussion

4.1 Trajectories of change on the city border: effects on vegetation

Our results for the MAS were similar to those found by Inostroza *et al.* [9] and followed analogous patterns identified in other Latin-American metropolitan and mid-size cities [9,47-49]. The MAS exhibited a fragmented, dispersed urban growth pattern [12] that included a large area of new urban developments along the city's border.

Vegetation analysis showed a decrease in NDVI over the study period as a result of urbanization and climate processes. The MODIS analysis provided insight into the overall trend of vegetation reduction pathways over the study period. The results of these analyses coincide with findings of a land cover change analysis from Central Chile, including the identification of native vegetation remnants and disturbed areas [39,50]. Schulz *et al.* [50] reported an increase in urban and agricultural land cover and a decrease in native scrublands and forests. In the MAS, predominantly agricultural land was converted to urban land towards the west side of the city, while predominantly forested land was converted to urban land in the Andean piedmont area. Pavez *et al.* [32] reported similar results in an earlier study, where accelerated urban growth was linked to a reduction of agricultural land and scrublands.

Urban growth does not always have a negative impact on vegetation cover [39]; this impact often depends on the preservation of vegetation and ecosystems surrounding the city as well as the type of new development under construction. For example, urban growth in the Andean piedmont has resulted in an increase in vegetation cover, in contrast to the trends found in the peripheries of other Latin-American cities and other areas of the MAS [12,33]. Along other urban peripheries there was severe loss of ecosystem services from the conversion of agricultural lands into new urban developments lacking vegetation [31]. The Andean piedmont has also been subjected to urbanization; however, new urban developments introduce vegetation that may increase the supply of some ES but also require additional resources such as irrigation that lead to higher maintenance costs [51]. Nevertheless, our research indicates that at least two ES, sense of place and recreational opportunities, could be negatively affected if specific native vegetation remnants that residents value greatly become urbanized. Although not included in this study, urbanization could also affect other elements such as aesthetic and spiritual ES [7] or ES

associated with native biodiversity (e.g., birds, mammals, plants).

Contrasting with the analysis of the MAS's urban core, the Andean piedmont exhibited an increase in the vegetation index over time. This could be due to the replacement of native vegetation by ornamental species with higher NDVI values. Native sclerophyllous vegetation has a slow growth rate and low photosynthetic rate; therefore, it has a lower NDVI value than the fast growing species and lawns commonly used in new developments.

Ornamental vegetation incorporated within new developments increases the NDVI values indicative of vegetation cover; however, the vegetation's ability to provide the same level of ES as native vegetation is questionable due to its poor resilience in the face of the prolonged droughts characteristic of Mediterranean climates. In contrast, native vegetation is well adapted to regional climatic conditions. Sustainable cities must consider climate change and variability when protecting native vegetation remnants. Given the potential disturbances that threaten the region, resilient peri-urban remnants of native vegetation represent a sustainable source of ES for local inhabitants.

4.2 Importance of peri-urban remnants for urban ecosystem services

Throughout our analysis of the ES provided by El Panul, we demonstrated the importance of protecting and conserving native vegetation remnants along the peripheries of cities. This effort is valuable from an ecological and social perspective. Our results allowed us to quantify the importance of a potential peri-urban park as a climate regulator during summer and provider of cultural services such as recreational opportunities and sense of place. Future studies should evaluate the potential of these remnants as climate regulators in winter by including other climatic variables such as wind or humidity, and evaluate more profound 'sense of place' attributes as well as other cultural ecosystem services. Maintaining remnants of original vegetation as peri-urban parks close to new developments facilitates the continuous delivery of ES for new inhabitants, without the time lag associated with the development of new green spaces. In addition, they generally have lower maintenance costs. In this direction, sense of place can be strengthened by initiatives oriented on highlighting the value of native vegetation for example as representative of local identity and natural heritage.

Recreational opportunities available in peri-urban

parks vary from the opportunities incorporated into the design of traditional urban parks. As in other peri-urban parks within the MAS, El Panul offers multiple recreational activities for a variety of users, including trekking, bird and nature watching, in addition to other more traditional activities such as walking and biking [18]. Only a few of them were mentioned in the interviews, suggesting the need for promotion to develop higher degrees of 'sense of place'. Furthermore, the area's inherent recreational opportunities have positive effects on individual mental and physical wellbeing and have been shown to prevent or reverse obesity, psychosocial stress, depression and cardiovascular and respiratory diseases [43].

The sense of place associated with El Panul has been linked to community identity, the community's emotional ties and attachment to the park which have been shown to increase both the social and physical bonds between individuals and native ecosystem remnants [44]. 'Sense of place' can also be connected to opportunities for education, including the development of living labs and promoting conservation awareness. Results showed little evidence of valuation or the expectation of taking advantage of these opportunities.

The air temperature analyses revealed the importance of El Panul in local regulation of the impact of the urban heat island effect. Climate change and the intensification of climate variability will extend drought periods and increase temperature extremes in the MAS [14] affecting human well-being [52]. Natural peri-urban parks are resilient and can withstand these changes; they serve as extremely efficient climate buffers that do not require irrigation or sophisticated maintenance.

The methodology adopted to quantify the ES provided by a native vegetation remnant combined GIS analyses, interviews and air measurements to provide a series of robust datasets; it is transferable and may easily allow for the monitoring of ES provided by other parks in the region. The GIS analyses used to measure access to green spaces has been suggested as a better, more comprehensive proxy by which to identify the supply of recreational services compared to the area of green spaces per capita in a given territory (e.g., [53]). However, this method is somewhat limited by physical barriers, mobility patterns or the configuration of routes not considered in the analysis. The analysis of the quantity and accessibility of green spaces can be further improved by adding information about their qualitative characteristics, including physical conditions and uses, among other attributes, especially if maximization of ecosystems services is the goal [54-57]. Interviews that inform our understanding of the use, demand and/or valuation of cultural ecosystem services

are a robust method for assessing these characteristics and have the advantage of capturing both qualitative and quantitative dimensions of a given service [58]. Such results also support the use of sensors and data-loggers to capture environmental variables such as air temperature to quantitatively manage human and environmental health [59], as well as development. Their use would increase our understanding of how ecosystem services flow from an ecosystem to its beneficiaries [60,61].

4.3 Implications for sustainable urban planning

Our results reveal the importance of having robust urban planning tools in place to enable the effective conservation of native vegetation within peri-urban areas, especially vulnerable ecosystems such as native Mediterranean forests. By maintaining these remnant populations within the new peripheries of the city, sustainable development is reinforced and ES are ensured for public well-being.

New sustainable planning approaches need to be included in the urban planning efforts of developing countries, especially considering peri-urban areas often contain native ecosystems remnants. To this end, if people value and demand ES that are currently being provided by a peri-urban remnant, it becomes a powerful argument for protecting such ecosystems [62]. However, in the Latin American context there is a lack of participation in decision making processes, and not everyone is properly informed, as the survey answers showed. As a result, urban conflicts and social movements emerge and become the only means of drawing the attention of other neighborhoods, decision makers and scholars. In the long term social movement and dissent could potentially stimulate discussion on how to plan the city, and what to officially protect, providing opportunities for innovation in urban planning [29,63].

In the MAS, peri-urban remnants are only partially conserved by urban planning due to the presence of other mechanisms that allow urban development to occur in those areas. Some municipalities within the MAS have addressed this problem by including such areas inside their growth boundaries, restricting urbanization and designating those areas as urban parks. Municipalities and their residents can use the assessment of the benefits of native vegetation remnants within and around cities can be used in the participatory stage of the urban planning process to include such elements as conservation areas in those plans [64].

5 Conclusion

Although urban expansion in a Latin-American capital such as the MAS leads to a systematic loss of vegetation, there are remnants of native vegetation that resist and provide valuable ES. Sustainable urban planning instruments should protect public interest and well-being by ensuring the supply of ecosystem services. In El Panul ecosystem services have not been considered in the current planning scheme, missing a great opportunity to first, recognize the existence of the natural area and the services it provides, and second, the possibility and actively pursue human interaction with nature.

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