Unlinking of Green Areas with Natural Systems in Temuco, Chile

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Abstract Strategic intervention of green areas in cities with environmental problems can be an opportunity for sustainable urban development under an integral and systemic planning point of view. This study approaches the potential of natural systems inserted in the urban area of Temuco to contribute to environmental, socio-cultural and economic pertinence of the city. Methodologically, a cadaster was constructed with GIS and field work, which allowed the quantitative-qualitative evaluation of landscape indicators associated to the endowment, distribution and accessibility of green areas. We identify that despite surpassing the WHO’s standard, there are problems of territorial equality and integration with existing natural systems within the city. Therefore, this good standard of surface area is not contributing to sustainable development, mitigation of environmental problems or natural risks. This favored by Chilean urban regulations that encourage the development of green remnant area.

1. Introduction

The definition of green areas of Chile is given by the General Ordinance (OGUC) which outlines them as “land surface destined preferably for amusement or pedestrian circulation, conformed generally by vegetative species and other complementary elements [1].” However, in the majority of sustainably developed cities, this definition is obsolete given that green areas are reduced to recreational and landscaping aspects. For example the City Council of Vitoria-Gasteiz considers them as fundamental areas to promote social-ecosystem functions and services, important for constructing green infrastructure [2].

As established by prior research, green areas have an important function for quality of life, ecology and urban environment. Green areas cushion the explosive growth that cities have suffered; a situation that is no different for Chilean cities. Annual growth rate for the 26 main cities in Chile (during the last 20 years), has reached 4.2% [3]. This growth has impacted urban environmental systems through pollution, ground impermeabilization, deforestation and erosion. Due to these consequences, green areas become more and more important, not only for social interaction but for regulation and provision of ecological and social services. Green areas also help minimize the risk of natural disasters and environmental problems in modern cities.

From a landscape metric, green areas have a minimum area in order to be considered as such, conforming to their ecological and urban-social functions; where there exists a direct relationship between size and quality of service. In this regard, Reyes y Figueroa [4] establish that for Santiago,
Chile, green areas less than 500 m² do not fulfill this function, filtering many residual spaces of ornamental character such as medians or roundabouts. At the same time, spatial distribution is fundamental to identify potential ecological connections, which according to Romero [5], together with patches of vegetation, allow the measurement of the environmental quality of life index. The largest fragment index establishes the relationship between the largest magnitude polygon and total green areas of the study. This author indicates that for intermediate cities in Chile, a result less than 20% is unfavorable, giving evidence of a lack of green areas with real contribution to urban ecosystems. Finally, the WHO establishes a minimum of 9 m² and a desirable 12 m² of green area per resident [6].

According to a study by the OCED published in 2013 [7], in Chile, the average area of maintained green areas per person is 4.15 m², well below the standard established by the WHO [6]. Legal responsibility to maintain green areas is that of the municipality, according to Article 5 of the Constitutional Organic Law of Municipalities [8]. This situation generates large disparities between counties with higher income and those dependent on the General Fund. In this way, residents of counties with lower income tend to have less access to green areas; meanwhile, those who live in sectors with higher incomes have better access to green areas.

Graph 1. Per-capita municipal income and Per-capita green areas.

Source: Author elaboration from the database INIM-SUBDERE, 2016.

The same study states that Temuco has 10.98 m² of green areas per person, which together with Punta Arenas, are the cities with the highest average in Chile. In comparison, Arica and Quillota have 0.7 and 0.5 m² per person, respectively. Temuco not only surpasses the WHO standard, but doubles the national average, positioning it as a city with high potential for sustainable development.

However, the study does not specify regarding the size or distribution of these areas, understanding that from a landscape ecology view, large size allows higher diversity and vegetation richness. In this way, there exists more diversity of fauna [4], contributing to regulation of temperature, rainwater, CO2 sequestration and erosion.

Therefore, our research question is the following: How can Temuco, with a comparable green area index to that of New York City (11 m² per person [9]), present serious environmental problems and a perception of a lack of green areas.

If green areas are contributing little to environmental problems, there are relevant aspects that have not been studied such as their size, location, degree of dispersion, fragmentation and distribution. Answering these questions would contribute to the creation of strategies to consolidate an integrated system.
2. Methodology

2.1. Urban Temuco as a Study Area

Temuco is located in the Araucanía Region, 688 km south of Santiago; it has a population of 221,375 [3], being considered an intermediate city on a national scale.

The municipality of Padre las Casas is included with the metropolitan area of Temuco. Padre las Casas has absolute political-administrative autonomy. For this research, the study area is the urban zone of Temuco, established by the Community Regulator Plan (CRP).

![Figure 1. Study Area.](image)

Source: Author Elaboration Based on Municipal Coverage, 2016.

2.2. Construction of the Green Areas Cadaster Map

The methodology to construct the cadaster map was structured in two stages:

- Information collection through photointerpretation of satellite imagery (2016). Green area polygons were identified in the software ArcMap 10.5. These polygons were verified with regulatory-administrative information such as the CRP, lot maps, properties from the national Housing and Urbanism Service, such as the Regional Ministerial Secretary of National Assets and municipal archives of residential lots.

- Complementarily, in situ verification was carried out, where an information collection form was applied for the construction of a database. Included in this information form was information about: location, type of green area, surface area, vegetation, existing structures, type of maintenance, owner and current use of the space. This data was used for analysis and information crossing.

The Cerro Niéol Natural Reserve (NR) was not considered, given that it is an area protected by the Monuments Commission and administered by the National Forestry Corporation. Therefore, it does not have municipal management as a green area; and as an environmental buffer, it is not considered part of the urban area.

2.3. Spatial Analysis of Green Areas

Green areas were characterized in relation to their magnitude and spatial distribution, considering indicators such as: number of polygons (NP) and surface area (SA), organized in 8 macro-sectors from the CRP, percentage of green area surface area with respect to the macro-sector and the city (PSTM and
PSTC) and the index of largest fragment (IFMG). These last indicators were used to analyze the partition of the largest green area compared to the total green area surface area and degree of physical connectivity between them. All these indicators were analyzed with ArcMap 10.5.

Magnitude of green areas was established based on Reyes y Figueroa [4] for Santiago:

| Table 1. Green Areas (GA) Classification |
|-----------------------------------------|
| Categorías                              | Rango (m²)  |
| Remnant Areas GA                        | 0 - 500     |
| Minor GA                                | 501 - 1.000 |
| Intermediate GA                         | 1.001 - 5.000|
| Large GA                                | > 5.000     |

Source: Taken from Reyes and Figueroa, 2010.

Segmented green areas (islands or medians) were not considered, except for four parks which are in a four-axis design (long and narrow): Javiera Carrera, Pablo Neruda, Balmaceda y Gabriela Mistral.

Analysis of accessibility was done from municipal maps, using green areas and other lands as keys. This information was contrasted with the number of residents per macro-sector according to the 2002 Census (CENSO 2002), as well as complimentary projections for parts of the city that did not yet exist. These projections were calculated in relation the number of residences multiplied by the number of inhabitants per residence, 3.8 (INE). In this process, all long green areas less than 10 m wide were removed (even though they had more than 5000 m²), because they do not fulfill their basic function.

Accessibility was defined based on the standard proposed by English Nature [4], which establishes that “persons should not live more than 300 m from a green area of at least 2 Ha.” Considering that the average magnitude of the mapped polygons were mostly buffer green areas (retazo), we propose adjusting this standard, defining a minimum surface area of 5,000 m² as argued by Reyes and Figueroa for Santiago [4].

2.4. Contrast with Natural Urban Systems

Mapping and analytical information was contrasted with the coverage of relevant natural systems in Temuco by superimposing layers of alluvial plains, flood plains, fields, wetlands and natural risk areas from the CRP. This was done in order to identify congruencies, tendencies and incompatibilities. This last step resulted in strategic planning objectives in order to consolidate an integrated system of green areas and natural urban spaces for the city.

3. Results

Through the mapping, 2,173 polygons were identified, with a total surface area of 3,065,266.4 m² of green areas. Of this total, the municipality maintains (externally) 73.9% and another 4.4% by direct administration, with a total management of 78.3% the total green areas of the city.

3.1. Quantity and Distribution of Green Areas

Of all green areas, only 4.7% of polygons are large green areas; however, they constitute 52.8% of total surface area. These areas are associated to 6 urban parks and 4 lineal parks currently within Temuco. On the contrary, buffer green remnant areas comprise 55.5% of polygons, but with 8.8% of total surface area.
Upon analyzing these data by macro-sector, it is evident that Poniente not only has the highest number of polygons, but also the highest percentage of green areas at 27.3%; in contrast, El Carmen only has 5.3%.

| Macro-sector     | Large GA > 5,000 M² | Intermediate GA 5,000 – 1,000 M² | Minor GA 1,000 – 500 M² | Remnant GA 0 – 500 M² |
|------------------|----------------------|----------------------------------|-------------------------|-----------------------|
| Amanecer         | 227,125              | 141,703                          | 58,698                  | 50,180                |
| Centro           | 147,477              | 42,629                           | 13,715                  | 14,144                |
| Costanera Cautín| 196,134              | 82,468                           | 27,987                  | 17,837                |
| El Carmen        | 86,147               | 48,408                           | 15,653                  | 9,594                 |
| Labranza         | 172,644              | 81,475                           | 23,180                  | 11,245                |
| Pedro De Valdivia| 124,213              | 153,381                          | 41,651                  | 41,666                |
| Poniente         | 442,240              | 210,187                          | 73,334                  | 93,205                |
| Pueblo Nuevo     | 139,946              | 101,661                          | 40,159                  | 29,018                |
| Total            | 1,618,934            | 878,031                          | 299,249                 | 269,053               |

Source: Author Elaboration Based on Municipal Data, 2016.

These buffer remnant areas are homogeneously distributed throughout the entire city, with a higher concentration in the Poniente Macro-sector (34.9%) and Amanecer (18.8%). These are residential sectors that are characterized by having roads with medians or irregularly-shaped fragments that result from roadway intersections.
3.2. Distribution and Participation of Green Areas

Regarding the partitioning of green areas, again Poniente had the highest percentage (26%) in contrast with El Carmen, that only had 5.4%. This is because El Carmen was developed through a Land Use Change mechanism, generating a new residential area outside of the urban area.

Table 3. Partition of Total Surface Area and IFMG by Macro-sector

| Macro-Sector       | PST  | IFMG |
|--------------------|------|------|
| Poniente           | 26.0%| 24.0%|
| Amanecer           | 15.3%| 26.6%|
| Pedro de Valdivia  | 9.9% | 32.5%|
| Costanera del Cautín | 11.0% | 16.9%|
| Pueblo Nuevo       | 10.1%| 12.6%|
| Labranza           | 9.9% | 32.5%|
| Centro             | 7.3% | 16%  |
| El Carmen          | 5.4% | 33.5%|

Source: Author Elaboration Based on Municipal Data, 2016.

Regarding IFMG, there are three macro-sectors with indicators less than 20%, which means that they do not have parks. The highest values are registered in Pedro de Valdivia (32.5%), Amanecer (26.6%) and Poniente (24.0%) due to the presence of urban parks such as German Becker and Rivera Venecia.

In relation to the WHO indicator of green areas per person, once again Poniente leads the ranking with 16m² per person, doubling the standard. On the other hand, Pedro de Valdivia has the lowest (6.8 m² per person), given that this sector has an abrupt geography that makes habitation, maintenance and use of public space difficult.

In this way, 5 macro-sectors present indicators over the WHO standard, and 3 below. Temuco as a city has 10.2 m² per person. However, the indicator defined by the “System of Indicators and Standards of Quality of Life and Urban Development” [11], considers a minimum 14 m² per person, and only the Poniente macro-sector would meet this standard.
Regarding the relationship between population and green areas, it is observed that various macro-sectors present similar numbers of inhabitants, such as Amanecer with 41,574, Pedro de Valdivia with 47,187 or Poniente with 48,381 residents. However, the quantity of green areas is not proportional to the population indicator. Considering that the city grows at 15.1% [3], and that Poniente is the urban sector with the most growth, this relationship is even more affected. On the other hand, this sector is associated with the highest purchasing power, marking more territorial inequality.

Graph 2. G.A. / Population ratio.

Source: Author Elaboration Based on Municipal Data, 2016.

3.3. Accessibility and Area of Influence of Large Green Areas
As was indicated in the methodology, to calculate the area of influence, only large green areas were considered, applying the adjusted English Nature standard [4]. In this way, some communities are complete bare, such as Amanecer, one of the oldest districts in Temuco; as well as the historical district of Santa Rosa and a large part of Alemania Avenue. The two largest gaps are associated to their self-construction in the 1960s. Without any planning, highly precarious residential sectors were consolidated, which were later urbanized and regulated. On the other hand, the sector of Alemania Avenue, due to being a commercial sub-center has been maimed regarding public spaces.
Figure 5. Area of Influence of Large G.As.

Source: Author Elaboration Based on Municipal Coverage, 2016.

Pedro de Valdivia has almost null access to large green areas. Few measurable spaces are dispersed around the community with difficult accessibility due to geographic conditions.

3.4. Green Areas and Natural Urban Systems

Finally, upon comparison through layering green areas vs. natural urban systems, it is possible to visualize the contrast between the high prevalence of fragmented and disperse green areas, in relation natural and environmental spaces that have survived urbanization. These spaces are associated with alluvial plains, fields and watershed borders that allow the city to evacuate and regulate its rainwater. Also, these areas refill underground aquifers that supply water to the population. Several of these spaces are under strong pressure, presenting problems with artificial fill and drainage that hinder their functioning.

Figure 6. Green Areas vs. Natural Urban Systems

Source: Author Elaboration Based on Municipal Coverage, 2016.
These natural systems make up intercommunal systems and highly relevant biological corridors. It is evident that existing green areas do not integrate or comprise systems.

4. Discussion y Conclusions
This research demonstrated that, as indicated by the OECD, Temuco surpasses the WHO standard. This report indicated 10.8 m2 per person, and it was possible to confirm a real indicator of 10.2 m2. The difference is because the OECD report included Cerro Ñielo which has 89.5 Ha.

However, there is evidence of problems with distribution and typology according to size and accessibility to green areas. There is a strong predominance of buffer green remnant areas, associated principally to residential zones. In these zones the OGUC regulates new urbanization projects (residential lots), and establishes that green areas must be created that are proportional to the size of urbanization (between 7% and 10%), without considering residential density, relegating these areas to residual spaces. This aspect is under improvement through the new Law 20.958 “Contribution to Public Space” [10].

At the same time, current urban planning instruments do not have legal reach that allows a real approach to planning. This is because the only binding instruments are regulatory plans. However, these plans do not generate prospective planning mechanisms or investment that has the necessary coherency between these instruments and the development of the city in a prudent timeframe.

On the other hand, Temuco has advanced considerably in the construction of parks, from 2 in 2000 to 7 at present. However, this study shows differences in the distribution of large green areas throughout the city, where parks do not arrive equally to the entire population, especially to the most vulnerable areas.

Currently, urban policy incentivizes the development of more green areas, but strategic planning is lacking on how to locate them in such a way that improves indicators such as accessibility and distribution.

In this sense, the CRP stipulates 1,255,198,2 m2 of new green areas, through Areas Affected to Public Utility (AAUP). This reservation of space however does not guarantee their strategic location to contribute to the safeguard of natural systems. At the same time, it is fundamental to establish sustainable design criteria that minimize maintenance costs. This is because the county is under heavy pressure (economic and technical) because of more surface area that it must administer, especially under inefficient conditions due to dispersion and typology.

Some areas of the city do have patches of green areas, but they are not interconnected, and therefore cannot form systems. It is here where urban arborization and road-cycle path projects could be strategic. Regarding the interaction of natural systems, this study shows that they are not part of green areas. Natural-environmental spaces are currently regulated by Risks Zone and AAUP. However, there is a strong pressure to liberate them for real estate, appealing to mitigation mechanisms, such as fillers. The concept of “solutions based on nature” presents an opportunity to strategically approach actions that support ecosystems. The latter in order to respond to different urban challenges such as climate change, food security or risk of natural disasters, without necessarily increasing the surface area of these spaces.

From this same perspective, these natural spaces make up a cultural territory with intrinsic values for the 24 Mapuche communities that live within Temuco’s urban area. The Mapuche peoples have an ancestral bond with the Earth: mapundungun, their language means “talk with the Earth,” and the word Mapuche means Mapu-Earth Che-People (“people of the Earth”) [11]. In this culture, taking care of streams is vital “wiñoko” given that they act as interconnected systems (water, biodiversity, herbs, trees, and fauna) that give the Earth the ability to develop crops and raise animals. In the same manner, the cliffs and valleys “mawiza” must be cared for, associated with native vegetation, considered structural elements to achieve equilibrium. Also, areas where water is accumulated making wetlands “menokos” (a marshy site with a variety of vegetation, mostly herbaceous) where “Lawen” is collected (medicinal herbs used by the Machi).

Finally, this study shows that the green areas are not contributing to mitigate environmental problems facing Temuco. Some of these problems are noise pollution (roadways surpass 65 dBA), atmospheric
pollution (MP 2.5 189, when the limit is 50) [12], and other problems such as constant flooding, waterlogging and increasing urban temperature.

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