An integrative approach to assess urban riparian greenways potential: The case of Mapocho River in Santiago de Chile

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Abstract

Santiago is the 7th largest major city of Latin America with almost 8 million inhabitants and is situated in a fairly closed watershed, surrounded on the eastern side by the high Andean mountain chain with altitudes of 5,000 m. From the Andean mountains, the Mapocho River and a set of large and small streams transport -often torrentially- water and sediment.

In thirty years, Santiago has increased its size two fold, replacing previous agricultural lands, native forests and shrubs with urban land uses, and occupying rivers beds and streams. These land use and cover changes have had dramatic environmental consequences.

The mentioned urban dynamic has produced a city in constant collision with the natural system. This structural disarticulation produces many environmental problems such as an increase in city's surface and air temperatures, an accelerated disappearance of vegetation, a major interruption in wind, sediment and water flows, and finally, increasing people's exposure to environmental hazards.

Since streams, canals and rivers are structural components of Santiago's landscape, they can function as key links between the urban-social and natural system and provide multiple ecosystem services, helping to reduce environmental problems and ensure long-term urban sustainability.

Traditionally, the analysis of river and streamsides has been focused on rural and natural landscapes as well as on environmental protection and nature conservation. Nowadays, there is an increasing interest and necessity to understand the environmental status, functions and possibilities of riparian zones in urban environments in order to delineate and plan greenways, which provide social and ecological benefits. Green infrastructure such as urban greenways is a key component of sustainable cities.

Few studies have been conducted to evaluate the socio-ecological status of urban riparian zones and even fewer to assess these areas in terms of their potential as multifunctional greenways. New efforts should be conducted to develop analytical application-oriented frameworks in the green infrastructure field.

This research elaborates and proposes a transferable conceptual-methodological framework for evaluating the potential for multifunctional riparian greenway development. An analytical application-oriented framework to assess the potential for multifunctional green infrastructure development is proposed by articulating and improving three analyses hitherto used separately: multicriteria, least cost path and opportunities-challenges. The Mapocho River was selected for the application and testing of the proposed conceptual-methodological framework to contribute to multifunctional green infrastructure planning in Santiago as a city representative of the structure and processes of megacities in Latin America.

First, the main ecological and social characteristics of the Mapocho's riparian zone are analyzed, making a synthesis of the socio-ecological status. Second, the suitability to provide multiple ecosystem services of the riparian zone is spatially explicitly modelled, first separately, as mono-functional suitability, and then, integrated into a multifunctional suitability evaluation. Third, the opportunities and challenges perceived by government actors are identified and analyzed as well as those derived from an institutional and regulatory analysis. Finally, the assessment phase concludes with a discussion on the main potential for the development of a greenway, resulting from the synthesis and integration of the most relevant findings of the suitability and opportunities analysis

The socio-ecological status of the riparian zones is characterized by being highly altered in ecological terms, diverse in social terms, and highly used by the metropolitan transport infrastructure with a concentration of green areas in a few municipalities. This means that the riparian zone provides limited physical support for important social and ecological functions characteristic of these zones in urban environments: habitat, aesthetic, cooling, transport route and flood mitigation. The results reveal a significant east-west gradient in the socio-ecological status of riparian zone, which gradually decreases from east to west. The riparian zone of the Mapocho River in Santiago has good suitability as a wind corridor, providing a cooling effect and to mitigate flood hazards.

The main challenges for the development of a multifunctional urban greenway in the Mapocho River corresponds to low levels of inter-jurisdictional and inter-sectoral coordination and cooperation, maintenance costs and the existence of urban highways in the zone. On the contrary, the main opportunities are the existence of important sectors of vacant land, increased political and social importance of urban green areas and the existence of a set of consolidated riparian parks.

In synthesis, the assessment developed in the Mapocho River identifies the most important aspects to be considered and the greatest potentialities to capitalize in planning a multifunctional greenway along the Mapocho River. This is key when thinking about a possible master plan for the Mapocho River that returns the river to the city and values it as an axis for urban integration.

The development of a multifunctional greenway in Santiago can considerably contribute to the social and ecological connectivity and thereby mitigate the socio-ecological segregation and disconnection characteristic of cities in the region. It may also contribute significantly to reconcile urban growth with ecological health and people's quality of life, maintaining functions and key ecosystem services and mitigating the negative effects of urbanization.

Keywords: Urban greenways, multifunctional green infrastructure, ecosystem services, Santiago de Chile

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List of abbreviations

AHP	Analytical Hierarchy Process
CLP	Chilean Peso
CONAMA	Comisión Nacional de Medio Ambiente, National Environmental Commission
DAO	Departamento de Aseo y Ornato, Facilities Department
DEM	Digital Elevation Model
DGA	Dirección General de Aguas, Central Water Directorate
DOH	Dirección de Obras Hidráulicas, Department of Water Works
DOM	Departamento de Obras Municipales, Department of Municipal Works
E-W	East - Weast
ENSO	El Niño/Southern Oscillation
ES	Ecosystem Service
GDP	Growth Domestic Product
GEOBIA	Geographic Object-Based Image Analysis
GI	Green Infrastructure
GIS	Geographic Information System
GORE	Gobierno Regional, Regional Government
IGM	Instituto Geográfico Militar, Geographic Institute of the Military
INE	Instituto Nacional de Estadísticas de Chile, National Statistics Institute of Chile
IRS	Internal Revenue Service
LCP	Least Cost Path
LGUC	Ley General de Urbanismo y Construcciones, General Law for Urbanism and Construction
LULC	Land Use/Land Cover
MCA	Multicriteria Analysis
MEA	Millennium Ecosystem Assessment
MINVU	Ministerio de Vivienda y Urbanismo, Ministry for Housing and Urbanism
MMA	Ministerio del Medioambiente, Ministry for the Environment
MOP	Ministerio de Obras Públicas, Ministry of Public Works
MTT	Ministerio de Transportes y Telecomunicaciones, Ministry for Transport and Telecommunication

NGO	Non-Governmental Organization
OTAS	Bases para un Ordenamiento Territorial Ambientalmente Sustentable en la Región Metropolitana de Santiago, Basis for an Environmentally Sustainable Territorial Planning in the Metropolitan Region of Santiago de Chile
PDUC	Proyectos de Desarrollo Urbano Condicionado, Conditioned Development Projects
PLADECO	Plan de Desarrollo, Comunal, Communal Development Plan
PNDU	Política Nacional de Desarrollo Urbano, National Policy on Urban Development
PPDA	Plan de Prevención y Descontaminación Atmosférica, Atmospheric Decontamination and Prevention Plan
PRC	Plan Regulador Comunal, Municipal Regulatory Plan
PRI	Plan Regulador Intercomunal, Intercommunal Master Plan
PRMS	Plan Regulador Metropolitano de Santiago, Metropolitan Land-Use Plan for Santiago
PROT	Plan Regional de Ordenamiento Territorial, Regional Plan on Territorial Planning
PSAD	Provisional South American Ellipsoid
PUC	Pontificia Universidad Catolica de Chile, Pontifical Catholic University of Chile
RM	Región Metropolitana, Metropolitan Region
RS	Remote Sensing
SECPLAC	Secretaría Comunal de Planificación, Municipal Secretariat for Planning
SEIA	Sistema de Evaluación del Impacto Ambiental, System for the Evaluation of Environmental Impact
SEREMI	Secretaría Regional Ministerial, Regional Ministerial Secretariat
SERVIU	Servicio de Vivienda y Urbanismo, Office/Service for Housing and Urbanism
UFZ	Helmholtz-Zentrum für Umweltforschung, Helmholtz Centre for Environmental Research
UHI	Urban Heat Island
WGS	World Geodetic System
WO	Weighted Overlay
WSO	Weighted Sum Overlay

Chapter 1

Introduction

This chapter briefbly presents the problem delineation - futher developed in Chapter 2-, research goal and questions as well as Santiago as a case study, particularly in terms of a series of environmental problems derived from the disconnection between an accelerated physical expansion and a prominent geophysical background. The creation of green infrastructure in Santiago based on key components of landscape such as the Mapocho River, may contribute to reconcile urban growth, quality of live and ecological health.

1.1 Background and problem delineation

Firstly, green infrastructure is presented as a strategy to conciliate urban growth and environmental protection. Secondly, the importance of watercourses and greenways in ecological and social terms and their contribution to the integrity of landscape are analyzed. Finally, the situation of Santiago is presented, highlighting the relevance of this research and the selection of Santiago as a case study.

1.1.1 Green infrastructure and relevance of urban riparian greenways

Since nowadays more than 50% of the population lives in urban areas, the conflict between urbanization and environmental protection is a global issue (UN, 2015). Cities have a tremendous impact on ecosystems derived from the demand of resources and the generation of waste and emissions (Sukhdev, 2013), and according to UN (2015) the "sustainable development challenges will be increasingly concentrated in cities, particularly in the lower-middle-income countries where the pace of urbanization is fastest" (p. 17). In general, related problems are concentrated in lower-middle-income countries (e.g. Chile) and in areas adjacent to biodiversity hotspots (e.g. Santiago de Chile) (Seto et al., 2013).

In this contex, green infrastructure emerges as a strategy based on the use of nature and its services to solve some of these problems and contributing to territorial cohesion (EEA, 2011) and landscape integrity (Hellmund & Smith, 2006)

It is only in the eighties, that the concept of green infrastructure has been implemented in the design and planning of the urban and peri-urban environment (Tzoulas et al., 2007). It emerged as an approach to reconcile urban growth, human health, and environmental protection, emphasizing ecological and social services provided by green spaces in and to cities such as climate regulation, air purification, noise reduction, harborage of native species, provision of places for recreation, leisure, and contact with nature (Benedict & McMahon, 2006).

An innovative feature of the green infrastructure concept is that it emphasizes the intrinsic responsibility and active social role involved - not only for the protection and preservation of green spaces but also for their planning, development, and maintenance. This means moving from “nice to have” to “must have” (Day, 2011).

Some green spaces that require special attention are urban wetlands, rivers, forests, and riparian corridors, because they are key structural components in the urban landscapes and critical links for ecological processes taking place in cities. Girling et al. (2000) call them environmental assets. Proper recognition, valuation, and consideration of these environmental assets in urban planning, land uses and cover allocation, and urban design could help to ensure the integrity of urban ecosystems and, for this reason, long-term urban environmental health and sustainability (Girling et al., 2000; Jackson, 2003).

Riparian zones, also called river or streamsides, have tremendous potential for green infrastructure development since they are unique ecosystems between water (waterbodies and watercourses) and land. Riparian zones are considered key landscape components because they are hotspots of physical and biological functions, especially in semi-arid regions where they are often named linear oases (Groffman et al., 2003; Arizpe et al., 2008). Riparian areas provide many ecological functions such as improving environmental quality of the mainstream, controlling lateral erosion, providing habitat for wildlife, regulating climate, reducing noise and water temperature, and facilitating water soil infiltration (Schreier et al., 2004; Maekawa & Nakagoshi, 1997; Apan et al., 2002).

According to National Research Council (NRC) (2002), riparian zones “perform a disproportionate number of biological and physical functions on a unit area basis” (p. 2) and for that reason they have a higher relative potential to provide ecosystem services. Ecosystem services are the benefits humans obtain from ecosystems (Millennium Ecosystem Assessment (MEA), 2005). For this reason, riparian zones conservation and restoration efforts are extraordinarily efficient.

Greenways are commonly defined as linear vegetated areas for multiple social and ecological functions. Their development has taken place commonly associated to riparian zones. Well preserved riparian zones can act as effective greenways, providing valuable ecological functions (such as the before mentiontioned) and also social benefits including sites for non-motorized transport (walking, hiking, and biking), opportunities for leisure and contact with nature, cultural heritage conservation, and aesthetic quality (Hellmund & Smith, 2006).

Traditionally, the analysis of river and streamsides was focused on rural and natural landscapes as well as on environmental protection and nature conservation (Groffman, 2003). However, nowadays there is an increasing interest and necessity to understand the environmental status, functions, and possibilities of riparian zones in urban environments in order to delineate and plan greenways which provide social and ecological benefits. Green infrastructure planning and development is a key component for increasing adaptive capabilities of cities (resilience) (Foster et al., 2011; Lovell & Taylor, 2013), particularly since cities face scenarios of uncertainty related to global changes, such as climate change.

Few studies were conducted to evaluate the environmental status of urban riparian zones and even fewer to assess these areas in terms of their potential as multi-functional greenways. New efforts should be conducted to improve and complement these first approaches (Miller et al., 1998; Conine et al., 2004).

According to Conine et al. (2004), greenway planning and delineation must be performed following systematic approaches due to their great services in areas of ecological protection, recreation, and alternative transportation. Designing for cultural and social needs, allowing people to maximize their benefits without generating future social and environmental problems, is becoming one of the most difficult challenges (Miller et al., 1998). This dilemma points out the need for new multi-objective greenway planning methods.

1.1.2 Santiago as study case

Andean cities are located in the center of large watersheds. In earlier times, between 1500 and 1700, and following strict Spanish ordinances, the location of cities was determined by water availability and drainage, good defence capabilities against the indigenous population, and suitable agricultural lands for food supply (Romero & Vásquez, 2007).

Santiago de Chile is situated at 33°26'S - 70°39'W and 567 masl, in a fairly closed watershed, surrounded on the eastern side by the high Andean mountain chain with altitudes of 5,000 amsl and at the western border by the Coastal Range of lower altitudes. From the Andean mountains, the Mapocho River and a set of large and small streams/creeks transport water and sediments, often torrentially, towards the Pacific Ocean, located just 250 km away from the Andean summits.

A Mediterranean climate with a long dry season dominates the city. The semi-arid conditions are a relevant geographical feature in Santiago, the annual average rainfall is only 350 mm concentrated in just twenty days a year, between May and August (the winter months). Large annual variability is another relevant climate feature. During El Niño years, rainfall can reach 800 mm, but when La Niña takes place, the annual rainfall could be just above 100 mm (Romero, 1985).

In geomorphologic terms, three macro forms exist: the mountain slopes, the floodplains, and the foothills. The Andean foothills surrounding the eastern border of Santiago form an interface between mountain slopes and floodplains, drained by several creeks and streams.

The fact that these draining rivers and creeks have large watershed sizes and that precipitation events frequently show torrential character results in the phenomenon that many of these sporadic streams are re-activated by storm flows and can overflow into older floodplains where houses have been built.

In summary, Santiago de Chile has a geographical background that has become a challenge for a fast growing megacity. Water scarcity, floods, landslides, limited ventilation are common phenomena in Santiago's watershed, which should be carefully considered by urban planning.

Santiago, the capital city of Chile, is the 7th largest major city of Latin America with almost 8 million inhabitants and by far the largest and important city of Chile, since it concentrates 42.7 % of the Growth Domestic Product (GDP) (in 2006, INE 2009) and 40.3 % of the national population (in 2009, INE 2009). As a consequence of this high demographic importance and economic dynamics, Santiago has almost doubled its size during the last thirty years, from 34,792 in 1975 to 65,543 ha in 2004 (Romero et al., 2007), replacing previous agricultural lands, native forests and shrubs with urban land uses and occupying river beds and streams (Romero et al., 2007). These land-use and land-cover changes have had dramatic environmental consequences.

The mentioned urban dynamics produced a city in constant collision with the natural system, including negative impacts on the state, structure, and flow of matter and energy characteristic of the dominant geographical conditions. This structural disarticulation produces many environmental problems such as an increase of sealed surface and consequently of atmospheric temperatures (Aceituno & Ulriksen, 1981; Molina, 2007), an accelerated disappearance of vegetated areas (Vásquez & Romero, 2007a), a major interruption of wind/ventilation corridors (Romero & Vásquez, 2006), of sediment and water flows, and finally, increasing exposure of the local population to environmental hazards (Müller, 2011).

Molina (2007) demonstrates how the city gradually develops an Urban Heat Island (UHI) in the daily course, whereby the downtown area presents air temperatures that are on average 4°C higher than the city's rural environment. That accentuates the thermal discomfort and the convergence of polluted air masses. Vásquez & Romero (2007a) and Vásquez & Romero (2007b) describe the progressive disappearance of vegetation cover in Santiago, demonstrating that in some sectors that were urbanized thirty years ago, less than 5% of green spaces are left. Moreover, Santiago exhibits an uneven distribution of urban green areas such as that some municipalities provide only 0.38 m^2/hab and others 8.11 m^2/hab of public green areas (Rivas, 2005).

All problems mentioned above put the long-term environmental sustainability of Santiago into question and point out the urgent need to restore and improve the link between natural and socio-urban systems. This necessarily involves recognizing and properly valuing green and open spaces that provide critical environmental services in urban environments (Girling et al., 2000; Gill et al., 2007).

Streams, canals, and rivers are structural components of the Santiago landscape. Santiago was founded on the southern riverbank of the Mapocho River, and since colonial times it has been seen as a source of drinking and irrigation water, but also as the greatest threat for urban development due to frequent flooding. Flooding problems in Santiago have increased together with the subsequent explosive urban development, and other additional issues, such as diseases and unpleasant odors, appeared to be associated with watercourses. Pavez (2008) points out that some of these problems can apparently be stimulated or accelerated by the lack of consideration of the Mapocho River in urban planning and practices.

Urban watercourses in Santiago, especially the Mapocho River as the major urban river, have an enormous potential to serve as a basis for greenway development. Urban riparian greenway planning and implementation can become a cost-effective planning strategy for landscape integrity as they can (1) function as key links between the urban-social and natural system, (2) provide ecosystem services, and (3) thereby help to reduce environmental problems described before and ensure the long-term urban suitability.

1.2 Research goal and questions

This section presents the goal and research questions that guide this study.

Although an extensive revision of the current state of research - including resarch gaps – is presented in Chapter 2, it is important to mention here that despite the increase in scientific research on green infrastructure, there is still a lack of an analytical-conceptual framework focused on the implementation and practice of urban planning (Hansen & Pauleit, 2014). This is especially true for multifunctional greenway planning. As proved in Chapter 2, there is a lack of methods for multifunctional greenway planning particularly in large cities. This research explores how to articulate and improve the three analyses hitherto used in isolation: multicriteria analysis, least cost path and opportunities-challenges, into a transferable conceptual and analytical framework for greenways assessment and planning.

The case study area in Santiago is used to apply the conceptual and methodological framework, since Santiago provides the opportunity to explore its scope and applicability in a city representative of the structure and processes of megacities in Latin America, but is still smaller compared to others.

1.2.1 Research goal

The main research goal is to develop an integrative approach to assess the potential for multifunctional riparian greenway development and to gain understanding of the socio-ecological state and functions of the Mapocho's riparian zones in Santiago de Chile, in order to provide scientific knowledge as basis for the urban planning process.

1.2.2 Research questions

How can the greenway potential be assessed in a way that the manifold functions are properly incorporated? (method)

What are the current environmental characteristics and functions of the Mapocho's riparian zones in social and ecological terms?

What is the potential of the Mapocho's riparian zones in Santiago de Chile to become multifunctional greenways? (application)

The first research question and the first part of the research goal are mainly addressed in Chapter 3, where a transferable conceptual-methodological framework for evaluating the potential for multifunctional riparian greenway development is presented. The second and thirth research question as well as the second part of the research goal are developed along Chapter 6, 7, 8 and 9.

1.3 Thesis structure

The following is a general overview of the structure of the thesis (Figure 1.1).

Chapter 1: The research problem is presented, characterizing its most relevant aspects in terms of research need and relevance. In addition, this chapter specifically describes problems related to the case study and how the development of a riparian greenway can contribute to the mitigation of them. The research objectives and questions are also presented.

Chapter 2: A state of the art review is done, defining and discussing the most relevant concepts for the research. Additionally, the approaches used in the study of greenways are discussed to outline research needs and opportunities to improve the methods used hitherto.

Chapter 3: This chapter elaborates and proposes a transferable conceptual-methodological framework for evaluating the potential for multifunctional riparian greenway development. The framework defines and articulates the key concepts and associated methodological approaches.

Chapter 4: Chapter four presents Santiago and specifically the Mapocho River as a case study to test the conceptual-methodological framework proposed in the previous chapter. The information presented allows a general understanding of the biophysical, social and institutional context in which the evaluation is located. Finally, the riparian zone to be evaluated is operationally defined.

Chapter 5: Outlines in detail the data and methods used in the implementation of the proposed framework to evaluate the potential of a multifunctional greenway in the riparian zone of the Mapocho River in Santiago.

Chapter 6: This chapter presents the results from the socio-ecological analysis that corresponds to the first stage of the assessment phase. The analysis shows the main ecological and social characteristics of the riparian zone, making a synthesis of the socio-ecological status of this. These results partly feed the following analysis.

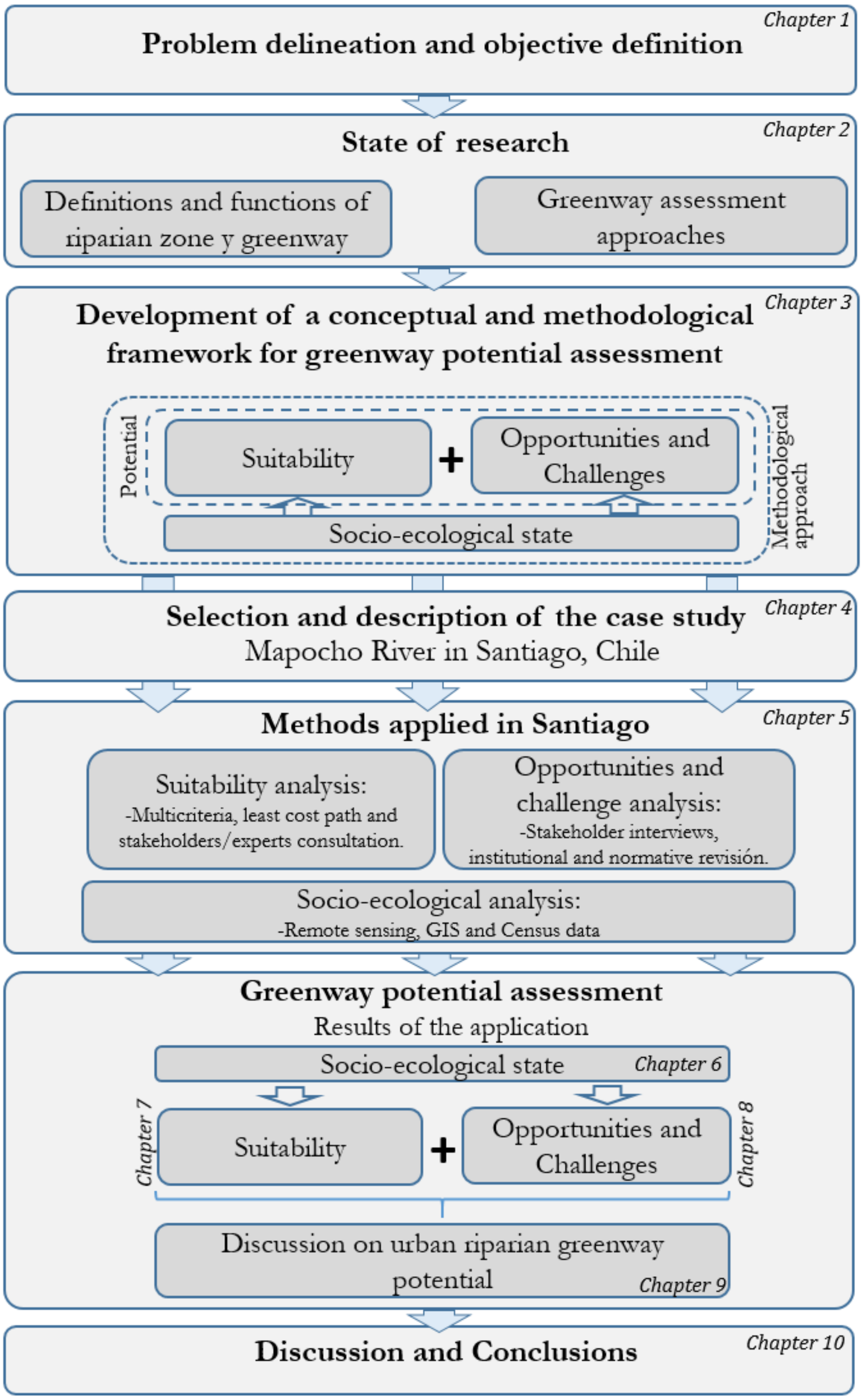
Chapter 7: This chapter presents the suitability analysis results. A spatially explicit modelling of the suitability to provide multiple ecosystem services of the riparian zone is developed, first separately, as mono-functional suitability, +and then, integrated into a multifunctional suitability evaluation.

Chapter 8: Consists of the results of the opportunities and challenges analysis perceived by government actors and identified through an institutional and regulatory analysis. Opportunities and challenges for the development of a multifunctional greenway in the Mapocho River are identified and analyzed.

Chapter 9: Presents the final stage of the assessment phase and discusses the main potential for the development of a greenway, resulting from the synthesis and integration of the most relevant findings of the suitability and opportunities analysis.

Chapter 10: This chapter discuss the limitations of the research and the meaning of the results in light of the research questions. This chapter also outlines the main conclusions of the study, integrating and summarizing the main findings and contributions of the research. In addition, the academic and practical implications of the results are presented.

Figure 1.1: Thesis structure.



Chapter 2
Current state of research

This chapter reviews the state of the art in urban riparian zones research and multifunctional greenways potential assessment. First, in Section 2.1 the social and ecological importance of riparian zones is discussed with emphasis on ecosystem services they can provide, and the lack of knowledge about them in urban environments. Second, various definitions of greenways are analyzed to find common aspects of the concept, including relevant socio-ecological functions. Third, the main approaches used in studying riparian zones and assessing multifunctional urban greenways are reviewed.

2.1 Riparian zones as key landscape components

Originally, the term riparian derives from "life on the bank" according to its Greek root and has been associated with water law and rights (riparian rights) in Europe and the USA since aforetime (NRC, 2002; Verry et al., 2004). According to NRC (2002), the term "riparian" has been recognized in basic sciences (e.g. biology, ecology and geomorphology) since only 1970; producing an explosive increase in scientific research on hydrologic, ecological, cultural, and social dimensions of riparian areas.

Riparian zone, riparian system, riparian area and riparian buffer are all terms associated to the same idea of a "riparian environment" located between water and land. However, a single definition has not yet emerged because historically the term "riparian area" has been interpreted in divergent ways by different scientific disciplines, managers, agencies and landowners, and it even has different meanings in different regions (Verry et al., 2004).

Riparian areas are defined as land adjacent to stream and water bodies (Lathrop & Haag, 2007), as unique ecosystems along rivers and around lakes (Groffman et al., 2003; Arizpe et al., 2008), and as ecotones between aquatic and terrestrial ecosystems (Verry et al., 2004; Ivits et al., 2009).

Most definitions mention: (1) a specific location adjacent to water (or between water and land), (2) transversal, longitudinal, and vertical hydrological connection, and (3) specific biota as their characteristics.

Verry et al. (2004) made an accurate revision of past riparian area definitions, and tried to offer a consistent riparian area definition and delineation applicable in any valley in any climate: "riparian ecotones are three-dimensional spaces of interaction that include terrestrial and aquatic ecosystems that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water laterally into the terrestrial ecosystem, and along the watercourse at a variable with" (p. 91).

Although Verry's definition has been well accepted and cited, there are still researchers and agencies preferring the definition of riparian zones as an ecosystem in itself, which can help to point out their uniqueness and value.

Because definition and delineation are very closely related, criteria and procedures for riparian zone delineation likewise vary. Consequently, Verry et al. (2004) propose an operational identification that includes the floodprone area and 30 m landward along the valley, which is derived from valley and stream geomorphology. However, this procedure is highly demanding of information and field work and is consequently time-consuming and costly/resource intensive.

Most researchers use distances from the water's edge to delineate riparian areas, supported by the evidence that relates distances to the watercourse or body with specific conditions and functions that define the ecological integrity characteristic of riparian environments. This normally ranges from 30 m, where a strong functional riparian relationship exists according to Richards (1996), to 400 m to protect all components of biodiversity (Brison et al., 1981). This perspective supports guidelines of buffer widths used in riparian management in many countries (Lee et al., 2004).

The NRC (2002) states that the most important ecological functions performed by riparian areas are related to (1) hydrology and sediment dynamics, (2) biogeochemistry and nutrient cycling, and (3) habitat and food web maintenance. Additionally, Lee et al (2004) pointed out that most research and management efforts focus on the transversal dimension of riparian areas and their associated properties since their role of controlling erosion and sedimentation, moderating stream temperature and light, maintaining invertebrate communities, fish communities, near shore vegetation, bird communities, and mammals are regarded as being the most significant.

The longitudinal dimension was explored by riparian corridor research because riparian areas facilitate plant and animal movements along watercourses and thereby act as an ecological corridor (Naiman & Décamps, 1997; Nagler et al., 2008; Akasheh et al., 2008; Meek et al., 2010).

Research on riparian areas was mainly carried out in natural and rural environments by natural scientists from fields like geomorphology, hydrology, ecology, biology, and chemistry, whereby dominant definitions and studied ecological functions do not incorporate the human dimension.

Recently in the early 1990s, a few studies started incorporating human aspects on riparian areas research by following two main approaches: (1) studying human activity as ecological stressor and the threat to ecosystem functioning and quality (Pennington et al., 2008; Burton et al., 2009; Ivits et al., 2009; Pennington et al., 2010; Fernandes et al., 2011), and (2) analyzing the social value of selected ecological functions offered by riparian areas (William, 1990; Steiner et al., 1994; Fry et al., 1994; Lovett & Price, 2007).

The main human impacts on streams and riparian zones are alterations of hydrology, geomorphology, and habitat (Paul & Meyer, 2001), that are principally produced by removing riparian vegetation, soil sealing, and engineering of stream channel. According to Hellmund & Smith (2006) these three practices can be considered as ecological disasters because they dramatically modify the function and state of riparian ecosystem including:

- Reduction of vegetation cover and plant diversity (Moffat & Mc Lachlan, 2004; Pennington et al., 2010; Ives et al., 2011; Dallimer et al., 2012)
- Increase of erosion susceptibility associated to de-vegetated soils (Paul & Meyer, 2001; Hellmund & Smith, 2006)
- Stream length reduction (Riley, 1998; Hellmund & Smith, 2006)
- Reduction of infiltration capacities and increase of runoff (Riley, 1998; Paul & Meyer, 2001; Hellmund & Smith, 2006)
- Downcutting effect (Groffman et al., 2003)
- Diminution of water tables and frequency of overbank flow (NRC, 2002)
- Hydrological disconnection between riparian zone and adjacent stream channel (NRC, 2002)

The approach number (2) offers an alternative to introduce stronger social and economic arguments for the conservation, preservation, and restoration of riparian areas in human dominated landscapes such as urban and peri-urban areas. William (1990) explicitly added a category referring to socio-economic functions of riparian areas to the existing physical/hydrological, chemical, and biological function groups. In addition, he states that the major socio-economic concerns are their consumptive value for farming, fuel, hunting, fishing, and fiber and the lack of consumptive benefits for views, recreation, education, science, and history.

Subsequently, Fry et al. (1994) developed and applied an approach to evaluate riparian areas in Arizona and rank river segments based on natural functions, values, and benefits. The assessment included flood control, erosion control, wildlife habitat provision, and recreation opportunity functions.

According to William (1990), it is difficult to identify when a (ecological) function is transformed into a value. As a result, the term benefit can be used when it is impossible to clearly separate a function from a value. The debate on ecosystem services has been trying to illuminate this conceptual ambiguity for the last two decades (See discussion in Section 2.2.3).

Humans historically have a preference to stay/settle near freshwater sources like rivers, streams, and lakes to use them for drinking water and food supply, irrigation, transportation, and industry purposes (Groffman et al., 2003; Steiner et al., 1994). Throughout history, many prominent human settlements have developed intimately with relation to big rivers and lakes. Also small cities, towns, and villages have followed the same pattern. As a result, most present-day cities are located near freshwater sources or were even built on wetlands and riparian areas (Steiner et al., 1994).

Despite the close and long-established relation between all ranges of human settlements, especially cities and riparian areas, the vast majority of riparian research is still concentrated on rural and natural landscapes (Riley, 1998; Groffman et al., 2003). Moreover, most riparian research intentionally avoids urban areas leaving it as a black box or an ecological sacrifice zone. For this reason, Groffman et al. (2003) highlighted "urban riparian ecology is a topic that requires further study in urban areas across the globe "(p. 316).

As result, there is a lack of understanding of 1) the ecological and 2) social state and functioning of riparian zones in urban environments, and on 3) how prominent human-related factors present in cities affect riparian ecosystems and 4) how this can influence social well-being. On the one hand, this produces deficient scientific knowledge about the suitability of elaborated definitions and delineations for urban environments; and on the other hand, that urban planning and decision-making processes insufficiently incorporate this information.

2.2 Greenways: definitions, terms and functions

Greenway mainstream has a long history in the USA and Europe but just recently in the early 1990s it emerged as an international movement. It can be corroborated by the first special issue of Landscape and Urban Planning dedicated to greenway planning in 1995 (Fábos, J. and Ahern, J.). However, that special issue was essentially fed by articles from North America.

A second special issue was published in two parts (2004 and 2006) due to the newly gained international popularity of greenway mainstream since 1995. This second issue had a broader scope, contained works from North America, Europe, Asia, Oceania, Africa, and South America, and has contributed to capitalize the first impulse and obtained a place in landscape planning research (Fábos & Ryan, 2004 & 2006).

The American urban planner William White is considered to be the person who coined the term greenway in his book "Securing Open Space for Urban America" published in 1959 and Little (1990) suggests that it could have emerged from a combination of parkway and the British term greenbelt. Since that time, scholars have continued to work on offering a precise greenway definition for wide acceptance and unification of the variety of other terms based on the same concepts.

2.2.1 Definitions

A greenway can be broadly defined as a swathe of vegetated or open land, because there is a consensus on linearity as key feature on their definition. However, linearity is shared as being a key feature by related terms such as ecological corridors, environmental corridors, ecological networks, parkways, linear parks and recreational corridors.

An important type of greenways are those running along watercourses, which are called riparian greenway. According to Fábos & Ryan (2006), who can be considered as a major leader of the international greenway movement, reflects on this: "Yet, the most significant aspects of greenways planning remain constant-the great majority of greenways are part of natural drainage areas of local, regional, and national territories. These riparian corridors need to be handled with special care. River corridors are the most significant part of the landscape for natural protection, for recreation opportunities, and for proper planning of cultural heritage areas, at every scale" (p. 6).

Ahern (1995) offered a more comprehensive definition to differentiate greenways from other related terms and to include terms mentioned above that had been used as synonyms or considered as proto-greenways. He was concerned about the difficulties of communication and knowledge exchange derived from the little agreement on greenway related terminology, which could be reinforced by the internationalization of the movement and therewith could become a major problem. Ahern (1995) defined greenways as "networks of land containing linear elements that are planned, designed and managed for multiple purposes including ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land use" (p. 134). The definition pretends to be as inclusive as possible and is based on five main ideas:

1) linearity as spatial configuration,

2) linkage as spatial functionality,

3) multifunctionality including social and ecological functions,

4) land uses consistent with the concept of sustainable development, and

5) distinct spatial strategy.

This definition includes ideas that have been present for long time in greenway research and adds other original thoughts. The last three ideas are more innovative compared to the first two that have been used in greenway movement and connected terms. The 5th feature is not explicitly included in the definition, but he discusses how it becomes some kind of emerging feature later in the same paper.

Linearity: greenways follow linear landscape components such as watercourses and abandoned rails, but recently also electrical distribution lines and highways (Searn, 1995; Viles & Rosier, 2001; Yu et al., 2006). They cross kilometers of urban, rural, and natural landscape without interruption and keep a high spatial continuity. This spatial configuration is the basis for the spatial linkage performed by greenways.

Linkage/connectivity: greenways can serve as corridors for people, seeds, animals, sediments, water, and other materials. They facilitate movements along the strip connecting non-linear landscape elements distant from each other, that otherwise remain functionally disconnected and isolated (Kent & Elliot, 1995; Arendt, 2004; Hellmund & Smith, 2006). Nowadays, greenways are seen as a promising instrument to tackle landscape and especially habitat fragmentation.

The term Network employed by Ahern (1995) in his definition doesn't help to elucidate the major debate on a conceptual distinction between greenway and green infrastructure. Benedict and McMahon (2002) defines green infrastructure as "the interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks, and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for America's communities and people" (p. 6). This suggests two issues: (1) green infrastructure is mostly nature conservation oriented, and (2) greenways are a sub-type of green infrastructure, characterized by linking other non-linear sub-types of green infrastructure such as wetlands and major parks.

Multifunctionality: greenways provide multiple functions such as habitat protection, wildlife corridor, recreation, historic preservation, and aesthetic beauty. The simultaneous existence of some uses or functions raises complex sceneries with intrinsically conflictive functional relations and trade-offs, but it also offers an enormous potential to generate consensus on the convenience and priority of greenway development.

Supporting sustainable development: greenways must be planned and managed to help balance environmental protection, social justice and economic development. In other words, they should promote sustainable development principally through offering ecological, economic, and social benefits derived from multifunctionality.

Distinct spatial strategy: greenways can be associated to a particular spatial strategy because it is based on the planning and management of linear elements and systems as key landscape components. This means putting effort on maintaining, protecting, and restoring a linear network over the whole landscape.

The introduction of multifunctionality to the greenway concept by Ahern (1995) has a wide acceptance and might be the most essential idea of Ahern's definition, inasmuch as greenways as spatial strategy and how much they support sustainable development depend on greenway multifunctionality. According to Searns (1995), the idea of multi-purpose greenways arose circa 1985, but Ahern (1995) might be the first who integrated it into a more comprehensive definition.

Multi-objective greenways are the most contemporary face of greenway definition. However, there is no agreement yet on how this idea was originated.

Ahern (1995) suggests this may have emerged from an extension of wildlife corridors and ecological network purposes, such as habitat protection and biodiversity conservation, to include social purposes such as recreation and aesthetic benefits. This perspective is based on landscape ecology progress and affirms even nowadays that the main goal of greenways is to provide a supporting network for biodiversity.

In contrast, Searn (1995) developed a rigorous historical review of the greenway notion evolution. According to his work, greenways appeared simultaneously with urban and landscape planning, and the greenway multifunctionality consequently results from adding ecological purposes (e.g. habitat protection and erosion control) to the typical recreational and non-motorized transport objectives.

Two notions are still outlining the conception and main focus of greenway research and planning: (1) ecological purposes and/or (2) social purposes. Only little research was done on multifunctional greenway assessment and planning.

2.2.2 Greenway research extension and associated terminology

Although the international greenway mainstream has expanded rapidly during the last two decades, the theoretical and methodological development of the greenway framework basically emerged from experiences in the USA and secondly in Europe (Yu et al., 2006). Therefore, research and planning in this field is highly influenced by these specific social and cultural backgrounds, leaving doubts about its applicability in other regions such as Asia, Africa, Oceania, and Latin America.

Greenway research in Asia experienced an impetuous extension providing knowledge on an Eastern World perspective. Yu et al. (2006) point out three main foundlings of their research on greenway planning and implementation in China: (1) China has been planning and implementing greenways for more than 2000 years, where, however, they are named in different manners and planned for diverse objectives; (2) greenway planning and implementation are top-down processes, characterized by a deficient scientific basis and public participation; (3) production and protection (e.g. flood and soil protection) have been the main functions of greenways in China.

Tan et al. (2006) affirm that the greenways movement started in the late 1980s in Singapore associated with forming park connectors between greater parks as part of the Green & Blue Plan. They discuss planning and implementation strategies in densely and rapidly urbanizing areas that may represent other developing cities. Yokohari et al. (2006) found out that changes in Japanese society have originated from the fear of crime, and hence public's perception and resident fear emerge as a key factor in greenway management. In contrast to Yu et al. (2006), Tan et al. (2006) & Yokohari et al. (2006) do not reflect about the implication of their work of using concepts and methods coined and developed in a different socio-cultural background.

African and Latin American scholars have been almost absent from the scientific debate on greenway conceptual development, which does not seem to be changing even nowadays. Fast growing cities and megacities in this highly urbanized and populated region offer new challenges to test the current methodological and conceptual framework for greenways assessment, planning and implementation.

Only few studies on greenways in South America can be found in scientific literature, suggesting an embryonic state of greenway movement in this region. Most of greenway research was developed in Brazil which has a different origin, idiom, and culture than the rest of the continent. Frischenbruder & Pellegrino (2006) and Giordano & Riedel (2008) point out that *parque linear* (linear park) is the equivalent to greenway in Brazil, given that the Portuguese corresponding term *caminho verde* is not in widespread usage. However, other terms such as *corredor verde* and *corredor ecologico* as well green corridor have also been used to refer to the greenway concept (Penteado & De Alvarez, 2007; Rocha, 2011).

According to Frischenbruder & Pellegrino (2006), *parques lineares* can be found at a local and state level, and in an urban and rural context, but most of them focus on flood protection, soil, and habitat conservation. The lack of greenway research and literature is more severe in Spanish America. Academic debates and discussions are in an initial stage where appropriate greenway related terminology, definitions and origins have not been developed yet. This can be exemplified by the absence of consensus on the analogous Spanish term of greenway.

Vía verde is the Spanish translation used by the European Greenway Association (2000). This expression became popular in Spain since the *Fundación Ferrocarriles Españoles* started its *Vías Verdes* program in 1993 to develop hike-bike paths along abandoned railroads (Luengo, 2004). The *Vías Verdes* program follows the same main idea like the Rail-to-Trails movement developed in the USA in the 1960s, which characterized the second greenway generation (Searn, 1995) focus on non-motorized transport and did therewith not fit the contemporary greenway definition. According to Pisa (2004), the *Vías Verdes* program is now part of a larger program called *Caminos Naturales* that also incorporates livestock routes, historic trails, and paths along rivers and canals. In this way, Caminos Naturales is a broader term that includes tourist goals in a more notable manner.

There is no rooting of either *vías verdes* or *caminos naturales* in Latin America. Scholars and practitioners have preferred the term parque lineal or parques lineales in urban and sub-urban landscapes (Bravo-Colunga, 2004; Figueroa, 2009; Molina-Mainieri et al., 2010), and corredor ecológico or biológico in rural and semi-natural areas (Miller et al., 2001; Somma, 2006).

Parque lineal corresponds to the English term linear park, which is a representative type of the second greenway generation (Searns, 1995). *Vía verde* and *parque lineal* do not seem to be appropriate Spanish terms to represent the more complex and broader greenway definition associated with the latest greenway generation.

While there is ambiguity in using terms like *via verde*, *parque lineal*, *corredor verde*, and *corredor ecológico* as synonyms, some authors from Spain and South America reserve *corredor verde* to express an idea closer to the greenway definition offered by Ahern (1995).

Penteado & De Alvarez (2007) defined greenways as a type of corridor, principally based on Forman's (1995) corridor definition, and stated that "as greenways, Corredores Verdes Urbanos have multiple purposes including ecological, cultural, aesthetic objectives, and sustain the five key ideas mentioned before (those proposed by Ahern (1995))" (p. 3).

Pozueta (2009) in Madrid and Pavez (2008) in Santiago focused on *corredor fluvial* as a key term exploring how they have been incorporated in urban planning. Pozueta (2009) prefers to use *corredor fluvial* in his research, but he considers *corredor fluvial* and *corredor verde* as synonymous. On the other hand, Pavez (2008) does not seem to consider these two terms as identical. Rather, she thinks that a *corredor fluvial* can serve as basis for *corredor verde* development.

2.2.3 Functions and ecosystem services provided by greenways

As discussed in the previous section, the current definition of greenway essentially involves the notion of multifunctionality, which according to Hansen & Pauleit (2014) can be assimilated to the provision of multiple ESs. However, in the current literature about green infrastructure and specifically about greenways, the term function has been very importantly preferred over ecosystem services to refer to the benefits that the population obtains from ecosystems.

The Millennium Ecosystem Assessment (MEA) publication in 2005 was the result of a worldwide scientific collaboration of over 1,300 researchers and it reflects the growing importance of the ecosystem services concept and research. The number of papers addressing ecosystem services is rising exponentially (Fisher et al., 2009).

Ecosystem services research focuses on the relation between ecosystem function-state and well-being. The MEA (2005) defines ecosystem services as the benefits people obtain from ecosystems and ranges from the more tangible such as water and food, to those of psychological or spiritual character, such as feelings of peace and relaxation experienced from contact with nature. According to MEA (2005) they can be classified into four groups: (1) provisioning services (e.g., food, water, fiber, and fuel), (2) regulating services (e.g., climate regulation, water, and disease), (3) supporting services (e.g., primary production and soil formation), and (4) cultural services (e.g., spiritual, aesthetic, recreation, and education).

Although the definition and classification of ecosystem service offered by the MEA (2005) has been widely used and accepted, it does not adequately satisfy all purposes and applications, whereby the conceptual distinction between ecosystem functions, ecosystem services, and benefits is still being discussed (Boyd & Banzhaf, 2007; Wallace, 2007; Fisher et al., 2009; Haines-Young & Potschin, 2013).

Today, there is debate regarding that some of the ESs in this classification should rather be considered ecosystem functions, as long as no direct benefit to society is reported. Even Boyd & Banshaf, 2007 and Fisher et al. (2009) proposed to distinguish between final and intermediate ESs, the former being those associated to direct social benefits.

For example, the regulation of nutrients by the ecosystems is not necessarily a function that is associated with a direct benefit to the population, even the natural ecosystem regulation could end up resulting in a soil nutrient concentration harmful to the population. A rather elaborate discussion can be consulted on the issue in Wallace (2007), Haase et al. (2014) and Haines-Young & Potschin (2013).

In the case of ESs such as purification of air and water, provision of water and food, or provision of spaces for recreation, the direct social benefit is evident.

Despite the great development of ecosystem services research, there is not much clarity in the greenways literature regarding the differential use of the concepts function and ecosystem service. An example of this is that in referring to the functions or benefits of greenways, these are normally grouped into ecological, social and economic classifications, without using the classification proposed by MEA (2005) or another in line (Haines-Young & Potschin, 2013) for ES.

Greenways, like other green spaces, can provide a multitude of ecosystem services in urban environments. The variety and intensity of the provision of ES are associated with the type of green space (European Environment Agency, 2011; Landscape Institute, 2009) and the characteristics of the environment where it is located (Gruehn & Hoffmann, 2011). However, in general these include the four ES groups proposed by MEA (2005).

The Table 2.1 presents a generic list of the main benefits of green spaces in urban environments according to the classification normally used in GI literature that differentiates between ecological, social and economic benefits.

Normally, assessments of the provision of ecosystem services in urban environments use as analysis units different types of green spaces, also named element or type of green infrastructure (Landsacape Institute, 2009; European Environment Agency, 2012 and 2014; Haase et al., 2014). These green infrastructure elements are commonly associated with streams, rivers, wetlands, meadows, hills and patches of remnant forests. However, urban environments may also include other types of green components of the landscape, that despite being of artificial origin, support important ecological processes.

Examples of areas within the city that can be considered green infrastructure elements are gardens, plazas, parks, cemeteries, irrigation canals and military bases (Girling et al., 2000; Hellmund & Smith, 2006; Elmqvist et al., 2013). The specific types of green infrastructure present in a given city and suburban environment will depend on the original physical geographical context and distinct dynamics of urbanization.

Table 2.1: Main benefits of green spaces in urban environments, modified after Benedict & McMahon (2002), Tyrväinen et al. (2005) and Pauleit et al. (2011).

Abiotic	Biotic	Social	Economic
Soil development process	Provision of genetic reserves	Better connection to nature and sense of place	Increased property values
Erosion control	Biomass production	Improvement of work and home enviroments	Provision of material and food
Noise reduction	Habitat for generalist species	Physical recreation	Decreased costs for stormwater management
Regulation of climatic extremes	Habitat for specialist species	Improved health	Decreased costs for water treatment systems
Sequestration of carbon	Species corridors	Provide a sense of solitude and inspiration	
Air and water purification	Maintenance of disturbance and successional regimes	Stimulus of artistic/abstract expression(s)	
Maintenance of hydrological regime(s)	Support of flora and fauna interactions	Experience and interpretation of cultural history	
Surface and ground water interaction		Opportunities for healthy social interaction	
Buffering of nutrient cycling		Environmental education	

Currently, there is a lack of analytical frameworks that specifically identify and address ecosystem services particularly provided by greenways and therefore, a priority in their evaluation and planning. However, by reviewing the literature specific to urban greenways, it is possible to detail the most frequently analyzed functions (Searns, 1995; Benedict & McMahon, 2002; Hellmund & Smith, 2006; European Environment Agency, 2011).

a) Facilitate flow of organisms, matter and energy: Greenways connect distant parts of the landscape, allowing exchange between them. Greenways can act as a habitat for certain species of animals and plants, and as biological corridors for others. As biological corridors, they contribute to the dispersion of species, habitat connectivity and consequently the establishment of viable metapopulations. When considering riparian corridors, where the role of the watercourse is added, flows contributed by the greenway include sediment, seeds, air and water. Greenways also facilitate the movement of people into the cities, since they provide attractive and safe routes to move from one place to another. Hence, they are very importantly used as non-motorized transport routes, as part of routes for sports (running, walking or bicycling) and tourism.

b) Climate regulation: Greenways contribute to climate regulation of cities through two effects (1) moderating temperature extremes and decreasing air temperatures produced from tree shade and evapotranspiration, and (2) acting as fresh air corridors and circulation.

c) Provision and purification of water: Like other green spaces, greenways allow groundwater refill and runoff into wetlands, ponds, streams and rivers. At the same time, greenways improve water quality before it reaches water bodies and watercourses through the removal of sediment and pollutants. This effect is especially important in riparian greenways.

d) Reduction of damage from flooding: Greenways can accumulate and absorb excess runoff after rainfall. Additionally, the corridors can maintain strips of land excluded from urbanization around watercourses, avoiding damage to people and infrastructure caused by overflow.

e) Preservation of the historic and cultural heritage: The designation of a greenway around a landscape component of historic significance contributes to the protection of the historic and cultural heritage of the territory. Linear components of the landscape with historic value include former railways, aqueducts, rivers and ancestral migration routes or religious pilgrimage.

f) Habitat for plants and animals: Greenways, especially riparian, can contain a variety of habitats in a relatively small strip of land. This function strictly depends on the type or specie of animal or plant that the evaluation is focused on.

g) S*ocial interaction and recreation:* Greenways provide important opportunities as a space for individuals to meet, social interaction and community cohesion. They also offer spaces for recreational activities both passive (contemplation, relaxation and contact with nature) and active (sports, tourism and active travel-oriented sports). As well as spaces for social interaction or recreation, greenways offer greater physical access to these services due to its linearity

h) Scenic beauty and increased property value: Corridors contribute to the beauty of cityscapes, providing green spaces to the urban environment and also because they normally follow the path of unique and attractive natural linear components (rivers, streams and slopes) and cultural (bridges, canals and railroads). Therefore, the existence of a greenway means an increase in the value of land and neighboring properties.

Normally, these functions have different priorities in evaluating greenway potential. Based on the availability of information, local characteristics and expert opinion, Miller et al. (1998) selected (in order of importance) wildlife habitat, recreation and riparian corridor as the most relevant functions to delineate greenways in Prescott Valley, AZ, USA. In contrast, Teng et al. (2012) did the same but prioritizing corridors that could help conserve local biodiversity, provide spaces for recreation and protect main water bodies.

In both cases, the idea reaffirmed the use of generic functions of green spaces (habitat and recreation) instead of the consistent use of priority functions of greenways, for example, those associated with movement.

Considering this, it is possible to find some basis that could guide the development of an analytical framework that differentiate between ecosystem services specifically provided by greenways.

For example, green infrastructure components are often classified into a hub, core and corridor using an approach based on the matrix-patch-corridor model developed in landscape ecology (Forman & Godron, 1986). The hubs are ecosystems in good condition and functioning, which support key ecological functions, such as provide habitat for native species, the cores are land adjacent to the hubs that significantly contribute to water purification, flood control, carbon sequestration and recreation of the population, and finally, corridors are linear elements that connect cores and centers, and are essential to the movement of animals, plants and people (Benedict & McMahon, 2006; Hellmund & Smith, 2006; Chicago Wilderness Green Infrastructure Vision Task Force, 2012). This classification provides light on the most important functions of corridors.

Although there is great development of this functional approach to classify landscape components in the field of conservation ecology, this is much less developed concerning the social functions of different types of green infrastructure as well as on how this approach is connected with the paradigm of ecosystem services.

There is a need of a framework that connects ecosystem services research with the spatial components of a green infrastructure system that contributes to clarify the priority ecosystem services in each green infrastructure element. This may occur due to the difficulty of attributing generic functions or services to spatial components of the landscape, as these may vary depending on many factors such as size and users (species-people) considered.

Finally, according to an exhaustive revision of Hasse et al. (2014), the study of ESs in urban environments has been marked by (1) the lack of studies in regions such as Africa, Asia and Latin America, and therefore, their low participation in the international academic debate, hinders knowing the adequacy of the conceptual and methodological approaches to different geographical and socio-cultural contexts, (2) the evaluation of only one or two ES and thus, the inability to perform an analysis of trade-offs and identification of multifunctional green infrastructure, and (3) a deficit in historical analysis especially for periods longer than 40 years.

The assessment of ESs in urban environments in Chile is extremely scarce and has concentrated on empirical studies at a local scale. For example, Escobedo et al. (2006)

evaluated the role of urban trees as a mechanism for air pollution control in Santiago de Chile, and Vergara & Vásquez (2014) evaluated the provision of five ESs in a greenway also in Santiago. Nevertheless, there are no published studies developed in Chile that simultaneously consider multiple ESs in urban environments at a city or landscape scale, or that are based on the potential use of GIS for mapping ESs and its subsequent application to land use plans.

The development of indicators for assessing potential provision of multiple ESs is an emerging field and under development in international science (Haase et al., 2014). Consequently, an important aspect is the adaptation and development of indicators for use in diverse urban environments in Chile, that fit their different spatial scales and regional contexts.

In this context, progress in Chile in this matter appears as an important contribution to the scientific knowledge in construction and its application to planning sustainable cities.

2.3 Greenway assessment research

Greenway research has been focused on three main issues (1) greenway concept elaboration and transferability analysis as well as revision of greenway planning experiences, (2) evaluation of greenway impacts and functions, and (3) development of greenway delineation and planning methods.

The first group includes works elaborated by Turner (2006) in Britain, Ribeiro & Barao (2006) in Portugal, Frischenbruder & Pellegrino (2006) in Brazil, Yu et al. (2006) in China, and Molina-Mainieri et al. (2010) in Costa Rica. For example, Turner (2006) studied how the greenway concept is understood and how it is used in Britain through questionnaires distributed among local authorities. He found that Ahern's definition is the most supported and that greenways have a notable potential as a landscape planning tool. The other studies mentioned above also support the idea that greenways have great potential for supporting more suitable landscape around the world.

Research on greenway impacts (second group) has demonstrated a variety of positive effects on ecological and social spheres. In social terms, Lindsey et al. (2004) studied greenway impacts on property value and recreational benefits in Indianapolis. They found that most greenways have a significant positive effect on both analyzed factors. Meanwhile, Schafer et al. (2000) pointed out that users perceive that greenways in Texas contribute to quality of life through resident's health, provisioning natural areas, and resident's pride.

In ecological terms, Mörtberg & Wallentinus (2000) found that green space corridors support seven red-listed breeding forest birds in a Swedish urban environment. Tewksbury et al. (2002) pointed out the importance of greenways as biological corridors for plants inasmuch as they found that seeds of two shrubs were dispersed by birds more effectively when habitat fragments were connected by corridors.

Research on greenway delineation and planning methods (third group) is by far the least developed, producing a lack of scientific basis to support successful and sustainable planning processes. According to Frischenbruder & Pellegrino (2006) and Yu et al. (2006) this research gap is even more accentuated outside North America or Europe. As a major focus of this thesis, research on greenway assessment, delineation and planning will be discussed in detail in the following.

The first experience of systematic greenway planning can be found in Phillip Lewis' work in the early 1960s. Lewis was a professor at the University of Wisconsin in Madison and took part in the new movement in planning and design with strong emphasis on ecology. He identified environmental corridors in Wisconsin and Illinois by overlaying and analyzing transparency maps of natural characteristics and resources (Lewis, 1964). A similar approach was later popularized by McHarg's book "Design with Nature" published in 1969.

Steiner & Brooks (1981) made a literature review and found common phases in existing ecological planning methods. They distinguished seven steps that follow the transformation of data: 1) define planning goals, 2) ecological inventory and analysis, 3) suitability analysis, 4) alternatives, 5) implementation, and 6) administration, and 7) evaluation.

Scientific knowledge is especially required in steps 2, 3, and 4, whereas the remaining steps have a stronger emphasis on political and economic factors. Steps 2 and 3 can be considered essentially as the assessment stage. As stated by Cook (1991), inventory and description constitute the first part of an assessment, which consists of evaluating the relative ecological worth or quality of an area. In this manner, the ecological inventory and analysis and the suitability analysis described by Steiner & Brooks (1981) can together be considered as the assessment phase.

The ecological inventory and analysis incorporate the relevant physical, biological, and social factors that characterize the study area. It may include geology, physiography, groundwater, surface water, soils, climate, vegetation, wildlife, population size, population structure, and land uses (Boyden, 1979; Steiner & Brooks, 1981).

In the case of riparian greenways, other factors identified as relevant in the assessment of riparian environment can be included (see Table 2.2).

Most greenway planning experiences have followed these steps and sequences. However, due to the boom of landscape ecology and its conceptual and methodological framework, suitability analysis has often been replaced by landscape elements rating. As a consequence, it is possible to identify different approaches for distinct conceptual streams.

Analytical approaches of greenway planning can be classified into two main groups: (1) those based on landscape analysis and (2) those based on suitability analyses. Nevertheless, Teng et al. (2011) identified three classes (a) landscape process based methods, (b) structural landscape indices methods, and (c) suitability analyses. The main difference between (a) and (b) is that the landscape process based methods analyze potential interactions (flows) among nodes (patches) that belong to a network beyond structural landscape characteristics. However, as (a) and (b) have a common foundation derived from landscape ecology principles and perspective, they can be considered as part of a wider group of landscape analysis.

Table 2.2: Additional relevant factors in riparian environment to include in the ecological inventory.

Factor	Reference
Composition and structure of riparian vegetation	-Munné et al. (2003) -Del Tánago et al. (2006)
Connectivity between the streambed and riparian zones	-Del Tánago et al. (2006)
Alteration of riparian soils	-Del Tánago et al. (2006)
Impervious cover (%)	-Center for Watershed Protection (2004)
Riparian woodland cover (%)	-Munné et al. (2003) -Center for Watershed Protection (2004) -Del Tánago et al. (2006)
Road crossings	-Center for Watershed Protection (2004)
Channel alteration	-Munné et al. (2003)

Works reported in Baschak & Brown (1995), Ndubisi et al. (1995), Linehan et al. (1995), Cook (2002) and Teng et al. (2011) have conducted greenway planning processes based on landscape principles and techniques of landscape assessment. This approach commonly identifies landscape elements as corridors, nodes and patches, recognizing their internal integrity as well as the integrity at a landscape level. Landscape structure metrics analysis, connectivity and network analysis, identification of valuable areas, assessment of social and ecological services, and land-use/cover change analysis are also key components of this approach.

Conversely, the approach with a focus on land suitability analysis has been advocated by Miller et al. (1998), Giordano & Riedel (2008), and Du et al. (2012). They used computer-assisted overlay mapping and multicriteria analysis (MCA) methods to identify specific sites that satisfy a set of features. This approach provides a greater replicability than the approach described previously and permits the joint consideration of very different aspects like social benefits, conservation requirements, and development needs. However, aspects related to landscape functioning or changes over time are not included.

Although the actual conception of greenways is defined by their multifunctionality and capacity to provide social and ecological functions simultaneously, the majority of efforts have been put on monofunctional greenway planning and implementation. In the following, the three most relevant analytical methods existing hitherto for multifunctional greenway planning, which also represent the main two planning approaches described above, are described in detail.

Miller et al. (1998) developed a suitability analysis in the town Prescott Valley, Arizona (U.S.) to identify sites for greenway development. They used a method composed of five steps: (1) identification of land-use functions, (2) spatial data collection, (3) development of weighting values, (4) data integration and analysis, and (5) output evaluation.

The land-use functions or goals defined using the Prescott Valley Plan and considering advice from community officials and general public comprise of wildlife habitat, recreation, and riparian corridor. At the same time, four or five suitability factors for each function were identified as most relevant by literature review and expert opinion. The spatial data collection was focused on information related to these factors. Subsequently, a participatory procedure with experts and stakeholders was carried out to rank (1) functions, (2) factors within functions, and (3) classes within factors. Wildlife habitat (weight=1.0) was identified as the most important function followed by recreation (weight=0.86) and riparian corridor (weight=0.65). Factor layers were overlaid to obtain a suitability map for each function. The maps were then combined to produce an overall greenway suitability analysis. This integrative suitability map was evaluated by a panel of experts to provide feedback.

Although Miller et al. (1998) overcame most criticism against suitability analysis (lack of soft information and participatory approaches) some drawbacks remain. For example, they assigned an average weight to each factor and function derived from a mathematical mean calculated using all single weights collected through interviews and questionnaires. This procedure hides the large complexity associated with the variety of opinions and interests expressed by different weights. A second limitation of the suitability analysis, which is even more difficult to overcome, is its inability to evaluate processes and spatial interactions.

Moreover, Teng et al. (2011) applied a method based on landscape process analysis consisting of a least-cost path model, a kernel density analysis, and a proxy index to plan a priority greenway network. They applied this approach to the metropolitan area of Wuhan (China) as a pilot area of changing cities. Their research follows three stages: (1) identification of goals and objectives, (2) demarcation of potential greenways for various purposes, and (3) designation of a comprehensive greenway network.

Initially, biodiversity conservation, recreation, and water protection were identified as the main objectives of greenway development through a literature review. Secondly, sources/destination points for conservation and recreational functions were selected and the least-cost paths between each pair of source-destination points were delineated. The cost value used for conservation of focal assemblages was associated to (1) costs of travelling through each type of land cover, (2) costs of overcoming the influences of anthropogenic disturbances (Euclidean distance between the analyzed cell and the nearest built-up cell), and (3) the construction costs (according to the existing vegetation condition). Teng et al. (2011) used only one global cost value for recreational greenway analysis.

Next, the least-cost paths were transformed into points and the kernel density was calculated to estimate the potential utilization intensity of the corridors. The greenway network for biodiversity conservation and recreation were delineated by linking areas with a high kernel density value. The greenway network for water protection was directly delineated by buffering watercourses and water bodies. Finally, these three networks were integrated into a composite greenway network.

The study of Teng et al. (2011) is a step forward in using potential interaction analysis at landscape level for multifunctional greenway network planning. However, it shows the common problem of a high asymmetry of quality and complexity of assessment procedures of greenway potential for different functions or objectives. In this case, the assessment procedure for biodiversity conservation greenway delineation was extraordinarily more sophisticated and meticulous without explicit reasons. This was consequently reflected on the multifunctional greenway network proposed.

The last relevant study was performed by Conine et al. (2004) in Concord, a small city located in North Carolina (U.S.). They proposed a methodology consisting of seven steps: (1) identification of goals and objectives, (2) assessment of potential demand areas, (3) assessment of potential connectivity supplies, (4) assessment of site suitability, (5) assessment of accessibility, (6) delineation of corridors, and (7) evaluation.

Recreation, environmental protection, and alternative transportation were identified as goals by meetings with city officials and are based on requirements of the community. In the same manner, parks, schools, residential areas, and employment centers were evaluated as areas of high connectivity need or demand areas. In parallel, potential connectivity supplies provided by linear elements such as floodplains and roads were evaluated.

A suitability assessment was performed using factors and weights selected by focus groups of planners, experts, and local citizens/activists and using connectivity supplies identified before. Lastly, the accessibility of suitable areas by existing transportation infrastructure for potential trail users was also evaluated.

In the end, the suitability and connectivity maps were overlaid and a composite score was calculated. Three greenway alignments were created linking the cells with the highest composite scores to connect areas of high demands.

This methodology can be considered as an embryonic integration of landscape analysis and suitability analysis approach, bringing together a generic suitability analysis and a connectivity analysis. However, some limitations can be pointed out.

Connine et al. (2004) mentioned to have used the procedure proposed by Xiang (1996) to find the best path to link areas of high demand following the highest composite scores, but it seems that this procedure was performed manually with the associated lack of replicability. Furthermore, the assessment was focused on generic suitability factors and connectivity aptitude, but the three goals identified were not directly addressed. As a result, it is impossible to know which areas have more aptitude to provide a given function.

This revision shows the relevance of improving the existing methods for multifunctional greenway planning especially in large cities. Any progress in this area should address: (1) the spatial, functional, and political complexity inherent to the nature of multipurpose landscape elements, (2) the opportunities and challenges that represent urban environments, especially large cities, for multifunctional greenway planning and implementation, and (3) an integration of those two approaches described before (suitability and landscape analyses) as well as a stringent elaboration of associated concepts and terminology.

Chapter 3

Development of a conceptual and methodological framework for riparian urban Greenway Potential Assessment

According to the review conducted by Hansen & Pauleit (2014), despite the increase in scientific research and discourses on the context and approach to green infrastructure, there is still a lack of an analytical-conceptual framework focused on the implementation and practice of urban planning. These authors also point out that there is only little research on the implementation of green infrastructure from a socio-ecological perspective. As Hansen & Pauleit (2014) suggest, there are important gaps in the different approaches to GI (green infrastructure) assessment and development that need further development:

. The use of the term function is not clear

. The operationalization of multifunctionality as a planning principle

. The definition of demand according to certain functions

. The use of the (average) added value of multifunctionality

. Relationships among different functions

The following proposal offers a transferable conceptual and analytical framework intended to bidge the above mentioned gaps and contribute to greenways assessment and planning. This chapter states the principles of the model, defines the concept of potential, and presents a methodological framework that can be applicable to other urban environments.

3.1 The principles of the conceptual framework

The clarification of key concepts and how these are related are necessary for further work.

3.1.1 Ecosystem services and functions

Much of the literature on green infrastructure (GI) focuses on the concept of function to refer to the role and ecological, social and economic benefits related to GI. There are also allusions to the concepts of objective and purpose (Ahern, 1995; Teng et al., 2011) to refer to these same roles and benefits, this time with an emphasis on the intention pursued during the design and planning of GI.

Moreover, the definition of greenways proposed by Ahern (1995) and used in this conceptual framework includes the terms of purpose: "networks of land containing linear elements that are planned, designed and managed for multiple purposes including ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land use" (p. 134).

In order to avoid this ambiguity, and according to Hansen & Pauleit (2014), this research proposes the use of the concept of ES (ecosystem service) due to its consolidated theoretical basis and its clear and shared definition. In this sense, this paper adopts the perspective of Boyd & Banzhaf (2007) and Fisher et al. (2009) —which is discussed in Section 2.2.3— with the intention of choosing a nomenclature and a definition related to a final or second-class ES that is clearly differentiated from ecological functions.

The ESs that appear in the MEA (2005) classification (see Section 2.2.3) should not be considered as such or should be reformulated. For instance, climate regulation should be classified as an ecological function and not as an ecosystem service. In this case, the ecosystem service may be the cooling effect or the decrease in extreme temperatures.

3.1.2 Specific characteristics of ecosystem service within the context of greenways

Of all the ecosystem services discussed in Sections 2.2.3, there is a need to identify those related to greenways in terms of their geometry and function within an integrated green infrastructure network.

In the context of the spatial and functional structure of a green infrastructure system, the major features of corridors are linearity, connectivity and flows or movements (Benedict & McMahon, 2006). This emphasizes, in first place, the specialization of greenways - as a specific type of corridor – in providing connectivity and facilitating the exchange among other green infrastructure components (cores and hubs), and in second place, that others types of green infrastructure are less capable of providing the green infrastructure system with this functions.

In the field of urban ecology, Forman & Godron (1986) identified six functions of corridors: conduits, habitat, barrier, source, sink, and filter. Although a greenway has the potential for all these functions, they should be devoted to those which cannot be provided by hubs and cores, including to promote flow and movements and to act as a filter or buffer of pollutants, noise and water. The buffering function is especially important in riparian greenways.

Since the identification of these functions is focused on the conservation of biodiversity and role of green spaces as a habitat, it is difficult to extrapolate the other functions (habitat, barrier, sink and source) to the social and economic dimension involved in an urban greenway. For this reason, the functions of habitat, sink and source are used mainly in research on cores and hubs.

As mentioned in Section 2.2.3 a greenway can serve as a habitat, moderate temperatures and serve as space for recreation, but this will depend essentially on that the size and width of the corridor are sufficient to permit the development of internal resources (e.g. vegetation and facilities) that support these functions.

These considerations help in understanding and defining the role of greenways within the context of a broader and more strategic planning framework for green spaces, and support the classification of urban ecosystem services based on the degree of greenway specialization presented in Table 3.1. A separate description of these ecosystem services and associated references can be found in Section 2.2.3.

The ability of a greenway to provide a determined ES is highly influenced by (1) characteristics of the corridor such as width, length, type of vegetation and facilities, and (2) the type of user that is considered, either a specie or focal assembly in particular or a group of people defined according to socio-economic status, age or any other characteristic. Consequently, it is extremely difficult to develop a generic or comprehensive classification of ecosystem services that may be provided and the intensity of provision from greenways. However, the following presents a proposal is elaborated that is sensitive to the role of corridors in the context of a green infrastructure system and therefore, to the services that should be devoted.

The classification proposed distinguishes four categories of ESs associated with greenways, based on the role that greenways meet in a green infrastructure system and the priority the ecosystem services should have in their planning and management. Additionally, it guides the method for evaluation according to class (see Section 3.3.2).

Table 3.1: Classification of ecosystem services according to the degree of greenway specialization.

Primary	Secondary	Tertiary	Quaternary
Flow and movements	*Buffer and protection*	*ESs may benefit from linearity*	*ESs may harm from linearity*
Increase biological connectivity (biological corridor)	Noise control	Recreation	Cooling effect
Fluvial corridor	Retention of sediments	Esthetic value	Provision of habitat
Local and regional ventilation Wind/fresh air corridor	Filtration of pollutants	Increase in the value of properties	Spiritual value
Provision of route for non-motorized transportation	Flood hazard mitigation		
Provision of route for sport-related activities			
Preservation of heritage-historical route			

Source: Author's own elaboration based on Forman & Godron (1986), MEA (2005) and Hellmund & Smith (2006).

Primary Ecosystem Services of greenways:

There is a group of ecosystem services particularly offered by greenways, which are determined by their linear shape and function connecting other green spaces. This group of ES is related to flow and movement of people, fauna, seeds, water or any other material and/or energy. Primary Ecosystem Services are defined by the linear shape of greenways that facilitates landscape connectivity, thus serving as corridors or conduits.

The benefits of greenways acting as a biological corridor or route for non-motorized transportation of people, and the consequent increase of biological and social connectivity, are key in defining this group.

Secondary Ecosystem Services of greenways

The Secondary Ecosystem Services are related to situations where a resource or value is surrounded by the greenway, which can be a course of water, a railway or a historical route.

In these cases, the corridor serves as a buffer that protects a given resource either by reducing or controlling the levels of noise, erosion or pollution.

This group also includes the cases in which the greenway protects the urban matrix (infrastructure and people) from the potential impacts and negative effects derived from linear components of the landscape, such as overflowing or flooding events, the noise pollution caused by highways or detriment to landscape quality caused by high-voltage lines.

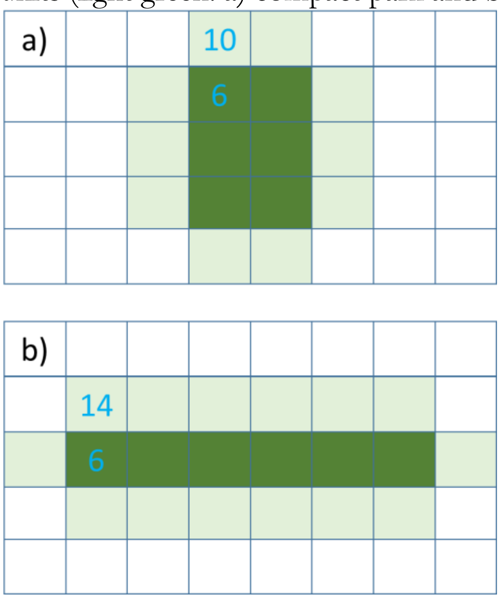
Tertiary Ecosystem Services of greenways

In the third place, there are the Tertiary Ecosystem Services, which are generic ecosystem services that can be provided by any green area or green infrastructure type, but these may benefit from the linear nature of greenways.

Due to the area/perimeter ratio, linear areas facilitate access to more people since direct neighbors and the exposed perimeter of a greenway are greater than that of a compact park of the same area. Therefore, greenways can be more important than other green areas in terms of absolute access to recreational spaces.

Figure 3.1 illustrates how the shape of a green area affects the quantity of neighboring spatial units. It can be observed that, while a compact park distributed among six cells has ten neighboring cells (see Figure 3.1a), a linear park distributed among the same six cells has 14 neighboring cells (see Figure 3.1b).

Figure 3.1: Effect of green area's shape (dark green) on the quantity of neighboring spatial units (light green. a) compact park and b) linear park.



Source: Author's own elaboration.

Quaternary ecosystem services of greenways

Finally, there are other ecosystem services that can be offered by other types of green spaces and can be negatively affected by the linear nature of greenways. In opposition to Tertiary Ecosystem Services, elongated green spaces with small area-perimeter ratios, more edge effects and small core areas may negatively affect the provision of ecosystem services based on interior environmental conditions. Ecosystem services such as habitat for animals, plants and cooling effect are better provided by large and compact green spaces.

3.1.3 Multifunctionality and trade-offs of ecosystem services in linear spaces

One of the basis of the concept of greenways —and any type of green infrastructure— is multifunctionality. Since the concept of multifunctionality has been widely used in the context of GI, and according to the above discussion on the preference of the concept of ES over the concept of function, this conceptual framework uses the notion of multifunctionality as a synonym for multiple ecosystem services. Therefore, multifunctionality is understood as the capacity to provide multiple ecosystem services at the same time.

According to the idea proposed by Ahern (1995) and Hellmund & Smith (2006), multifunctionality should include the provision of multiple ecosystem services in order to combine social welfare with environmental health. Consequently, this notion should necessarily involve the provision of two or more ESs and include at least one cultural service —as those described by MEA (2005).

Another important aspect to consider when thinking of the provision of multiple ecosystem services is the kind of relationships existing between them, especially when referring to synergy and trade-off (Haase et al., 2012). A synergistic relationship can be defined as the positive interaction between the provision of two or more ecosystem services, namely the increase in the provision of an ecosystem service as the result of the provision of another service. Furthermore, a trade-off between ecosystem services occurs when the provision of one service reduces the provision of another service.

This kind of relationship between ecosystem services defines two possible —and opposite— types of spatial configuration within the context of planning multifunctional greenways.

Firstly, when there is a trade-off or a predominance of incompatible ecosystem services, the solution is to choose planning options that involve spatial segregation. In other words, the idea is to define different segments or areas along the greenway that provide only a single ecosystem service. This produces a mosaic composed of areas that provide a unique service (monofunctional), thus conferring a multifunctional character on the corridor as a whole.

Secondly, in the case of synergistic ecosystem services, the solution would be the establishment of multifunctional zones throughout the greenway. In this sense, each zone would provide multiple ecosystem services.

In this second model, it is particularly difficult to achieve the maximum potential provision of ecosystem services in given spatial units, because of the intrinsically conflictive nature of the relation between cultural ES and the other ESs (provision, regulation and support).

Likewise, these spatial strategies can also adopt hybrid models that combine both perspectives, including mono- and multi- functional sections.

Lastly, another important aspect to consider is the dependence of Primary Ecosystem Services on a continuous strip of land that should not be interrupted by other type of uses and/or activities. Unlike the spaces intended for recreation, infiltration or climate regulation, which can have compacted and fragmented configurations, all the ESs related to flow and movement require at least structural connectivity throughout the whole greenway.

3.2 The potential of multifunctional greenways

The term Potential has different definitions that include the change from a current state (or situation) to a future state; the more the possibilities, the more the potential to achieve a given condition. Therefore, the concept of potential is related to the capacity to develop or transform into something in the future.

Hence, the term potential is determined by the presence and magnitude of certain conditions that modify the current state of a phenomenon or situation. Therefore, in order to assess the notion of potential, there is the need to clearly define at least three aspects, namely, (1) the current state; (2) the assessed future state (which may be desired or non-desired); and (3), the conditions that affect the possibilities of the current state to become an assessed state.

Within the context of highly dynamic and interacting socio-ecological systems —as urban systems—, changes in the state and functioning are simultaneously determined by the ecological, social and built environment features and the perceptions and interests of those involved in decision-making processes. Moreover, in some urban ecosystem models human decisions emerge as a driver that generate and control the changes that occur in the city (Pickett et al., 1997; Alberti, 2008).

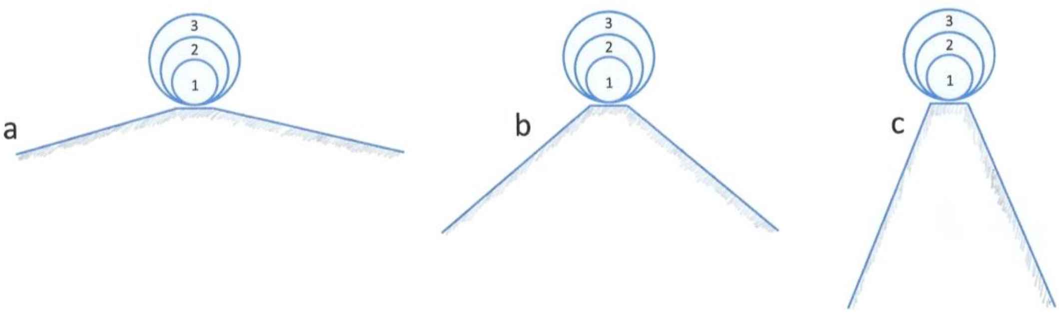
In this context, the chances for a current situation (or feature of the urban system) to change into a desired state —namely the potential—, depend on both the capacity of socio-ecological conditions to become those desired and how much decision makers perceive the opportunities to materialize the expected situation.

This research proposes that the potential concept, within the context of the development of multifunctional green infrastructure, is determined by (1) the suitability to provide multiple ecosystem services and (2) the opportunities and challenges for the development of the green infrastructures envisaged by decision makers. Within this conceptual framework, while the suitability to provide ecosystem services is defined by the socio-ecological characteristics of a given area of the city, the opportunities and challenges represent the possibilities identified by stakeholders in a given political-institutional system to generate an expected change.

According to Figure 3.2, the position of the sphere in relation to the terrain represents a current condition prior to the development of urban green infrastructure (at landscape or site level) and the position at the end of the slope corresponds to the desired situation that has already been developed in terms of green infrastructure. In this way, the concept of potential is defined as the capacity of the sphere to reach the desired position, which depends on the force field resulting from the configuration of a system or situation. The latter is represented by the size of the sphere and the slope of the terrain.

The size of the sphere illustrates the suitability for the provision of multiple ecosystem services and the gradient below the sphere represents the political-institutional conditions within the context of opportunities and challenges. Likewise, 3>2>1 symbolizes suitability aspects and c>b>a represents opportunities (values are reversed in the case of challenges).

Figure 3.2: Model of different combinations between suitability and opportunities-challenges enable the definition of different levels of potential. 3>2>1 in terms of suitability and c>b>a in terms of opportunities



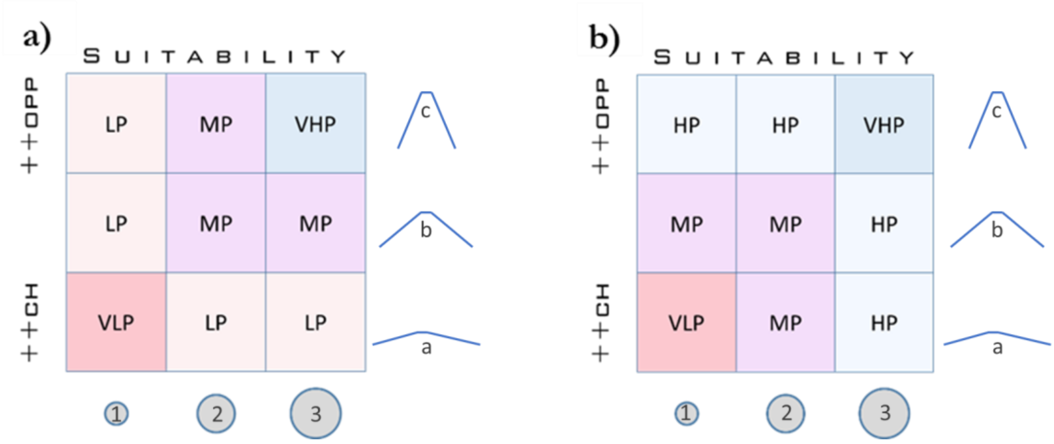
Source: Author's own elaboration.

Therefore, different combinations between suitability and opportunities-challenges enable the definition of different levels of potentiality (see Figure 3.3). A potential rated as very high is associated with high levels of suitability and a predominance of opportunities over challenges when it comes to the development of green infrastructure. On the contrary, a potential rated as very low represents a situation in which socio-ecological characteristics are directly associated with both a low suitability for the provision of multiple ecosystem services and the predominance of challenges over opportunities in terms of the development of multifunctional green infrastructure.

In this context, intermediate categories can be determined by using approaches focused on a previously assessed (weighted) dimension or being more (Figure 3.3a) or less

(Figure 3.3b) demanding with the acceptable levels of suitability and opportunities-challenges for the development of a given potential.

Figures 3.3a and 3.3b: Different combinations between suitability and opportunities-challenges enable the definition of different levels of potential. ++CH= more challenges, ++OPP= more opportunities, VHP= very high potential, HP= high potential, MP= medium potential, LP= low potential, VLP= very low potential.



Source: Author's own elaboration.

Finally, this diagram could be used and adapted to conduct different analyses at different spatial scales, ranging from regional and landscape perspectives —in order to evaluate a complete network of green infrastructure — to local scales —in order to evaluate the potential to implement concrete plan intended to develop a specific type of green infrastructure, such as wetlands, forests and greenways.

3.3 Proposed methodological framework

In the following, a comprehensive methodological framework for multipurpose urban Greenway Potential Assessment is proposed, which has been developed to improve the existing methods discussed in Section 2.3 and according to the conceptual framework outlined in Sections 3.1 and 3.2. After providing an overview about the main steps of this study, the single methodological steps are described in more detail.

The Greenway Potential Assessment permits the identification of areas with the highest potential as multifunctional greenways. A key element of the proposed methodological design is the organization of information into three levels that represents increasing stages of data integration:

1) Socio-ecological analysis: involves the identification and mapping of raw data for abiotic, biotic, and cultural resources, organized to permit an identification of social and ecological state and functions as well as the development of scientific inputs for the following two stages. The socio-ecological analysis provides a summary picture

as well as a better understanding of current social and environmental characteristics and functioning of the riparian zones.

2) Greenway suitability analysis: The purpose of this step is to estimate the suitability of riparian zones for the provision of ecosystem services within a GIS environment. In the case of Primary ESs, optimal route models (or similar) should be implemented. In the case of Secondary or Tertiaty ESs, multicriteria evaluations are preferred. The results of these analyses are spatially explicit and correspond to a single suitability map for each ES and different suitability maps for multiple ESs.

3) Opportunities and challenges analysis: involves the identification of opportunities and challenges for greenway development in order to provide a description of the key factors to consider in greenway planning. This phase permits the understanding of possible gaps or overlaps of competences, regulations, and administrative procedure as well as the reasons of environmental degradation issues identified during the socio-ecological analysis.

4) Multifunctional greenway potential: the purpose of this step is to integrate and discuss the spatial and non-spatial information produced in previous analyses (1), (2) and (3). The potential-based model outlined in Section 3.2 should be used to reflect on the potential of the analyzed strip for the development of a Multifunctional Greenway. Such a process should be conducted in terms of the suitability for ES provision and the identification of opportunities and challenges.

These four stages provided at the same time increase scientific knowledge about the environmental status and potential of riparian zones and specific products for the next research stage.

3.3.1 Socio-ecological analysis

According to Baschak & Brown (1995) an inventory of the main features of the study area is the first step in an assessment procedure. In the same way, Ribeiro & Barao (2006) and Xu et al. (2012) identify that the current conditions of the target area are the basis for the further assessment and planning steps.

The socio-ecological analysis involves the description, mapping, and recording of natural, social, recreational as well as cultural characteristics of riparian zones. The latter are organized to permit an identification of social and ecological functions as well as the current state of riparian zones.

The thematic maps and outcomes of this step are the basis for further assessment and discussion.

Firstly, this phase involves collecting and organizing information about the social and ecological aspects of urban riparian areas. The latter should involve the development of an alphanumerical and geospatial database and implementation into a GIS for further stages.

Secondly, this raw information should be used for the analysis of the social and ecological characteristics of the area.

In social terms, the analysis of the distribution of population and its demographic and socio-economic characteristics is needed. In this context, it is recommended to recognize the areas where the population is concentrated as well as its socio-economic condition and age structure. In addition, the analyses of the urban aspects that give us insights into the structure and physical configuration of neighborhoods —including the type, size, quality and height of dwellings, the price of land and the distribution of public green spaces— should be included. It is also important to know the land use/land cover in order to recognize industrial and residential zones or the presence of vacant lands in the riparian zone.

All of this helps to understand and delineate special needs and basis for the green infrastructure planning.

In ecological terms, it is important to know the distribution of vegetation, the composition of flora, the channel alteration and the temperature and wind patterns of the analyzed area.

Thirdly, the Socio-Ecological Analysis identifies patterns within the spatial distribution of the mentioned characteristics. Longitudinal gradients along the watercourse of given features can be performed. For example, to analyze the variation of industrial areas or the percentage of native flora along the riparian zone. In addition, gradients perpendicular to the river may also be evaluated in order to test, for example, distance-decay functions in the proportion of native species, population density and air temperature.

Lastly, the Socio-Ecological Analysis includes the development and implementation of indicators on the state and/or functioning of the riparian area in relation to its social and ecological dimensions. These indicators should be based on available information and features identified as important in previous phases. For instance, it is possible to include the percentage of green spaces or vacant lots as well as the percentage of industrial areas or bikeways.

These analyses - especially those related to the use of indicators - may cover either the complete riparian area under analysis (as a whole) or segments within them. These segments or spatial sub-units may result from the division of the analyzed area through the use of regular intervals or communal and neighborhood borders.

3.3.2 Greenway suitability analysis

The Greenway Suitability Analysis consists of two complementary approaches: 1) using a multicriteria analysis (MCA) technique and analytical hierarchy process (AHP) (Liu et al., 2007) to assess the suitability of specific sites to provide selected greenway environmental services (Miller et al., 1998; Conine et al., 2004) (Fig. 3.6), and 2) using optimal route or least cost path (LCP) models to find a continuous swath for provisioning greenways' Primary Ecosystem Services (see Section 3.1.2), such as a biological corridor, wind corridor or as route for bicycling (Teng et al., 2011).

3.3.2.1 Multicriteria analysis and analytical hierarchy process

Based on information developed in the previous step, experts and stakeholders identified the most relevant ecosystem services in terms of needs that a riparian greenway could provide on different scales (1) in the city and (2) in specific segments of its course. This includes defining the relative importance of each ecosystem service and assigning weights that permit their further integration. One of the essential aspects of this phase is the identification of the interests and priorities of the different stakeholders involved in the planning and development of riparian greenways.

The first outcome is related to the understanding of the agreement or disagreement among stakeholders as to the most important ESs. Approaches such as those described in Agbenyega et al. (2009) may be used to assess the different preferences and their relation to the discipline of each stakeholder (Ministry of Environment vs. Ministry of Housing or academic field vs. real estate companies).

The second outcome of this phase is related to the selection of the most important ESs, which are intended to be used during the suitability analysis. Likewise, apart from selecting the ESs for the elaboration of further studies, it is important to identify the class of ES —described in Table 3.1. These ESs may be regarded as Primary, Secondary and Tertiary.

In the case of Secondary and Tertiary ESs, the suitability analysis is principally based on the development of a multicriteria analysis (MCA) technique and analytical hierarchy process (AHP) (Liu et al., 2007) in a GIS environment; it involves identifying sites that satisfy a set of rules or characteristics. This analysis is focused on the structure and characteristics of spatial units.

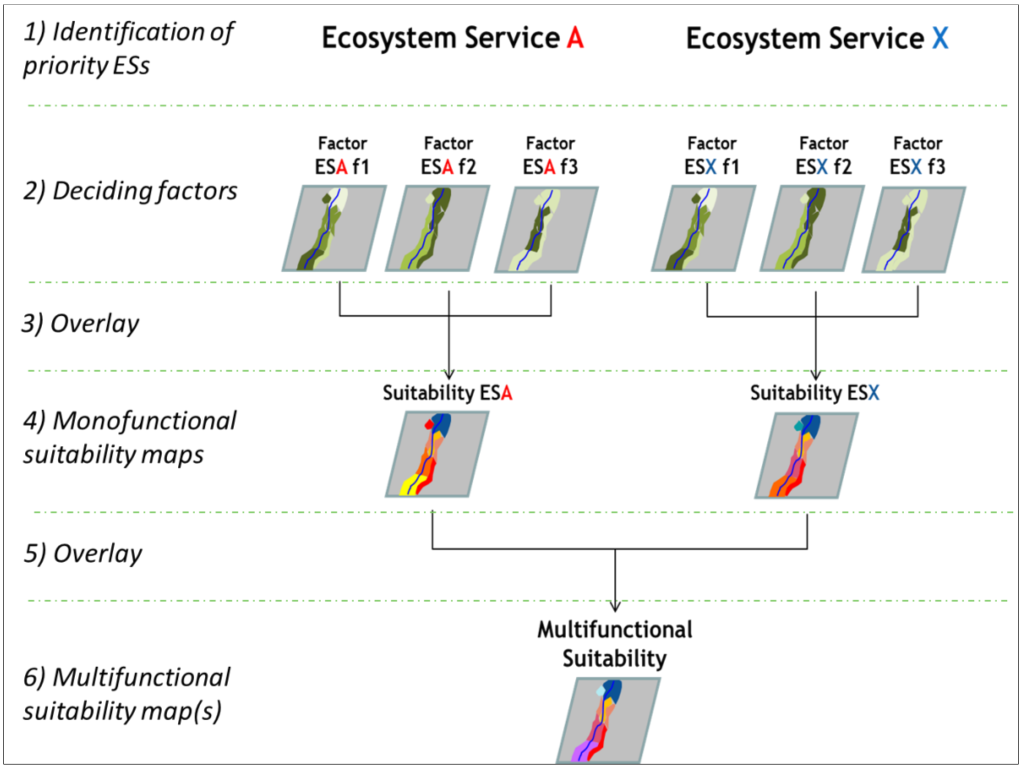
According to Miller et al. (1998), specific suitability factors should be selected for each ES before analysis AHP; this would avoid the use of a single set of factors for the estimation of the suitability for the provision of multiple ESs. This generally occurs due to problems in the definition of the most important ESs and ignores the fact that the provision of different ESs is affected by different factors.

Factors should be represented by thematic maps presenting the spatial variation of associated values. Several of these maps should be generated either during the Socio-Ecological Analysis or during this stage.

The Figure 3.4 shows the AHP used for multifunctional suitability estimation. First, suitability factors are overlaid to develop a set of mono ES suitability maps (see Figure 3.4 steps 3 and 4). Second, monofunctional suitability maps are overlaid in order to obtain a multifuctional suitability map (see Figure 3.4 steps 5 and 6).

Though there are different forms to conduct an overlay analysis —the most common being the Weighted Overlay (WO) and the Weighted Sum Overlay (WSO) Analysis—, this study uses the Fuzzy Overlay Analysis, which is based on set theory. Fuzzy Overlay Analysis has some advantages over WO and WSO analysis such as (1) addressing the inaccuracies in the attribute of spatial data derived from the use of crisp sets and (2) modeling the suitability in order to obtain different solutions or trade-offs between standards or controlling the risk aversion level as far as decision makers are concerned.

Figure 3.4: Proposed Multicriteria analysis and analytical hierarchy process for Greenway Suitability Analysis.



Source: Author's own elaboration.

By enabling the trade-off between criteria, the Fuzzy Overlay Analysis allows us to explore different levels of suitability (within set theory weighting criteria is not applicable). When single suitability maps overlap (see Figure 3.4 step 5) it is important to explore the effects of using AND (no trade-offs) /OR (trade-offs) operators on multifunctionality values and spatial configuration.

This may also be addressed through decision rules that enable exchange between ESs of the same type (either of supporting or cultural), but prohibiting any trade-off between cultural ESs and other type of ESs. The latter is due to the fact that a greenway should have multiple ESs and at least one cultural ES (see Section 3.1.3).

The complexity derived from multifunctionality in terms of conflicts and complementarities between ecosystem services should be taken into account to define strategies of spatial segregation and integration of them. This also affects the procedure to produce the final integrated maps of suitability for multiple functions. It is possible to include some rules in the overlay procedure for keeping incompatible ecosystem services spatially separated.

Another point is the complexity derived from multifunctionality in terms of priorities and interests of different sectors involved such as NGOs, academics, and government. In the same manner, it is possible to distinguish between governmental services and institutions such as regional government, ministry of public works, municipalities, etc.

This can be addressed using the weights assigned by the different groups of stakeholder sectors to each ecosystem service for elaborating multifunction suitability maps that represent their interests. By comparing these maps it is possible to identify areas of potential conflicts and agreements.

These results, which may be regarded as possible scenarios, provide useful information for planning purposes and draw attention to the uncertainties and complexities underlying the estimation of suitability factors —which are inherent in the MCA — (Hanse & Pauleit, 2014; Scheuer et al., 2013). This approach sets itself up in opposition to the common use of average values, single final results and aggregated values.

3.3.2.2 Least-cost path model

In the case of Primary ESs, the suitability analysis should be conducted according to process-based methods (Teng et al., 2011), as in the case of the least-cost path (LCP) model. This method allows optimal route identification —in cost-saving terms— to connect two points. These process-based methods are less used than other approaches (such as those related to suitability and landscape) aimed at designing potential greenways, because these procedures have been recently developed and are time-cons

uming and complicated. In the case of riparian greenways, this model intends to find the most suitable space for the provision of biological corridors or routes for non-motorized transportation within the analyzed riparian strip.

The cost used in the LCP model may be determined by the amount of energy required for mobilization purposes, either in the form of fuel or human effort. There are other variables that influence this cost such as the slope and the distance to be travelled; for the purposes of this model, these variables may be represented by continuous images serving as a resistance surface to motion or cost.

Therefore, in the case of Primary ESs, the development of a single suitability map is proposed —in the same manner as those maps generated for Secondary or Tertiary ESs. The second suggestion refers to the implementation of the LCP model by using the opposite procedure for the generation of single suitability maps as a cost surface. The result of this process is the definition of a route that maximizes the global suitability (accumulated throughout the whole route) for the provision of the analyzed ES. Otherwise, the modelled route avoids sectors (pixels) with low suitability and prioritizes the connection between those with maximum suitability values.

Finally, the routes generated for Primary ESs should be overlaid on the multi suitability maps, since they are essential for corridor functioning and their spatial continuity should be ensured.

3.3.3 Opportunities and challenges analysis

The objective of this phase is to shed light on the social system that complements the quantitative and spatial information generated by the Socio Ecological Analysis. The Opportunities and Challenges Analysis is focused on the use of qualitative approaches in order to reveal the significant aspects that affect the actions and decisions made by stakeholders (Zipperer et al., 2013) in relation to riparian zones and the possible development of greenways (or other type of green infrastructure).

Moreover, there is a need to generate information about political-institutional (a set of ideas regarding the achievement of social objectives) and cultural aspects (attitudes, beliefs and values that characterize collective reality). These dimensions are two core areas of the social analysis within the socio-ecological system (Red et al., 2004) that contextualize the perceptions and interests of the actors involved in decision-making processes.

The above may be performed using the institutional analysis framework intended to identify relevant actors (public, private and civil society) and their interaction systems (including the effectiveness of organizations and their respective procedures) (Kim, 2011; Hellmund & Smith, 2006). The institutional analysis should include the identification of stakeholders and their competences, a revision of regulations and administrative procedures as well as the identification of the attitudes and values of stakeholders in relation to green space issues.

The final result of this phase corresponds to the identification of opportunities and challenges for the development of multifunctional greenways, which are especially determined by the possibilities for the implementation of changes observed by stakeholders within the context of a political-institutional system. The identification of opportunities and challenges should be incorporated into an analytical summary (Smaniotto et al., 2008).

The most common way to conduct this method is through a combined approach between in-depth interviews with stakeholders and literature review on relevant legislation, land ownership, plans and projects.

In-depth interviews may be conducted in person or by telephone and should include all relevant stakeholders —either from the public/private sector or the civil society— (Ryan et al., 2006). However, when this is not possible, public officials directly involved in the planning and management of green spaces (Haaland et al., 2010; Kim, 2011) should be interviewed. Smaniotto et al. (2008) suggest attending workshops and seminars as these courses —as opposed to the static vision of in-depth interviews— provide a more dynamic and interactive vision about the points of view of stakeholders.

The analysis of contents for the identification of opportunities and challenges can be organized according to current proposals; however, these recommendations should be properly adapted to the needs of specific cases.

Smaniotto et al. (2008) suggest three categories of problems: spatial (unequal distribution), organizational (lack of cooperation) and financial (lack of funding); and three categories of opportunities: spatial (clear green space infrastructure), functional (public access) and ecological (well-preserved areas).

Erickson & Louisse (1997) propose the existence of four difficulties for the implementation of multi-jurisdictional greenways, which may be used for the identification of challenges. However, these suggestions may also be used to structure issues that allow the identification of opportunities for overcome the challenges. Therefore, the proposed formulation is described as follows: coordination among governmental agencies; regional governance; funding; and public perceptions. Likewise, according to Ryan et al. (2006), two new issues can be added to these set of difficulties: property rights and physical state.

3.3.4 Multifunctional greenway potential

This is the last phase of the evaluation process, which corresponds to the final synthesis of the two main elements —namely, the suitability analysis and the opportunities and challenges analysis. The objective is to organize and systematize the most important findings of these two analyses in order to highlight the potential of the riparian strip identified as a greenway. The latter may be associated with the analytical summary suggested by Smaniotto et al. (2008), which serves as the final part of the analysis and the basis for a strategy oriented towards the development of urban green spaces.

This phase poses a major challenge due to the need for integrating the spatial information generated by the suitability analysis and the non-spatial information obtained from the opportunities and challenges analysis.

Therefore, the diagrams presented in the Figures 3.2 and 3.3 are used as a framework for the analysis of suitability and opportunities. In this way, the first step is the identification of the circumstances (or the combination between suitability and opportunities) that give shape to the different levels of potential.

Such a diagram should prioritize the interpretation and reflection on the highest levels of potential, which are closely related to (1) high or very high suitability conditions for the provision of multiple priority ecosystem services, and (2) the existence of favourable conditions in the institutional system for multifunctional greenways development.

Finally, the analysis may lead to the identification of segments of the riparian zone with the highest potential and the key institutional aspects for the future development of greenways.

Chapter 4
Study area

The study area corresponds to the Mapocho River in Santiago, Chile.

The application of the conceptual and methodological framework - developed in Chapter 3 - in the city of Santiago provides the opportunity to explore its scope and applicability in a city representative of the structure and processes of megacities in Latin America, but is still smaller compared to others. The Mapocho River is the main river in the city of Santiago, and has marked its character and evolution as a city. In the first part of this chapter, the background is presented for understanding the geographic, demographic and urban situation of Santiago that serves as context to the Mapocho River as a main urban feature. In the second part, the main characteristics are described of the Mapocho River and the relevant urban planning. Finally, the riparian zone is operationally defined to be evaluated in this research.

4.1 Santiago overview

This section presents relevant information of the biophysical, social and institutional context in which the evaluation is located.

4.1.1 Climate and vegetation

Santiago is located in the Chilean central zone and extends between 33°39'S – 70°52'W and 33°15'S – 70°26'W (Figure 4.1). This part of the country is dominated by a subtropical dry climate, or according to the Köppen-Geiger classification, a subtype of Mediterranean climate called Csb (Peel et al., 2007), and it is characterized by warm and dry summers and rainy winters.

Santiago is under the influence of the South Pacific subtropical anticyclone that causes a prevalence of dry conditions for a large part of the year. This is occasionally interrupted by mid-latitude fronts and associated rainfall during the southern winter (Aceituno & Montecinos, 1996).

Moderated temperatures can be observed in the coldest and hottest month, with an average of 7.7°C in July and 21.2°C in January. Annual rainfall reaches just 350 mm and is concentrated between May and August, but rainfall events often have torrential character due to a high daily intensity (85 mm in 24 hours).

The general pattern described above changes at the local scale under orographic influence. Thus, colder and drier conditions can be observed in the mountain surroundings where nival accumulation takes place above 2,000 m. Romero & Vinagre (1985) describe a gradient between 850 and 2,000 mamsl in the Andean piedmont, in the eastern part of Santiago, where a rainfall increase from 450 to 900 mm can be observed.

In the same manner as the most of the pacific basin, the climate in Santiago de Chile is influenced by the El Niño/Southern Oscillation (ENSO). One of the most significant effects of ENSO in central Chile is the rainfall amount, in the sense that during La Niña years the arid conditions are intensified and annual rainfall can be just above 100 mm while it reaches 800 mm in El Niño years. This enormous annual variability associated to ENSO is a characteristic feature of the dominant climate in Santiago.

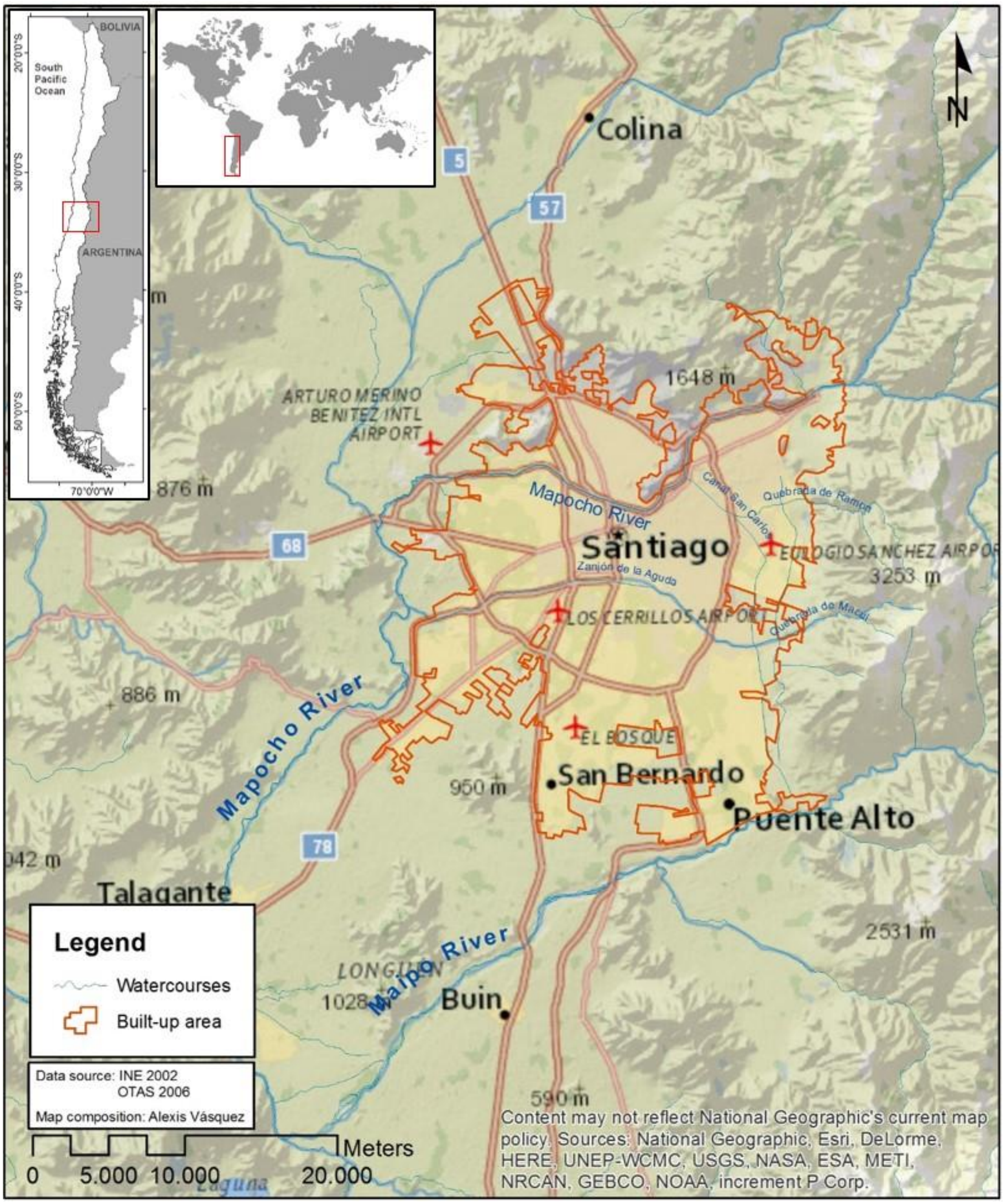
Urban climate in Santiago is characterized by 2-6°C temperatures warmer than in its rural surroundings, principally associated to an Urban Heat Island (UHI) phenomenon that has its maximum expression at night (Aceituno & Ulriksen, 1981; Romero et al., 2007). Ihl et al. (2000) also describe the existence of micro UHI over industrial and commerce districts, giving more spatial complexity to urban thermal patterns in Santiago.

Romero et al. (1999) point out that predominant regional SW winds penetrate the watershed along the main river and stream channels. Local wind patterns show a strong daily cycle since slope winds and valley winds are descending during the night (E) and ascending after midday (Romero et al., 1999; Ihl et al., 2000).

Chilean *Matorral* is the terrestrial ecoregion that occupies central Chile and is characterized by *Sclerophyll* vegetation which is adapted to survive the severe water stress associated to a long and hot summer drought (Dallman, 1998). According to Gajardo (1996) and Dallman (1998) the most important natural plant communities in Santiago and its surroundings are *Espinal*, *Matorral* and *Sclerophyll* woodlands. In many cases, *Espinal* is the result of the *Matorral* degradation.

The presence of watercourses produce optimal conditions for a dense *Sclerophyll* forest development, typically composed of evergreen trees, including *Cryptocarya alba* and *Lithrea caustica*. Some species of trees such as *Luma chequen, Otholobium glandulosum* and *Drimys winteri* are present only around watercourses since they provide cooler and wetter environments (García, 2010).

Figure 4.1: Santiago is located in the Chilean central zone in the Central Valley, at the center of the Río Maipo watershed.



Within the built-up body, vegetation covers 16.5 % of the urban area whereby 88 % of tree species are exotic - mainly brought from the USA and Australia (De la Maza et al., 2002; Hernández, 2008). The most abundant specie is *Robinia pseudoacacia* with 11.4 %.

Additionally, urban vegetation in Santiago exhibits a severe unequal distribution at the inter-municipal scale (De la Maza et al., 2002; Reyes & Figueroa, 2010, Weiland et al., 2011) as well as at the intra-municipal scale (Vásquez, 2009; Romero et al., 2012) that is very well related to the income group distribution. In contrast to low income areas, municipalities and neighborhoods inhabited by high income groups are well equipped with public green spaces, private gardens and show high species richness.

4.1.2 Geomorphology and hydrology

Central Chile is characterized by three macro landforms: the Andean mountains, the Central Valley, and the Coastal Cordillera. Santiago is located in the Central Valley, at the center of the Río Maipo watershed and is flanked by the Andes on the eastern side, the Coastal Cordillera on the western part and by secondary extensions of these two on the northern and southern sides.

The Central Valley has been shaped by fluvial processes, principally through deposition of alluvial sediments eroded in the headwater basin. Between the main fluvial plain, where most of Santiago is located, and the Andes, it is possible to observe a band consisting of several large and small spatially coalescent alluvial fans that give rise to Santiago's Andean foothills or piedmont (Araya-Vergara, 1985). This area is prone to floods and landslides.

The hydrological network in Santiago is extensive and well developed, framed by two main rivers, Maipo and Mapocho, a set of intermediate and small natural watercourses, and canals.

In the same manner as all main rivers in Chile, the Maipo and Mapocho River flow from the Andes westwards towards to the Pacific Ocean. The Maipo River forms the southern boundary of Santiago and is the largest river in this region. The Mapocho River is the second largest river and flows through the city crossing the historical city center. Since the upper part of both watersheds reach altitudes above 5,000 mamsl they have a pluvio-nival regime, showing a first stream flow peak in winter and a second one in spring.

In the piedmont area there are several small and medium-sized streams characterized by a pluvial regime with maximum stream flow during winter time, often characterized by torrential discharges. They remain dry for most part of the year and only carry water periodically as response to rainfall events in winter time and sometimes result in snow melt during spring. The Quebrada de Ramón and the Quebrada de Macul, the largest streams of Santiago's piedmont, show a pluvio-nival regime because their headwaters soar altitudes above 3,000 mamsl (Romero & Vásquez, 2005).

According to Piwonka (1999), the Spanish conquistadors found a broad network of Inca irrigation channels or "*acequias*" in Santiago valley which conduct water from streams and rivers to agricultural fields. However, watercourses were gradually channelized or piped underground in the process of urban growth.

Today, just three watercourses cross the city: Mapocho River, the Quebrada de Macul, and the Canal San Carlos.

The Mapocho River was the main source of drinking water for the city during the colonial period, but also a continuing threat because flooding. In 1885 the first fluvial defenses were constructed, it was followed by a continued channelization process that ended up giving origin to a completely artificialized watercourse on its way through the city. In the same way, the urban segment of Quebrada de Maculs was completely channelized and is currently known as Zanjón de la Aguada.

Piedmont streams such as Quebrada de Ramón, Quebrada Nido de Águila, Quebrada Lo Hermida, and many more were also channelized and interrupted when the urbanization began to reach these upper elevations. Some streams that only carry water periodically were even substituted by main avenues that today follow the exact course of the original streambeds.

The situation described above periodically produces flood problems on the eastern border of Santiago and occasionally also along the Mapocho River and Quebrada de Macul/Zanjón de la Aguada. Solutions for flood problems have been focused on storm water infrastructure construction as a mitigation measure, and less on channel or riverbed restoration (Müller, 2011).

4.1.3 Administrative boundaries and urbanization process

According to the last census, 9 out of 10 Chileans live in cities and almost one in four of them reside in Santiago. Santiago de Chile is the 7th major city of Latin America with almost 8 million inhabitants and by far the largest and important city of Chile, since it concentrates 42.7 % of the Growth Domestic Product (GDP) (in 2006, INE 2009) and 40.3 % of the national population (in 2009, INE 2009).

In administrative terms, Chile is subdivided into regions, provinces, and municipalities. Other territorial units including districts and building blocks are spatial information units only used for census data (INE, 2002).

The Metropolitan Area of Santiago (AMS) is a conurbation that compromises of 36 municipalities within the Metropolitan Region of Santiago. These 36 municipalities are autonomously administrated by local governments with their own mayor, council, and budgets. There is no administrative boundary defining Santiago de Chile as a city and territorial entity (Figure 4.2).

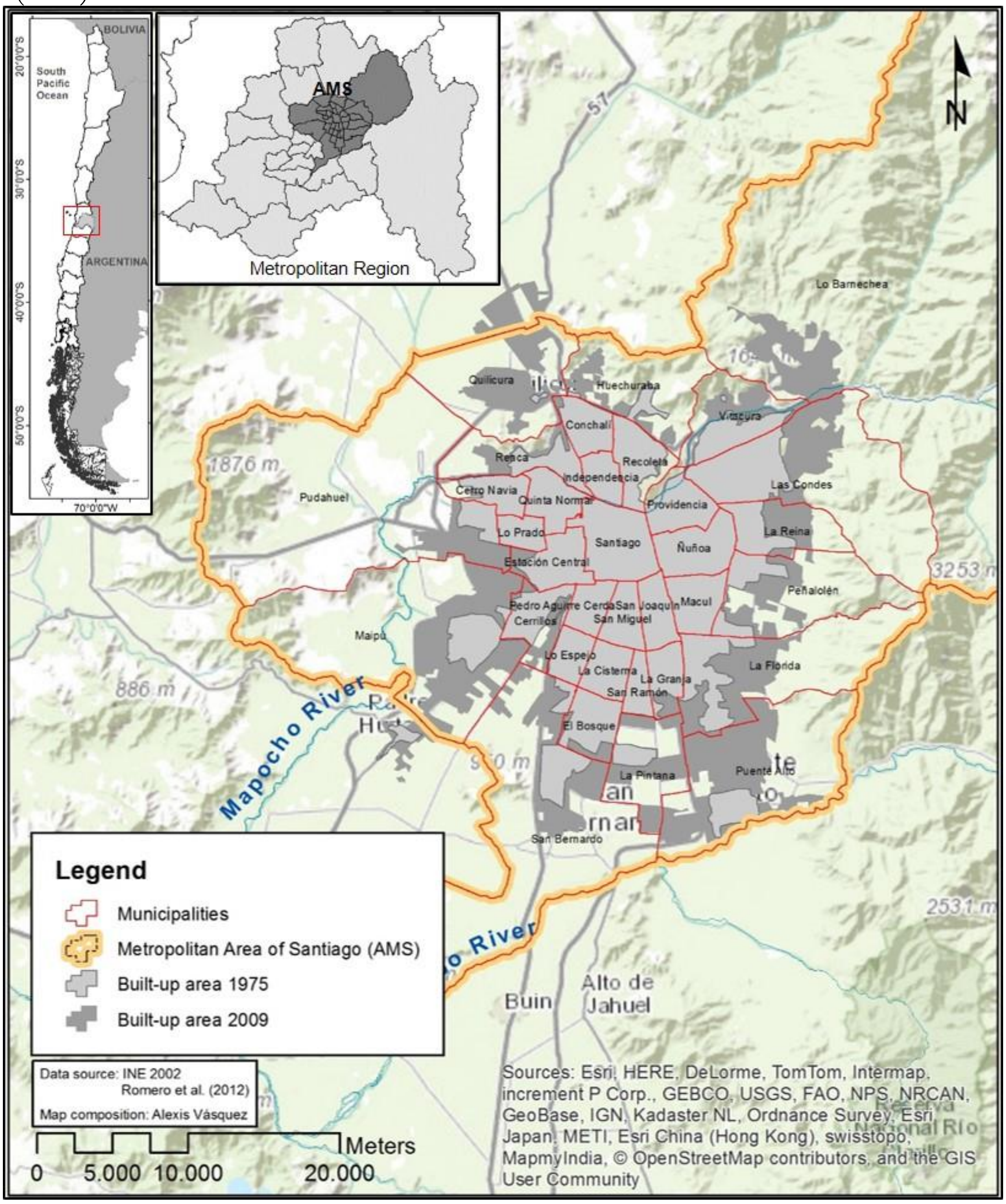
Santiago has experienced a continuous and very rapid urbanization process that characterizes megacities. According to Reyes et al. (2003) urbanization rates show a significant increase after 1965, as the urban built-up body grew from 21,000 ha to more than 31,000 ha from 1960 to 1970. Banzhaf et al. (2013) reaffirm that this tendency it still present until today.

According to Romero et al. (2007 and 2012), urban growth has been characterized by increasing expansion rates with a strong inflexion in 1998. As a result, built-up areas grew from 33,963 ha in 1975 to 61,679 ha in 2009 which means an expansion of 27,716 ha.

Santiago has expanded to all but the northern directions. Romero et al. (2007) found two main land use/land cover change dynamics: (1) the replacement of natural and semi natural vegetation for low density urbanization dominated in the eastern part of Santiago, and (2) cultivate land has been covered by high density urbanization in the southern and western fringes.

Borsdorf et al. (2002) developed a model of Latin-American urban development, where it is possible to follow the evolution of Latin-American cities from the compact city distinctive of colonial times to the fragmented city that is well-established nowadays.

Figure 4.2: Administrative boundaries and urban expansion, after Romero et al. (2012).



Fragmented cities emerge as result of global change influencing Latin-American urban development with economic and political changes being the main driving factors. They are characterized by a high spatial and structural complexity. The higher urban heterogeneity and complexity are expressed in an insular or cellular pattern, with urban "islands" associated to (1) micro-commerce and financial centers usually materialized in malls and shopping centers, (2) gated communities for upper and middle classes located in low-income municipalities, and (3) social housing projects poorly connected and informally separated (Borsdorf & Hidalgo, 2010).

Santiago has likewise experienced this functional and spatial restructuration through the transition from a polarized to a fragmented city structure. This process has resulted in a decrease of physical distances between areas inhabited by different socio-economic classes, which consequently produces a reduction of the spatial scale of urban segregation (Sabatini et al., 2001; Borsdorf et al., 2006). Socio-economic homogeneity at a municipal level has decreased considerably, particularly in the middle class peripheral areas such as Peñalolén, La Florida, Maipú, Pudahuel, and Quilicura. Urban segregation can now clearly be observed at intra-municipal and neighborhood levels.

According to Romero et al. (2012), social segregation is accompanied by an environmental segregation which produces different urban environments for different social classes, in a way that the poorest socio-economic income groups are overloaded by environmental problems and have restricted access to environmental amenities. Santiago shows a lack of environmental justice. An extraordinarily unequal social distribution of environmental features is evident in terms of green spaces access (Vásquez, 2009; Reyes & Figueroa, 2010), air quality (Romero et al., 2010a), flood risk (Fuentes, 2009; Vásquez & Salgado, 2009), and heat nucleus (Romero et al., 2010b).

Orellana (2009) states that the lack of a metropolitan government in Santiago produces many problems including overlaps and gaps in multi-level governance and administration between the national government, regional government, and municipal governments. In his research he also found that socio-economic disparities at inter-municipal level become a critical factor for the structure of power within the metropolitan area, since wealthy municipalities such as Las Condes, Providencia, Vitacura, and Lo Barnechea are better able to incline public and private actions to support their own goals.

4.1.4 Urban planning

The neoliberal policies implemented by the Chilean military regime between the 1970s and 1980s had consequences on urban planning and urban policy-making processes.

Urban policies implemented from 1979 onwards transferred most of the responsibility for land-use allocation and urban development to private actors and the real estate market. Such an action reduced the ability of the State in this area through a deregulating process that enabled the access of private interests and the real estate market to the development of cities.

This situation provided the context for a limited State involvement in urban and territorial planning, characterized by the prevalence of indicative over regulatory planning instruments and an important place for influence and leadership by real estate-oriented private interests.

Urban planning instruments in Chile can be classified according to their strategic and planning nature and their spatial and administrative scale.

Table 4.1 shows that at a national level, the guidelines on the faculties, responsibilities, sanctions, procedures and processes related to urban planning, urban development and construction are provided by the LGUC and the OGUC. These two regulations were prepared in accordance with the 1979 urban policy.

Table 4.1: Urban planning instruments in Chile.

Level	Strategies and Policies	Planning Instruments	Institutions
National	-National Policy on Urban Development (Política Nacional de Desarrolo Urbano, PNDU) -General Act on Urbanization and Construction (*Ley General de Urbanismo y Construcción,* LGUC) -General Ordinance on Urbanization and Construction (*Ordenanza General de Urbanismo y Construcción,* OGUC)	None	Ministry of Housing and Urban Development (*Ministerio de Vivienda y Urbanismo*, MINVU)
Regional	-Regional Development Strategy	Regional Plan on Territorial Planning (*Plan Regional de Ordenamiento Territorial*, PROT)	-Regional Office of the Ministry of Housing and Urban Development (*Secretaría Regional Ministerial del Ministerio de Vivienda y Urbanismo,* SEREMI-MINVU) -Regional Government (*Gobierno regional*, GORE)
Intermunicipal	Regional Development Strategy	-Intercommunal Master Plan (*Plan Regulador Intercominal,* PRI) -Metropolitan Master Plan (*Plan regulador Metropolitano*, PRM)	-SEREMI MINVU -GORE -Municipalities
Minicipal	Communal Development Plan (*Plan de Desarrollo, Comunal*, PLADECO)	Communal Master Plan	-SEREMI MINVU -Municipalities

Source: Author's own elaboration based on Arenas (2003).

In 2014, a new PNDU was launched. However, this initiative is undergoing a socialization process and is expected to have a concrete impact on the LGUC and OGUC in coming years.

At a regional level it is possible to find the Regional Development Strategy. This strategy was not associated to any spatial planning instrument until 2010, which is when the PROT (Exempt Decree 3288) was created by GORE. The PROT is an indicative planning instrument, as a consequence there are no legal obligations involved. The PROT replaced the Regional Development Strategy, which was exclusively focused on urban areas. The Santiago Metropolitan Region's PROT is still under development.

At an inter-communal level, the PRI —or PRM in cases where the conurbation has more than 50,000 inhabitants— defines the land-use, the limits for urban expansion, the provision of metropolitan facilities and protected areas, among others.

These regulatory plans, as well as their elaboration, fall within the competence of SEREMI-MINVU prior authorization issued by GORE. In the case of Santiago, the PRMS has been in force since 1994. The PRMS is comprised of a set of regulations (*ordenanza*), a collection of maps and an interpretation (*memoria*).

Since 1994, the PRMS has been amended 100 times, the most important being those undertaken in 1997, 2007 and 2013.

Initially, the PRMS covered 34 out of the 52 municipalities belonging to the Metropolitan Area of Santiago (AMS). Subsequently, in 1997 the PRMS was expanded in order to include the province of Chacabuco and since 2007 has been applied to the entire region. Finally, in 2013, the PRMS was amended for the hundredth time, thus being known as PRMS-100.

At a communal level it is possible to find the PLADECO and PRC. These plans are intended to guide the development of municipalities and define the physical planning of the urban area, respectively. Municipalities are required by law to develop both a PLADECO and a PRC; in the event a municipality does not have a PRC, the municipality should be governed by the respective PRI or PRM.

The PRC is a regulatory instrument and, in the case of Santiago, should be aligned with the PRMS. Given the differences of scale between the PRMS and the PRC, local governments —according to their own criteria— should interpret the proposals made by the PRMS and translate them into the PRC.

4.2 Mapocho River

The Mapocho River originates in the Andean region at the confluence of the streams *Yerba Loca* and *Leonera* and the rivers *San Francisco* and *Molina*. Once in the urban area, the water flow of the river is increased due to the confluence of tributaries such as the *Arrayan* stream —located in *Lo Barnechea* (east end)—, the *San Carlos* canal, the *Lampa* stream and the *Zanjon de la Aguada*; the latter being located on the border of the city (west end).

According to different authors (Ferrando & De Luca, 2011; Piwonka, 2008) the *Mapocho* possesses the character of a mountain torrent due to both the presence of pronounced thalwegs and its morphology governed by the lack of meander.

The name of the *Mapocho* is derived from the Mapudungun name *mapu-chun-ko*, which means "water that vanishes into the earth". This name was given because, prior to its canalization, the river disappeared through infiltration in the current *Santiago-Quinta Normal* municipal border to then reemerge in the *Pudahuel-El Monte* area.

4.2.1 Watershed

According to Ferrando (2000), the basin of the Mapocho River has an area of 900 km^2 with an average elevation of 2,700 mamsl (Peña & Nazarala, 1983).

Although average precipitation in Santiago is only about 300 mm, the orographic effect produces increased rainfall of 1,000 mm in the high mountains of the basin. In these cases, precipitation is in the form of rain or snow.

Snowfall is common over 2,500 mamsl during the winter season, which contributes to the relatively permanent snow cover at this height. During rainy days, the snow line commonly varies between 1,500 and 2,500 mamsl; the latter implies some important variations of the tributary basin (Peña & Nazarala, 1983).

4.2.2 Hydrological regime

The Mapocho River has a pluvial-nival hydrological regime, and flows 110 km from its origin in the Andean region to its confluence with the *Maipo* River (Segura et al., 2006) in *El Monte,* 26km away from the city.

The river experiences two significant seasonal flow variations, reaching a peak of 13.6 m^3/s in November and a minimum of 2.3 m^3/s in April (Segura et al., 2006). Peak flows occur in spring and are associated with snow-melting processes.

According to Piwonka (2008), the water flow of the Mapocho increases four times on its path through the urban area of Santiago —from 3.1 m^3/s to 13 m^3/s. Apart from the input of wastewater from the city, the Mapocho also receives water from the San Carlos canal. This canal was constructed to irrigate the eastern part of Santiago, and diverts water from the *Maipo* River into the Mapocho in the Providencia area.

During the winter and spring the Mapocho swells as a result of rainfall and snow-ice melting processes in the upper river basin, respectively (Ferrando, 2000). However, on some occasions heavy rain results in extreme increases in the volume of water during wintertime (Peña & Nazarala, 1983).

In morphological terms, Cade-Idepe (2004) suggests that the riverbed of the Mapocho between *El Arrayán* and *Quinta Normal* has some arms and channels that adapt themselves to the banks and bars of rubble and gravel. Then, in the *Pudahuel* area, the river flows in a single channel through a terrace composed of cinerita. Downstream, the river presents an anastomosing channel.

4.2.3 Administrative boundaries and urbanization process

Since its foundation, the city of Santiago has been closely related to the Mapocho River, not only for being a source of fresh water or receiving wastewater discharges, but also for becoming an intrinsic part of the structure and form of the city —either due to constant flooding or for being used as a common place— (Laborde, 2008).

At an early state, the city began to reclaim land from the river through land fill processes —especially in the south bank (Laborde, 2008; Piwonka, 2008). As Laborde (2008) suggests, the river used to flow two blocks (250 m) away from *Plaza de Armas*; today, after a number of infilling processes and hydraulic works, the river flows five blocks (520 m) away from this place.

Both the damage to the city as the consequence of flooding as well as the establishment of marginalized groups and their activities related to the extraction of aggregates —including slums and low-class *cocinerias*— prompted authorities and politicians to channelize the river and clean this part of the city (Castillo, 2009).

Work began at the end of the 1800s in the central part of the city (in what is now the Municipality of *Santiago*); this involved reclaiming land from the river as the result of channelization and elevation of surrounding areas. A segment of this land was planted with trees, thus giving rise to what is known as *Parque Forestal* (Castillo, 2009).

Several flooding episodes have occurred in the recent history of the Mapocho River; even *Capitán General Pedro de Valdivia* described a massive flooding that threatened the then nascent city of Santiago in 1544 (Rodríguez, 1990).

The banks of the Mapocho located in the eastern area of Santiago have been enhanced through filling processes due to the construction of residential areas and road infrastructure (Rodríguez, 1990).

Over the years, canalization works were also conducted in the eastern and western parts of the city, thus providing new spaces for the emergence of residential areas, road infrastructure and, to a lesser degree, parks and squares.

Vásquez et al. (2010) describe the changes in land use/land cover in the riparian zone of the Mapocho for the years 1955, 1992 and 2006-2007. These authors show that the land uses related to residential areas, commercial/industrial activities, green spaces and urban highways are those that have increased the most. High, medium and low density residential areas account for 35 % of the riparian area of the river. Conversely, the percentage of green areas increased from less than 5 % to 15 %.

Although riparian zones were initially used for the construction of road infrastructure, it was not until 2006-2007 when urban highways emerged as the element that defined the nature of important segments of the Mapocho (Vásquez et al., 2010).

The urbanization process has led to the replacement of croplands and the loss of native vegetation in the riversides (Vásquez et al., 2010).

Today, the Mapocho River crosses 11 municipalities in its path through the built-up area of Santiago. These municipalities ordered from east to west are Lo Barnechea, Vitacura, Las Condes, Providencia, Recoleta, Santiago, Independencia, Quinta Normal, Renca, Cerro Navia and Pudahuel (Figure 4.3).

These municipalities have extreme social and economic differences, with a distinct gradient in the decreasing socioeconomic status of the population from east to west. In addition, the municipalities of Santiago and Providencia concentrate most offers of employment, education and services, and the other peripheral municipalities located to the west of the city serve as *Municipalidades Dormitorio*.

4.2.4 Urban planning context

The Mapocho River has been incorporated into urban planning initiatives since the 1960 Santiago Intercommunal Plan, which included the development of an urban intercommunal corridor running from the Andean piedmont to its confluence with the *Maipo* River. This pathway covered an area of 690 ha of public land intended for roads and recreation.

This proposal was considered during the development of the PRMS in 1994, this led to the creation of the *Parque Metropolitano del Rio Mapocho*. The term *parque metropolitano* (metropolitan park) refers to public green spaces at a city level.

In 1994, the PRMS defined the *Parque Metropolitano del Río Mapocho* associated to riparian floodplains intended exclusively for parks, recreational-sport activities, leisure and outdoor tourism. However, regulations also allowed the allocation of 30 % of these strips of land to the construction of road infrastructure. In this context, the different PRCs thoroughly defined the route design and characteristics of parks.

Since the PRI in 1960 to the PRMS-100, the regulated strip along the *Mapocho* has been considered for two opposite purposes: the provision of green spaces and road infrastructure.

It is important to point out that neither the PRMS nor the PRCs include an investment plan or a project portfolio intended for the materialization of projects such as the *Parque Metropolitano del Río Mapocho*. These planning instruments are focused on harmonizing public and private investment; however, such an approach is far beyond the scope of these instruments. As a result, private and sectoral investment come into conflict with planning proposals.

4.2.5 Riparian zone definition

In this research, the riparian zone is defined as a portion of land adjacent to a watercourse (Lathrop & Haag, 2007), because other definitions discussed in Section 2.1., such as those that are ecosystem-based, have not proven their applicability in highly urbanized environments like Santiago.

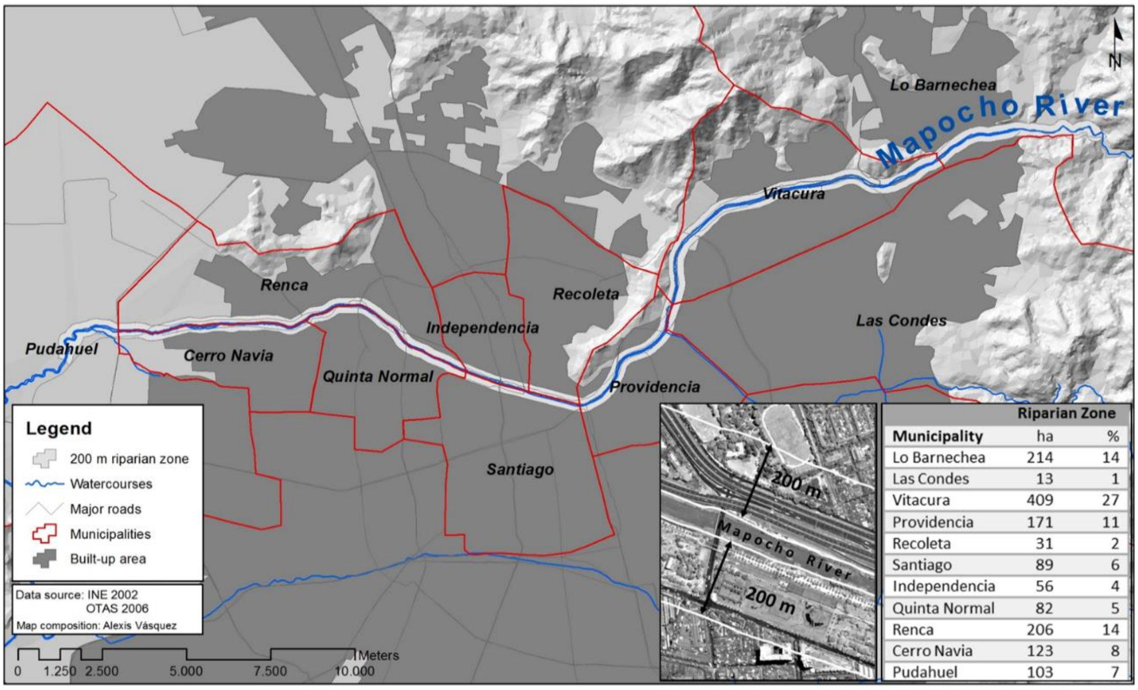
As presented in Section 2.1., the width for the riparian zone delimitation around the main course on the basis of biophysical functions varying between 30 m (Richards, 1996) to 200m (Brison et al., 1981). Moreover, planning in Santiago includes buffer strips for the Mapocho River of 50 m and 200 m according to urban and rural areas respectively (SEREMI-MINVU, 1994).

In order to meet ecological and urban planning criteria in this research, a 200 m riparian zone is analyzed around the Mapocho River. Additionally, in some cases a 50 m riparian zone is also analyzed for comparative purposes (Chapter 6).

According to Vásquez et al. (2010), the urban riparian strips located in Santiago are not exempt from the urbanization process and it is common to observe housing developments in these areas. As for the urban riparian zone of the Mapocho River, these authors point out that 30 % of the area is occupied by housing developments, industries and urban highways. However, there are still similar proportions of green and open spaces along the riparian corridor, which, when linked together, may reach high levels of spatial connectivity.

For the purposes of this study, the riparian zone is operationally defined by a buffer of 200 m along the course of Mapocho River within the city of Santiago, with the addition of 2,000 m prior to entering the built-area and other 2,000 m downstream after crossing the limits of the city (see Figure 4.3). The riparian zone under analysis as a length of 54 km and 1,498ha.

Figure 4.3: Definition of the riparian zone.



	Riparian Zone	
Municipality	ha	%
Lo Barnechea	214	14
Las Condes	13	1
Vitacura	409	27
Providencia	171	11
Recoleta	31	2
Santiago	89	6
Independencia	56	4
Quinta Normal	82	5
Renca	206	14
Cerro Navia	123	8
Pudahuel	103	7

Chapter 5

Data base and methods applied in Santiago

Though it is true that the methods used in this research correspond to those proposed in the methodological framework presented in Section 3.3, this section provides detailed information about the specific features of databases, pre-processes and analyses applied in Santiago.

5.1 Data base and pre-processing

This section describes both the data used in the different analyses conducted during this research and the pre-processing required for each case.

An overview about methods and the data used in this study for each of the three main steps in greenway potential assessment is given in Table 5.1.

Table 5.1: Methods and the data used in Santiago for each of the three main steps.

Analysis	Method	Data Used
Socio-Ecological Analysis	• Field campaigns • Geospatial analysis using GIS • Remote sensing • Statistics	• Measured air temperature and wind speed and direction data • Measured woody plants floristic composition • Measured channel naturalness • Land use/land cover (Quickbird) • GIS data about transport network, flood risk & public green spaces • Census data
Suitability Analysis	• Geospatial analysis using GIS • Remote sensing • Focus group and online surveys	• Land cover (Quickbird) • GIS data about transport network, public green spaces, elevation & structural food protection measures • Census data • Completed questionnaires

Opportunities and Challenges Analysis	• Interviews	• Completed questionnaires

Source: Author's own elaboration

5.1.1 GIS and remote sensing data

Vector data used in this research are briefly described in Table 5.2.

Table 5.2: Vector data used in Santiago

Format	Item	Scale	Data source
Vector	Transport network	1:50,000	MOP
Vector	Public green spaces	1:50,000	GORE
Vector	Structural food protection measures	1:50,000	DGA
Vector	Contour lines	1:50,000	IGM
Vector	Administrative units	1:50,000	INE
Vector	Flood prone areas	1:50,000	OTAS project

Source: Author's own elaboration

Since the development of a nationwide Spatial Data Infrastructure (SDI) is at an early stage, the geospatial information required for this research was available in different governmental offices and consulting firms. In this context, the first step was the conversion of all GIS data to UTM Coordinate System Zone 19s with the ellipsoid WGS84.

The following step consisted of the review of the thematic and spatial quality of information through simple observation. Such a procedure was conducted by using Quickbird images as reference in order to identify and correct errors in GIS layers.

In this way, municipal borders were manually corrected by adjusting them to the image and the official borders laid down in the respective PLADECO. In addition, this step included the correction of topological errors —such as double or incomplete segments and overlapping polygons— in the transport network and public green areas. Finally, missing areas were added to the vector file of public green spaces and classification errors (square, park, road median, etc.) were corrected.

These corrections were applied over an 800 m strip that runs along the watercourse, which is 400 m wider than the riparian area under analysis. This avoided unnecessary effort in areas other than those studied and minimized calculation errors along the edges of the 200m-long riparian area.

5.1.2 Remote sensing

Two pre-processed Quickbird pansharpened images were provided by the UFZ. As point out by Digital Globe (2012), standard Quickbird images delivered to customers are corrected for radiometric, sensor and geometric distortions. However, additional corrections were applied by Ebert & Höfer (2009) within the Risk Habitat Megacity Project. The pansharpening process was conducted through a Principal Component Analysis (PCA), as detailed in Ebert & Höfer (2009).

The study area is covered by two overlapping Quickbird pansharpened images (Table 5.3); therefore, further analyses prioritize the use of the 2007 image where available.

Table 5.3: Quickbird pansharpened images used for remote sensing analysis.

Item	Resolution	Date	Data source
Quickbird pansharpened	0.61 m	December 19, 2006.	UFZ
Quickbird pansharpened	0.61 m	January 06, 2007.	UFZ

Source: Author's own elaboration based on Ebert & Höfer (2009).

5.1.3 Census and internal revenue service data

This research uses data from the 2002 Census. Despite being conducted on a ten-year basis, this is the most recent census data available as the 2012 Census was declared invalid by the Government due to its procedure problems and inaccurate results. This led to the Government announcing that there will be a new Census taking place in 2017.

Census data is available in the form of tables generated with the software REDATAM+. These tables are related to census blocks that correspond to the basic spatial units containing census information. The joint is achieved using a single identification code (ID) assigned to each polygon (census block) and each row within the table.

The vector file of census blocks containing new census information is linked to relevant IRS data, which include land use and price of land (for further details, please refer to Section 5.2.1.3).

IRS data was provided by the *Observatorio de Ciudades* at PUC which, through partnerships and consulting services, has access to information from public offices. This information is then made available for public access through an online requesting system.

5.1.4 Field campaigns

Field campaigns were conducted with the support of the Laboratorio de Medioambiente y Territorio at the University of Chile, of which Alexis Vasquez is a member.

These campaigns obtained additional funding from the FAU 004 Research Project and involved the participation of proficient scholars, research assistants and geography students.

Field campaigns involved the measurement of physical parameters and the collection of data for validation or correction of GIS and remote sensing information. Field work was conducted from November, 2010 to February, 2011.

Three different types of information were collected during the above period:

5.1.4.1 Validation and correction

Information was collected in order to verify and correct GIS and RS data, especially that related to public green areas, land use/land cover and the channel alteration. Changes and updates were implemented by modifying the features and geometry of vector files.

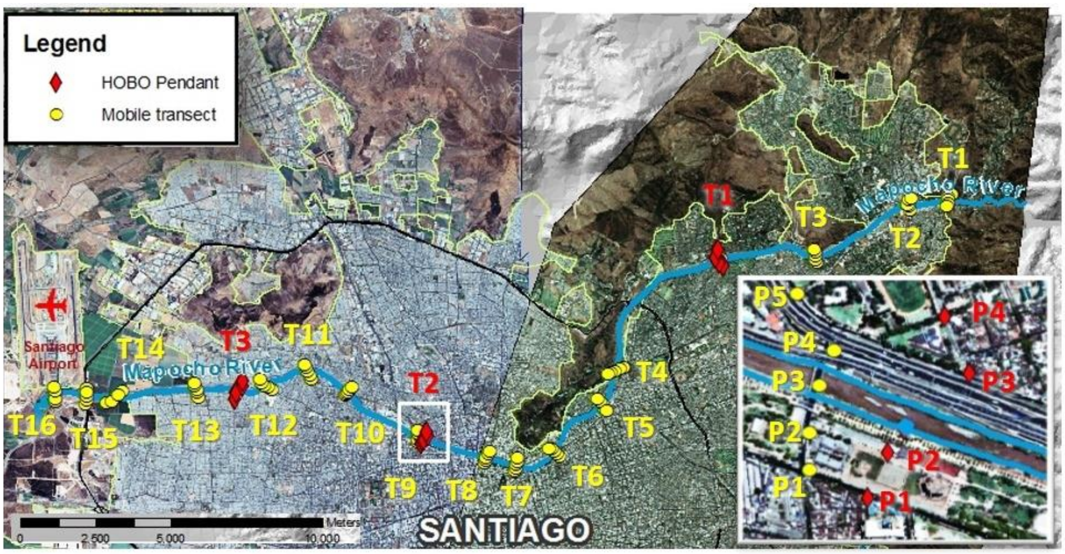
5.1.4.2 Meteorological parameters

There are two complementary types of measurements; while the first one is related to the use of fixed temperature data loggers, the second one is based on the use of mobile transects.

Fixed temperature data loggers

12 HOBO® Pendant® Temperature Data Loggers were installed in three transects along the Mapocho River during February, 2011. The three selected areas contain public parks and are distributed from east to west (1 in the east, 1 in the center and 1 the west) (see Figure 5.1).

Figure 5.1: Mobile transects and HOBO® pendant distribution.



Source: Author's own elaboration.

Each transect was provided with four HOBO® installed on each riverbank —100 m and 200 m away from the watercourse (Figure 5.1)— within specifically designed weather-shelters (Figure 5.2). These devices were programmed to record the air temperature on an hourly basis and collected for analysis every four months.

Figure 5.2: HOBO® installed within specifically designed weather-shelter.

Despite the efforts undertaken to camouflage these devices and the coordination with the park staff, the HOBO® loggers installed in the western transect (T3) were stolen twice. For that reason, there were no data available and the area was discarded.

The transect located in the downtown area (T2) generated the largest amount of information with all HOBOs® operating for almost a year.

The data was collected using a HOBO® Optic Base Station. Then, data was subject to consistency tests in order to identify and remove anomalous information derived from sensor damage or third-party actions (Smith, 2011). This procedure produced a table containing information regarding hourly air temperatures.

Mobile Transects

On January 11, 2011, 16 transects were performed along the Mapocho River and distributed according to land uses and the presence of bridges (Figure 5.1). Each transect consisted of five measuring points —one located over the river and two on each bank 100 and 200m away from the main watercourse.

As Romero et al. (2010b) suggests, manual measurements of air temperature and wind speed and direction were performed three times a day (morning, afternoon, night) (Figure 5.3). Properly calibrated thermo-anemometers were used.

Measurements were performed in the shade at an altitude of 1.5 m according to a protocol introduced to the participants during a training session. These measurements were recorded in field data sheets, which were then digitalized and organized in tables for further analysis.

Figure 5.3: Manual measurements of air temperature and wind speed and direction using thermo-anemometer.

Due to the availability of staff and thermo-anemometers, teams of two people had to perform three or four transects; this meant that the measurement of the 16 transects was not performed simultaneously. However, measurement of four to five transects were taken simultaneity during each measurement session.

5.1.4.3 Woody species distribution

Sampling sites randomly distributed along the riparian area were used to identify woody species. However, where the specie identification was not possible, samples and pictures were taken and presented to an expert for further analysis.

The information obtained was documented in field record sheets, which were then digitalized and organized in tables for further analysis.

5.1.5 Consultation with stakeholders and experts

Consultations with stakeholders and experts were conducted in three ways.

5.1.5.1. Focus Group

Participants were selected according to their relevant knowledge of green spaces and watercourses in Santiago. All participants received an invitation together with a cover letter by email that described the context of the research and the expected contribution for priority ESs selection.

The focus group was also used to discuss other subjects related to this research, which contributed to having a general overview and a better sense of the problem. For a detailed list of topics, participants and the program of the focus group, please refer to Appendix A.

Figure 5.4: Focus group conducted on January 26, 2011.

The focus group lasted two hours long and included the participation of 17 experts, one facilitator and three assistants who were in charge of the materials and the documentation (graphic and written records) (Figure 5.4). In order not to lose relevant information, the focus group was recorded in audio and video. For further consultation and analysis, backup files were available in *.mp3 and *.wmv formats, respectively.

5.1.5.2. Questionnaires

This research used two types of questionnaires, (a) one for stakeholders, which was related to ESs; and (b) one for experts, which was related to suitability factors. In both cases, cover letters and help guides (including a glossary) were sent to participants.

Questionnaires on ESs for stakeholders

31 questionnaires were applied to stakeholders from November 2011 to March 2012.

A snowball sampling technique was employed to recruit participants, who are involved in the decision-making processes that affect the riparian zones and public green spaces of Santiago. Although most of these respondents work in public offices, there are also experts from universities that occasionally act as consultants on these matters.

This was an online questionnaire developed with Google Drive, in which stakeholders were asked to define the most important (in term of needs) ecosystem services for Santiago and the riparian zones along the urban segment of the Mapocho River.

Participants were asked to identify the most important ESs and rank them on a scale from 1 to 3, with 1 being the most important.

Questionnaires on Factors for Experts

This questionnaire was applied to two experts per each priority ES, who were asked to select the three most important suitability factors. Experts were selected because of their expertise in the issues related to each ES, such as urban climate or urban biodiversity. The cover letter also contained a help guide on how to answer the questionnaire. Participants were given the opportunity to ask questions and make comments. The consultation period lasted from October 2011 to November 2012.

Experts were provided with a list containing five/six suitability factors developed based on a literature review and available spatial information. The objective was to define the most important suitability factors for each ES. In general, experts agreed on the three most important factors. However, when there were discrepancies, each expert expressed his stance until reaching an agreement. One expert on habitat for native fauna was not avalilable to finish the consultation process.

The results of this exercise led to the development of a list containing three suitability factors for each ES.

5.1.5.3. Interviews

Nine semi-structured interviews were conducted in order to obtain information regarding the opportunities and challenges for the development of urban riparian multifunctional greenways. Interviewees come from the public sector and are involved in the planning and management of the riparian zones and green spaces of Santiago.

Respondents were sent a cover letter by email describing the research project and the topics to be addressed during the interview. For further details, please refer to Appendix A.

Interviews were conducted in Spanish and in person when possible or otherwise by telephone. These interviews took place in the offices of respondents and lasted for 60 to 90 minutes. These conversations were recorded and then transcribed for analysis purposes.

5.2 Socio-ecological analysis

The environmental characterization comprised of an integration of many data sources including observations during field work, satellite images, land-use maps, census data, regional and municipal inventories, vegetation distribution maps, and socio-economic statistical information. Information on some important characteristics is available in governmental institutions and literature (GORE, 1998; Reyes & Figueroa, 2010), but most of the critical data for the characterization and further assessment was developed during the research based on secondary sources as well as intensive field work (Section 5.1).

The thematic maps and outcomes were the basis for the suitability analysis and the opportunity and challenges analysis.

The main social and ecological characteristics analyzed were selected based on the discussion elaborated in Chapter 2 and include those displayed in the Table 5.4:

Table 5.4: Social and ecological characteristics analyzed.

Dimension	Characteristic	Dimension	Characteristic
Land - cover			
Social	Social patterns	Ecological	Air temperature and wind patterns
	Urban patterns		Channel alteration
	Transport routes		Vegetation cover
	Urban green areas		Flood prone areas and population at risk (*)
			Woody species distribution (*)
Land-use(*)			

(*) included at the indicator derivation stage
Source: Author's own elaboration.

While others characteristic factors such as geology, soil, topography, archaeological sites and cultural monuments are often covered in similar analysis frameworks, they were not included in the current study because (1) the factors are not relevant in the highly urbanized environment of Santiago, (2) lack of information, and (3) some factors on a regional level are not useful for a detailed analysis and are qualitatively included in the study area description. In contrast, wind and air temperature pattern of the riparian zones were incorporated because they are relevant in the Santiago case.

5.2.1 Analysis of socio-ecological factors

Characteristics were analyzed to recognize and describe main features of the riparian zone in terms of condition and spatial patterns. The spatial variation of these indicators along longitudinal (E-W) and transversal (stream – 50 m and 200 m form both sides) transects was analized in order to explore the existence of environmental gradients and spatial patterns.

For the longitudinal gradient analysis, municipal borders were used to define the segments of municipal riparian areas. In this case, municipal riparian zones were the basic spatial units upon which the comparison of the E-W variation of features was based.

Transversal variations were analyzed by comparing the values of different features (such as the price of land) within 50 m, 200 m riparian zones and the whole municipality. Socio-urban and biophysical characteristics of the 50 m and 200 m riparian zones were compared with the situation in the respective municipality in order to identify a possible environmental singularity of the riparian zone into the communal context.

In the following, the methods employed in this stage are explained in detail.

5.2.1.1 Land-cover classification

The land-use/cover classification was performed through a Geographic Object-Based Image Analysis (GEOBIA) (Hay & Castilla, 2008) of two Quickbird pansharpened satellite images presented in Section 5.1.2.

Images were classified using GEOBIA as this provides better results than the traditional pixel based classification, especially for classifying images of very high resolution (e.g. Quickbird) and identifying objects composed of groups of pixels (Blaschke et al., 2014). GEOBIA utilizes spectral and contextual information in an integrative way in order to improve classification results (Blaschke et al., 2010).

This classification was elaborated with eCognition Developer 8.0 and by following the steps proposed by Blaschke et al. (2014) and Nussbaum & Menz (2008), which consist of (1) image segmentation, (2) classification and (3) accuracy assessment.

These steps were initially developed for a subset of the study area of 5,000 by 5,000 pixel (3 * 3 km), an appropriate size to ensure acceptable computing times in less than 10 minutes with stable performance (Müller, 2011). Once the process and transfer tests were concluded, the rule-set final developed for the test area was applied subset-by-subset to the complete study area.

Image segmentation

During this stage, pixels are grouped to create homogeneous objects by combining spectral and form information. This process is called segmentation. Throughout this study, a spectral difference segmentation was used at level 1 and a multiresolution segmentation was used at level 2, in which level 2 objects are smaller than level 1 objects.

The parameters used during the segmentation process are described in Table 5.5.

Table 5.5: Segmentation parameters.

Parameter	Level 1	Level 2
Segmentation type	Spectral difference	Multiresolution
Scale factor	100	10
Shape	0	0.1
Compactness	0	0.5

Source: Author's own elaboration.

The scale factors control the size of objects. As a result, the higher the value, the larger the objects. The shape determines the importance of the form vs. the spectral homogeneity within the segmentation process. In this context, high values diminish the importance of spectral information when it comes to defining objects. Finally, while high compactness values determine the emergence of rectangular-like objects, low values generate irregular objects.

Classification

After the segmentation process, a rule-set was developed in order to define a set of characteristics of individual objects and define the relationships among them within an organized and hierarchized system. The rule-set enables the identification of land covers at both segmentation levels (level 1 and level 2).

This rule-set is based on the characteristics of objects related to spectral and spatial information.

Finally, a rule-based classification was performed in order to categorize the objects of the image into the classes represented in Table 5.6. Due to the importance of green spaces for the provision of ESs, the vegetation category was the only section included at level 2.

Table 5.6: Land cover classification scheme employed.

Level 1	**Level 2**
Classes	*Sub-classes*
Impervious	
Barren land	
Vegetation	Woodland
	Grassland
Shadow	

Source: Author's own elaboration.

Accuracy assessment

The accuracy assessment was conducted by using a confusion matrix and the Kappa coefficient. For this purpose, a random sampling of 430 ground truth points was compared with the land cover classification. Table 5.7 provides further details on these outcomes.

The overall accuracy of the classification was 92 %, which is considered acceptable. A Kappa coefficient of 0.89 suggests strong agreement and good accuracy.

The results of the land cover classification were used to estimate the surface covered by each type of cover within the whole riparian zone and each municipal riparian zone. Subsequently, the coverage percentages of 50 m and 200 m riparian zones were compared.

Table 5.7: Results of the accuracy assessment.

Overall Accuracy: 92% **Kappa Coefficient: 0.89**							
		Classification					
		Imp	**Bar**	**Woo**	**Gra**	**Sha**	**Row Total**
Ground Truth	**Impervious**	90	8	0	1	1	**100**
	Barren land	6	94	0	0	0	**100**
	Woodland	0	0	88	10	1	**99**
	Grassland	0	0	5	96	0	**101**
	Shadow	2	0	0	0	28	**30**
Column Total		**98**	**102**	**93**	**107**	**30**	**430**
Producer Accuracy		**92%**	**92%**	**95%**	**90%**	**93%**	
User Accuracy		**90%**	**94%**	**89%**	**95%**	**93%**	

Source: Author’s own calculations.

5.2.1.2 Social patterns

The indicators displayed in Table 5.8 were selected and analyzed to describe social patterns in Mapocho’s riparian zone.

Census data from 2002 and the pre-processing analysis described in Section 5.1.3 were used to estimate these indicators.

The population living in the riparian area was estimated as well as the population density, which was then compared with the population density of Santiago. These indicators were estimated for municipal riparian zones, which were used to create charts representing E-W variations.

Proxy indicators such as the level of education and the age structure of the population were used to describe socio-economic characteristics. This assumes that low socio-economic groups concentrate a higher number of individuals with university studies and a lower proportion of individuals under the age of 14.

In this context, the values of these two indicators for municipal riparian zones were compared with the values of each municipality. This procedure was intended to verify if the riparian area had specific characteristics within the municipal context.

Table 5.8: Indicators used to analyze social patterns.

Characteristic	Topic	Indicator
Social Patterns	Population	-Total population -Population density
	Education	-Percentage of people with university studies -Percentage of people with primary studies
	Age	-Percentage of elderly population (age ≥ 65 years) -Percentage of youth population (age≤ 14 years)

Source: Author's own elaboration.

5.2.1.3 Urban patterns

The urban characteristics of the riparian area were analyzed in terms of land structure, physical structure and land value. Table 5.9 shows the indicators used to describe these aspects.

Table 5.9: Indicators used to analyze urban patterns.

Characteristic	Topic	Indicator
Urban Patterns	Land structure	-Density of lots -Average lot size
	Physical structure	-Height of buildings -Housing quality
	Land value	-Average land value

Source: Author's own elaboration.

As discussed in Section 5.1.3, these indicators were estimated using data from the 2002 Census and the IRS. The basic spatial unit of analysis was the census block.

The height of buildings was analyzed by using the same information from the Census regarding the number of stories in buildings. This led to the calculation of the proportion of buildings from one to two stories; three to six stories; and >7 stories per block.

The quality of housing was obtained from the classification available at the IRS, which includes five categories —with a special focus on construction materials: very good, good, medium, bad and very bad. This analysis was based on the percentage of land covered by buildings of different quality.

The average land value is the average value per square meter within a census block. The land value used was that defined by the State (appraisal for taxation purposes).

All these indicators were estimated for the riparian zone as a whole and also for the different municipal segments, which were later compared for detecting possible longitudinal gradients.

The urban vertical structure (number of stories of buildings) and the value of land of the 50 m and 200 m riparian zones as well as the whole municipality were compared. The purpose of this comparison was to identify transversal patterns and possible effects of the proximity of the River on these indicators.

5.2.1.4 Transport Routes

The transport network map was developed on the basis of information provided by MOP, which was previously amended and updated (Section 5.1.1).

Firstly, the transport routes were classified into three types of main roads: streets, highways and bikeways.

Secondly, the transport network structure was analyzed by calculating the percentage of transport network used by each road. This process was also applied to the riparian areas of each municipality and then represented through an east-west gradient.

These analyses prioritized the identification and study of riparian segments dominated by the presence of highways and bikeways.

Finally, the percentage of highways and bikeways of 50m and 200m riparian zones and the municipality was analyzed. Such an exercise was intended to examine whether there are spatial preferences for locations near the river.

5.2.1.5 Urban green areas

This section refers to the public green areas recognized by official documents (CONAMA, 2002; GORE, 2009) (refer to Section 5.1.1 for further details on basic information and pre-processing).

At the beginning of this analysis, the different types of public green areas available in the riparian zone were identified: park, sport ground, plaza and road median. The number, area and size of these green spaces were then calculated.

Subsequently, the surface of the public green areas of each municipal riparian zone was calculated as well as the portion of surface used by each type of green spaces. These results were represented through east-west gradient graphs. Likewise, the most important riparian parks of Santiago were identified and described.

Finally, this analysis evaluated the spatial distribution patterns of public green areas in terms of their distance from the watercourse.

5.2.1.6 Air temperature and wind patterns

The types of data used in this analysis and the way they were measured during the field campaign are detailed in Section 5.1.4.2.

Firstly, in order to analyze air temperature differences between the riparian zone and the urban matrix, data for the summer of 2011 recorded by the four HOBO loggers installed in transect 2 —which is located in downtown Santiago— was compared with the information registered at the Independencia meteorological station —which is the nearest official station, located 1.8km north-east of the transect.

Secondly, February 17 and 18 were selected as the two hottest summer days recorded by the HOBO loggers for further analyses. For these two days, the air temperature recorded by the for HOBO loggers installed in transect 2 was compared with the information of Independencia meteorological station.

Since the Kolmogorov-Smirnov test ($p<0.01$) suggested that summer temperatures as well as the the temperatures of the two hottest days are not normally distributed; the Kruskal-Wallis non-parametric test —which does not require the assumptions related to normality or equality of variance— was used to compare the temperatures of the riparian areas (P1, P2, P3 and P4) and the urban matrix (Zar, 1999).

These comparisons were made using summer and the hottest days data as it would be easier to observe the cooling effect generated by the river and riparian areas (Bowler et al., 2010).

Subsequently, the information regarding air temperature and wind speed obtained from mobile transects in November, 2011 was plotted along the river. Although the 16 transects were available, most of these transects cannot be regarded as simultaneous (Section 5.1.4.2.). Therefore, they were used for the analysis of intra-transect transversal variations of air temperature and wind speed.

Though these analyses were performed in three daily measurements, they were focused on the afternoon measurement (2 pm.).

5.2.1.7 Channel alteration

The degree of *channel alteration* was evaluated through a photo-interpretation of Quickbird satellite images 2006/7 and later validated by a field trip in February 2011. The classification was based on the proposition of Comunidad Autónoma de Andalucia (2002) & Munné et al. (2003) for naturalness classification that includes the classes presented in Table 5.10.

Table 5.10: Channel alteration classification.

Channel alteration
Slightly modified
Fluvial terraces modified and constraining the river channel
Channel modified by rigid structures along the margins
Channelized river

Source: Author's own elaboration based on Comunidad Autónoma de Andalucia (2002) and Munné et al. (2003).

Further analysis consisted of calculating the percentage of the river belonging to each of the above categories. For this purpose, each category was measured in linear meters. In addition, alteration levels at municipal level were analyzed along an east-west gradient.

5.2.1.8 Vegetation cover mapping

The vegetation map was extracted from the land cover classification described in Section 5.2.1.1., distinguishing woodland and grassland.

Firstly, longitudinal and transversal variations in vegetation cover were analyzed by comparing the percentage of vegetation cover of each municipal riparian area as well as the 50m and 200m riparian zones.

Secondly, woodland and grassland distribution was analyzed using the same procedure describe above.

5.2.2 Synthesis of the state of socio-ecological factors

5.2.2.1 Indicators

This stage involved deriving different indicators in order to describe the socio-ecological state of the riparian zone, highlighting important aspects related to its functioning and potential as a riparian greenway (Table 5.11). These aspects are discussed in Chapter 3 and include social and ecological features.

These indicators were calculated for the riparian area as a whole and then analyzed in order to summarize the state of the social and ecological dimensions.

Subsequently, five indicators that offered information at a segment (municipal) level were included in this analysis. These indicators —1, 2, 4, 5 and 9 in Table 5.11— were used to generate spider diagrams for each segment in order to analyze its socio-ecological state. In spider diagrams, a larger area of the central polygon is associated with a better socio-ecological state.

For this reason, as high indicator values must have a positive meaning in the definition of socio-ecological state, the inverse values of two indicators were used: the percentage of high impact land uses (indicator 1) and the percentage of channelized channel (indicator 9). This produces the indicators NON- high impact land uses and NON-channelized. For example, if the percentage of channelized channel reaches 60 %, the remaining 40 % corresponds to NON-channelized.

Table 5.11: List of indicators used in the synthesis of the state of socio-ecological and their definition.

	Indicator	Definition
1	Percentage of high impact land uses	Percentage of surface covered by highly dense residential areas, highways and industrial/commerce/institutional zones in relation to the surface of the riparian zone.
2	Percentage of vegetation cover	Percentage of surface covered by vegetation (public or private) in relation to the surface of the riparian zone.
3	Percentage of bare land	Percentage of bare land surface in relation to the surface of the riparian zone.
4	Percentage of public green areas	Percentage of surface covered by public green areas in relation to the surface of the riparian zone.
5	Percentage of bikeways	Percentage of linear meters of bikeways within the transport network.
6	Percentage of highways	Percentage of linear meters of highways within the transport network.
7	Percentage of population at flood risk	Percentage of the population living in flood prone areas in relation to the total population living in riparian zone.
8	Percentage of slightly modified channel	Percentage of linear meters of a slightly modified channel in relation to the total linear meters of both riverbanks.
9	Percentage of channelized channel	Percentage of linear meters of channelized channel in relation to the total linear meters of both riverbanks.
10	Percentage of native woody species	Percentage of native woody species in relation to the total number of species.

Source: Author's own elaboration.

With the exception of indicators 1, 7 and 10, all indicators were derived from the results of previous analyses. In the case of 1, 7 and 10 indicators additional analyses were needed, which are described below.

5.2.2.2 *Woody species distribution*

Floristic surveys of woody plants were performed in summer 2009 and 2011. Sampling sites were 10 m x 10 m (Chytry & Otypkova, 2003) and randomly distributed along riparian areas.

Woody species were recorded as well as cover and average height of tree stratum, shrub stratum, and grass stratum. Woody species were mostly identified on site, but some of them were later recognized by an expert consultant.

The data was analyzed to estimate species composition, with a special focus on distribution of native species (Baschak & Brown, 1995).

5.2.2.3 *Flood prone areas*

Initially, flood prone areas were mapped using flood hazard assessment information from the Bases para un Ordenamiento Territorial Ambientalmente Sustentable en la Región Metropolitana de Santiago (OTAS) project (GORE, 1998; see Section 5.1.1)

Next, how much of the riparian zone is threatened by floods as well as demographics of residents was calculated. The flood prone areas used for this analysis are those affected by flooding events every 2 years. Finally, the number of inhabitants living in flood prone areas was calculated.

5.2.2.4 *Land use classification*

Classification of land-use was implemented through photo-interpretation of two Quickbird pansharpened satellite images (see Section 5.1.1), employing the classification proposed by Romero et al. (2007) and modified from CORINE (1990) and Pauleit et al. (2005) (Table 5.12).

Table 5.12: Land-use sub-classes identified in the riparian zone.

Classe	Sub-classes
Urban	Urban highway
	Industrial/commerce/institutional areas
	Residential dense areas
	Residential intermediate areas
	Residential disperse areas
	Urban barren land
	Urban green areas

Source: Author’s own elaboration based on Romero et al. (2007).

5.3 Greenway suitability analysis

The Greenway Suitability Analysis was conducted through a multicriteria analysis, which aims the identification of the most suitable areas for the provision of the priority ecosystem services. Furthermore, a least cost path analysis was developed for non-motorized transportation. These analyses were carried out using ArcGis 10.2.

5.3.1 Multicriteria analysis

This analysis was based on the approach suggested by Miller et al. (1998) for greenway suitability assessment. Similarly, an AHP was adopted to define and overlap (1) factors and (2) suitability maps. Step (1) gave rise to suitability maps for each ES (monofuctional suitability), and step (2) produced suitability maps for multiple Ess (multifuctional suitability).

In this study, a fuzzy logic multicriteria evaluation was implemented. Consequently, considerable importance was given to the definition of the fuzzy membership and overlapping functions through the use of the AND/OR operators. For further details on this matter, please refer to Section 3.3.2.

The steps taken for the development of the fuzzy logic multicriteria evaluation are described in the following.

5.3.1.1 Identification of priority ecosystem services

The ecosystem service identification is the first step to perform a multicriteria analysis. First, a focus group of experts and stakeholders identified the most significant ecosystem services that riparian greenways can provide in Santiago. They took into account the information generated in the socio-ecological analysis, their own knowledge of the study area as well as social and ecological needs (Conine et al., 2004). This produced a reduced list of seven ecosystem services; such a process involved the reformulation of their names and the elaboration of ad-hoc definitions.

Based on literature review, this study compiled a general list of 15 ecosystem services that may be provided by urban riparian greenways (See Table 5.13). This list was presented and discussed by a panel of 17 experts and local actors from ministries, municipalities, universities, companies and NGOs with the aim to choose the relevant ecosystem services for Santiago. This focus group took place on January 26, 2011 and lasted two hours.

The structure of this focus group and the list of participants are described in Appendix A.

Table 5.13: Ecosystem services that may be provided by urban riparian greenways.

Ecosystem service	Ecosystem service
Improvement of the environmental quality of the main watercourse	Provision of routes for alternative means of transport (hiking, running and cycling)
Control of lateral erosion	Provision of spaces for recreation, leisure and contact with nature
Provision of wildlife habitat	Improvement of the visual quality of the landscape
Climate regulation	Increase in the price of land
Reduction of noise and water temperature	Reduction of natural hazards on people and infrastructure
Facilitate the infiltration of water	Education opportunities
Facilitate the flow of wind	Cultural heritage
Air purification	

Source: Author's own elaboration based on Hellmund & Smith (2006).

Despite being an event moderated by the lead researcher, all participants had the opportunity to express their thoughts on the topics of discussion.

This discussion process identified seven priority ecosystem services that may be provided by urban riparian greenways in Santiago, including Mapocho's riparian zone.

Subsequently, these seven ecosystem services were rated by 31 stakeholders through an online questionnaire following the procedure described in Section 5.1.5.2. It involves the attribution of relative importance for each ecosystem service on the Mapocho River and Santiago.

The distribution of stakeholders and the entities they work for are described in Table 5.14.

Table 5.14: Distribution of stakeholders according to home institution.

Institution	Stakeholders
Ministry of Public Works	2
Ministry of the Environment	2
Ministry of Housing and Urban Development	4
Regional Government	5
Municipalities	9
Universities	9
Total	**31**

Source: Author's own elaboration.

These results were analyzed according to the number of times each ES was rated as the most important (1°), the second most important (2°) and the third most important (3°) service by stakeholders. In this way, the most important ES was the one that obtained the highest number of first preferences. If two ESs were ranked first, the ES that obtained the highest number of second preferences was regarded as the most important service. This pattern was also used if two ESs shared the second highest preference.

In addition, the preferences of stakeholders according to the home institution were also analyzed. This evaluated the relation between the importance given to ecosystem services and sectorial approaches and priorities.

5.3.1.2 Deciding suitability factors

A combination of published literature and expert opinion was used to identify relevant suitability factors for each ecosystem service. According to Miller et al. (1998) and Du et al. (2012) factors are discussed in

Each of the seven priority ESs identified in the previous stage were analyzed by two experts (Appendix A). Each expert was given a list containing six to twelve suitability factors previously selected as important according to literature review. In addition, a complete list containing the 26 factors available in the database was included. Both lists included definitions of each factor.

Experts were asked to select the most important suitability factors contained in the list of preliminary factors; they also had the opportunity to choose one factor that was not included in this list but available in the database of 26 factors.

Where there were discrepancies about the three most important factors, each expert expressed his argumentation for and against the factor in dispute until reaching an agreement.

5.3.1.3 Image of factors development and fuzzification

Initially, the attribute layer associated with each factor was derived from the analysis performed in the socio-ecological analysis as well as from published literature. According to literature, the images generated in the socio-ecological analysis correspond to the significant factors to assess the greenway potential. However, additional layers were generated ad-hoc for each case where it was needed.

The Table 5.15 shows a general overview of the attribute layers associated to each factor.

All factor layers were calculated using a 5 m * 5 m resolution. In the case of vector layers, a transformation to raster was conducted with the same resolution. Therefore, all cartographic results have a 5 m * 5 m resolution and at the scale of 1:18,898.

Table 5.15: Attribute layers associated to suitability factors.

Factor/Layer	Description
Vegetation cover	Percentage of vegetation cover within the cells of a fishnet of 5 m * 5 m. This was derived using the land cover classification.
Tree and bush cover	Percentage of woodland within the cells of a fishnet of 5 m * 5 m. This was derived using the land cover classification.
Impervious surface Land cover	Percentage of impervious surface cover within the cells of a fishnet of 5 m * 5 m. This was derived using the land cover classification.
Slope	Slope in degrees calculated using a DEM derived from contour lines at the scale of 1:50,000.
Channel naturalness	Degree of naturalness of riversides according to Table 5.10.
Height of buildings	Percentage of surface used by one- and two-story buildings per block.
Width of zones without buildings	A map layer of the strip without buildings running along the river was created using on-screen digitizing.
Flood mitigation works	A map layer of the flood mitigation works was created using on-screen digitizing.
Population density	Kernel Density using population centroids from the respective census block polygon shapefile.
Distance to the channel	Euclidean distance to the river's channel.
Distance to streets	Euclidean distance to streets.
Distance to public green areas	Euclidean distance to public green areas.

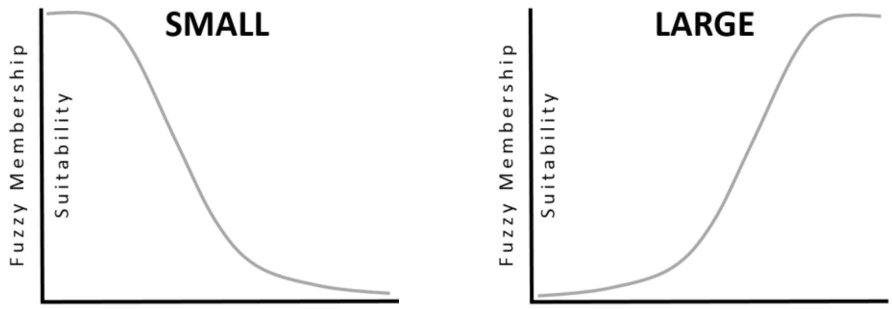
Source: Author's own elaboration.

Firstly, the conversion of original values of factor layers to the possibility of being suitable for providing an ES was performed through a fuzzification process.

The original values of these factors were reclassified on a membership continuum scale from 1 to 0 according to a predefined fuzzy membership function. In this context, low values imply low suitability.

The type of fuzzy membership function depends on the relationship between factors and the suitability for the provision of a given ES. For instance, high factor values (population density) may be associated with low suitability values for the provision of a given ES (habitat for wildlife fauna) (SMALL); on the contrary, high factor values (distance to streets) may be related to high suitability values for the provision of the same ES (habitat for wildlife fauna) (LARGE) (Figure 5.5).

Figure 5.5: Fuzzy membership function used.



Source: Author's own elaboration.

The fuzzy membership function used during the fuzzification process for each ES is detailed below (Table 5.16).

Table 5.16: Fuzzy membership function applied.

Ecosystem Service	Factor/Layer	Fuzzy Membership Function
Spaces for recreation	Vegetation cover	LARGE Midpoint: 50 – Spread: 7
	Distance to the channel	SMALL Midpoint: 100 – Spread: 5
	Distance to public green areas	SMALL Midpoint: 20 – Spread: 5
Routes for non-motorized transport	Tree and bush cover	LARGE Midpoint: 50 – Spread: 7
	Distance to streets	SMALL Midpoint: 20 – Spread: 5
	Distance to public green areas	SMALL Midpoint: 20 – Spread: 2
Wind corridor	Tree and bush cover	SMALL Midpoint: 50 – Spread: 9
	Height of buildings	SMALL Midpoint: 50 – Spread: 5
	Width of without buildings zone	LARGE Midpoint: 100 – Spread: 3
Flood hazard mitigation	Impervious surface land cover	SMALL Midpoint: 50 – Spread: 3
	Slope	LARGE Midpoint: 4 – Spread: 5
	Flood mitigation works	LARGE Midpoint: 2 – Spread: 3

Cooling effect	Tree and bush cover	LARGE Midpoint: 50 – Spread: 5
	Impervious surface land cover	SMALL Midpoint: 50 – Spread: 5
	Width of without buildings zone	LARGE Midpoint: 200 – Spread: 5
Habitat for native flora	Vegetation cover	LARGE Midpoint: 50 – Spread: 5
	Impervious surface land cover	SMALL Midpoint: 50 – Spread: 3
	Channel naturalness	LARGE Midpoint: 2.5 – Spread: 5
Habitat for native wildlife	Tree and bush cover	LARGE Midpoint: 50 – Spread: 7
	Channel naturalness	LARGE Midpoint: 2.5 – Spread: 5
	Population density	SMALL Midpoint: 200 – Spread: 3

Source: Author's own elaboration.

5.3.1.4 Overlay and monofunctional suitability maps

The elaboration of monofunctional suitability maps for each ES was carried out through the overlapping of factors using a linear sum (Eastman, 2006). In this context, the fuzzification process was used as a standardization technique for factors.

Since each factor has values ranging from 0 to 1, the monofuctional suitability maps presented variations ranging from 0 —in the case of unsuitable pixels— and 3 —in the case of pixels with the highest suitability. For this reason, the monofuctional suitability maps were subject to a fuzzification process by using a linear fuzzy membership function. The resulting maps were regarded as the final monofuctional suitability maps.

The monofuctional suitability maps were compared according to their average values, standard deviation and image frequency histograms.

The two Primary ecosystem services (routes for non-motorized transport and wind corridor) were excluded in further analyses as they require an approach that includes the flow or movement along the riparian corridor (Section 5.3.2.).

Next, the most suitable areas for the provision of ESs were identified by selecting the spaces with suitability values higher than 0.75. This analysis included the estimation of the total area and number of these most suitable areas —or patches—, including their average and maximum size.

These results were analyzed along an E-W longitudinal gradient by using the municipal riparian areas as spatial units of analysis.

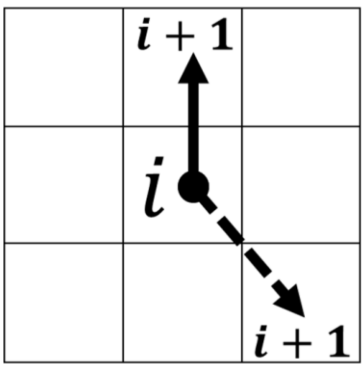
5.3.2 Suitability for primary ecosystem services

5.3.2.1 Routes for Non-Motorized Transport

The suitability for a route for non-motorized transport was calculated using a Least-Cost Path (LCP) model. The LCP has been used with good results for functional analysis of landscape (Adriaensen et al., 2003), especially to model processes or potential flows along greenways (Kong et al., 2010; Teng et al., 2011).

The LCP analysis was developed by using the Path Distance and Cost Path modules available on the Distance Toolset of ArcGis 10.2. The underlying algorithm for least-cost modeling is represented in Figure 5.6. According to Adriaensen et al. (2003), such an algorithm can be described as: "any given moment from pixel (cell) P_i to pixel P_{i+1}, the cumulative cost is calculated as the cost to reach pixel P_i plus the average cost to move through pixel P_i and P_{i+1}" (p. 235).

Figure 5.6: Underlying algorithm for least-cost modeling.



$$P_{i+1} = P_i + (r_i + r_{i+1})/2$$

or for diagonal directions

$$P_{i+1} = P_i + \sqrt{2} * (r_i + r_{i+1})/2$$

P_i = accumulated cost in pixel i
r_i = resistance value in pixel 1
i : source pixel
$i + 1$: target pixel

Source: After Adriaensen et al. (2003).

Least-cost path starts with the definition of the points of origin and destination. In this case, these were located in the east and west ends of the riparian area.

Next, the cost or resistance surface used during the calculation process was derived from the suitability map for non-motorized transport developed through the multicriteria analysis described in Section 5.3.1. However, the procedures referred to in Sections 5.3.1.3. and 5.3.1.4. generated a suitability map with values ranging from 0 in non-suitable places to 1 in highly suitable areas. Therefore, suitability values were inverted and transformed into a cost surface.

In this context, values equal to 1 in the suitability image should be converted to 0 in the cost image; and conversely, values equal to 0 in the suitability image should be converted to 1 in the cost image. Consequently, the suitability image was reclassified into ten classes (using the Jenks natural breaks classification method) and the values of the output image were inverted. Such a process meant that class 1 of the suitability image was transformed into class 10 of the cost image.

Finally, the Cost Path tool was used to model the least-cost path between the origin and destination points. The result corresponds to the most cost-effective route between these points as this route represents the minimum accumulative cost. In this case, the route minimized contact with low suitability pixels.

Lastly, the least-cost path was analyzed in terms of its length and extension. Likewise, the path of this route through the northern and southern riversides of the river and its distribution among municipal areas were analyzed.

5.3.2.2 Wind corridor

For the wind corridor, no LCP model or similar analyses were conducted as they define a route that replicates the course of the river. The objective of this step was to identify a spatially continuous and wide strip along the river that allows the flow of wind.

Hence, all areas with suitability values higher than 0.75 for the provision of this specific ES were selected. These areas are associated with low surface roughness (presence of buildings and trees) and segments with a wide undeveloped strip along the watercourse.

Finally, all small and isolated polygons from the central strip were removed. Accordingly, a single and spatially continuous polygon of highly suitable land along the River was identified as the wind corridor.

The analysis of the wind corridor was based on calculating its average width as well as its wider sections and the bottlenecks that may affect its functioning.

5.3.3 Multifunctional greenway suitability

Since a fuzzy-logic-based approach was used, the combined step of monofuctional suitability final maps explores the possibility that pixels are suitable for the provision of multiple ecosystem services.

In this study, two operators —AND/OR— were used to analyze the interaction among the different monofuctional suitability maps (Table 5.17).

The AND operator assigns to the pixels of the output image the minimum suitability values present in the monofuctional suitability maps used as inputs . The suitability map for multiple ecosystem services produced using the AND operator finds the locations that meet high suitability values for all ESs. This means that no trade-offs are allowed among monofuctional suitability maps; in other words, low suitability values for an ES cannot be compensated for by the high suitability values for another ES.

Table 5.17: Monofuctional suitability maps used for multifuctional suitability estimation.

Suitability map
Spaces for recreation
Flood hazard mitigation
Cooling effect
Habitat for native flora
Habitat for native wildlife

Source: Author's own elaboration.

Therefore, the AND multifunctional suitability map is the most demanding solution in terms of suitability levels for all ESs; this is why this map implies the maximum decision risk aversion.

On the contrary, the OR operator assigns maximum suitability values present in the monofuctional suitability maps used as inputs to the pixels of the output image. The multiple ecosystem services suitability map produced using the OR operator finds the locations that have high suitability for any ES.

Unlike the AND operator, the OR operator allows for compensation (and trade-offs) among the suitability values of the different ecosystem services. Accordingly, a specific location may be highly suitable in multifunctional terms despite having low suitability levels for the provision of one or more ESs. Therefore, this operator offers the least demanding solution in relation to the different suitability levels of each ES, thus suggesting the minimum decision risk aversion.

The final suitability maps for the multiple ecosystem services described (AND/OR) do not provide information regarding the composition of the final suitability value. Hence, it is not possible to know which ES offers the highest or lowest suitability value within a specific location.

Consequently, an RGB (red, green, blue) composite image was created by using the suitability images of the three most important ESs (excluding those belonging to the primary ESs group) as multiband raster datasets: recreation, cooling effect and flood hazard mitigation.

An RGB composite image assigns individual image values to the intensities of the red, green and blue components of a pixel color. In the RGB suitability image for multiple services, suitability values for flood hazard mitigation, spaces for recreation and cooling effect were assigned to by red, green and blue intensity colors, respectively (Table 5.18).

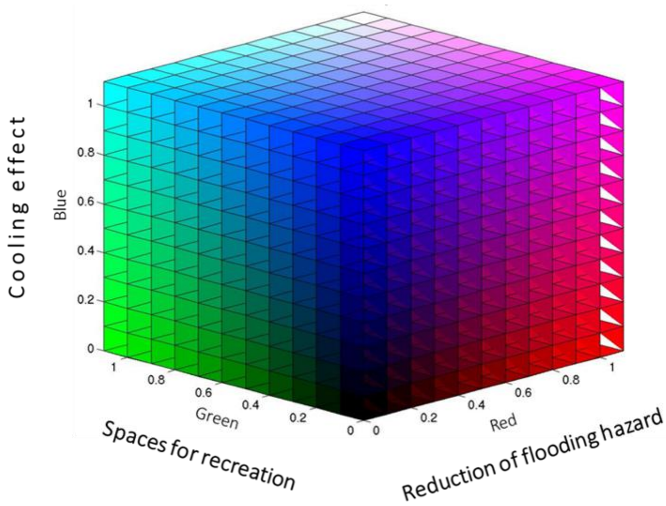
Table 5.18: Individual ES images assigned to the intensities of red, green and blue.

Channel	Ecosystem Service
Red	Flood hazard mitigation
Green	Spaces for recreation
Blue	Cooling effect

Source: Author's own elaboration.

Therefore, the composite RGB image displays visual information about the suitability values of pixels for the provision of the three selected ESs. While red colors are related to pixels with high values for flood hazard mitigation, blue colors are associated with suitable areas for the provision of cooling effect services. Figure 5.7 shows the different suitability combinations and associated colors.

Figure 5.7: RGB composition and suitability space.



Source: Author's own elaboration

The three suitability maps for the provision of multiple ESs were analyzed in terms of their differences, similarities and spatial patterns. Special attention was given to the identification of the areas that achieved high suitability values in both modeling processes (AND/OR). This analysis was supported by the suitability composition provided by the RGB image.

5.4 Opportunities and challenges analysis

This stage was based on semi-structured interviews to key stakeholders; in order to identify the opportunities and challenges for urban riparian greenways development. The perceptions and interests of stakeholders were contrasted with the analysis of regulations and the current institutional framework.

Nein semi-structured interviews were applied to key stakeholders —selected through snowball sampling— and lasted from 60 to 90 minutes. For further details, please refer to Section 5.1.5.3.

Respondents belong to the most important public agencies involved in the planning and management of green spaces and riparian zones in Santiago. Interviewed are senior government officials —such as head of departments— involved in decision-making processes.

The most recurring agencies were GORE —three respondents— and MINVU —two respondents. Although there were efforts to interview a larger number of municipal officials —especially those from the municipalities located in the western area of Santiago—, this however, was not achieved. This may be interpreted as a lack of interest or knowledge on the part of municipal officials regarding riparian areas.

Despite being an expert rather than a stakeholder, Jonás Figueroa (USACH) was included in this series of interviews because of his knowledge of the institutional and legal framework associated with the riparian zones of Santiago.

The interview topics are available in Appendix A. Interviewees had the opportunity to make comments about aspects other than those included in these topics.

Though the topics discussed during the interviews were focused on riparian zones and their potential as greenways, interviewees alluded in general to the public green areas of Santiago. Therefore, several of the aspects discussed with stakeholders are related to the opportunities and challenges for the public green areas development and preservation.

These interviews were recorded and transcribed. The software MAXQDA was used to perform a content analysis.

The qualitative content analysis is a process intended to condense raw data into categories based on valid inference and interpretation (Zhang & Wildemuth, 2009). In operative terms, the latter implies the assignment of a category to a passage of text.

The content analysis used throughout this research was based on a directed content analysis (Hsieh & Shannon, 2005) that included an inductive category development (Mayring, 2000). Tentative categories based on theories and evidence found in other studies were defined, which were reviewed in terms of their reliability and then modified during the analysis (Mayring, 2000). This meant the emergence of new topics.

According to the issues discussed in Section 3.3.3. and the suggestions made by Erickson and Louisse (1997) and Ryan et al. (2006), the following categories were used for the purposes of the content analysis:

- Coordination among governmental agencies
- Regional governance
- Funding
- Public perceptions
- Property rights
- Physical state

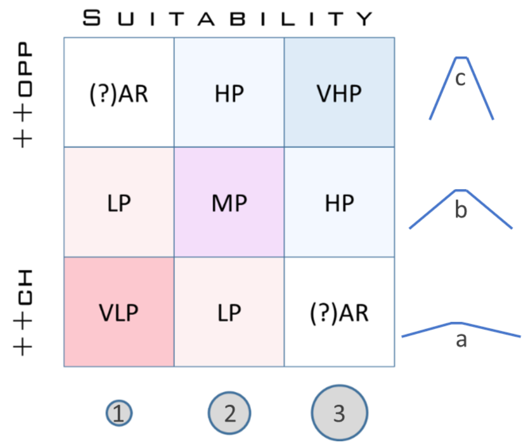
5.5 Multifuctional greenway potential

This stage involved the synthesis and integration of the main results of previous stages, in order to identify the potential of the riparian zone of the Mapocho River as a greenway.

The model for potential proposed in Section 3.2 was used as a general analytical framework.

Firstly, the combinations between suitability and opportunities-challenges defining different levels of potentiality have to be established. For the purposes of this study, an intermediate situation between the proposals described in Figure 3.3(a) and 3.3(b) has been selected (see Figure 5.8).

Figure 5.8: A Combination between suitability and opportunities-challenges representing an intermediate situation used in this study. ++CH= more challenges, ++OPP= more opportunities, VHP= very high potential, HP= high potential, MP= medium potential, LP= low potential, VLP= very low potential, AR(?)= assessment required.



Source: Author's own elaboration

Secondly, a list containing ecosystem services and the different sectors of the riparian zone arranged in order of decreasing suitability was elaborated. A second list containing different opportunities was arranged according to importance and associated challenges was also elaborated.

Finally, the highest suitability categories and most important opportunities were analyzed by using the conceptual and analytical method proposed in Section 3.2. One of the most important aspects was the identification of the interactions between the highest suitability categories and opportunities that produce a very high potential (VHP).

Chapter 6
Socio-ecological analysis

This chapter presents the results of the first stage of the greenway potential assessment. This is the first study that explores quantitatively and spatially explicit social and ecological characteristics of the riparian zone of the Mapocho River in the city, and therefore, is the basis for understanding the existing spatial patterns, socio-ecological state, needs and delineate guidelines for the development of a riparian greenway.This includes an analysis of relevant socio-ecological characteristics and their variation along transverse and longitudinal gradients of the river. A synthesis of the socio-ecological state is developed for the riparian zone as a whole and at a municipal riparian zone level.

Furthermore, the results of this chapter are used in Chapter 6 and 7 to lead discussions with actors and experts, and position the subsequent analyses.

6.1 Socio-ecological factors

This section presents the analysis of eight relevant socio-ecological factors.

6.1.1 Land cover

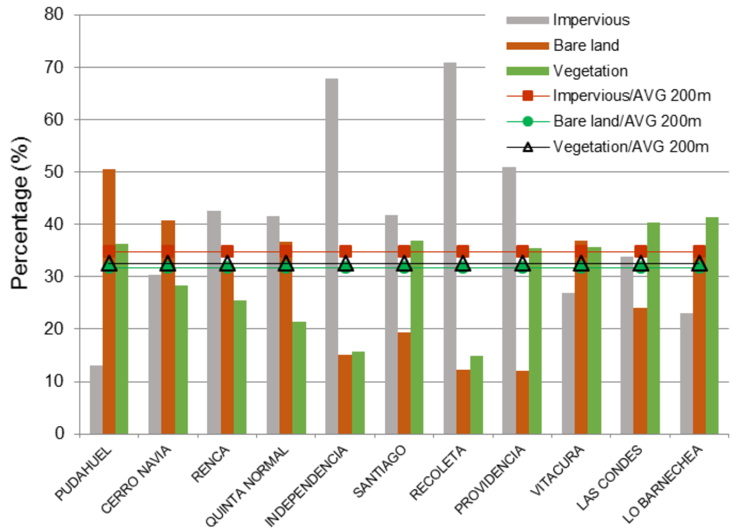
Land cover types are well distributed in impervious land, bare land and vegetation cover in the Mapocho's riparian zone. Each of these land cover types cover around 30 % of the riversides, but with a little difference in favor of impervious surfaces which reaches 35 %. Bare land (32 %) and vegetation covers (32 %) together represent 64 % of the riparian zone, in other words, most of the riparian zone remains unsealed by hard surfaces offering a chance for green infrastructure development.

However, Figure 6.1 and 6.2 shows a high variability in the land cover structure (distribution) along the river. It is possible to observe a decreasing gradient of vegetation cover from west to the city center, where it decreases progressively from 36.3 % in Pudahuel to 14.8 % in Recoleta. To the east of Quinta Normal the vegetation cover only decreases in the northern riverside as the southern riverside in the city center (Santiago municipality) 36.9 % is covered by vegetation.

The largest percentages of vegetation cover are exhibited at the eastern extreme by Las Condes (40.4 %) and Lo Barnechea (41.3 %), closely followed by Santiago (36.9 %) and Pudahuel (36.3 %) located at the western extreme.

The northern riverside in the city center (Independencia and Recoleta) is highly covered by impervious surfaces such as roofs, streets and parking lots, which represent around 70 % of the total area. Immediately to the east of Recoleta the riparian zone remains mostly sealed.

Figure 6.1: Variability in the land cover structure along the river.



Source: Author's own elaboration based on the land cover classification of Quickbird satellite images 2006/7.

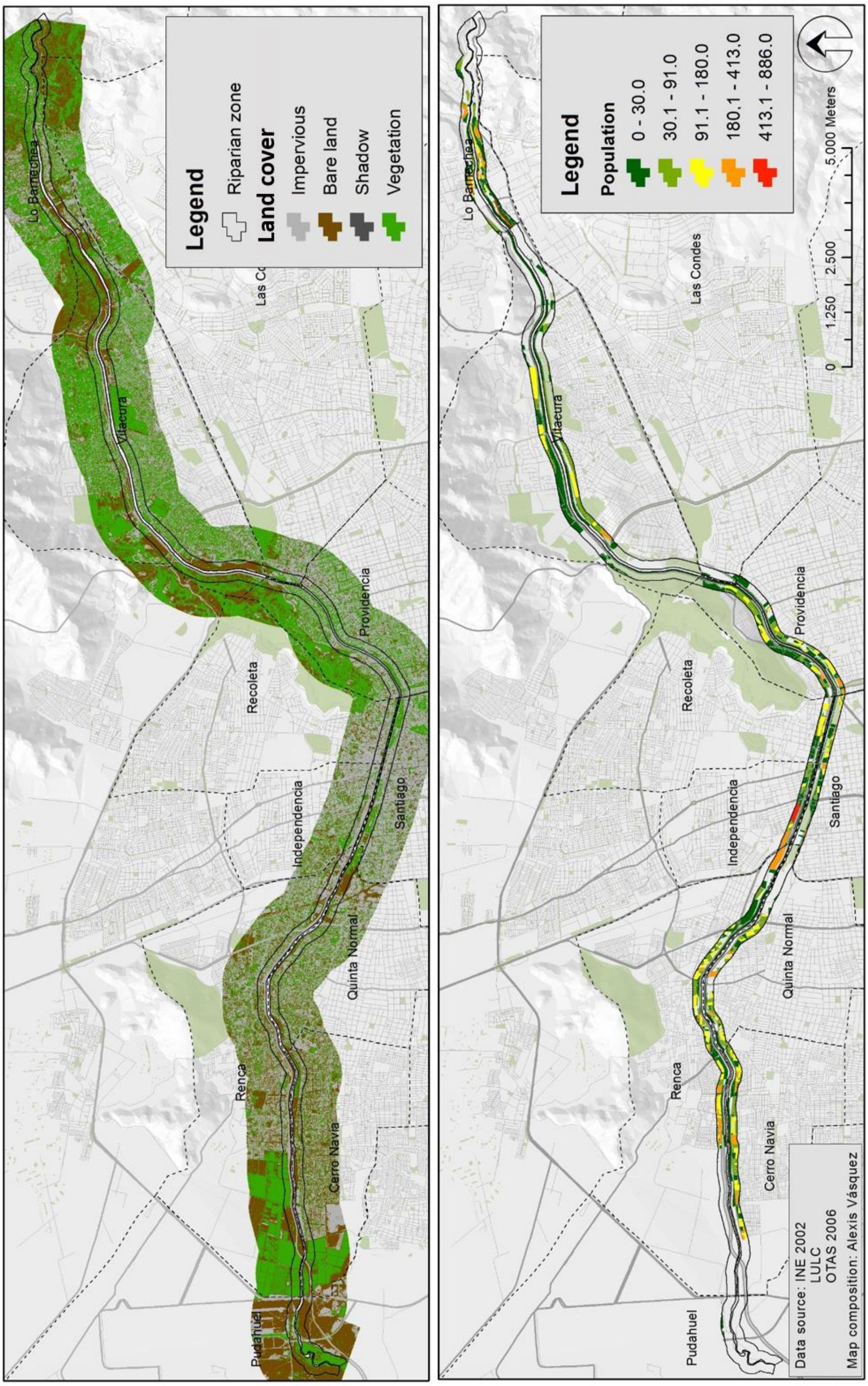
The percentage of bare land represents more than 30 % of the riparian zone in six of eleven municipalities, Vitacura and Lo Barnechea in the eastern section, and four in the western section: Pudahuel, Cerro Navia, Renca and Quinta Normal. The highest percentages of bare land can be found in the western section, especially in Pudahuel (50.4 %) and Cerro Navia (40.7 %).

A decreasing transverse gradient of vegetation cover can clearly be observed in three municipalities: Renca, Independencia and Vitacura, where the percentage of vegetation closer to the river is 2.3, 1.8, and 1.1 times lower, respectively. In these municipalities the 50 m strip immediately next to the river is less vegetated as well as at least 10 % less sealed in comparison with the 200 m buffer average (AVG).

In contrast, the riparian zone is better covered by vegetation closer to the river in Pudahuel (+23 %), Providencia (+11 %), Recoleta (+9 %) and Santiago (+6 %).

Bare land exhibits an increasing transverse gradient in Cerro Navia and Quinta Normal where the bare land closer to the river is 12 % and 17 % greater, respectively.

Figure 6.2: Land cover and population distribution.

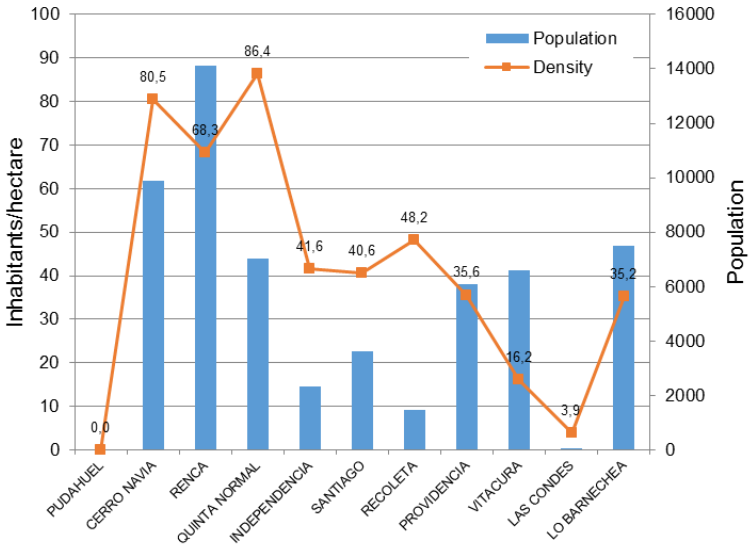


6.1.2 Social patterns

The analyzed Mapocho's riparian zone is 54 km long and comprises an area of 1,498 hectares. 56,183 people are living in this area and the density is 39.2 hab/hec., much lower than the 84 hab/ha of Santiago city.

Figure 6.3 shows how the population is distributed throughout the 11 municipalities crossed by the Mapocho River in the study area. Generally speaking, the population living in the riparian zone increases from the city center to the periphery since the city center concentrates commercial and institutional buildings as well as part of the financial district.

Figure 6.3: Population and population density.



Source: Author's own elaboration based on census data (INE, 2002).

53 % of the population is concentrated by three municipalities located downstream in the western section: Cerro Navia (17 %), Renca (24 %) and Quinta Normal (12 %). These three municipalities also have the highest population densities, quite similar to the average population density in Santiago. Moreover, Pudahuel is located at the western extreme of the study area and the riparian zone is still uninhabited (Figure 6.2).

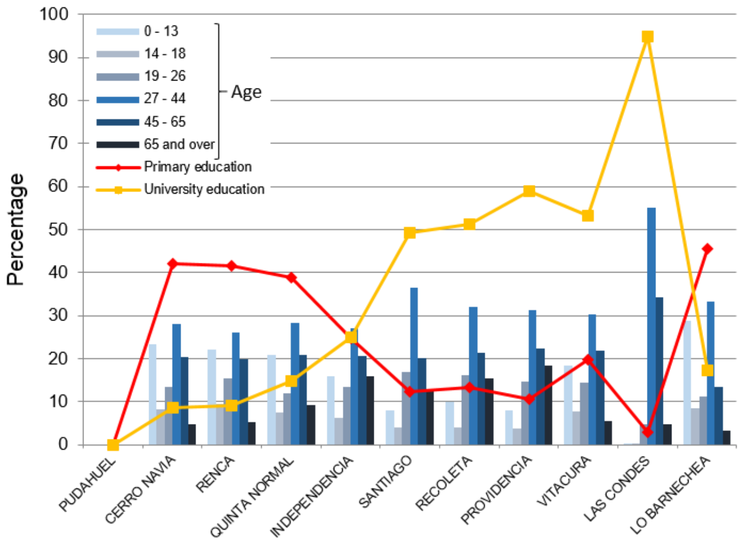
In general terms, it is possible to differentiate the low income western section downstream and the high income eastern part (Figure 6.4). This is representative of the existing pattern in Santiago.

To the west of the Santiago municipality (city center), the population is characterized by a low educational level and large families with many children (Figure 6.5). On the other hand, in the richer eastern section of Mapocho River more than 50 % of the population has completed university studies, which is closely related to high-income strata and high social status groups. As a consequence, any greenway project should prioritize its development in the western section of the river.

The riparian zone in Lo Barnechea can be considered an exception to this general pattern or socio-economic east-west gradient. Lo Barnechea municipality, although one of the richest municipalities in Santiago, hosts La Ermita de San Antonio housing project, which is one of the most important projects of social housing of eastern Santiago. This project as well as other social housing complexes and irregular settlements have been mostly located close to the river in this municipality.

The more central area constituted by Santiago, Recoleta and Providencia is inhabited principally by people between 27 and 44 years old and with a very low percentage of children below 13 years.

Figure 6.4: Population age structure and educational level.



Source: Author's own elaboration based on census data (INE, 2002)

This provides an idea of the existing social and socioeconomic diversity in the riparian zone of the Mapocho River as it passes through the city, with a marked east-west gradient in most of its attributes. It is expected that these differences in education, age structure and population density influence the needs and preferences for a greenway.

In addition to the longitudinal socio-economic gradient previously described, it is possible to identify a kind of transverse gradient of socio-economic characteristics in three municipalities. This means that people living in the riparian zone are quite distinctive compared to the rest of the municipality.

As previously mentioned, Lo Barnechea is a wealthy municipality where residential areas located in the riparian zone represent pockets of poverty (in need) (Figure 6.5 and 6.6) that are characterized by a lower educational level, fewer elderly and more children. Otherwise, riversides in Las Condes and Recoleta municipalities seem to have been attractive for the settlement of the highest socio-economic groups within the municipal territory (Figure 6.6).

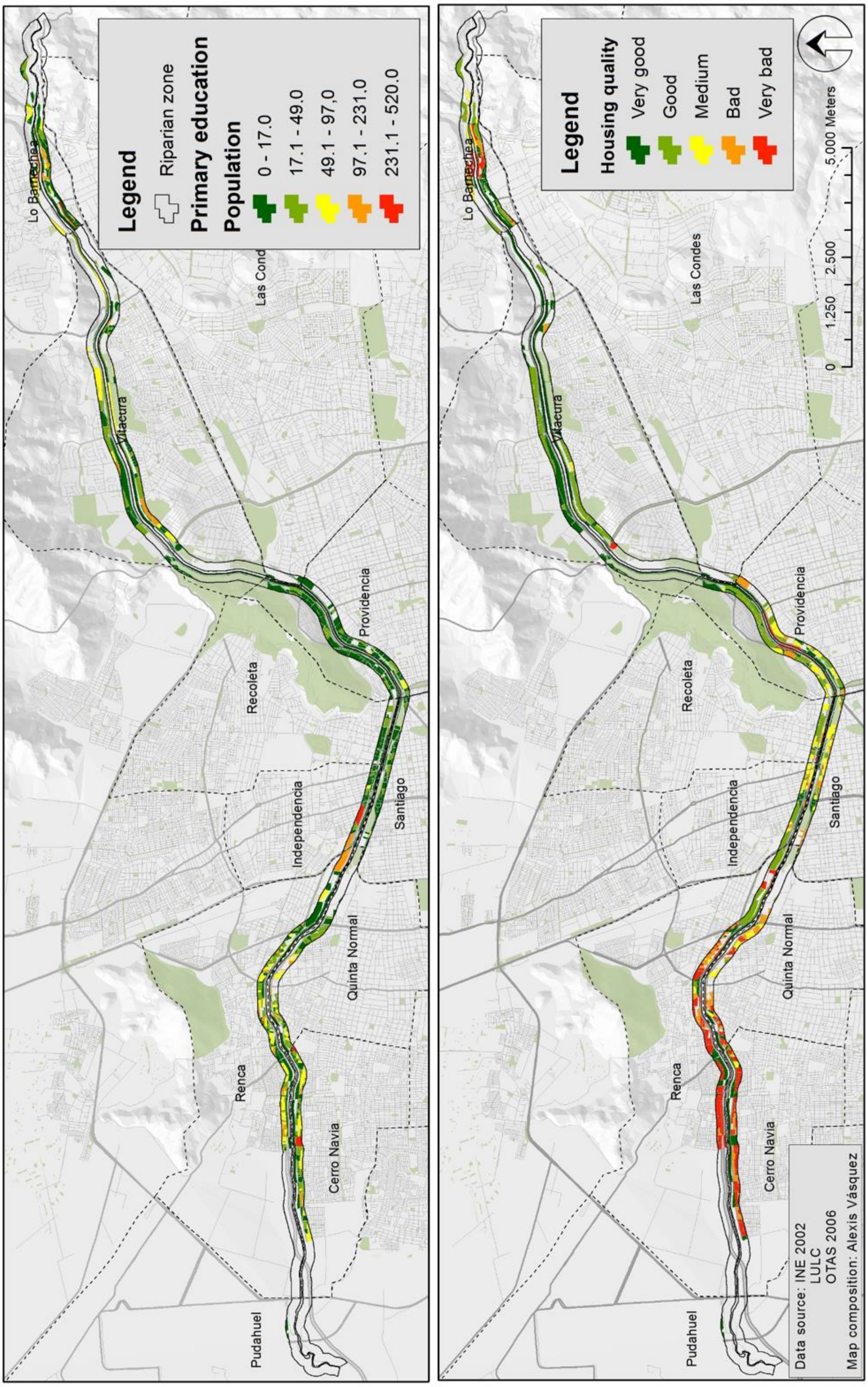
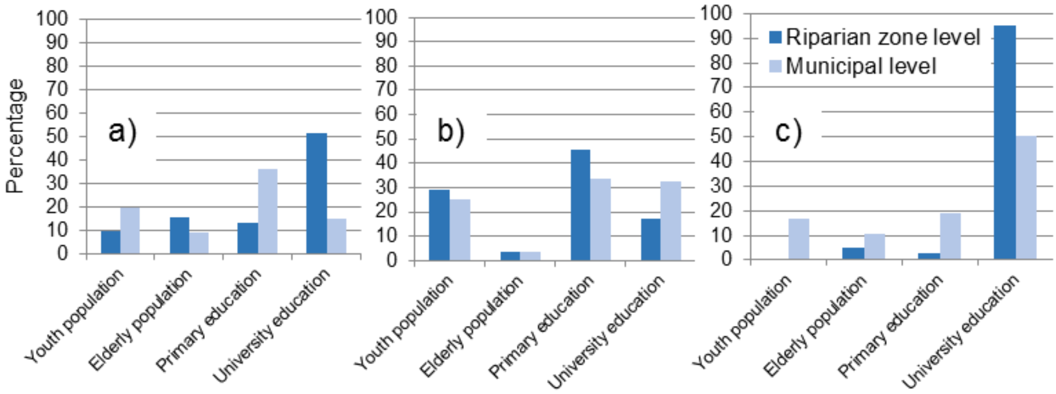


Figure 6.5: Population with primary education and housing quality.

It is important to consider for the development of a greenway that in social terms, the riparian zone of these municipalities is very different than the rest of the municipality and therefore, their requirements and needs may also be different..

Figure 6.6: Youth/elderly population and educational level as an indicator of socioeconomic level in (a)Recoleta, (b)Lo Barnechea and (c)Las Condes.



Source: Author's own elaboration based on census data (INE, 2002)

6.1.3 Urban patterns

In urban terms, the Mapocho's riparian zone is principally characterized by low-rise buildings. 75 % of buildings in these areas have six or less stories and 45 % of them have only one or two stories.

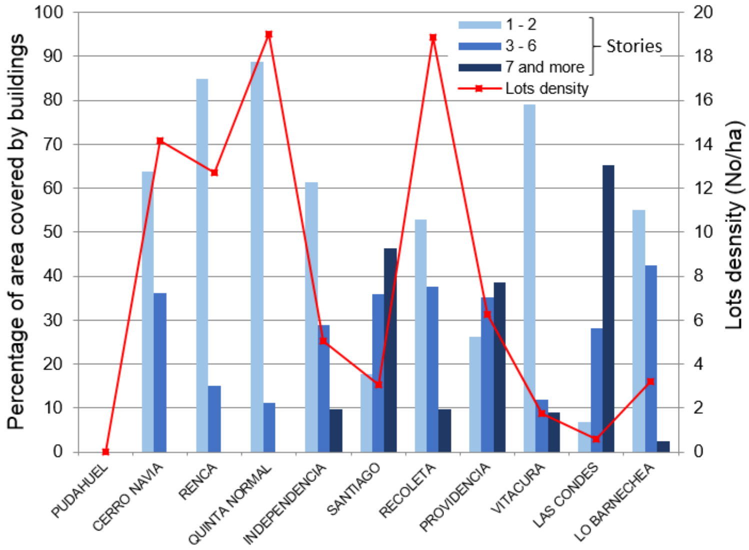
Figure 6.7 shows the percentage of area covered by buildings with varying numbers of stories and density of lots for the riparian zone in all municipalities. In the western section there is a large predominance of 1- and 2-story buildings without the presence of higher buildings (more than 6 stories) and a high lot density. A high lot density can be closely associated to small lots and high land property fragmentation.

It is only possible in the riparian zone of three municipalities to observe a greater presence of buildings with more than six stories: Santiago, Providencia and Las Condes. The spatially continuous section comprising Santiago and Providencia segments (around 8 km) represents a significant change in the urban vertical profile of Mapocho's riversides into high-rise buildings. Meanwhile, 65 % of Las Condes riparian zone is covered by buildings of more than six stories, but because of the small area and limited length of this section, a remarkable inflection in the vertical urban structure is avoided.

To the east of the Providencia municipality, the density of lots becomes lower and their size bigger than in the western section.

By comparing the vertical urban structure at a municipal level in the 200 m and the 50 m zones, it is possible to observe that closer to the river the average percentage of 3- to 6-story buildings increases progressively from 18.6 % in municipalities to 30.5 % in the 200 m zone and up to 39.1 % in the 50 m zone. This transverse gradient can be noted in all municipalities.

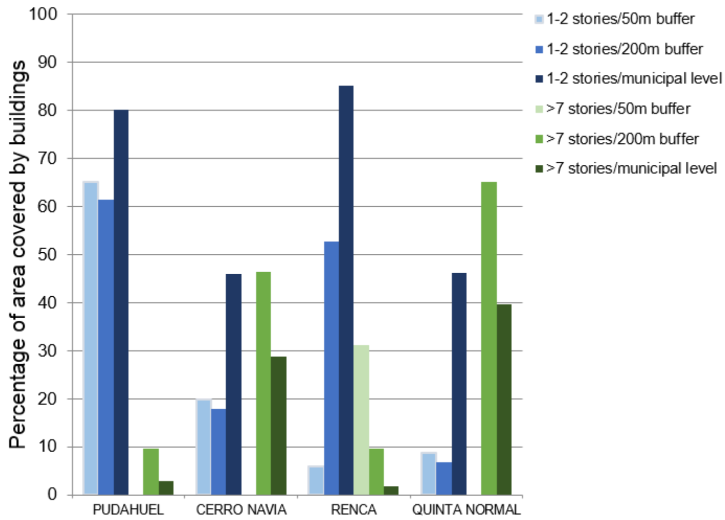
Figure 6.7: Area covered by buildings with varying number of stories and density of lots.



Source: Author's own elaboration based on census and internal revenue service data (INE, 2002).

Although average percentages of 1- and 2-story and 7- and above story buildings do not show a clear transverse gradient, the riparian zone in some municipalities is especially well populated by high-rise buildings. Independencia, Santiago, Recoleta, and Las Condes provide evidence of this with a higher percentage of 7 and above story buildings and decrease to 1- and 2-story buildings closer to the river (Figure 6.8).

Figure 6.8: Percentages of 1- to 2-story and 7- and above story buildings at different spatial levels.



Source: Author's own elaboration based on census and internal revenue service data (INE, 2002).

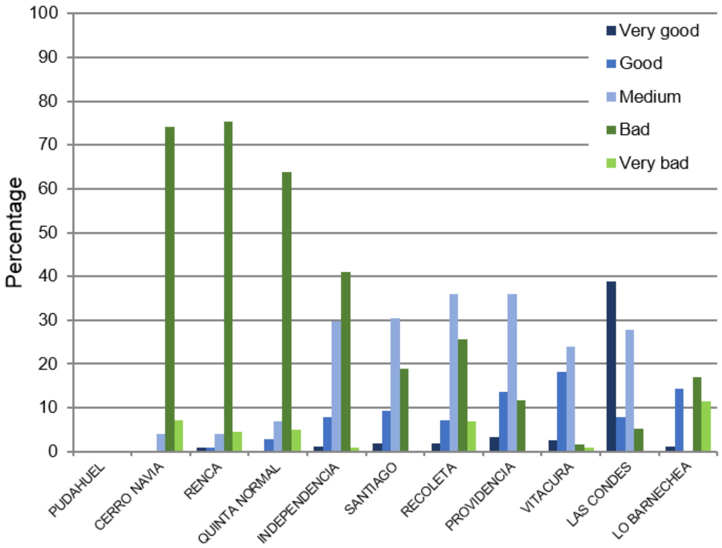
The housing quality follows the same east-west gradient of the other socio-economic and urban features. Generally speaking, the housing quality decreases from east to west (Figure 6.5) and the worst conditions can be observed in Cerro Navia, Renca and Quinta

Normal with 74 %, 75 % and 63 %, respectively, of dwellings being in "bad" condition. In contrast, in Vitacura around 20 % of dwellings are considered to have "good" quality and 40 % with "very good" quality in Las Condes (Figure 6.9).

Again, Lo Barnechea represents an exception to the prevalent good housing quality in the eastern part as 17 % of its dwellings have "bad" quality and it has the highest percentage of dwellings in "very bad" quality.

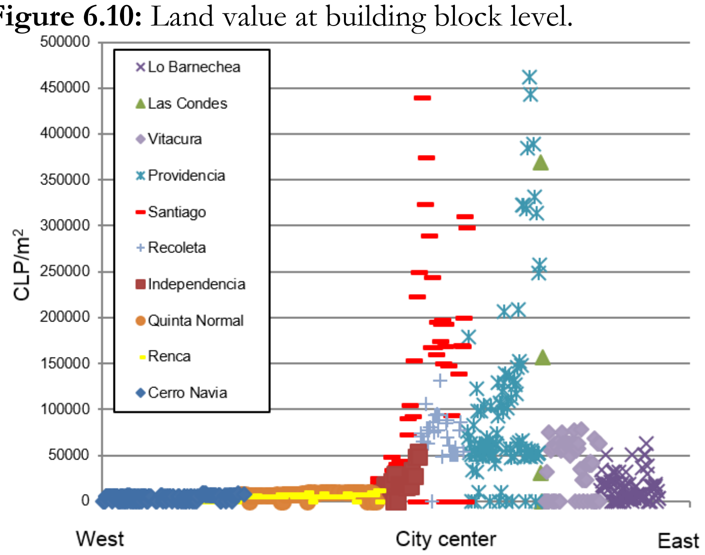
According to Figure 6.10, the central sector composed by Santiago, Recoleta and Providencia sections has consistently high land values in the riparian zone reaching average prices of 74,461, 57,286, and 75,639 CLP/m^2 respectively. Beside this central core of high land values, the riparian zone in Las Condes has the highest land value with around 200,000 CLP/m^2.

Figure 6.9: Housing quality along the river.



Source: Author's own elaboration based on census and internal revenue service data (INE, 2002).

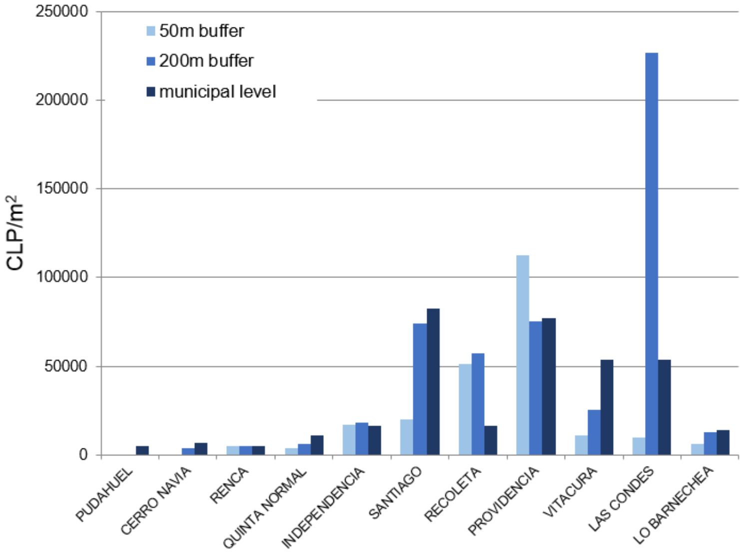
Figure 6.10: Land value at building block level.



Source: Author's own elaboration based on internal revenue service data (INE, 2002).

However, building blocks with high land values located in Santiago and Providencia have a higher frequency than in Las Condes and they reach the highest prices (Figure 6.10), which coincides with the existence of important riparian parks in these municipalities and that are described in section 6.1.5. In general, land values do not differ between the municipalities, the riparian zone and the 50 m strip along the river (Figure 6.11). Conversely, in Recoleta and Las Condes one square meter of land in the riparian zone is 251 % and 320 %, respectively, more expensive than the municipal average value. In contrast, in Vitacura land located on the riverside is 52 % cheaper than the average municipal average price.

Figure 6.11: Land value at different spatial levels.



Source: Author's own elaboration based on internal revenue service data (INE, 2002).

The above sheds light on how the development of a greenway in the western section of the river, on the one hand, would face less difficulties in terms of land acquisition due to the low price of land, and on the other, could mean a positive impact by raising the property value in this deprived zone.

6.1.4 Transport routes

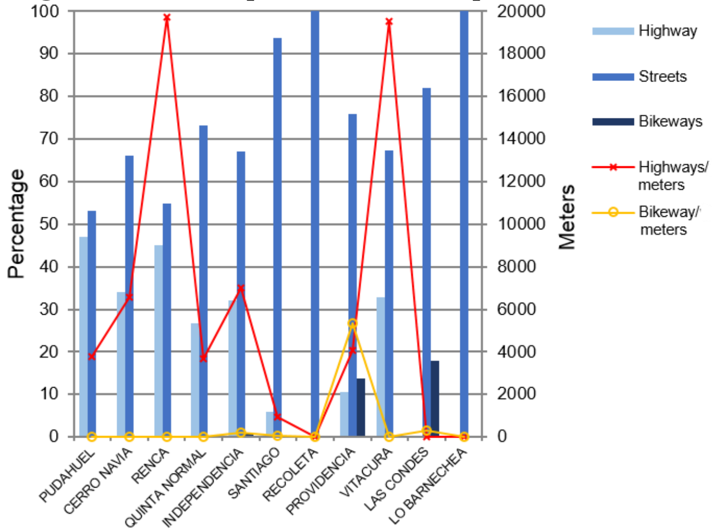
The transport network of the Mapocho's riparian zone consists of 72.2 % of streets (including small streets and avenues), 25.5 % of highways, and 2.3 % of bikeways. The transport infrastructure is clearly oriented toward motorized transport.

The longitudinal variation of the route network structure is seen in Figure 6.12. Streets are the most predominant type of road, making up more than 50 % of the transport system in all municipalities.

To the west of Santiago, urban highways are especially important, representing an average of 37 % of the transport infrastructure; even in Pudahuel and Renca this portion reaches 47 % and 45.2 %, respectively. Even though Vitacura has lower relative values than

Pudahuel and Cerro Navia, the absolute value of linear meters of highway in Vitacura is much larger and almost equal to that existing in Renca (Figure 6.12).

Figure 6.12: Transport network composition.



Source: Author's own elaboration based on data provided by MOP and field work.

The main urban highway in the Mapocho's riparian zone is the Costanera Norte, which runs along the northern riverside between Vitacura and Pudahuel (Figure 6.13).

In the city center - Santiago, Recoleta, and Providencia - the Costanera Norte was constructed underground. The Costanera Norte is also planned to be built to the east of Vitacura, but construction has not yet begun.

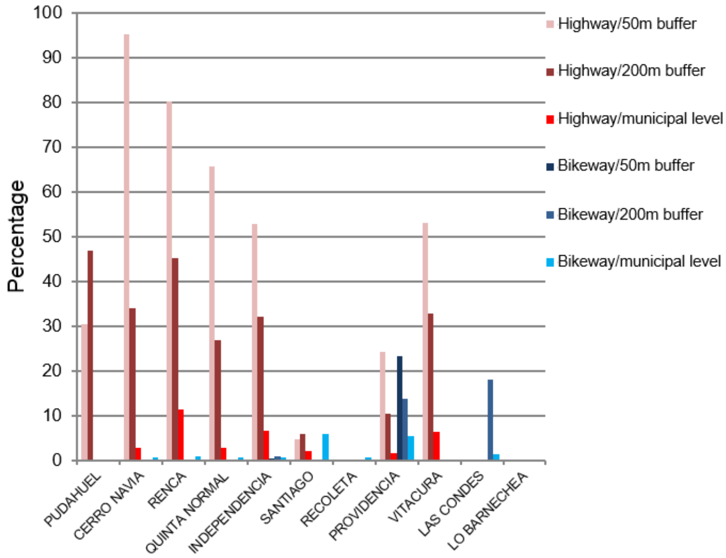
Figure 6.13: Contanera Norte (left) and Andres Bello Avenue (right) flanking the riversides.

Apart from the Costanera Norte there is a second highway that goes along the southern riverside: the Costanera Sur. Like the Costanera Norte the Costanera Sur is planned to follow the entire urban segment of Mapocho River, but currently it has been constructed only in the western section. The presence of both the Costanera Norte and Sur to the west of Santiago produces a remarkable change in the transportation network composition along the river.

Bikeways are not common in the riparian zone and only in Providencia and Las Condes are they slightly better represented with more than 10 % of the route system. Although in relative terms Las Condes has the highest percentage of bikeways, these consist of 310 linear meters contrasting with more than 5 kilometers existing in Providencia (Figure. 6.12).

Figure 6.14 shows how urban highways have been constructed especially close to the river. Cerro Navia, Renca, Quinta Normal, Independencia, Providencia, and Vitacura municipalities have an exceptionally higher percentage of highways in the riparian zone in comparison with the percentage of highways at the municipal level. Even more, within the riparian zone the highway construction has been concentrated in the 50 m closest to the riverbed. In other words, there is a relatively high concentration of linear meters of highways that are closer to the river.

Figure 6.14: Transport network composition at different spatial levels.



Source: Author's own elaboration based on data provided by MOP and field work.

Providencia presents a duality insomuch as the relative portion of bikeways and urban highways increases gradually from the municipal level to the 50 m strip.

6.1.5 Urban green areas

There are 425 public green areas along the Mapocho's riversides covering 292.63 hectares, which represent 19.5 % of the riparian zone. This situation results in an average of 52 m^2 green area per person, which is much higher than the average 3.9 m^2 per dweller in Santiago City and even higher than the minimum of 9 m^2 suggested by the World Health Organization. The main reason for this is that the riparian zone remains relatively unpopulated.

Table 6.1 shows the most important types of green areas in terms of area present in the riparian zone. Parks and sports grounds are less common than other types of green areas, but they are significant in terms of average size and covered area. Parks cover 702.3 ha with an average size of 14.9 ha, that is around 74 times larger than the average in Plaza and Road Median. However, only 20 of 47 parks present in the riparian zone are completely contained within it.

Table 6.1: Types of green areas.

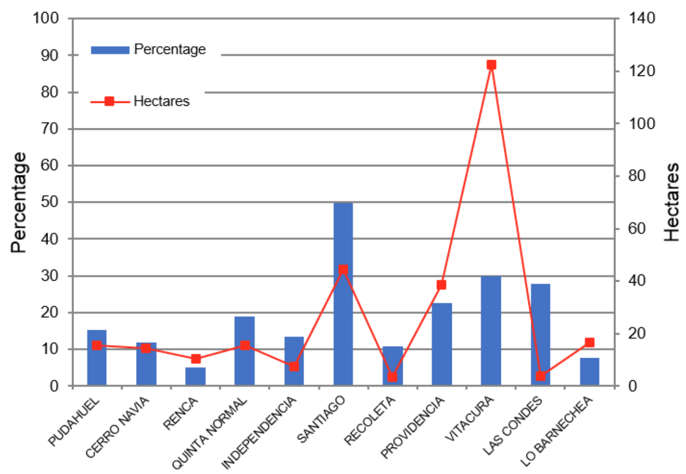
	Frecuency	Average size (ha)	Total area (ha)
Park	47	14.90	702.3
Sports ground	24	7.58	182.0
Plaza	190	0.20	39.8
Road median	136	0.19	25.9

Source: Author's own elaboration based on data provided by GORE and field work.

Road medians are classified and considered as public green areas, but they are mostly residual, disconnected spaces left by the road network development and have a very limited value as functional green space.

The proportion of green areas in the riparian zone is greater than 20 % in only four municipalities: Santiago, Providencia, Vitacura, and Las Condes (Figure 6.15). The presence of green areas is markedly important along the riverside of the Santiago municipality covering 49.7 % of the riparian zone. In contrast, Renca and Lo Barnechea riverine territories are relatively poorly supplied of green spaces.

Figure 6.15: Public green areas cover.



Source: Author's own elaboration based on data provided by GORE and field work.

The differences between the western and center-eastern sections, are not only related to the of number of public green spaces, but also concerning the quality and maintenance (Figure 6.16).

Figure 6.16: Contrast between public green areas in the western (left) and eastern (right) sections of the riparian zone.

The riparian zones in Vitacura possess 122.3 ha of green spaces representing 29.9 % of that segment. In absolute terms, Vitacura is followed far behind by Santiago with 44.4 ha.

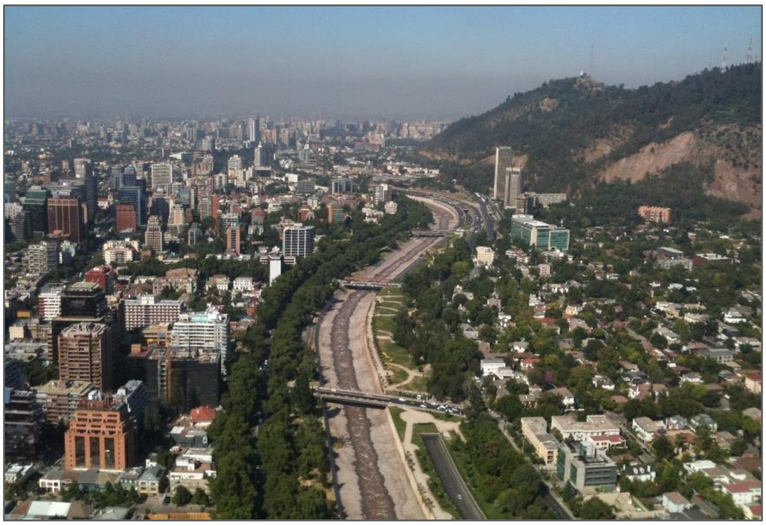
Santiago, Providencia, Las Condes, and Vitacura form an almost spatially continuous segment in the central and eastern parts of the river that are well supplied with green areas, which consist of parks in Santiago and Providencia and sports grounds in Las Condes and Vitacura.

Four of Santiago's largest riparian parks are located in Santiago and Providencia municipalities, all of them along the south shore of the Mapocho River (Figure 6.17 and 6.18). In order from west to east they are:

Parque de Los Reyes - Parque Forestal - Parque Balmaceda - Parque Andrés Bello (or Uruguay)

The Parque de los Reyes is located in the western part of Santiago municipality's riparian zone and was created in 1992. It has a length of 1,700 meters and an average width of 150 meters covering around 29 ha. Only this park and the Parque Ándres Bello (also called Parque Uruguay) are not separated from the river by a wide avenue allowing direct access to the river from the park.

Figure 6.17: Parque Andrés Bello and Balmaceda in the municipality of Providencia. Photo: Muriel Hernández.



The Parque Forestal is located 1,000 m to the east of the Parque de los Reyes and a few blocks away from the Santiago's Plaza de Armas. The Parque Forestal was created in 1910, occupying part of the old Mapocho's south riverside, and it is the oldest, most traditional and widest riparian park in Santiago. This park covers 1,172 m^2 from the former Mapocho railway station to Plaza Baquedano where the Parque Balmaceda begins. The Parque Forestal reaches its maximum width of 183 m in the central section between the Palace of Fine Arts and Purísima street and then narrows.

The Parque Balmaceda and Parque Andrés Bello are smaller and narrower than those mentioned above, but they constitute almost without interruptions, except for some bridges, 3,300 m of linear parks between Plaza Baquedano and Nueva Tajamar street. However, 2,200 m of this section are covered by the Parque Andrés Bello which is only 30 m wide.

In six of the eleven municipalities the riparian zone has a higher percentage of area covered by green areas than the entire municipal territory (Figure 6.19). In these municipalities, the riparian zone represents a strip especially well supplied with green areas.

This phenomenon is remarkable in the Santiago municipality, where the percentage of green areas in the riparian zone is 4.7 times greater than at the municipal level and even higher in the 50 m strip immediately next to the riverbed. In Santiago as well as in Providencia, the existence of the riparian parks described before helps to explain this higher proportion of green areas close to the river.

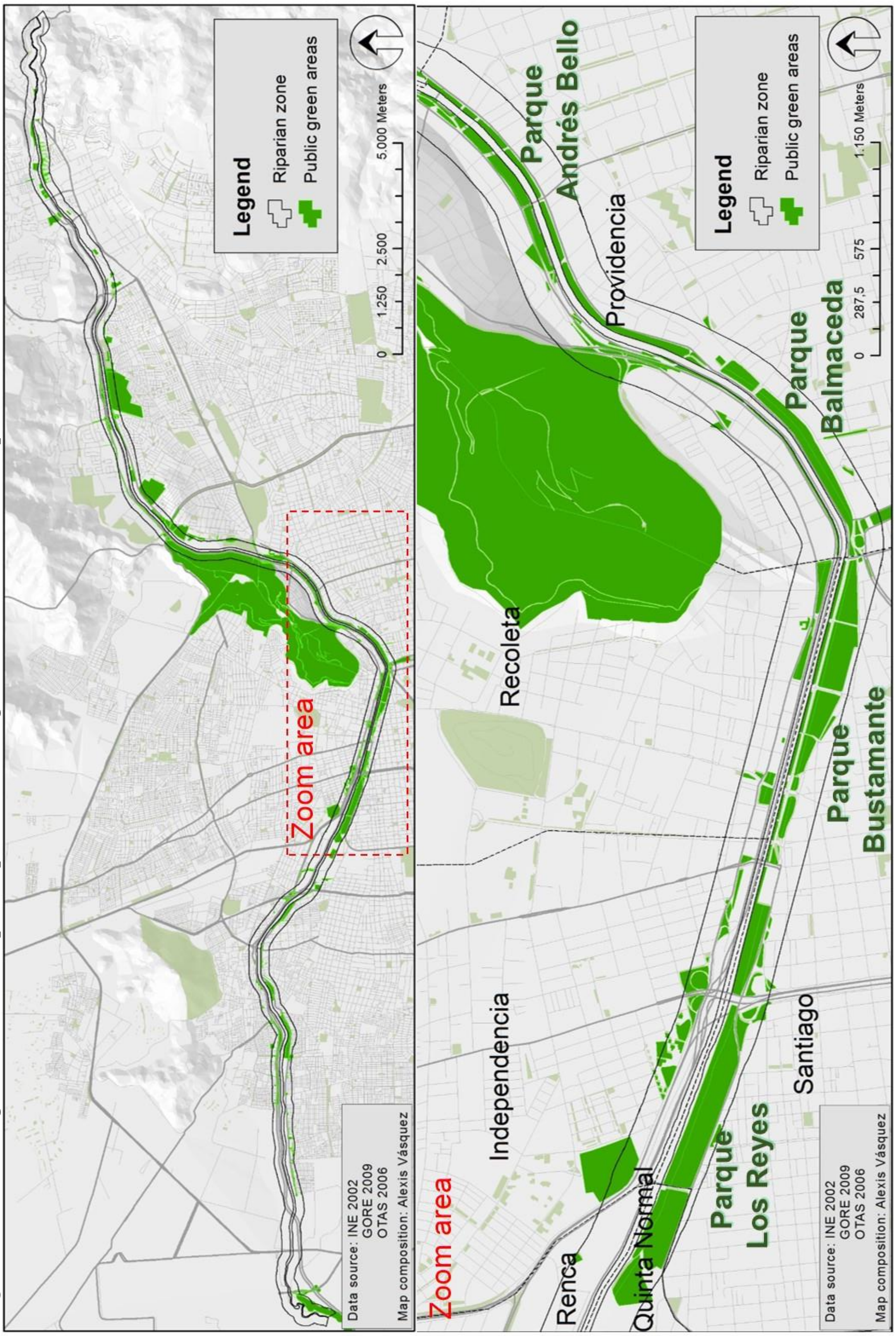
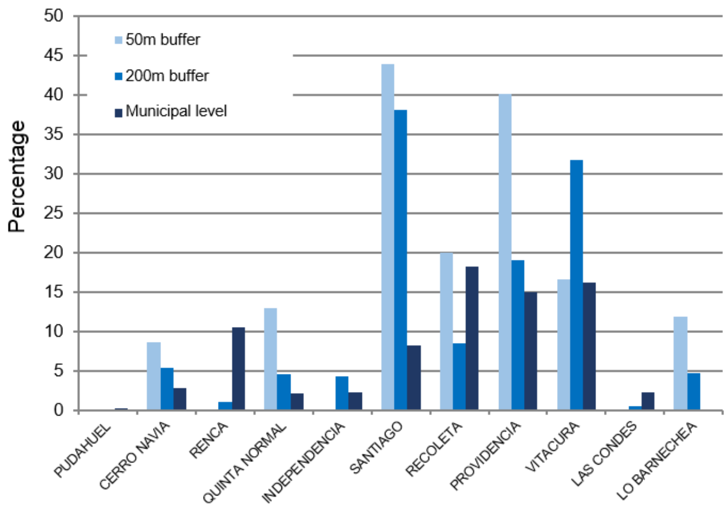


Figure 6.18: Public green areas and riparian parks in Santiago and Providencia municipalities

In the western section, the riparian zone in Cerro Navia and Quinta Normal is also especially well supplied with green areas in comparison with the entire municipality. The percentage of green areas in Cerro Navia and Quinta Normal increases from 2.9 % and 2.3 % at a municipal level to 8.6 % and 12.9 % at the 50 m buffer, respectively.

The Parque Mapocho Poniente is located in Cerro Navia and was created in 1996 as part of the Urban Metropolitan Parks Program, which was an attempt to provide parks for poor municipalities with a high deficit of green areas. This park of 8 hectares and 1,000 m long is maintained by the Ministry of Housing and Urban Planning (MINVU).

Figure 6.19: Green areas cover at different spatial levels.



Source: Author's own elaboration based on data provided by GORE and field work.

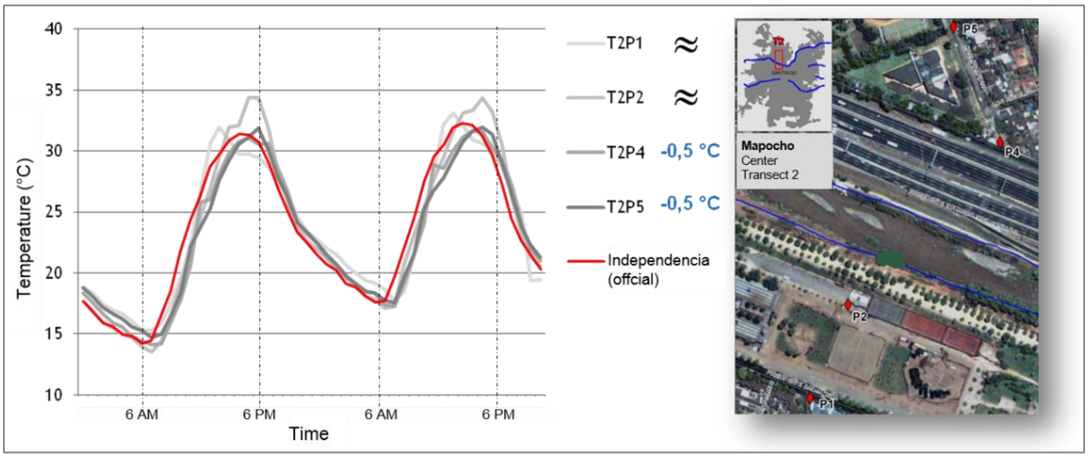
In contrast, the riparian zone in Renca has an extremely deficient cover of green areas compared with the municipality. At the municipal level, Renca is even more covered with green areas than Santiago, but the riparian zone in Renca is almost devoid of any significant green area, principally because of the presence of the Costanera Norte and highly dense residential areas.

6.1.6 Air temperature and wind patterns

The air temperature measured in the Mapocho's riparian zone does not differ from the temperature recorded in the urban matrix during summer ($p < 0.05$), which is the season of the year where the maximum difference of air temperatures can be expected between a watercourse, including its riparian zone, and the urban matrix.

Figure 6.20 shows the air temperature for the two hottest days registered in summer 2011 in one of the three cross transects implemented in the Mapocho River and the nearest official meteorological station. Although points 4 and 5 are 0.5°C cooler than Independencia Station located in the urban matrix, this difference of temperature is not significant in statistical terms ($p < 0.05$). In other words, the Mapocho's riparian zone is not providing a cooling effect on the city.

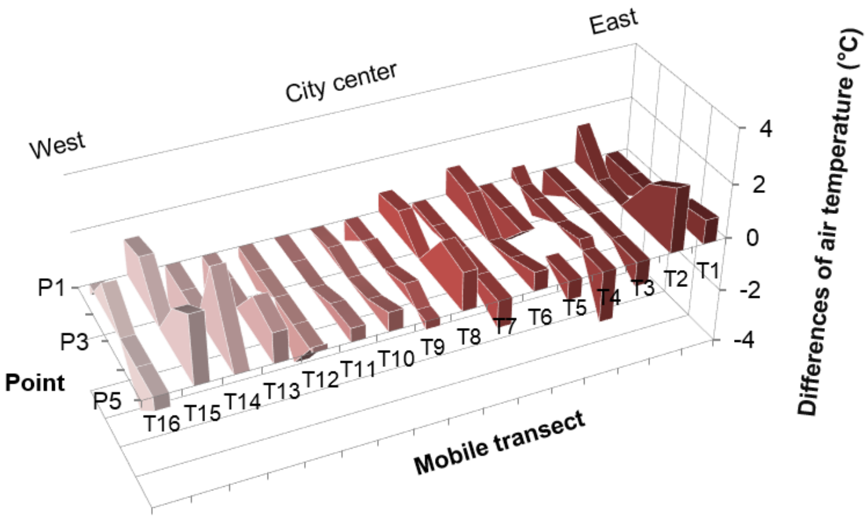
Figure 6.20: Air temperature for the two hottest days registered in summer 2011. T2=cross transect 2, Pn°= measurement point.



Source: Author's own elaboration based on measured air temperature data collected during field campaigns.

Mobile transects performed on November 11, 2011 allow analysis of the patterns exhibited by cross sections along the river. Figure 6.21 shows the complexity of air temperature variation in relation to the distance to the river (P3) in the afternoon.

Figure 6.21: Mobile transects of air temperature, noon 11/01/2011.



Source: Author's own elaboration based on measured air temperature data collected during field campaigns.

Only transects 2, 6, 8 and 15 display the characteristic decreasing of air temperature from the river to the surrounding areas in both directions. Transect 15 is the most notable case, since those points located 100 m (P2 and P4) and those located 200 m (P1 and P5) from the riverbed are an average of 1.65°C and 1.9°C, respectively, warmer than point 3 located above the river (Figure 6.21).

In contrast, temperatures registered above the river in transect 3, 5 and 7 are warmer than those recorded at 100 m and 200 m from the river.

The other transects do not present patterns clearly recognizable, since air temperature differences between the river and the surrounding land depend on which riverside is being considered, or even which specific point within a transect.

Generally speaking, wind patterns found in the riparian zone are determined by the characteristic mountain-valley winds dynamic present in Santiago described in Section 4.1.

The role of the Mapocho River and its riparian zone as a wind corridor can be observed just in the periphery during the night in which the wind speed is higher close to the river and even higher above the river channel. This phenomenon disappears at the transects located within the urban core, presumably because of an increase of the urban surface roughness associated with multiple barriers such as high-rise buildings, bridges and urban highways.

6.1.7 Channel alteration

As can be expected from an urban watercourse, the Mapocho River has been highly modified maintaining only 6.6 % of its course a channel with a low degree of modification (Table 6.2). In 13 % of the analyzed section of Mapocho River, its terraces have been modified (clearing/snagging and straightening) and in 67 % the channel alteration involves rigid structures along river margins.

69.2 % of the rigid structures are concrete retaining walls that produce a hydrological insulation of the watercourse from the riparian zone. The remaining 30.7 % is covered by gabions, which are rigid structures as well but they possess a certain degree of permeability allowing some exchange between the main stream and surrounding land.

13.4 % of the channel has been completely channelized. Channelization is the highest degree of alteration and involves the construction of an artificial channel over river banks and riverbed. This level of channel alteration results in a hydrological as well as biological disconnection between the watercourse and surrounding land (riversides and subsurface).

Figure 6.22 shows that the channelized section is located in the central part of the city, especially in Independencia, Santiago, Recoleta, and Providencia. The Mapocho runs completely channelized through Recoleta and almost the same as in Providencia (94 % channelization).

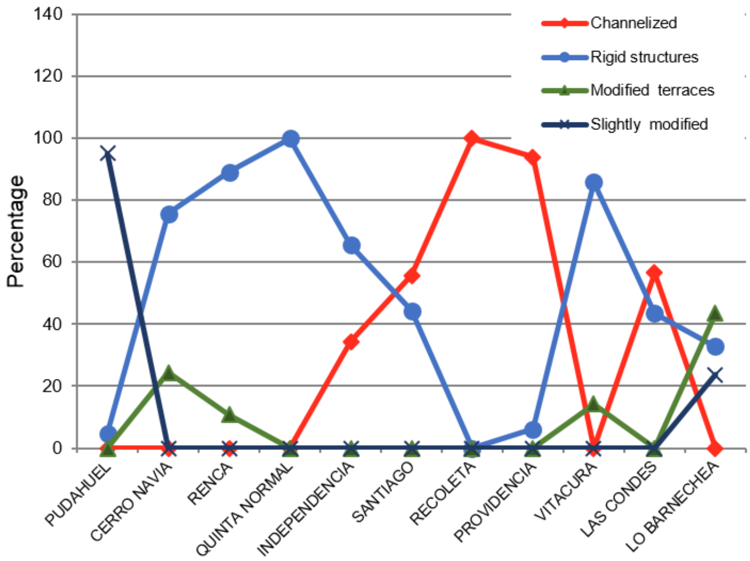
Table 6.2: Channel alteration.

Channel alteration	Percentage
Slightly modified	6.6
Fluvial terraces modified and constraining the river channel	12.9
Channel modified by rigid structures along the margins	67
Channelized river	13.3

Source: Author's own elaboration based on a photo-interpretation of Quickbird satellite images 2006/7 and field work.

The Mapocho's channel remains slightly modified only at the western and eastern extremes outside of the continuum built-up area or urban core. This low degree of alteration is especially important in Pudahuel, where 95.2 % of the channel has been slightly modified.

Figure 6.22: Channel alteration degree along the River.



Source: Author's own elaboration based on a photo-interpretation of Quickbird satellite images 2006/7 and field work.

In general, the degree of alteration of the channel is high and involves rigid structures that interfere with biological and hydrological exchanges between the main course and adjacent land. This, together with the fact that most of the year the river runs at a low flow, produces its appearance of more of a canal than a river (Figure 6.23).

Figure 6.23: Course and riparian zone in the city center (above) and the wester section (below).

In both the center and east of the city, the degree of artificiality presents enormous restrictions on the ecological functions of the riparian zone. However, in the most peripheral sections of the city there still exists sectors with more natural characteristics that, on the one hand, maintain vegetation spontaneously, and on the other, are used - especially in the western sector - for illegal waste deposits (Figure 6.24).

Figure 6.24: Areas located in the western sector used for illegal waste deposits**.**

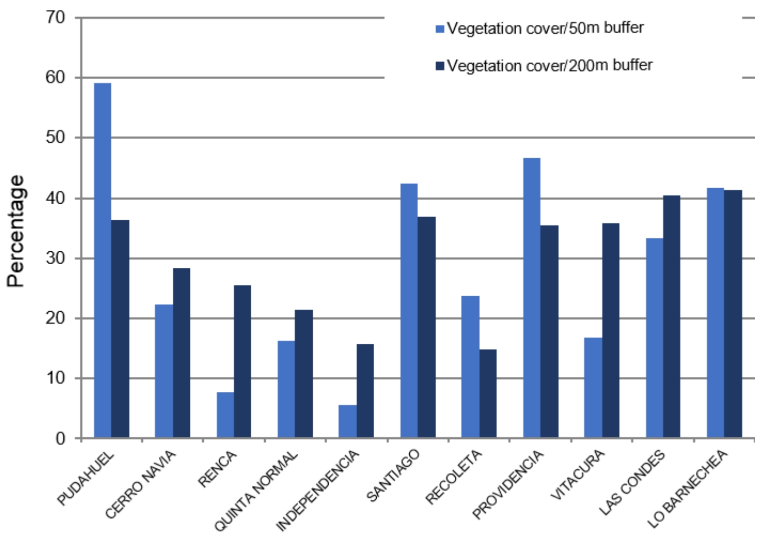
6.1.8 Vegetation cover

Generally speaking and as previously mentioned, there is a longitudinal as well as transverse gradient of vegetation cover variation.

First, a longitudinal increasing gradient can be observed from the city center to the extremes (Figure 6.25). However, the riparian zone in the Santiago municipality along with the southern riverside in the central section represent a remarkable exception as 36.9 % is covered by vegetation.

Even though this general gradient can be noticed to both directions (west and east), the average vegetation cover in the western section (Pudahuel, Cerro Navia, Renca, and Quinta Normal) is around 10 % lower than in the eastern section (by Providencia, Vitacura, Las Condes, and Lo Barnechea).

Figure 6.25: Vegetation cover.



Source: Author's own elaboration based on the land cover classification of Quickbird satellite images 2006/7.

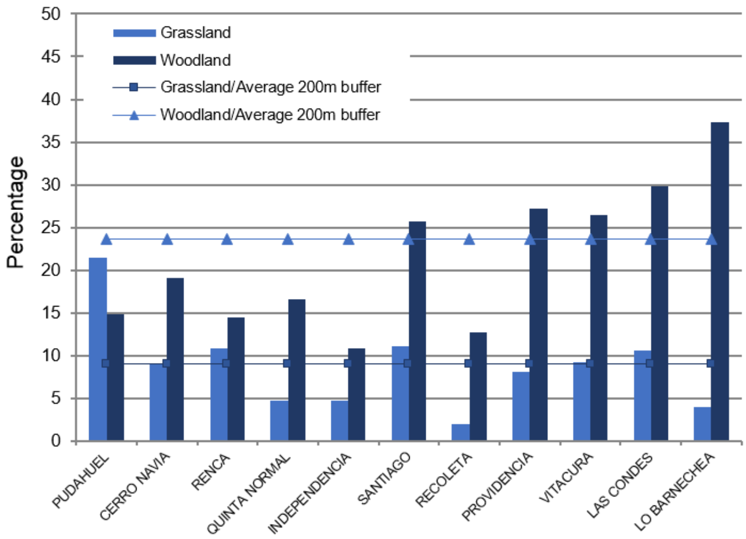
Secondly, the transverse gradient is more complex than the longitudinal gradient and depends on which specific section is under analysis (Figure 6.25). There is a decreasing gradient of vegetation cover from the river to the surrounding land in Pudahuel, Santiago, Recoleta, and Providencia, this means that the zone next to the river is greener in comparison with those most distant. The riparian zone in the remaining municipalities (except Lo Barnechea) indicates the opposite phenomenon, namely a vegetation cover increase away from the river.

The riparian zone in Vitacura, Lo Barnechea, Providencia, and Renca concentrate the highest absolute values of land cover by vegetation with 14.6 ha, 88.3 ha, 60.5 ha, and 52.5 ha, respectively.

Regarding the vegetation cover composition in the Mapocho's riparian zone, Figure 6.26 indicates that 75 % is covered by woodland and the remaining 25% by grassland.

Generally speaking, this distribution does not differ considerably along the river in all municipalities and follows the general pattern described above. However, in relative terms, Lo Barnechea and Recoleta are significantly more covered by woodland than the riparian zone average. In these two municipalities the vegetation covering the riparian zone is composed of around 90 % woodland. In contrast, Pudahuel is a unique case in which the type of vegetation is predominantly grassland (59 %).

Figure 6.26: Vegetation cover structure.

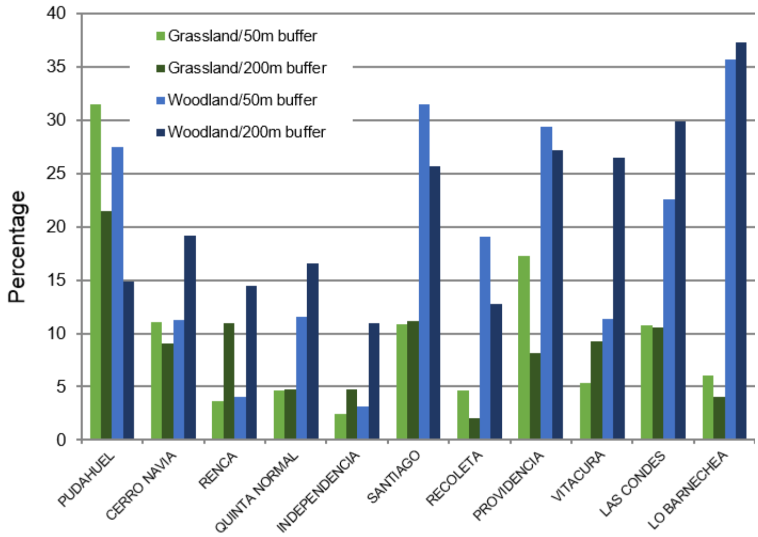


Source: Author's own elaboration based on the land cover classification of Quickbird satellite images 2006/7.

The eastern section has a higher percentage of both grassland and woodland than the western part, but this is especially notable regarding to woodland.

The changes in the percentage of grassland and woodland according to the proximity to the river are consistent with those changes experienced by the vegetation cover as a whole (Figure 6.27). Nonetheless, although the riparian zone closer to the river in the Santiago municipality has the same proportion of grassland as the furthermost land, the percentage of woodland increases by 6 %. In Las Condes and Quinta Normal the opposite can be observed, as the percentage of woodland next to the river decreases by 7 % and 6 %, respectively

Figure 6.27: Vegetation cover structure at different spatial levels.



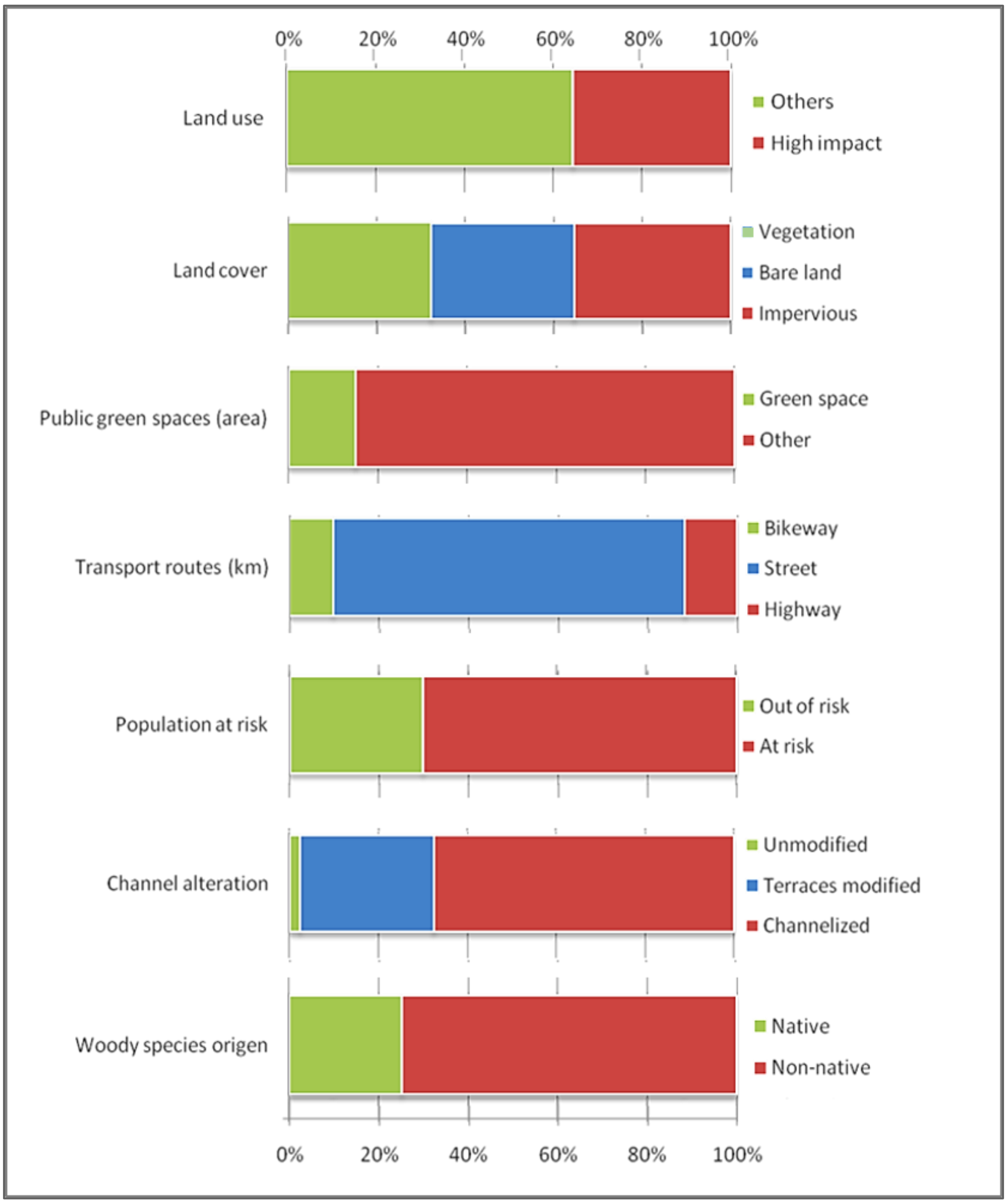
Source: Author's own elaboration based on the land cover classification of Quickbird satellite images 2006/7.

6.2 Synthesis of the socio-ecological state

As high intensity land use produces a significant impact on ecological state and functions, they should be sustained to areas away from riparian environments. However, Figure 6.28 shows that high impact land use covers around 40 % of the riparian zone. That means almost half of the Mapocho's urban riparian zone has been allocated for industries, highways and dense residential areas.

Industries and dense residential areas have mostly settled in the central and western part of the Mapocho River course (Figure 6.28). Until now, urban highways have been constructed almost exclusively along the north riverside.

Figure 6.28: Synthesis of the socio-ecological state using seven selected indicators.



Source: Author's own elaboration based on the land cover classification of Quickbird satellite images 2006/7, census data and field campaigns.

Nevertheless, there is still 32 % bare land and 32 % of vegetation cover. By adding bare land and vegetation, there is a 64 % of pervious land that is still unsealed in the riparian zone.

Spaces covered by vegetation constitute 72.5 % of woodlands (trees and shrubs) and 27.5 % of grasslands. This composition favors ecosystem services provided by urban green spaces because of the numerous benefits offered by trees and shrubs compared with those provided by grassy or herbaceous vegetation.

In spatial terms, impervious surfaces dominate the central part of the Mapocho River, and bare land and vegetation increase from the city center to the west and east extremes.

The 32 % of bare land as vacant land has high potential to be transformed into green spaces or built-up areas, and consequently, the bare land offers great possibilities for implementing a green space strategy. At the same time, urban vacant land is highly desired for urban development.

6.2.1 Social dimension

Only 15 % of the Mapocho's riparian zone has been allocated to public green areas. By comparing this amount with the 32 % of vegetation cover it is possible to assume that at least 17 % of vegetation is located in private areas such as gardens, sport areas and semi natural areas with restricted access.

Existing transport infrastructure in the Mapocho's riparian zone is highly dominated by streets with 78.6 % as constructed linear kilometers followed by urban highways with 11.6 %. Together they represent 90.2 % of the transport network in the riparian zone.

Bikeways represent just 9.8 % of the transport network, namely existing transport infrastructure in Mapochos's riparian zone is motorized oriented, promoting motorized transport especially for cars.

70 % of the population living within the Mapocho's riparian zone (around 40,000 people) is affected by floods every two years. Residential and especially dense residential areas have been built in the Mapocho's flood prone area, especially in the western section. In this respect, the riparian zone does not act as a flood protection buffer in most of its course.

It seems that the Mapocho's riparian zone provides social functions in a very limited way and its current state does not promote social wellbeing or enjoyment of the riparian environment.

6.2.2 Ecological dimension

In ecological terms, the streambed and streamsides have been importantly modified affecting the ecological connection between the main stream and the surrounding land. Most of the urban streambed and banks of the Mapocho have been sealed and channelized

(67.5 %) and 30.1 % of riversides have been protected by terraces to minimize lateral migration. Only 6.6 % of the analyzed section of Mapocho River remains unmodified, maintaining a more natural dynamic and condition.

The hydrological as well as biological disconnection has a major impact on the ecological process and therefore on the chances to maintain a healthy urban riparian ecosystem. This could help to explain the limited importance of the Mapocho's riparian zone as habitat for woody native plants and for climatic regulation.

Woody vegetation found in the riparian zone is predominantly exotic (74.8 %) stemming mainly from the USA and Australia. In contrast, just 25.1 % is of woody native species. However, 25 % of native woody species is around two times higher than the same percentage at the city level (12 %).

The air temperature and wind patterns exhibited by the riparian zone do not differ significantly from those existing in the urban matrix. No evidence was found that the Mapocho River and its riparian zone are functioning as a wind corridor or providing a cooling effect.

In summary, the current state supports limited social and ecological functions of the Mapocho's riparian zone and consequently, do not support the idea of the Mapocho River as a key socio-ecological link. In addition to this, almost all of the Mapocho River is surrounded by urban highways that isolate it from the city, preventing access to its banks, and no continuous strip exists hitherto that allows it to travel entirely from east to west.

6.2.3 Section level

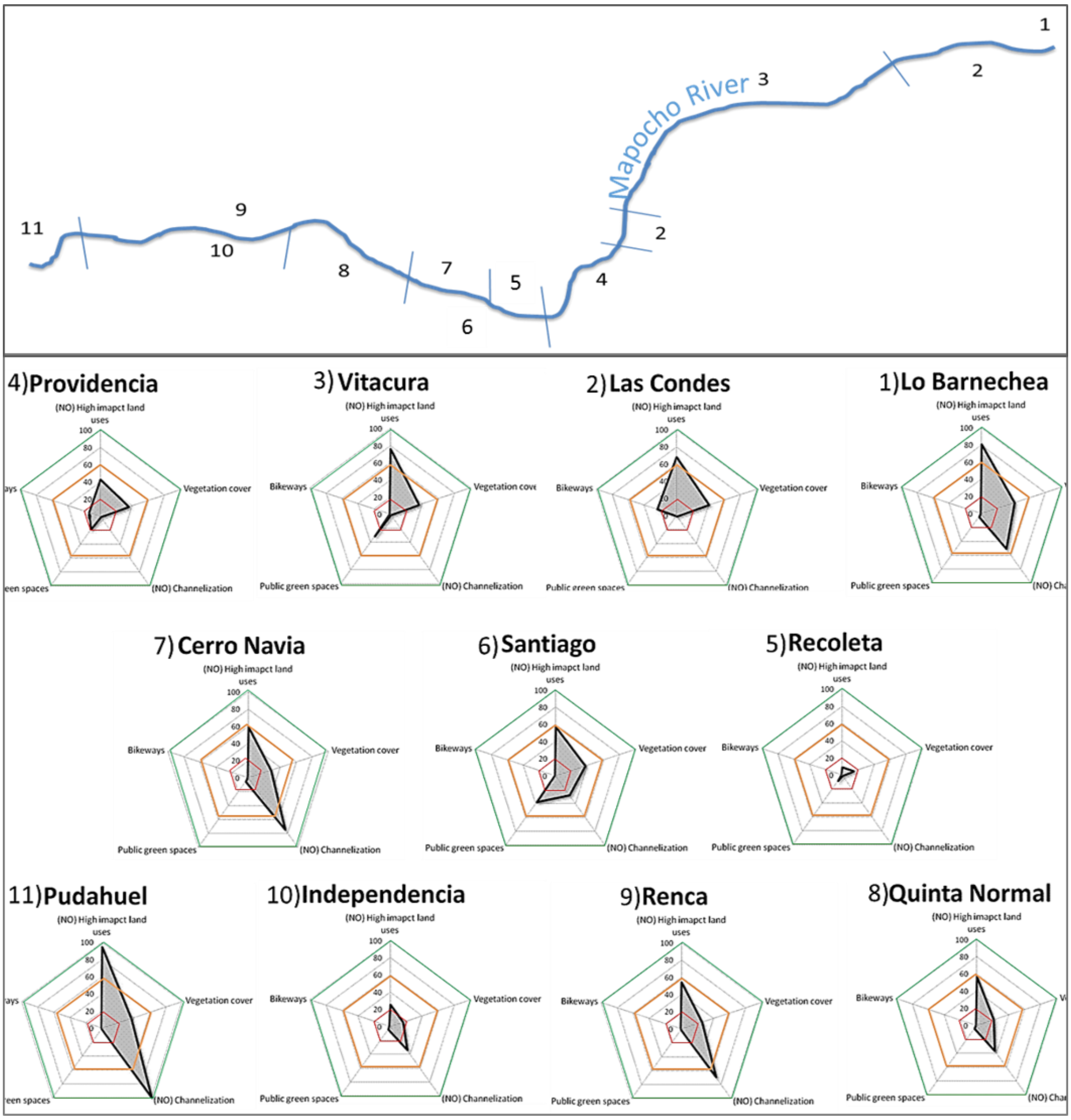
Figure 6.29 displays a synthesis of evaluated indicators for the riparian zone in each municipality. Generally speaking, both indicators related to the social dimension, amount of bikeways and public green spaces have low values in most sections. As exceptions, Las Condes, Vitacura, and Santiago are where at least one of these two indicators is higher than 20 %. The riparian zone in Providencia is an exceptional case, because both indicators maintain values around 20 %.

Spider diagrams indicate a corresponding structure of the indicator values for Lo Barnechea, Cerro Navia, Quinta Normal, Renca, Independencia, and Pudahuel. In this characteristic structure, only 3 out of 5 indicators reach values greater than zero, namely NON- High Impact Land Uses (NoHILU), Vegetation Cover (VC), and NON-Channelization (NoC).

The arrangement is such that the percentage of VC is one or two times lower than the percentage of NoHILU and NoC. This special arrangement of indicators can be seen in a range of values extending from Independencia (NoHILU (27 %) – VC (18 %) -NoC (39 %)) to Pudahuel (NoHILU (98 %) – VC (40 %) - NoC (100 %)).

The riparian zone in the Recoleta municipality has the worst socio-ecological state since all evaluated indicators are lower than 20 %. In contrast, the opposite riverside (southern) in the city center which comprises the riparian zone in the Santiago municipality displays the best current socio-ecological state, because it is the single case with values higher than 20 % in four of five indicators. The main problem in the riparian zone in the Santiago municipality is that it suffers from a lack of bikeways.

Figure 6.29: Synthesis of the socio-ecological state at section level.



Source: Author's own elaboration based on the land cover classification of Quickbird satellite images 2006/7, census data and field campaigns.

Chapter 7
Greenway Suitability Analysis

This chapter presents the results of the Greenway Suitability Analysis that together with the Analysis of Opportunities and Challenges (Chapter 8), address both dimensions involved in the concept of potential proposed in Section 3.2. This Greenway Suitability Analysis integrates multicriteria assessments and a least cost path analysis to identify the zones and routes with high suitability for the provision of ecosystem services. These analyses are applies differentially according to whether they are Primary ESs and or another type.

Firstly, the seven most important ESs for Santiago potentially provided by a riparian greenway according to experts and local actors are presented, and then are ranked by government actors. Then, through a multi criteria analysis the suitability to provide the seven selected ESs is calculated. In the case of the Primary ESs, subsequent analyses are performed to determine the path with highest suitability. The MCA uses essential information as factors developed and presented in Chapter 6, with the addition of other constructed ad hoc.

7.1 Identification of priority ecosystem services

In this section, the priority ecosystem services are identified and hierarchized.

7.1.1 The most important and necessary for Santiago

According to the focus group of experts and local actors (see Section 5.1.5.1), seven out of the fifteen ecosystem services that may be provided by riparian zones presented in Table 5.13 were regarded as important and necessary for Santiago (Table 7.1).

Table 7.1: Ecosystem services selected as the most important and necessary for Santiago.

Ecosystem Service	Type (MEA, 2005)
•Wind corridor	Regulation
•Cooling effect	
• Flood hazard mitigation	
•Habitat for native wildlife	Provision
•Habitat for native flora	
•Recreation	Cultural
•Non-motorized transport	

Source: Author's own elaboration based on the focus group experts.

The following is a definition of each of the potential and most important ESs elaborated based on definitions presented in Section 2.2.3 and modified according to the specific aspects discussed by the panel of experts.

Wind corridor: the potential function of the Mapocho River and riparian zones to facilitate the movement of air masses along these areas. The riverbed and the surrounding areas may act as urban canyons, thus routing the wind and breeze. Similarly, its low roughness may increase wind speed.

Cooling effect: the Mapocho River may contribute to the reduction in air temperature due to both the wind facilitation and the generation of air humidity resulting from the evaporation and atomization of transported water. Added to this is the contribution of riverside areas, especially parks, to the cooling effect on cities (cool islands) through evapotranspiration and shading.

Flood hazard mitigation: riparian zones may help control and minimize hazards related to overflowing, thereby keeping threatened areas free from urban development and protecting neighboring populations. These riparian areas also favor the rapid infiltration of rainwater and potential overflows.

Habitat for native wildlife: both the main course and riparian zones may provide proper spaces for the presence of native fauna within the city. These areas have the potential of being a refuge for a diversity of species adapted to aquatic, terrestrial and riparian interface.

Habitat for native flora: as in the case of wildlife species, the borders of the river and riparian zones may be a haven for the diversity of native flora. Plants adapted to humid conditions and plants growing in dry environments may proliferate in these zones.

Recreation: the Mapocho River and its riversides may provide green and open spaces for the development of recreational activities such as hiking, sports, relaxation, social meetings, pet walking and playing with children. These places are particularly chosen due to the river and the presence of riverside parks.

Non-motorized transport: linear spaces located along the river may serve as routes for non-motorized means of transportation such as walking, running or cycling from one point of the city to another. These spaces may promote the use of clean transport methods.

According to the Millennium Ecosystem Assessment (2005) classification, the seven ESs regarded as important are distributed into the regulatory (three), provision (two) and cultural (two) categories.

Regulating ESs include the role of the Mapocho River as a wind corridor and its cooling effect on air temperature. These ESs are related to climate regulation, which was regarded as a concerning issue by experts due to both the potential contribution of these areas to (1) the reduction of extreme hot temperatures and thermal discomfort experienced during summer, and (2) the air circulation generated within the basin, which may avoid critical episodes of atmospheric pollution —the latter being a common issue that takes place during the winter. Also included within the Regulating ESs is the role of the riparian areas of the Mapocho River in preventing considerable damage resulting from overflows, which has become a matter of concern for those living in the riverside area.

Those surveyed also regarded the Provisioning ESs as important related to the value of riparian zones as potential havens for native flora and fauna. The panel of experts acknowledged the importance of having native flora and fauna in Santiago, adapted to the prevailing and representative geographic conditions of original ecosystems. In addition, experts and local stakeholders considered that the presence of native species within the city might reduce the critical impact of urbanization on ecosystems.

Finally, the opportunities offered by the riparian zones of the Mapocho River in terms of recreation and provision of routes for non-motorized transport can be classified as Cultural ESs. This type of ES was included due to both the lack of public green areas and bike routes in Santiago, especially in the western area of the city, and the growing social demand for these amenities.

7.1.2 Hierarchy of ecosystem services

Table 7.2 shows the importance given to ESs on the part of interviewed local experts. ESs were classified according to the number of times each of them was chosen as the most important.

According to local actors, the wind corridor function is the most important and needed ES for the areas along the Mapocho River as it can provide ventilation for the entire city (Table 7.2). In the opinion of 22 out of the 31 experts (70 %), such a function is rated among the three most important services and nine of them regard the wind corridor as the most important service offered by the river.

Seventeen stakeholders (54.8 %) considered that the opportunities for recreation and the provision of routes for non-motorized transport are among the top three ESs. However, the general classification shows that non-motorized transport is rated second and recreation is rated third in terms of importance. This is because nine and six stakeholders, respectively, identified these features as the most important services (Figure 7.1).

Table 7.2: Importance of ecosystem services for the study area according to interviewed actors.

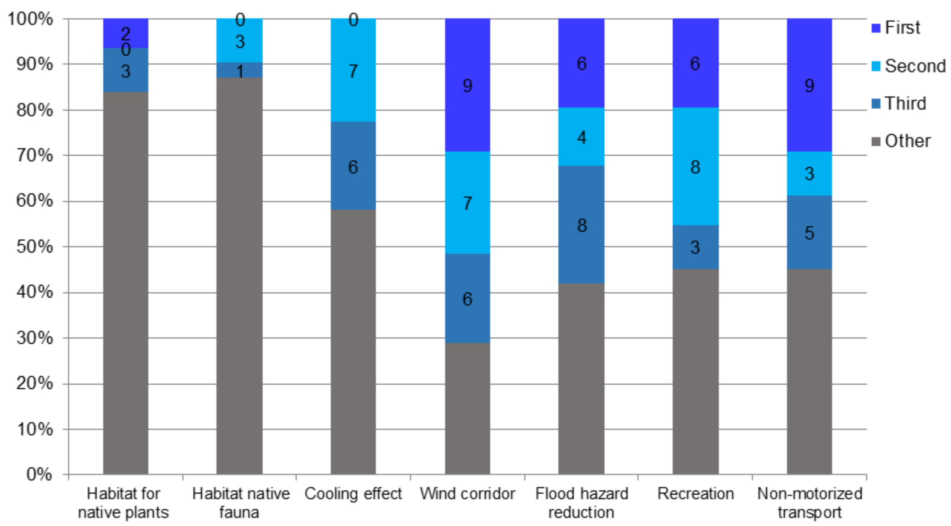
Importance	Ecosystem Service
1°	Wind corridor
2°	Routes for non-motorized transport
3°	Recreation
4°	Flood hazard mitigation
5°	Cooling effect
6°	Habitat for native flora
7°	Habitat for native wildlife

Source: Author's own elaboration based on 31 questionnaires.

The fourth ES is flood hazard mitigation. Although this ES was also regarded as the most important ES by six actors, it was defeated by recreation in the competition for the second place (four votes against eight).

The Provisioning ESs are the least important. Habitat for fauna and flora were included among the tree priority ES by only four (12.9 %) and five (16 %) actors, respectively.

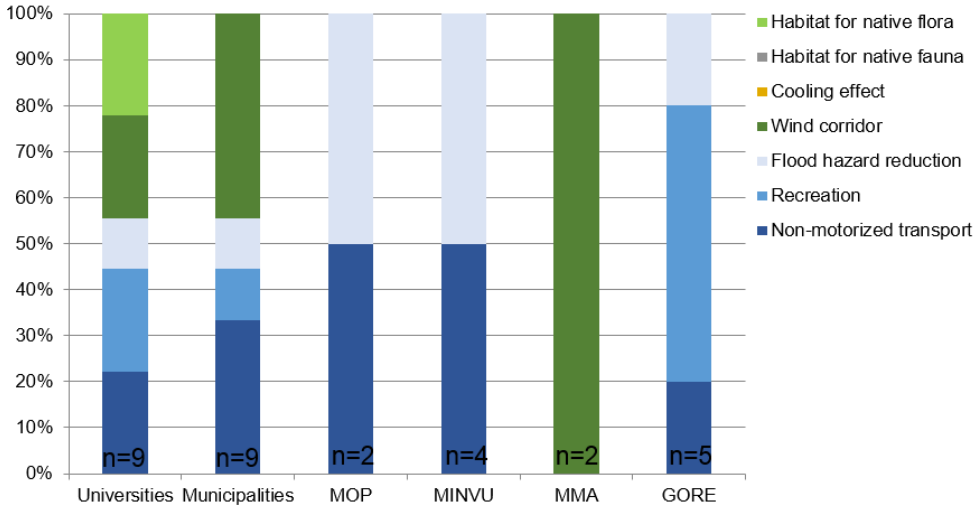
Figure 7.1: Importance of ecosystem services according to local actors.



Source: Author's own elaboration based on 31 questionnaires.

Figure 7.2 shows the preference of local actors according to their home institution, in terms of which is the most important ES (1°). It is possible to observe that those interviewed who work at MINVU, MOP and GORE regard Cultural ESs as important, such as recreation and non-motorized transport as well as flood hazard mitigation. In the case of MINVU and MOP, interviewees are divided between non-motorized transport and flood hazard mitigation; recreation is only a priority in the case of GORE.

Figure 7.2: Preference of local actors according to home institution.



Source: Author's own elaboration based on 31 questionnaires.

Those actors from the academic field and municipalities acknowledged the importance of the three groups of ESs (Cultural-Provisioning-Regulating). Public officials, as in the case of scholars, recognized the value of the Mapocho River as a wind corridor. Likewise, scholars were the only group that gave priority to the provision of habitat for native flora.

Finally, both individuals from MMA concurred that the wind corridor is the most important ES.

7.2 Deciding suitability factors

Table 7.3 shows the factors selected as relevant (see Section 5.3.1.2) and used to calculate the suitability to provide each ecosystem service. The explanation of these factors is displayed in Table 5.15.

These 12 factors can be divided into four essential classes related to: (1) land cover; (2) biophysical parameters of land; (3) urban structure; and (4) distance to urban elements.

There is a difference in the amount of suitability factors of each type considered in this analysis, while there are four factors related to urban structure, only two are associated with biophysical characteristics. Five of these factors were found as relevant for the assessment of more than one ecosystem service.

In this context, factors related to land cover are considered relevant to calculate the suitability for more ecosystem services than others. Tree and bush cover was the most important factor because it determines the suitability for the provision of four ecosystem services: routes for non-motorized transport, wind corridor, cooling effect and habitat for native wildlife. The following factor, in order of importance, was impermeable surface.

Table 7.3: Factors used to calculate the suitability to provide each ecosystem service.

	Factors											
	(1) Land cover			**(2) Biophysical**		**(3) Urban structure**				**(4) Distance**		
Ecosystem Services	Vegetation cover	Tree and bush cover	Impervious surface land cover	Slope	Channel naturalness	Height of buildings	Width of without buildings	Flood mitigation works	Population density	Distance to the channel	Distance to streets	Distance to public green areas
Spaces for recreation	x									x		x
Routes for non-motorized transport		x									x	x
Wind corridor		x				x	x					
Flood hazard mitigation			x	x				x				
Cooling effect		x	x				x					
Habitat for native flora	x		x		x							
Habitat for native wildlife		x			x				x			
Sum	2	4	3	1	2	1	2	1	1	1	1	2

Source: Author's own elaboration based on expert opinions.

Consequently, the suitability levels and their resulting spatial patterns are significantly influenced by those factors related to land cover. This is especially important in the case of the cooling effect and habitat for native flora, since its assessment uses two factors associated with land cover.

7.3 Suitability analysis

This section presents the suitability for the different ecosystem services that are later integrated into a multifunctional suitability analysis.

7.3.1 Suitability for the provision of ecosystem services

A comparison of the mean suitability values for the seven ecosystem services assessed is showed in Table 7.4 and Figures 7.3 to 7.6. The highest and lowest mean suitability values are related to wind corridor and non-motorized transport with 0.82 and 0.12, respectively. However, in both cases the suitability is not only defined by satisfying certain characteristics (criteria), but also by spatial continuity.

Table 7.4: Mean suitability values for the seven ecosystem services assessed in the riparian area of the Mapocho River.

	Recreation	Cooling Effect	Wind Corridor	Transport	Flood Hazards	Flora	Fauna
Mean	0.36	0.52	0.82	0.12	0.47	0.34	0.30
Std. Dev.	0.24	0.21	0.16	0.14	0.16	0.29	0.27

Source: Own calculations based on the suitability maps.

The distribution of suitability values data for the remaining ecosystem services are uniformly distributed in the case of recreation, cooling effect and flood hazards. In the case of flora and fauna, there is a marked distribution tendency towards low suitability values.

In general, the riparian areas located along the Mapocho River have low suitability values for the provision of the assessed ecosystem services. This is because four out of six ecosystem services show mean suitability values below 0.5, with the exception of cooling effect. The mean suitability value for recreation, flood hazard mitigation, flora and fauna is below 0.5. Likewise, ecosystem services related to the provision of habitat show low values near 0.3.

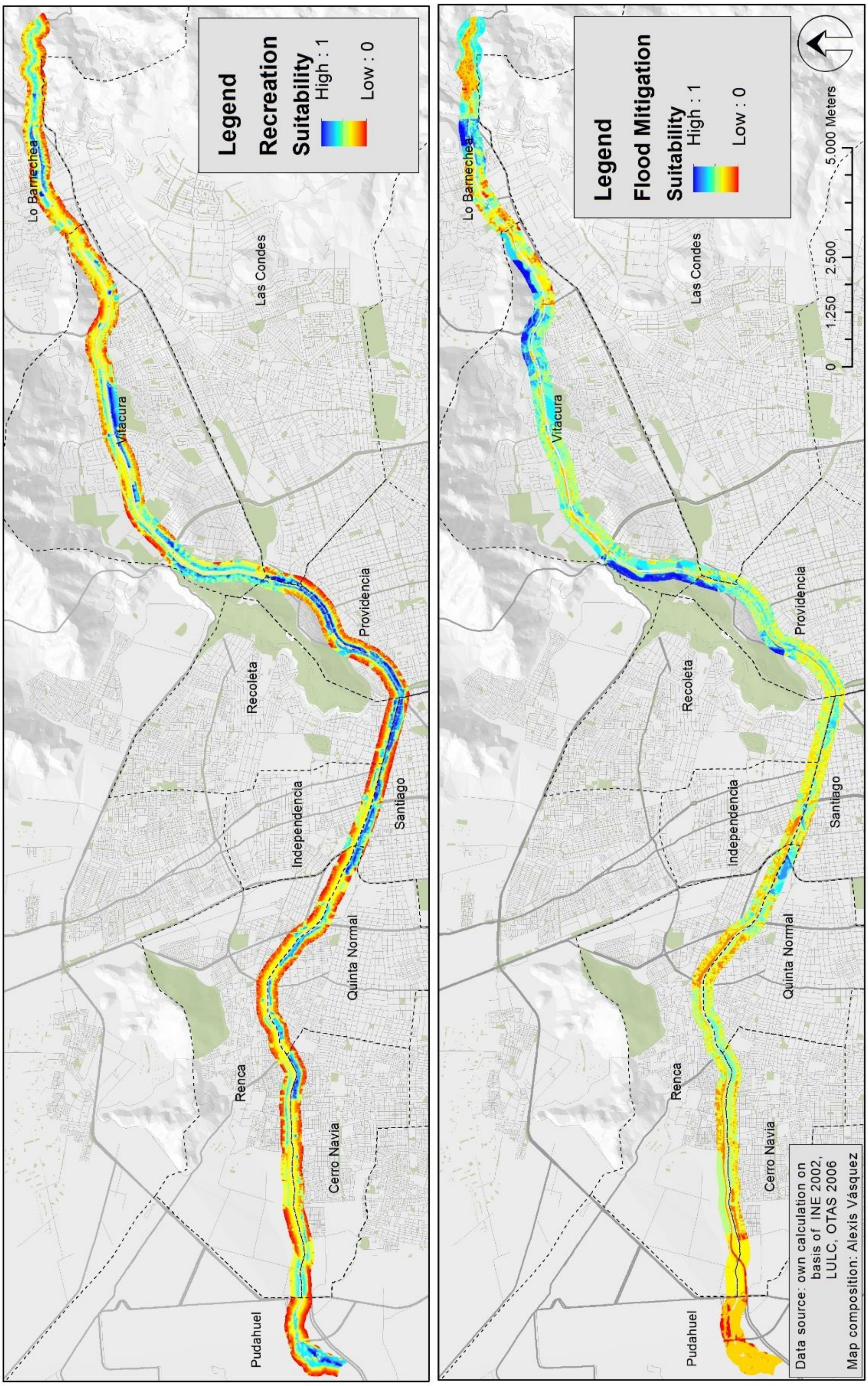
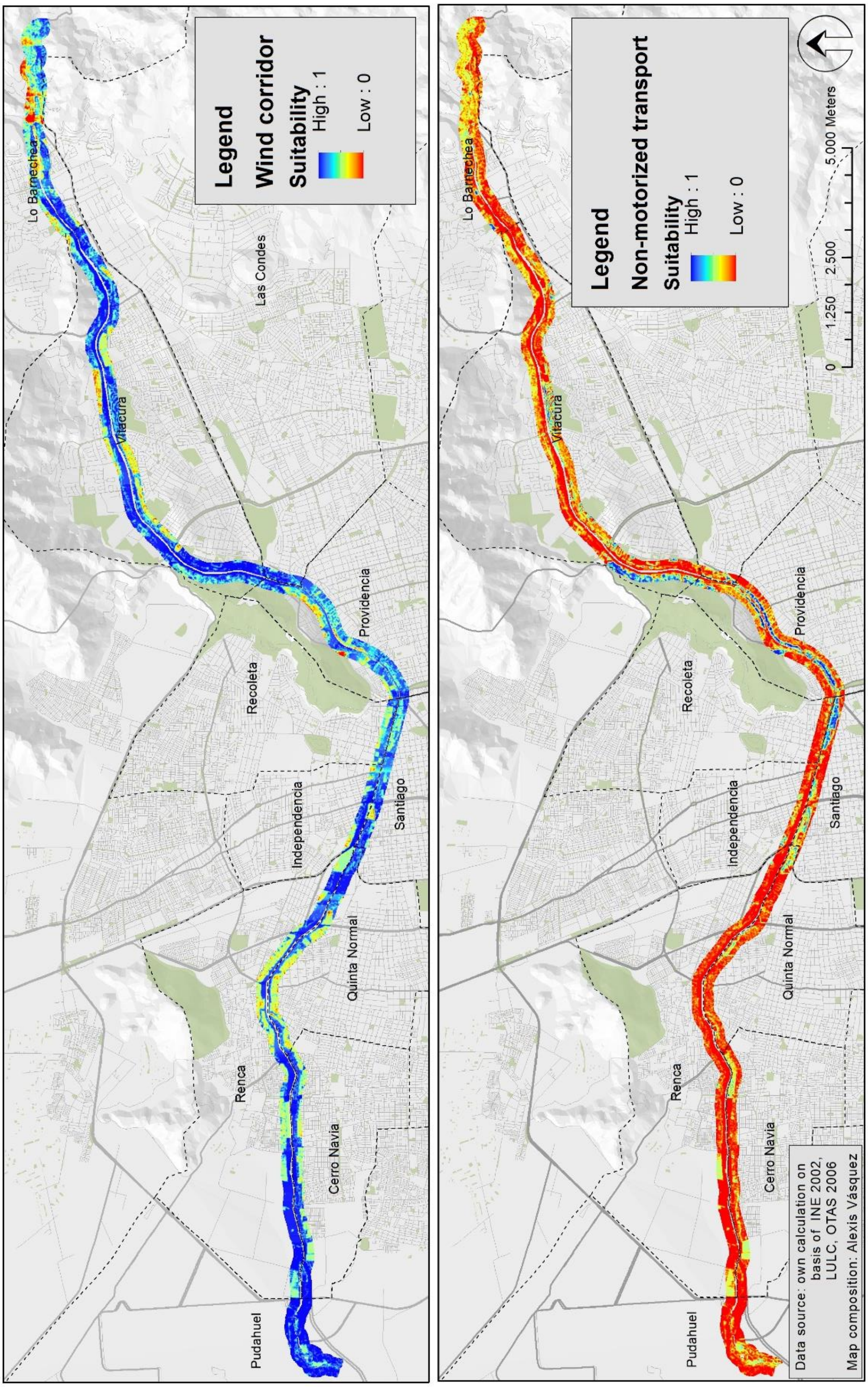


Figure 7.3: Suitability for recreation and flood mitigation.

Figure 7.4: Suitability for wind corridor and non-motorized transport.



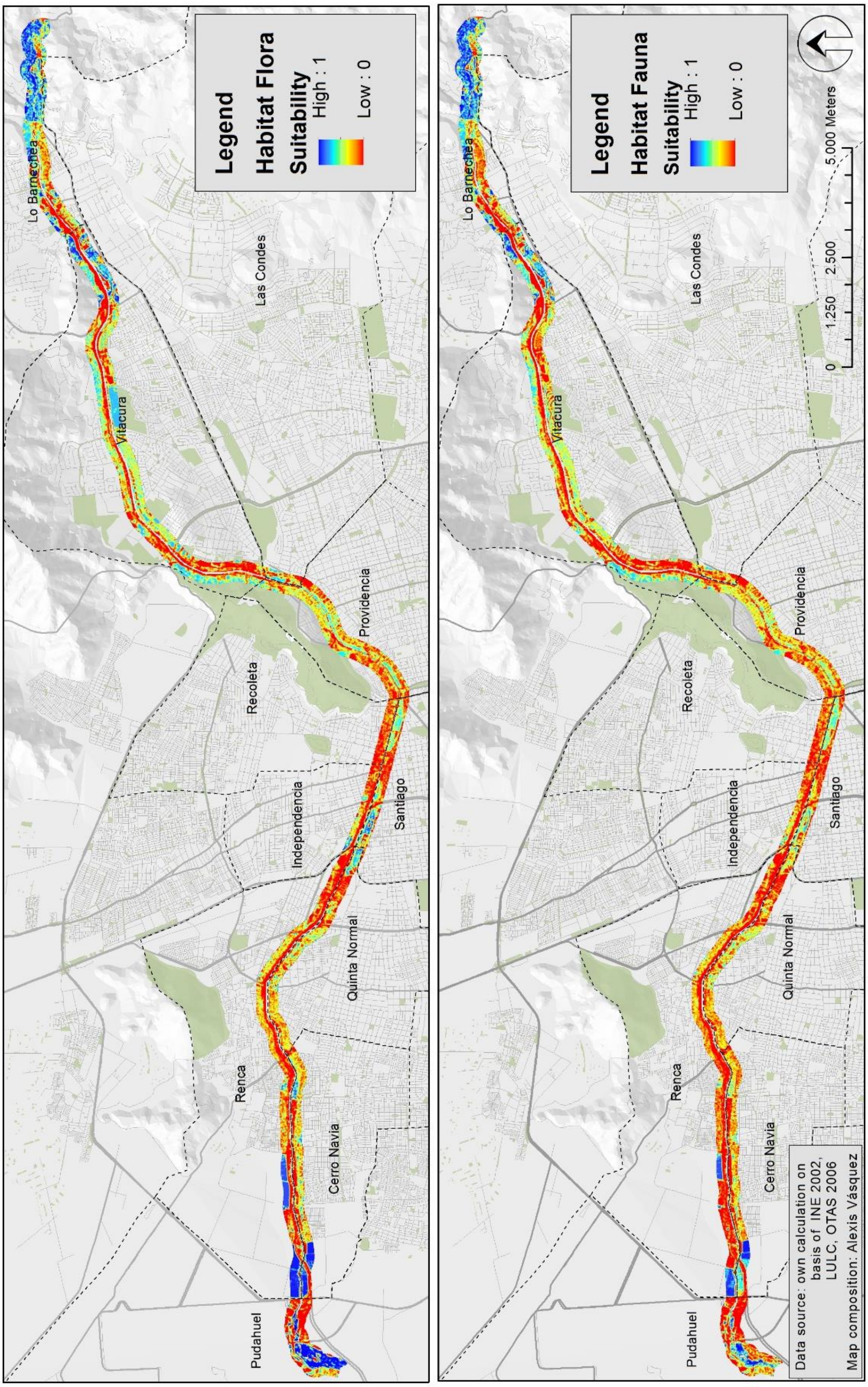


Figure 7.5: Suitability for habitat for native flora and fauna.

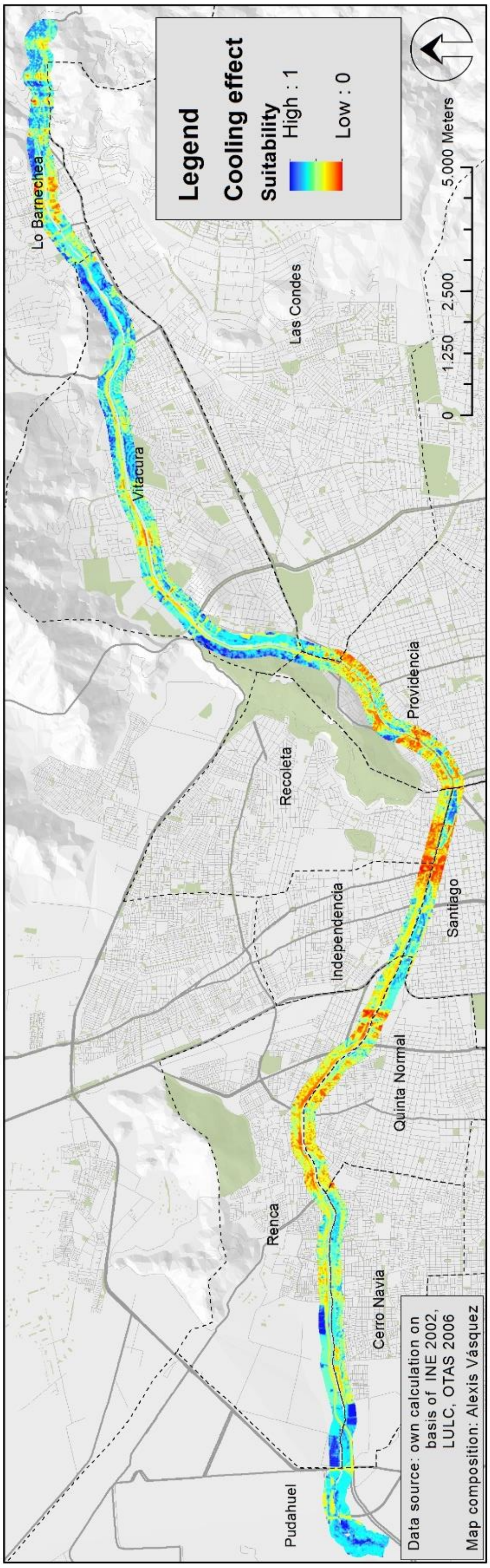


Figure 7.6: Suitability for cooling effect.

Despite the above-mentioned trend, it is possible to find high suitable areas (>0.75 – top 25 %) for the provision of ecosystem services along the riverbanks of the Mapocho River. The following is a detailed analysis of these areas.

Table 7.5 shows that according to the analysis of ecosystem services, these areas account for 8.2 – 15.2 % of the analyzed riparian area. In the case of cooling effect, the most suitable areas cover 15 % of the total riparian area. The mean suitability value of the riparian area for the provision of habitat for native flora is among the lowest recorded (Table 7.4); however, this is due to the high frequency of very low values rather than the lack of highly suitable areas. This is how these spaces account for a relatively high percentage of highly suitable areas (14 %).

As for the provision of habitat for native fauna, flood hazard mitigation and recreation, areas with values above 0.75 represent only 8 % of the total area, that is, half of the values for cooling effect and provision for native flora.

Table 7.5: Rating scale of the most suitable areas (above 0.75) according to ecosystem services.

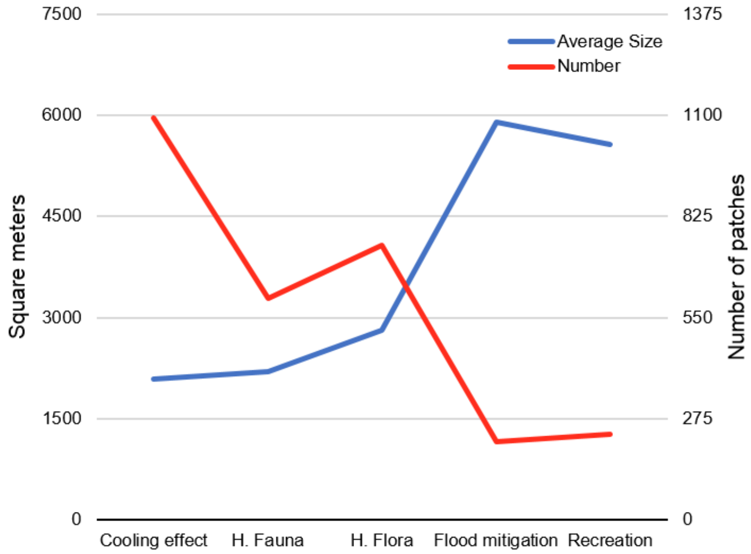
Ecosystem Service*	Suitability	Surface in Square Meters				Number of Patches
		Total	Patch size			
			Mean	Std. Dev	Maximum	
Cooling Effect	>0.75	2,287,200	2,090	11,162	196,900	1,094
		15.2 %				29.4 %
Fauna	>0.75	1,322,700	2,200	16,557	339,600	601
		8.8 %				8,5 %
Flora	>0.75	2,096,300	2,813	21,726	437,400	745
		13.9 %				9.2 %
Flood hazard mitigation	>0.75	1,243,100	5,891	31,233	392,800	211
		8.2 %				7.1 %
Recreation	>0.75	1,295,400	5,559	14,625	150,000	233
		8.6 %				12.2 %

* This analysis excludes Primary ESs (see Section 5.3.1)
Source: Own calculations based on the suitability maps.

Figure 7.7 shows the relationship between the number and average extension of these areas or highly suitable patches, thus providing an idea of the spatial structure of ecosystem services. It is possible to observe that areas for the provision of cooling services are fragmented in terms of space, as they are five times more common and three times smaller than spaces intended for flood hazard mitigation. The spaces for recreation are similar with respect to the areas intended for flood hazard mitigation as they are few but larger in size.

Highly suitable patches for the provision of habitat for flora and fauna are in an intermediate situation since there are 700 patches with an average size of 0.25 ha.

Figure 7.7: Relationship between the number and average size of these areas or highly suitable patches for the provision of ecosystem services.



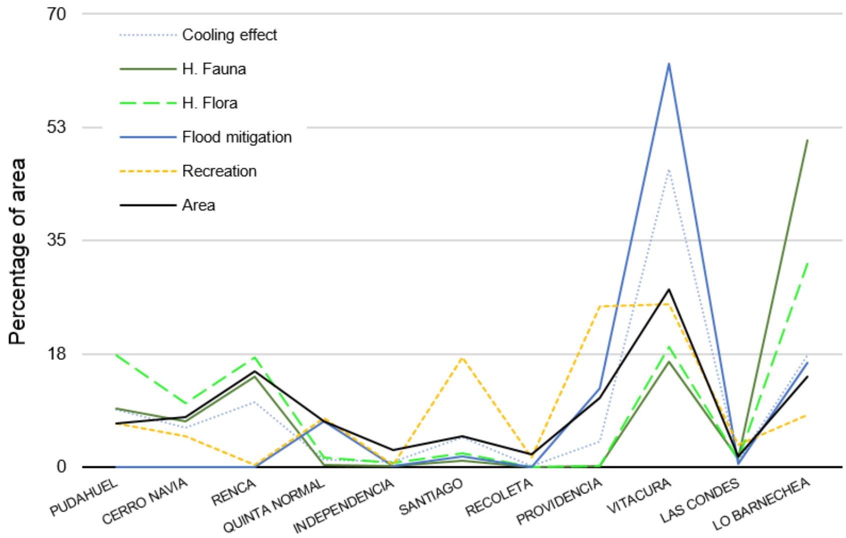
Source: Own calculations based on the suitability maps.

Figure 7.8 and Appendix B shows the distribution of the most suitable areas for the provision of ecosystem services along the Mapocho River. The black line indicates the percentage of riparian zone per municipality, which serves as a baseline to analyze the percentage of suitable areas concentrated in the riverbanks of each municipality.

The riparian areas of peripheral municipalities (Lo Barnechea, Renca, Cerro Navia and Pudahuel) concentrate suitable spaces for the provision of habitat for native flora and fauna, which decrease in importance as they extend towards the center of the city.

The most suitable areas for recreation are concentrated in the riparian zones of the municipalities of Santiago (17 %) and Providencia (25 %). Moreover, the municipality of Vitacura has a surface of highly suitable areas for the provision of cooling services (46 %) and flood hazard mitigation (62 %), above the percentage of riparian zone held by this municipality (27.5 %).

Figure 7.8: Distribution of the most suitable areas for the provision of ecosystem services along the Mapocho River.



Source: Own calculations based on the suitability maps.

7.3.2 Suitability for primary ecosystem services

7.3.2.1 Non-motorized transport

Least cost path for non-motorized transport along the Mapocho River is presented in Figure 7.9. This path has a total length of 39 km and runs through most of the south bank of the Mapocho River (71 %). To the east, this route covers the north bank of the river and then upon reaching the municipality of Providencia, it shifts to the south bank to continue its path through the municipalities of Santiago, Quinta Normal and Cerro Navia. The last section of this track covers a small segment of the north bank, located between the built-up area of Cerro Navia and the municipality of Pudahuel.

Figure 7.10 shows the contrast between the percentage of distance covered by the route in each municipality and the percentage of riparian zone per municipality. This Figure also indicates that the municipalities located north of the river; such as Recoleta and Independencia (city center) and Renca (western area) are not included in the design of this route for non-motorized transport.

On the contrary, the municipalities located south of the river such as Santiago, Quinta Normal and Cerro Navia have a higher percentage of route distance when compared to their actual proportion of riparian zone.

Figure 7.9: Least cost path for non-motorized transport and the wind corridor.

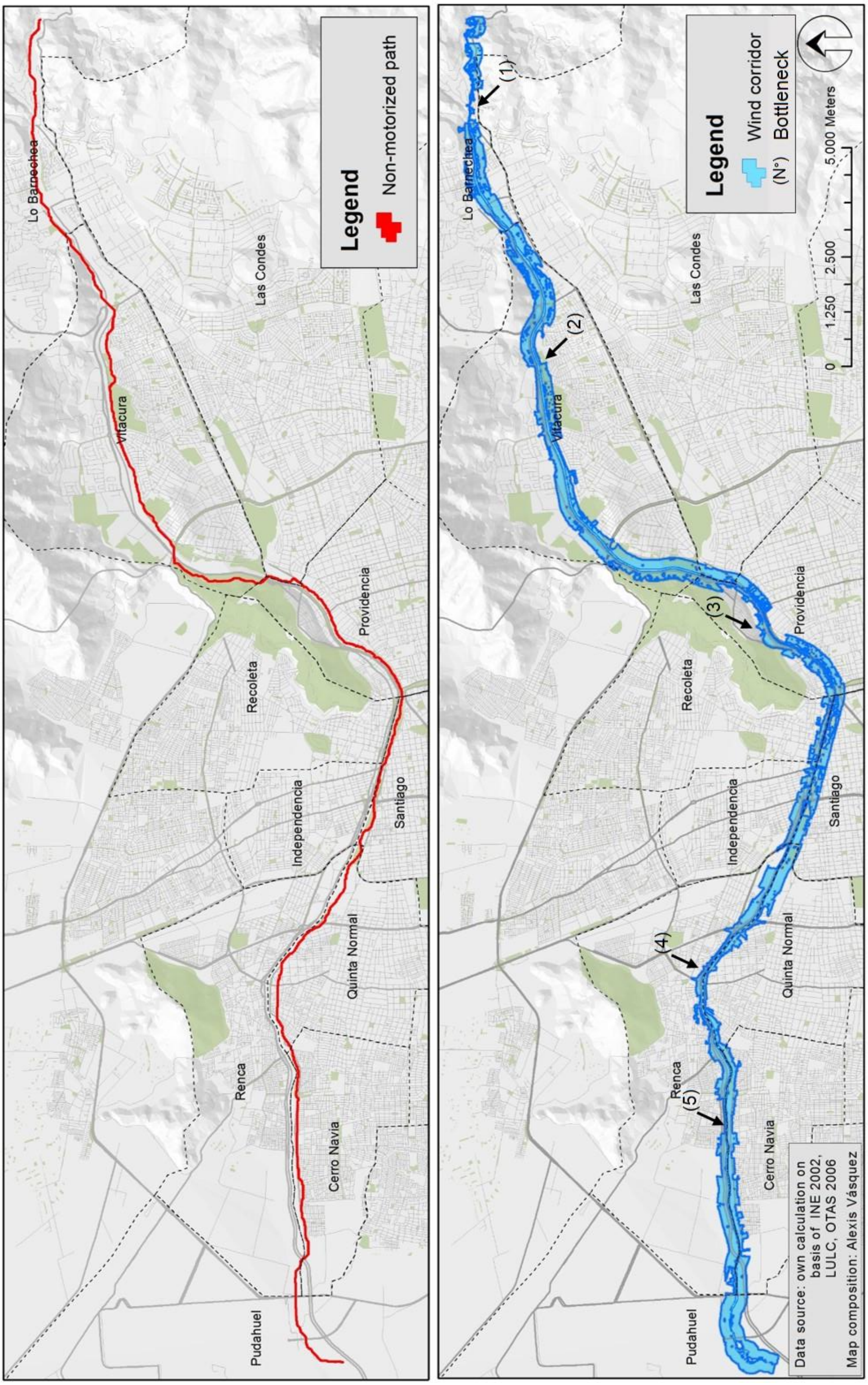
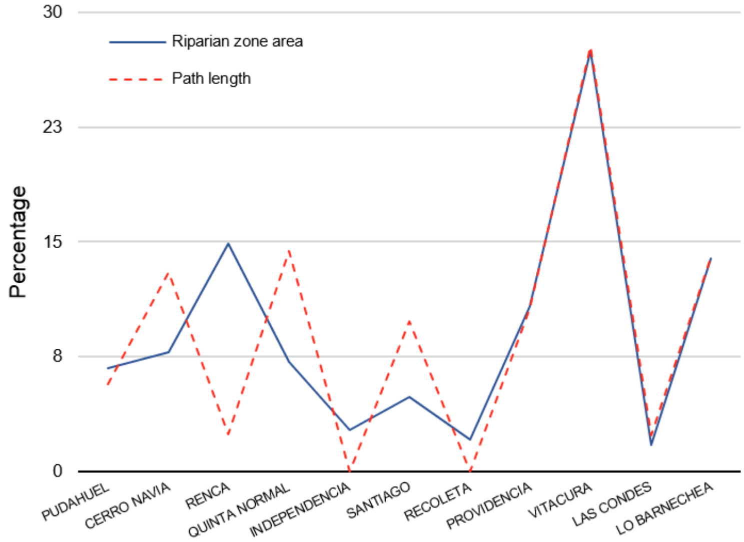


Figure 7.10: Percentage of distance covered by the route in each municipality and the percentage of riparian zone per municipality.



Source: Own calculations based on the suitability maps.

7.3.2.2 Wind corridor

The resulting wind corridor is shown in Figure 7.9. This wind corridor has an average width of 169 m and a maximum width of 569 m (including both the river channel and riversides).

The spatial configuration of this corridor has a series of bottlenecks that may affect the potential flow of fresh air.

The first and most important bottleneck (1) can be found in the municipality of Lo Barnechea, an area in which the corridor reaches its minimum width (20 m); it is worth pointing out that this section comprises almost exclusively the channel of the river. The second bottleneck (2) (55 m) is associated to the presence of a series of high-rise buildings near the river, and is located in the municipality of Providencia. Additionally, there are other areas where the corridor considerably narrows; these zones can be found in Santiago-Recoleta (3) (112 m), Quinta Normal-Renca (4) (134 m) and Cerro Navia-Renca (5) (169 m).

7.4 Multifunctional greenway suitability

Figures 7.11 shows the suitability maps for multiple ecosystem services through the use of AND/OR combinations (see Section 3.3.2 and 3.2.3 for detailed differences between AND and OR operators). As expected, the multifunctional suitability levels provided by the logical operator AND are markedly lower than those offered by the operator OR. This can be verified in the frequency histograms, in which the multifunctionality levels provided by AND are distributed towards the left of the chart and the multifunctionality values offered by OR are more uniformly distributed (Figure 7.12 (a) and (b))

Figure 7.11: Multifunctional suitability levels using AND and OR logical operators.

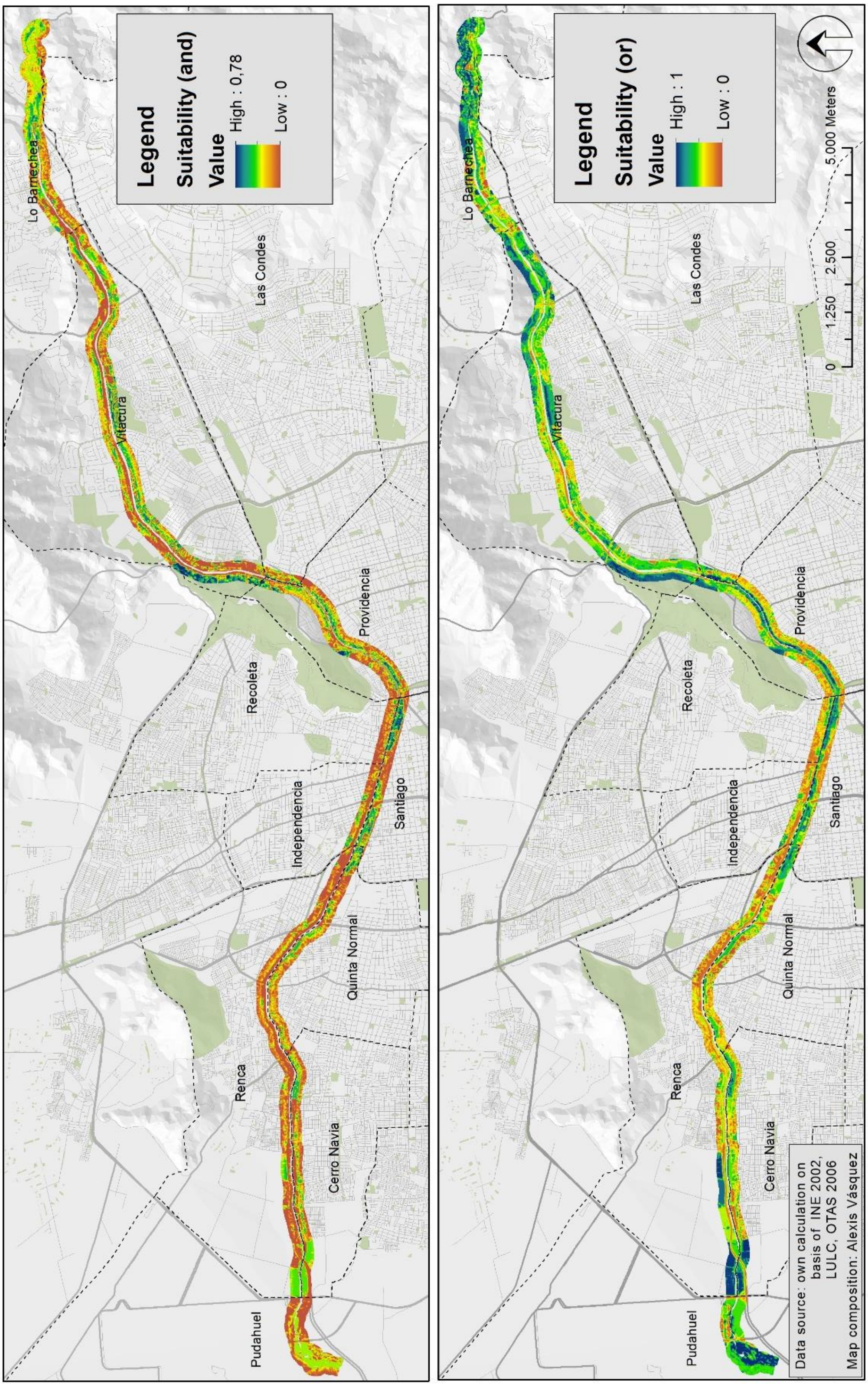


Figure 7.12a: Frequency histograms AND combination.

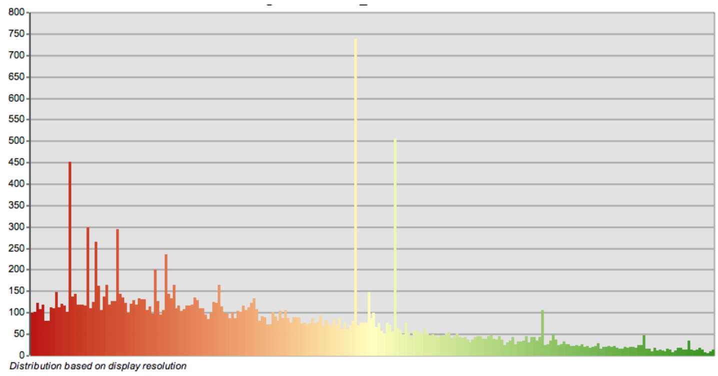
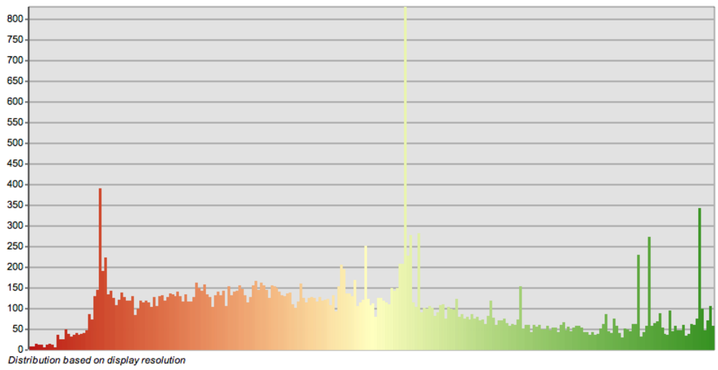


Figure 7.12b: Frequency histograms OR combination.



Source: Own calculations based on the multifunctional suitability maps.

Table 7.6 illustrates that in both cases the minimum value is 0; however, there are different average and maximum values.

The average (0.19) and maximum (0.78) multifunctionality values offered by the AND operator are well below the multifunctionality levels provided by the OR operator, in which the average value is three times greater (0.62) and the maximum value is 0.99.

In both results, there are no considerable differences between the south and north banks of the river in terms of suitability values.

Table 7.6: Statistics of OR and AND combinations.

	AND	OR
Min	0	0
Max	0.78	0.99
Mean	0.19	0.62
Std. Dev.	0.16	0.19

Source: Own calculations based on the multifunctional suitability maps.

As for the AND multifunctionality level, it is possible to observe that the most suitable areas for the provision of multiple environmental services have a more fragmented and disconnected spatial structure, thus giving rise to highly suitable clusters surrounded by areas with low suitability values. This is particularly important in the central and western parts of the city.

Given the fact that the OR multifunctionality level allows the identification of highly suitable areas for the provision of at least one ecosystem service, it is possible to recognize a relatively continuous series of high suitability values along the urban segment of the Mapocho River. The eastern part of the riparian zone has a greater surface covered with areas characterized by high levels of multifunctional suitability. Although these kinds of areas tend to disappear in central and western sections, it is still possible to observe a relatively continuous series of average and high multifunctional suitability values.

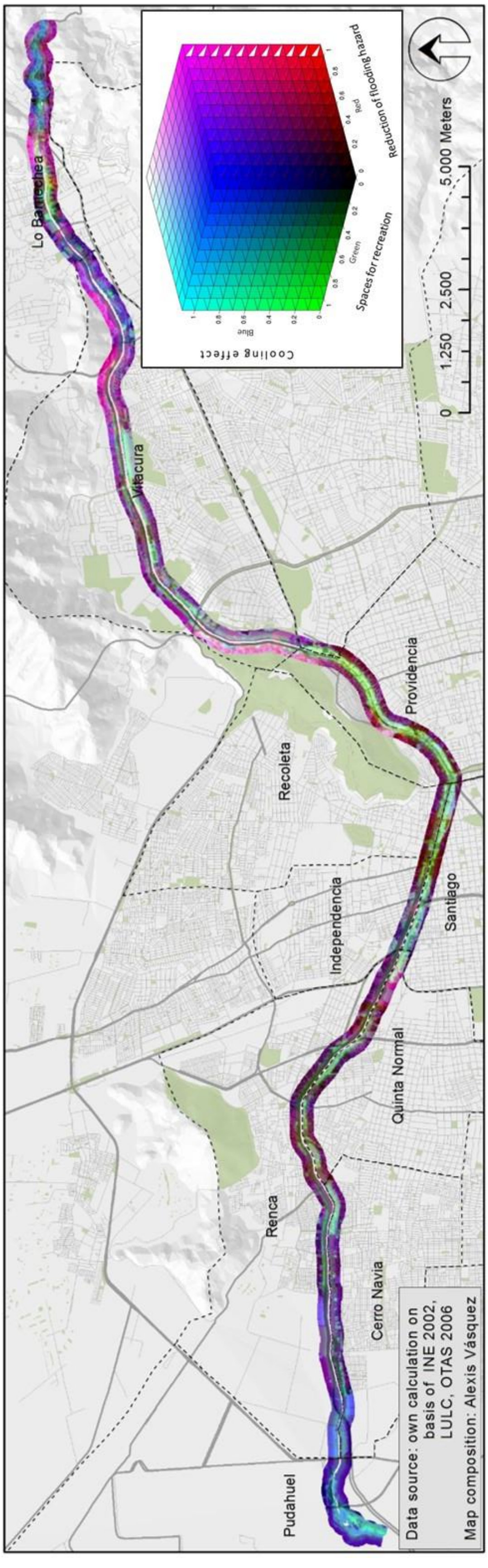
In addition, it is also possible to observe some areas with high multifunctionality values at both AND/OR levels. According to any of the two analyses, these places are zones with high suitability values for the provision of multiple ecosystem services. The eastern area comprises sectors with semi-natural vegetation, a golf club, riparian parks and part of a vegetation-covered slope of San Cristobal Hill. In the central area of the corridor, these spaces are associated almost exclusively with riparian parks and vacant lands. As for the western section of the corridor, the few riparian parks available are still important; added to these are some agricultural areas and slightly intervened vegetation-covered riversides.

Figure 7.13 shows the suitability of a given segment for the provision of ecosystem services related to recreation, cooling effect and flood hazard mitigation. This illustration offers the possibility to observe the integrated suitability for the provision of these three ecosystem services while identifying the appropriate suitability level for a single or multiple ecosystem services. For instance, light-green colors show suitability levels related to recreation and turquoise indicates high suitability levels for the provision of recreation and cooling effect services.

The diversity of colors represents the complexity and variety of suitability combinations for the provision of the abovementioned ecosystem services; this implies the difficulty in identifying clear suitability patterns. However, the central section of the corridor is primarily oriented towards the provision of spaces for recreation, which is commonly combined with high suitability levels for the provision of cooling services. The east end of the corridor, near Alvarado Hill, reveals a combination of services related to cooling effect and flood hazard mitigation, the former having slightly higher suitability values than the first one. Finally, the west end of the corridor has some areas with high suitability levels for the provision of all three ecosystem services, especially among them is cooling effect.

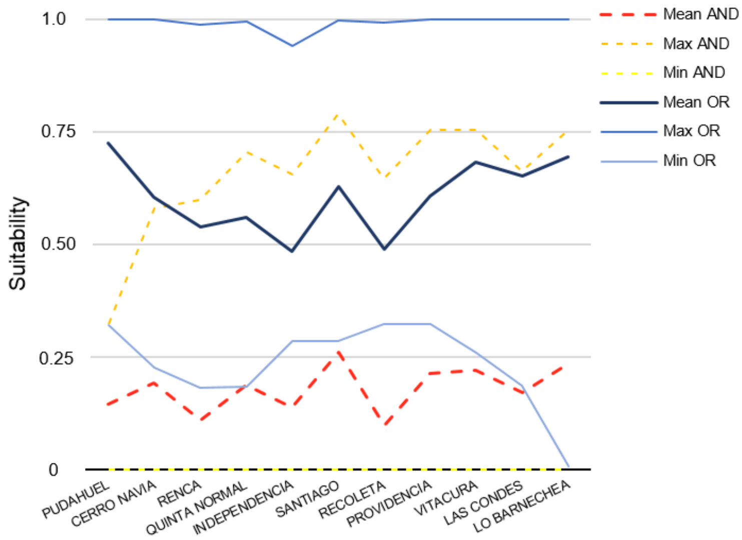
Figure 7.14 shows variations in the multifunctional suitability values for the AND/OR operators along the urban segment of the Mapocho River. These two assessment methods concur with the identification of peaks and troughs of the average suitability. While peak values are associated with the municipalities of Lo Barnechea, Vitacura, Santiago, Quinta Normal and Cerro Navia, trough values are associated with the municipalities of Recoleta, Independencia and Renca.

Figure 7.13: Suitability for recreation, cooling effect and reduction of flood mitigation integrated into a RGB



Moreover, the multifunctional suitability values for the OR operator tend to decrease from the outskirts to the center of the city, reaching a peak value in the municipality of Santiago.

Figure 7.14: Variations in the multifunctional suitability values for the AND/OR operators along the urban segment of the Mapocho River.



Source: Own calculations based on the multifunctional suitability maps.

Conversely, there is no agreement between the AND/OR multifunctional suitability values in Pudahuel as in this case they represent the lowest and highest values, respectively.

Figure 7.15 integrates the suitability for all ecosystem services evaluated. Layered over the multifunctional suitability (OR) for cooling effect, recreation, flood mitigation and habitat for native flora and fauna, is the wind corridor and the path for non-motorized transport.

This chapter evaluates the suitability of the riparian zone of the Mapocho River to provide seven selected ecosystem services later integrated to show the multifunctional suitability. Thus, the ecosystem services for which the riparian zone presents a greater suitability were identified as well as the sectors with greater suitability.

All of this gives an idea of the physical support of the riparian zone to provide multiple ecosystem services, which will be complemented with an analysis of institutional and legal aspects presented in Chapter 8 to identify in Chapter 9 the main potential of the riparian zone as a multifunctional riparian greenway.

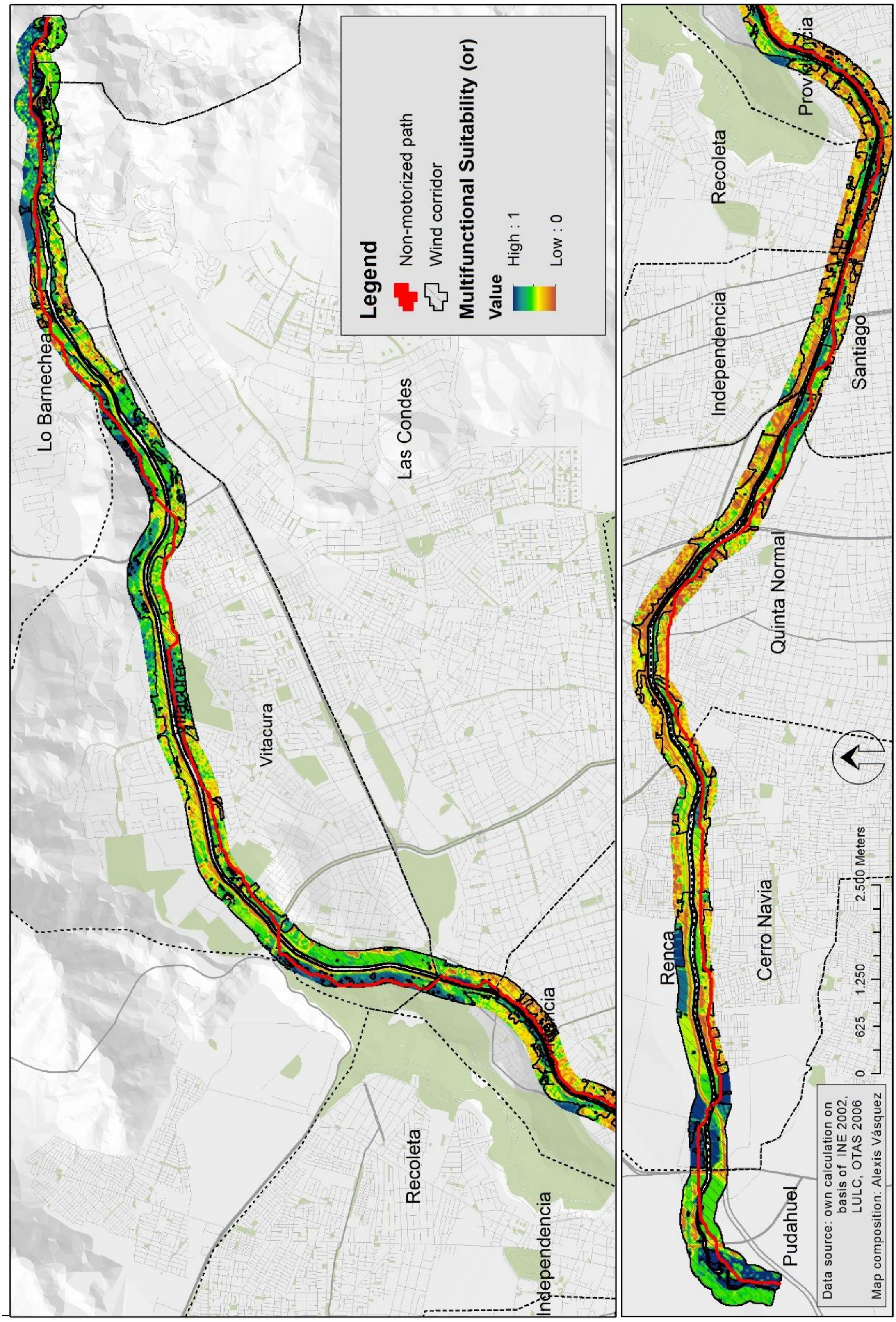


Figure 7.15: Synthesis of the suitability for all evaluated ecosystem services.

Chapter 8

Opportunities and challenges analysis

This chapter presents the results of the opportunities and challenges identification and analysis, complementing the quantitative and spatial analysis presented in Chapters 6 and 7 in the definition of potential (Chapter 9) for the development of a greenway in the Mapocho River. This is based on an institutional analysis that identifies stakeholders and their competences and attitudes in relation to riparian zones and green space issues.

The following five key issues for the development of the multifunctional urban riparian greenways are identified and discussed: regional government, funding, social and political relevance, intergovernmental coordination, and socio-ecological status. The main findings of Chapters 6 and 7 contributed as input in the interviews of satakeholders and especially to define the opportunities and challenges associated with the socio-ecological status of the riparian zone. Finally, a synthesis of opportunities and challenges for urban riparian greenway development are presented.

8.1 Intergovernmental coordination

Intergovernmental coordination is a key issue in greenway planning and development due to its interjurisdictional and intersectorial nature.

8.1.1 Institutional landscape at interagency level

Stakeholders agreed that multifunctional riparian greenways are a challenge for the highly fragmented national and regional institutional and regulatory framework. They mentioned that there are no institutions capable of addressing the complexity of the planning and development of multifunctional green corridors; this is why coordination among territorial jurisdictions like municipalities and among sectorial authorities like the regional services of different ministries are regarded as a major issue.

> In my opinion, the concept of a multifunctional greenway does not have a proper institutional framework…the understanding of greenways from a multifunctional perspective, including the different components of sustainable development, does not exist (E3, GORE).
>
> Today, the green spaces institution has some shortcomings (E2, SEREMI-MMA).

Ten public agencies (including sub-departments) were identified by stakeholders as relevant for riparian greenway development in Santiago. These public agencies have different hierarchies and jurisdictions at a municipal, regional and national level (see Table 8.1).

Table 8.1: Public agencies identified as relevant for riparian greenway development in Santiago.

Institution	Act/Instrument	Action/Competence
Communal Planning Secretariat (Municipalities)	Communal Master Plan	Zoning of possible and excluded uses in riparian areas. Creation of public green areas at municipal level.
Department of Facilities (Municipalities)	Constitutional Act on Municipalities	Creation and maintenance of municipal green areas.
Department of Municipal Works (Municipalities)	Constitutional Act on Municipalities	Reviewing and granting of planning permits on watercourses, prior to the submission of a report to the DOH. Reviewing and granting building permits.
Department of Urban Development (SEREMI-MINVU)	Metropolitan Master Plan	Zoning of possible and excluded uses in riparian areas. Creation of public green areas at metropolitan level.
Parque Metropolitano de Santiago (SEREMI-MINVU)	Urban Parks Program	Administration and management of 16 parks included in the Urban Parks Program.
Department of Water Works (SEREMI-MOP)	-	Authorization for the connection or enhancement of the primary rainwater drainage system. Revision and authorization of delineation requests that may affect the courses of rivers, lakes and estuaries. Revision of technical surveys; authorizing the definition or reduction of Restriction strips, which are related to the overflow of rivers.

Department of Roads (SEREMI-MOP)	Supreme Decree n°729 of August, 2008. Excempt Decree n° 762 of May, 2012.	Provision of road infrastructure services. Administration of public roads within the Metropolitan Region, created under Supreme Decree n° 729 (including the costanera norte and costanera sur highways).
SEREMI-MMA	Environmental Impact Assessment System	Review and authorization of investment projects. Request of mitigation, restoration and compensation measures; these may include restoration and compensation in the form of green areas.
SEREMI-MBN	Decree Act n° 3,274	Identification, administration and management of taxable assets. Definition of a strip corresponding to the national assets, which is intended for public use and is related to a specific watercourse and its banks.
Maipo Canal Society	Article 257 ff. of the Water Code	Canal Association in charge of the extraction and distribution of water from the Maipo River. Conservation and improvement of aqueduct networks under its administration.
CONAF	Urban forestation program	Provision of trees.

Source: Author's own elaboration.

At a local level, seven out of eight interviewees mentioned that municipalities are very important institutions for the development of green corridors. The urban segments of the Mapocho River and the Zanjon de la Aguada flow through 12 and 9 municipalities, all of them with different resources, priorities and problems.

> There is the direct investment and the direct concern of municipalities (E1, SEREMI-MINVU).

> Any municipality you want to intervene; this is an important matter, as the idea is to incorporate them; municipalities are the "owners" of the territory that is going to be home to these parks and green corridors (E5, GORE).

Stakeholders mentioned that coordination among different—and sometimes extremely different—municipalities is a major issue for the development of urban riparian greenways in Santiago. Municipalities, in their capacity of local governments, have a large measure of control and decision over their territories, including the establishment of specific territorial regulations and plans. Such a complexity, together with the laxity of the PRMS, results in different regulating landscape components of Municipal Regulatory Plan (Plan Regulador Municipal, PRC) of adjacent municipal jurisdictions, as in the case of riparian areas; this generates spatial fragmentation and affects the chances of maintaining the spatial integrity of riparian greenways.

> Poor coordination among territorial planning instruments at a municipal level that define a different vision or typology of each of the sections of the river (E3, GORE).

> The coordination that may exist among these institutions; it is difficult to relate a corridor with a municipality, a road means the union of different municipalities; for instance, the Mapocho River crosses different municipalities and the course of water also crosses four or five municipalities; eventually, this is a matter of coordination between these districts and the interests of neighbors (E5, GORE).

According to stakeholders, the lack of coordination among municipalities and the extremely limited experience in that field are not relevant. However, this could reveal great difficulties and barriers for inter-municipal dialogue and coordination.

At a regional level, stakeholders found that regional services of ministries are relevant actors for the future development of urban greenway. Although these services are settled in the region, they normally work towards the achievement of national interests and policy goals; this situation hinders partnership cooperation between regional and local institutions and development of a multilevel dialogue.

In addition, these public agencies have different interests and highly fragmented visions. Sectorial policies and regulations have narrow sectorial targets and they are normally developed within an insulated institutional environment, thus causing serious coordination problems.

> We are relatively independent, which is the elegant way to say we are disconnected and that we should make corporate decisions in conjunction with other services (E1, SEREMI-MINVU).

> You may know that we, as the Department of Water Works, are in charge of the maintenance of channels and river banks; however, we do not have to allocate resources for (park) irrigation and lighting purposes (E4, DOH).

> Today, there is an institutional framework related to environmental, public spaces and forestation issues… In fact, each of these institutions ensures the fulfillment of their own goals (E3, GORE).

The MINVU, MOP, and MMA are recognized as the most relevant sectors. According to stakeholders, the two public agencies with greater political power and resources directly involved in the development and administration of green areas are MINVU and the MOP. On the other hand, the MMA can act as a coordinating agency due to its broader, integral, and intersectoral approach; however, this body has a limited institutional capacity to intervene.

> The River Works Department and the River Works Authority, and I think that the Ministry of Environment has something to do with this (E4, DOH).

> The Ministry of Environment has competence in this matter, because a concept such as a corridor, which is an area that connects natural areas or spaces of environmental significance, is a multisectorial issue (E2, SEREMI-MMA).

> The Ministry of Environment should deal with this issue; however, the Environment Committee is in charge of assessing projects that include a considerable number of services (E1, SEREMI-MINVU).

Stakeholders recognized that despite the great potential of the MMA for articulating different sectorial visions, there has not been any real opportunity to develop that potential.

> This is an issue that has been underestimated within the Ministry of Environment (E2, SEREMI-MMA).

8.1.2 Intra-agency institutional arrangement

In addition to inter-ministerial or municipal coordination issues, coordination among different departments or sub-areas within a ministry or municipality is also a critical problem. At municipal level, the development and maintenance of green spaces lies with the DAO, which is a body with a secondary role within the municipal structure. Coordination and dialogue issues between this office and the Department of Municipal Works (Dirección de Obras Municipales, DOM) —a unit with greater institutional authority responsible for urban development—are often the result of power asymmetry and narrow fields of competence.

The Ministry of Housing and Urban Planning is in charge of two important issues: (1) the provision of housing solutions, especially for the most vulnerable population, and (2) urban planning. The responsibility for the planning of green spaces within cities lies with SEREMI-MINVU as part of urban planning. Stakeholders mentioned that in Santiago, housing solutions and the planning of urban green areas are conflicting goals that produce internal tensions reflected in inconsistent actions and regulations issued by MINVU.

> The real estate market and SERVIU—which belong to the State—exert a lot of pressure to purchase land at low cost and they are given the go-ahead; this issue is not properly addressed, this riparian strip is not sufficiently safeguarded (E2, SEREMI-MMA).

> The Ministry of Housing does not prioritize the green spaces issue; there is some priority given to streets or the solution of other type of problems; the municipalities rather than the Ministry should attach importance to this matter (E8, Municipality of Vitacura).

The MOP has two main goals related to the planning of riparian greenways: (1) the provision of transport infrastructure and (2) the cleaning and maintenance of waterways. Despite the fact that both issues are handled by different sub-areas within the ministry, stakeholders mentioned that there are no perceptible conflicts or coordination problems and even both areas have been very well articulated around a sectorial strategic axis such as the development of urban highways in riparian zones. In this case, the department in charge of cleaning and maintaining waterways (DOH) has been aligned to the major purpose of highway construction.

> The DOH, I think that is the name, belongs to the MOP and channels, since we are talking about green corridors, fall within the jurisdiction of the DOH; this unit is administered by the MOP and this ministry is in charge of the construction of highways and corridors, there is some clash of interests (E7, Parque Metropolitano).

8.1.3 Experience on intersectorial cooperation

The *La Aguada* Flood Park is a rare example of intersectorial cooperation for the development of urban riparian parks. On the one hand, the MOP—and the DOH in particular—was required to develop infrastructure for flood mitigation in the middle section of the Zanjon de la Aguada, since many people are regularly and seriously affected by floods. On the other hand, MINVU was concerned about the lack of urban green areas in that area of Santiago. The Parque Inundable La Aguada was a joint effort carried out by the MOP-MINVU and articulated by the Regional Government to address these mentioned goals, (1) flood mitigation and (2) the provision of public green spaces.

> This project is led by two ministries, MINVU and the MOP—the former deals with the parks issue and the latter deals with water-related issues (E5, GORE).

Stakeholders pointed out that this initiative reveals multiple coordination problems not just among ministries, but also between ministries and the Regional Government. This includes different priorities and a lack of coordination of programs and administrative procedures.

> There might be coordination problems as MINVU may say that expropriation was not carried out due to lack of funds and the MOP may have already allocated resources for the enclosure process; then my financial year is lost as I have to execute this plan and the expropriation has not been ordered because the other ministry has not received funds; each institution, each ministry has something to do with this, MINVU is in charge of expropriations and the MOP has to deal with water-related issues… we, as GORE, have to build parks; however, we should be authorized by MIDEPLAN (E5, GORE).

Stakeholders did not mention the opportunities that can be learned about the intersectorial cooperation behind the planning and implementation process of La Aguada Flood Park.

8.2 Regional government

Administrative fragmentation existing in Santiago, together with the absence of a major city mayor point to the key role of the regional government in greenway development.

8.2.1 The role of the regional government

Regional Governments (Gobiernos Regionales, GOREs) were created in 1993 according to the Constitutional Act n°19,175 as a major promotion for decentralization. GOREs are responsible for the equitable economic, social and cultural development of regions.

Although GOREs were created in Chile as an effort to promote decentralization, they still do not have enough political, human and financial resources to effectively lead regional development. Consequently, it is not surprising that only one interviewee, apart from those from GORE, mentioned GORE as a relevant institution for the development of urban green corridors in Santiago. All participants involved, such as municipalities, ministries and other national governmental agencies declared eachother as relevant institutions, but not GORE.

> Certainly, municipalities have competences in terms of how to regulate master plans; regional ministries have competences in terms of urban planning; and surely the canal society has competences (E7, Parque Metropolitano).

> GORE is the only regional institution that can deal with this issue as a whole; as this body has a comprehensive, rather than a sectorial, approach to the events that take place at regional level (E3, GORE).

An example of weak regional governance is the failed Santiago Verde Plan (2006-2011)—proposed and led by GORE—which aimed to increase and improve public green spaces and develop an interconnected network of green spaces at a regional level (including some riparian greenways) through the coordination of municipal and sectorial initiatives. Those involved pointed out that although this plan was relatively well conceived, it basically remained at the conceptual and proposal stages.

> Well, in the light of the results, this is a plan that has not been implemented; this has been rather a planning process, a certain unsuccessful perspective of the need to raise this issue (E7, Parque Metropolitano).

> Plan Verde is a nice plan; this is an initiative that remained on paper and I don't know, this is a matter of priorities and resources (E5, GORE).

> It hasn't worked at all because we haven't seen it. These are only intentions; authors are deified for their mere good intentions, but there is no concrete plan to help us to identify a specific issue (E9, USACH).

For those involved it becomes evident that initiatives like Santiago Verde exceed the capacities of GORE.

> The idea was that GORE, through the green spaces management plan, suggested the municipality submit the proposal for the creation of a park on this site and thus receiving funds to purchase that plot of land; however, Santiago Verde failed as this park had to be built according to certain characteristics in order to be included within the metropolitan system of green spaces (E3, GORE).

> Plan Verde was designed, conceived, there was a logic behind its elaboration, all required studies were conducted, it's very old, there is no continuity within the system and this is because of governments. A Change of government means a change of priorities (E5, GORE).

Stakeholders from GORE have an integral vision of regional development and other issues that go beyond sectorial and municipal boundaries, which characterizes all other actors. However, the strategic and intersectoral perspective of GORE lacks some institutional power and attributions.

8.2.2 The metropolitan land-use plan for Santiago

The main purpose of the Metropolitan Land-Use Plan for Santiago (*Plan Regulador Metropolitano de Santiago*, PRMS) is to provide a normative framework to guide land development in the Metropolitan Region, through strategic lines, which include (Zegras & Gakenheimer, 2000):

- Establishing urban expansion zones and urban growth limits,
- Increasing urban densities,
- Zoning of residential, commercial, industrial and other land use areas,
- Defining conservation areas, green spaces, flood prone areas and other restricted zones.

Different stakeholders regarded the PRMS as an important instrument of regional governance and a key element for future green corridor initiatives. However, the PRMS was elaborated by the Regional Office of the Ministry of Housing and Urban Planning (*Secretaria*

Regional Ministerial del Ministerio de Vivienda y Urbanismo, SEREMI-MINVU) and not by GORE. This leads to the fact that the PRMS is highly influenced by the sectorial interest and vision of SEREMI-MINVU and is consequently the object of high criticism on the part of other actors.

However, and despite the above references, it was surprising that stakeholders from regional services of the Ministry of Public Works (*Ministerio de Obras Públicas*, MOP) and the Ministry of Environment (*Ministerio del Medioambiente*, MMA)

did not know about the proposal for a new PRMS (called PRMS-100), which is currently being discussed.

> In reality, I haven't been involved in the PRMS-100, I don't know the details, (…) I don't know more details about the modifications entailed by this initiative (E2, SEREMI-MMA)
> What is PRMS-100? I had no idea about it (E4, DOH).

In the same way, during the mentioned process of discussion to modify the existing PRMS, many municipalities showed great reluctance to accept the changes proposed by SEREMI-MINVU—and related to urban public green areas.

> The PRMS-100 adds 10,000 ha to Santiago, most of municipalities showed great reluctance to accept this initiative as a considerable number of green spaces were included in such a project (E1, SEREMI-MINVU).

Both situations described before call into question the representativeness and inclusivity of the PRMS and its final proposal.

Other major issue related to the PRMS as an instrument for regional government and planning, especially for spatial planning, is (1) the modifications at specific locations through sectorial procedures, and (2) different interpretations and applications at municipal level through local governments.

In the first case, conditions that apply to a specific area can be modified by sectorial permission of a relevant (competent) ministry or service. For example, the width of restricted areas for urban development and urban watercourses (related to flood risk) established by the PRMS can be reduced at specific segments by urban developers by presenting a flood risk assessment to the Department of Water Works (*Dirección de Obras Hidráulicas*, DOH) proving that the area is safe from floods with a likely return period of 100 years.

Surprisingly, all stakeholders regarded this process as a threat to both the initial strategic vision of the PRMS for this areas and the spatial continuity of a potential riparian greenway. Even two stakeholders from competent public services did not know the administrative mechanism behind the modification of the PRMS.

> Well, some of those areas are protected by the master plan of the city of Santiago… today, only the recreational use of green spaces is allowed, and there is the risk issue. I don't see any willingness to change their restricted use (E2, SEREMI-MINVU).

> As far as I know this can't be reduced because if you have a trench here the law doesn't allow you to have any kind of construction, since that area has already been declared a flood zone; therefore, any dwelling you build will be affected by floods (E5, GORE).

In the second case, a stakeholder mentioned that local governments tend to interpret and apply general zoning and regulations in different ways according to municipal interests and priorities. This has the potential to produce highly heterogeneous regulations and consequently a barrier for the spatial continuity of linear landscape components and potential corridors passing through multiple municipal boundaries.

> Poor coordination among territorial planning instruments at municipal level that define a different vision or typology of each of the sections of the river. A municipality has the vision of green spaces; another municipality may construct towers on the banks of the river; other municipalities may deal with the issues of some dwellings; and other municipalities may build a highway or an urban road, therefore there is a lack of an integral vision (E3, GORE).

> There will be a contrast between municipalities and you will have to figure out how to resolve those differences as well as the union between municipalities, as one municipality has green spaces thanks to its resources and the other municipality is completely dried out (E5, GORE).

These situations may compromise the integrity of the initial concept planning of the PRMS, affecting regional strategy and long-term spatial planning.

8.2.3 Free market-oriented urban planning

The National Policy on Urban Development (Política Nacional de Desarrollo Urbano, PNDU) of 1979 emerged from the establishment of the neoliberal policies promoted by the military dictatorship. Statements at that time defined that urban land wasn't a scarce resource, which was freely traded; consequently, the State had to eliminate restrictions to the natural growth of urban areas driven by the market. Since then, urban planning has remained under this conception, commanded by economic rationalities and without recognizing social and environmental demands.

The free market nature of urban planning is another major issue that reinforces weak regional governance. This promotes individual and singular initiatives and stresses differences among municipalities in terms of budget, power, human and technical resources.

Stakeholders mentioned that apart from differences in municipal budget and priorities, the negotiation capacity of privates and ministries for the development of green spaces greatly affects the chances of constructing intermunicipal green corridors.

> A good management capacity is required on the part of municipalities, the political management of a municipality with private investors and public services as most of compensations are negotiated directly between the municipality and the investor (E3, GORE).
>
> This is particularly due to political variables; there are municipalities that have a close relationship with the MOP, the awarding of concessions, regional governments and those who support the implementation of projects; they exert more pressure than others (E2, SEREMI-MMA).

8.3 Funding

Like other countries, the costs of construction and management of urban green spaces is a key issue in Santiago.

8.3.1 Municipal budget for the management of green spaces

Stakeholders pointed out that funding is a major issue when it comes to creating and managing green spaces. Urban green areas are the responsibility of municipalities and for that reason, the municipal budget is the main source of funds for the development and management of public green areas.

However, stakeholders mentioned that the municipal budget intended for the management of public green areas is not enough because there are other needs of greater social priority.

> There are other needs that should be filled such as education, health, housing and urban development projects; these shortcomings defer these issues (E1, SEREMI-MINVU).

Although there is agreement that green areas represent just a very small portion of the municipal budget, stakeholders recognize that funds for the management of these spaces vary in relative terms as well as in absolute values among municipalities.

Low-income municipalities suffer from a combined effect of low municipal budget and high social needs (education, housing, health and employment) when compared to eastern high-income municipalities. Therefore, resources for the management of green areas are particularly limited.

> Most of the population living in municipalities where the price per square meter is cheap may be regarded as vulnerable; the truth is that there are so many demands and so many needs that green spaces become less important in the generation of municipal budget (E1, SEREMI-MINVU).

> The fact is that municipalities can build a park; however, the maintenance of such a space is not cheap; this is the problem of municipalities, especially those located in the west area; they have other needs, people have other kind of needs because they have access to fewer resources (E8, Municipality of Vitacura).

All stakeholders argued that maintenance costs of urban green areas are more important and challenging than construction or implementation costs. The semi-arid conditions of Santiago and the inappropriate selection of vegetal species involve enormous irrigation costs.

> Maintaining a park costs up to three times the money allocated for its construction, we are talking about huge sums of money (E1, SEREMI-MINVU).

> Ministries of Housing and Municipalities like parks; however their maintenance cost is very expensive. You need irrigation and lighting systems, you have to maintain them (E4, DOH).

In some cases, the construction cost of green areas is fully assumed by MINVU or urban developers, but from then on, the municipality is required by law to take over maintenance costs, without exception. Therefore, the construction of new urban green spaces—by both important public actors and private developers—is putting municipalities in a situation of financial stress, particularly in the case of low-income municipalities.

> It suddenly turns out that the Ministry of Housing builds a park that is transferred to a disadvantaged municipality; then, over the course of two years this municipality has no resources to maintain such a park (E8, Municipality of Vitacura).

> Municipalities reject projects conceived here (GORE) because they don't have resources to maintain them; they barely maintain themselves, then allocating resources for irrigation and lighting systems… maintenance is the big problem concerning parks (E5, GORE).

In this context, several vulnerable municipalities showed great reluctance to accept the PRMS-100 since an integral part of that proposal includes the implementation of a large amount of hectares of new urban green spaces, especially in the poorer municipalities located in west Santiago. The central problem here is that the PRMS is a spatial planning instrument that defines green spaces at metropolitan scale without providing any resources for their creation or maintenance.

> There is the case of Quilicura, the Cruces River; if I'm not mistaken, some municipalities such as Maipu expressed that parks included in this plan may lose municipal funding (E1, SEREMI-MINVU).

> The criticisms of municipalities is that the dimensions of larger and more structural green spaces were reduced (E3, GORE).

8.3.2 Potential instruments to generate private financing for urban green spaces

In general, stakeholders in Santiago are optimistic about the inclusion of private resources and actors in the implementation of urban green areas. This can be done through a series of mechanisms contained in some specific environmental and urban development regulations, including carbon credits, mitigation and compensation for environmental damages and the use of public-private concession models.

Clean Development Mechanisms (CDM) can be used for the creation of green areas through forestation or reforestation projects. In Santiago, this is mainly related to the creation of green areas through the development of new industrial projects located in the Metropolitan Region as compensation for the emission of particulate matter.

> Well, an important possibility is the transaction of carbon credits in which the most polluting industries strike a balance between the negative impact on the environment and the positive contribution to certain green spaces (E1, SEREMI-MINVU).

> The programmatic CDMs, through the transaction of carbon credits, will finance part of these important intervention projects (E3, GORE).

However, the CDM proposed by the Atmospheric Decontamination and Prevention Plan (Plan de Prevención y Descontaminación Atmosférica, PPDA) for the Metropolitan Region—managed through the Environmental Impact Assessment System and compensation mechanisms for the disaffection of green areas as the result of the construction of infrastructure and urban facilities—has not worked as expected. The lack of strategic coordination between these private individual actions has resulted in the concentration of green areas in Parque Metropolitano and other areas outside of the city.

> Today, most of green spaces are concentrated in Parque Metropolitano, San Cristobal and other nearby formations that retain most of investments (E1, SEREMI-MINVU).

> Today, the awarding of compensations is sectorial in nature; for instance, transport mitigation should be specific, it is not possible to focus a mitigation project on a

> specific area of the city; private actors still can decide where to implement a mitigation or compensation project (E3, GORE).

Some municipalities have successfully attracted private resources in the form of green areas as the result of these compensation mechanisms. This is a critical issue since the location of these new green spaces depends exclusively on private investors. The success of these municipalities is closely related to the quantity and quality of human resources available to negotiate at a technical and political level both with the private sector as well as with ministries and other governmental agencies. As a result, negotiation capacity differs greatly among municipalities according to resources and social status; in general, low-income municipalities are less capable of creating new green areas.

> A good management capacity is required on the part of municipalities, the political management of a municipality with private investors and public services is essential as most of compensations are negotiated directly between the municipality and the investor; then mitigation and compensation come into play as part of a normal, regular process; however, the leadership ability of the Major when negotiating the type and standard of green spaces with private investors is fundamental (E3, GORE).

> This is particularly due to political variables; there are municipalities that have a close relationship with the MOP, the awarding of concessions, regional governments and those who support the implementation of projects; they exert more pressure than others (E2, SEREMI-MMA).

In addition to the funds raised from the abovementioned mechanisms, stakeholders pointed out that Conditioned Development Projects (Proyectos de Desarrollo Urbano Condicionado, PDUC)—included in the Master Plan of the City of Santiago in 2003—represent a great chance for private investment not only in terms of the development of urban green areas, but also in terms of the maintenance of public green spaces.

> Within the framework of the elaboration of conditioned urban development projects, private actors have the obligation to maintain these green spaces over a period of five years (E3, GORE).

Both mechanisms (compensation and PDUC) represent a step forward since developers are not only responsible for implementing urban green spaces but also for maintaining them over the first five years. This measure aims to avoid municipal spending on the construction of green areas and during the first stage of vegetation establishment and initial growth, which is usually highly demanding in terms of resources; such an initiative is particularly important for low-income municipalities.

However, stakeholders expressed that after five years, maintenance costs have to be incurred by municipalities; therefore there is some uncertainty about the future of these areas since municipalities cannot mobilize enough resources to that end.

> The obligation is to maintain these spaces over a period of five years; however, there is no certainty about what it is going to happen after those five years (E3, GORE).

> The Vespucio Norte highway built the parks put up for tender in the municipalities of Recoleta and Conchali. These parks are well-maintained in Recoleta; however, Conchali has no resources to preserve them (E5, GORE).

According to stakeholders, it seemed that the only instrument or mechanism to attract private investment in the maintenance of green spaces on a long-term basis is the one that involves public-private partnerships in the form of concession models; such a method has been widely used in Chile to facilitate public services and the provision of goods such as water, health, transport and infrastructure (Hölzl & Nuissl, 2014).

As part of the concession model that is applied to public green spaces, private investors can use 20% of a public green area to build facilities or infrastructure and provide profitable services such as soccer pitches, playgrounds and cafeterias in return for implementing and maintaining the remaining percentage of the area in good condition.

> They created a safe space that was granted to this sport organization that is in charge of the maintenance of this area; despite being frequently leased for different events and parties, this is a clean and well-maintained place, you can see the pitches there; they care about the preservation of this area and raise funds to maintain it (E5, GORE).

> The elaboration of projects that allow both the profitable use of the territory as well as the creation and maintenance of green spaces through concessions. This is the case of Macul and the project that involves different municipalities, the idea of burying some containers to create eco-parks in the northern border with Peñalolén seems to be a plan to collect classified waste. Plastic, paper and other type of rubbish will be disposed in these containers and a company will make use of such material in return for maintaining this park (E1, SEREMI-MINVU).

However, this option is focused on two critical issues: (1) the provision of resources for the implementation of public green areas—designated by the PRMS—that remain undeveloped and vacant and (2) the provision of private funds for their conservation on a long-term basis; some stakeholders are critical about the administration and scope of this mechanism.

People against such a measure think that this program is not capable of attracting a significant amount of private projects, thus preventing it from showing its real impact. They have expressed doubts as to the results of this initiative even in those cases when a park concession model has been implemented; this skepticism is born from the fact that 20% of a public green area is lost and there is no significant investment in its implementation or maintenance.

> The atmospheric prevention and decontamination plan, Article 117, was thought to promote the creation of green spaces as there is a large proportion of unconsolidated green areas; as you may know, green spaces are underestimated and remain undeveloped; this initiative was intended to encourage the creation of this type of areas but there hasn't been any change at all (E2, SEREMI-MMA).

> This is disastrous as they are looking for funding. In the past, 20 % of each park was intended for funding purposes through the construction of urban developments. However, they do not raise funds for parks; they use this 20 % and do not do anything. I do not know of any case where funds have been raised for the construction of green spaces in return for the transfer of land (E9, USACH).

8.4 Social and political importance

Stakeholders found it difficult to discuss the development of riparian greenways, probably because they are not familiar with this concept. They rather tended to speak about urban green areas in general.

Despite the fact that stakeholders agreed on the great importance of urban green areas, the public and political importance of this topic is not enough to either become a priority within the urban planning and development in Santiago or be included in public discourses. For this reason, public and political interest in this issue—as well as the knowledge about specific types of urban green areas such as riparian greenways—is even lower.

8.4.1 Priorities driving urban decision making processes

Generally speaking, stakeholders mentioned that economic considerations are more important than social and environmental considerations within the urban decision making process; this explains the prevalence of economic assessment in public and private urban intervention projects.

> I can tell you that the economic assessment is more important than the environmental assessment (E1, SEREMI-MINVU).

> Obviously, political and economic factors are more important than social and environmental factors; as is so often the case, this situation prevails in different fields (E2, SEREMI-MMA).

Public green spaces designated by spatial planning instruments such as the PRMS and the Municipal Master Plan (MMP) are normally under urban development pressure, especially when it comes to housing and the construction of urban facilities and infrastructure.

> They are not sufficiently assessed; the real estate market and SERVIU—which belongs to the State—exert a lot of pressure to purchase land at low cost and they are given the go-ahead; this issue is not properly addressed, this riparian strip is not sufficiently safeguarded (E2, SEREMI-MMA).

Priorities driving urban decision making processes have been such that urban highways and new urban developments have been built within the riparian buffer, affecting the chances for the implementation of riparian parks included in the PRMS.

From the perspective of stakeholders, keeping urban riparian environments undeveloped to favor the implementation of public riparian parks and provide protection against floods is much less important than using these buffers for the construction of highways. This is mainly because transport infrastructure and connectivity needs, including associated benefits, are particularly significant for stakeholders, especially when it comes to the socio-political importance of this issue and its impact on local economy.

> The economic benefit of having continuous strips is the goal of this road project; it would be ideal if these strips crossed the consolidated city, having the State as sole owner and thus avoiding negotiation with different proprietors; costs would drop and the economic returns of projects would be maximized (E3, GORE).

> Motivation is clear; the goal is to favor large investments demanding both manpower and financial resources and use communication channels to meet a strong demand (E2, SEREMI-MMA).

According to stakeholders, the fact that this topic was accorded low priority in public offices is another example that reveals the lack of importance given to public green spaces. At a municipal level, the Facilities Department (Departamento de Aseo y Ornato, DAO) is in charge of the development and maintenance of green spaces. This municipal department has multiple duties, a very limited budget and minor political importance if compared to other departments such as the DOM.

> In principle, municipalities deal with this issue; however, this is seen as an ornamentation matter (E2, SEREMI-MMA).

> The Facilities Department has operated for over 50 years. Municipalities have the ability and are interested in green spaces (E8, Municipality of Vitacura).

At a national and regional level, MINVU and SEREMI-MINVU are responsible for the planning of urban public green spaces. However, they are also in charge of urban development and housing matters; according to stakeholders, these kinds of issues should be the priority of these entities.

> Especially in the Ministry of Housing, which has been focused on the housing issue rather than on financial aspects; historically, there has been no place for city-related issues (E7, Parque Metropolitano).

Stakeholders mentioned that public importance and the demand for urban green spaces may vary from one municipality to another according to the socio-economic status of people. Low-income municipalities fail to meet the needs of their residents in the fields of education, health and housing; this is why the provision of green spaces is not accorded high priority.

> Most of the population can be classified as vulnerable; the truth is that there are so many demands and so many needs that green spaces become less important in the municipal budget. There are other gaps that should be filled such as education, health, housing and urban development projects; these shortcomings defer these issues (E1, SEREMI-MINVU).

> In other parts of the city, in the poor and more disadvantaged areas—so to speak—these issues have still not been addressed by the population as there are more urgent matters to deal with such as health and medical amenities, collective transport services and public transport (E9, USACH).

However, stakeholders mentioned that there is a high social demand for public green spaces in vulnerable municipalities due to the size and design of public housing projects, which are characterized by high-density buildings and a lack of private gardens.

> Houses have less and less space and families, especially young children, need spaces for their development; today, these spaces are provided by squares rather than houses (E1, SEREMI-MINVU).

> There are non-renters and people living in large buildings who use these hallways as courtyards (E5, GORE).

Finally, damage and degradation further illustrate the low public importance given to urban green spaces. Broken trees, damaged street lighting and playgrounds, wall vandalism and waste demonstrate the lack of social awareness regarding the value of public green spaces.

> Nobody claims ownership over parks and nobody feels obliged to maintain it; we need to raise environmental awareness among us (E1, SEREMI-MINVU).

> It is all about culture. There is no point in investing if people do not take care of parks (E9, USACH).

Two possible reasons behind the situation described by stakeholders are (1) the emphasis on economic aspects to the detriment of environmental and social aspects within decision making processes and (2) the lack of awareness regarding the different socio-ecological benefits of urban green spaces—apart from aesthetic and recreational values.

Despite the reduced social and political importance of green spaces in terms of urban planning and management in Santiago, all stakeholders were very optimistic about the increase in the public interest in the value of urban green areas.

> We envisage that there will be more space to debate on city-related issues and there will certainly be more possibilities to address these matters (E7, Parque Metropolitano).

> This is an interesting issue that could be developed through a plan intended to fill the gap between strategic definition and the Presidential Cabinet (E3, GORE).

8.4.2 Political support for urban and riparian parks

Politicians are becoming aware of the iconic and visual importance of large urban parks for—especially those located alongside the river—for the city and urban inhabitants. A large riparian park and the Mapocho Navegable project (Navigable Mapocho) were campaign promises of the former President of Chile, Sebastian Piñera.

The Project is located west of the Santiago municipality and consists in the intervention of a 1km segment of the Mapocho River, the creation of a 20 ha park and a lake intended for water sports (non-motorized watercraft).

Despite all the criticism of the design and impact of this project, Mapocho Navegable has become a presidential priority, thus receiving attention and resources from all public agencies as part of the special program entitled Legado Bicentenario. The implementation of this initiative has already started and the first phase was opened in January 2015.

> Why do so many cases define political priorities and depend on specific circumstances? Right, specific circumstances, projects that are more important than others; I would say that there has been a public interest in certain types of projects rather than others (E7, Parque Metropolitano).

> Political reasons may give you a clue about this. The President of the Republic was one of the promoters of the Navigable Mapocho plan; then he mobilizes all political and institutional resources to support that idea in order to be remembered (E9, USACH).

Stakeholders identified political support and presidential backing as key factors for the development of this project.

> This is the result of the Mapocho Navegable; then, the political willingness to be integrally involved is one of the mechanisms to facilitate this type of project (E3, GORE).

The Aguada Flood Park is mentioned as an example of increasing political interest in the development of urban green spaces and the management of urban watercourses. The Aguada Flood Park is a 4.7 km. linear park that runs along the Zanjón de la Aguada, thereby reaching five municipalities located within the city of Santiago. The cost of this project is estimated at 39 billion CLP and is intended to both solve the problems related to the floods that affect the southern area of Santiago and provide a new park for this area of the city. The last construction phase of this park will be completed by 2015.

According to stakeholders, this park is being implemented as the result of the interest of two influential ministries, the MOP and MINVU.

> The Aguada Flood Park bicentenary project—developed by the MOP—was intended to deal with the floods that affected people from different settlements; they figured out how to solve that problem and the solution was the enclosure of certain zones; then, the MOP and SERVIU decided this was not a water-related issue and the development of parks was given the go-ahead (E5, GORE).

At a municipal level, Parque Bicentenario was opened by the Mayor of Vitacura in 2011; at 30 ha, Parque Bicentenario is the largest riparian park in Santiago. Both the Mayor of Vitacura and Parque Bicentenario have attracted public attention not only from other municipalities but also from the rest of the city.

> We want the river to be a gathering point and a source of recreation; we cannot turn our backs on it. This is why we have improved this area; the best green spaces are located along the Mapocho River (E8, Municipality of Vitacura).

> In the perspective of the Mayor, the park is intended to hold events, congregate people and demonstrate that this space is alive; the idea is to celebrate activities every weekend (E8, Municipality of Vitacura).

Stakeholders mentioned that the discussion, elaboration and the potential rapid promulgation of the Regional Policy on Green Areas illustrates the increasing political interest in this topic.

> I am struggling to encourage national policies, you know, I want ministries or ministers to say "ok, this is what we want" and thus facilitating the launch of initiatives, guidelines and institutional regulations; this is because there are shortcomings in the institutional framework of green spaces (E2, SEREMI-MMA)

8.4.3 The emergence of new social actors

There is an increasing number of NGOs concerned about urban sustainable development, urban ecology and urban green spaces. For instance, the Red de Defensa de la Precordillera protects remnant patches of native vegetation in the Pre-Andean area, and Mi Parque and Cultiva develop urban green areas in vulnerable neighborhoods through a community participatory approach and private donations.

> Another interesting plan is implemented by a private foundation known as Mi Parque, which consists of people interested in the development of green spaces; this entity has financed large extensions of green spaces in socially vulnerable settlements (E3, GORE).

The emergence of different NGOs and other related social movements indicate that public awareness about the importance of urban public green spaces is increasing and becoming part of social demands; in this sense, citizens mobilize for collective action.

> Today, environmental institutions and civil society organizations—mainly the environmental ones—would resist this type of decision (E3, GORE).

However, no NGO has focused on the development or protection of urban green areas in riparian zones.

In contrast, other social actors are showing interest in urban riparian environments, especially those found in the Mapocho River. The Mapocho 42K project was developed by the School of Architecture of the Catholic University of Chile and has made its way from the academic world to urban policies. This project involves the development of a system of interconnected riparian parks, including cycle lanes along 42 km of the Mapocho River.

The academic team managed to include this idea and project as well as its importance in the agenda of public institutions in Santiago. Then, as in the case of Mapocho Navegable, this project was included in the Legado Bicentenario program, which is a special initiative intended to finance iconic projects developed in connection with the commemoration of the 200th anniversary of the independence of Chile.

> The University has been a very important institution capable of providing certain visions about the future and help ministries to make correct decisions. I think the University is an essential actor because the public policies program of the Catholic University is intended to be shared among different actors. These are projects that despite being led by university teams are closely involved in the discussion with relevant bodies; these are sound proposals (E7, Parque Metropolitano).

The Mapocho Pedaleable project was developed by two private actors and is a response to the public demand for the construction of cycle lanes on the banks of the

Mapocho River. This idea has attracted massive social support, especially from the growing social movement of urban cycling; following this argument, the MOP is evaluating different options and designs for the implementation of such a project.

Finally, one stakeholder from the SEREMI-MINVU mentioned that households have an increasing interest in urban green areas because they are becoming aware about the potential impact of public green spaces on the value of properties and heritage.

> They defend a heritage aspect; I am not saying they do not like the maintenance of these green spaces; these areas are maintained because otherwise there would be economic damage (E1, SEREMI-MINVU).

8.5 Socio-ecological status

The spatial and physical aspects are relevant as challenges and opportunities for a riparian greenway in the Mapocho River.

8.5.1 Urban riparian highways as a major issue

Stakeholders pointed out that the urban highways constructed and planned along watercourses can be regarded as the major issue affecting the socio-ecological status of riparian environments in Santiago.

High-speed highways such as Costanera Norte, Costanera Sur and Autopista del Sol cover a significant portion of the urban riparian zones of the Mapocho River and the Zanjón de la Aguada.

Stakeholders are concerned about four main negative consequences related to these highways.

Firstly, urban highways cover a large extension of riparian zones, which is going to increase due to the construction of new roads along these watercourses. In some segments, the riparian zone is almost completely covered by urban highways leaving no space for compatible land uses such as open areas, riparian parks, cycle lanes, viewpoints and gardens.

> All these highways pose a threat in terms of occupation, this includes the use of available plots to build parks and our relationship with the river (E7, Parque Metropolitano).

Secondly, highways have been normally constructed and planned immediately next to rivers, thus preventing access to watercourses; this generates a disconnection between these water bodies and the city. For example, some riparian parks do not have direct access to watercourses.

> Due to this threat there was discrimination in Costanera Norte and there is discrimination in Costanera Sur; what we can do to prevent them from being segregated from the city and remain in the borders; what we can do with the limited space we have and avoid losing this relationship with the river, especially in the case of the Mapocho River (E7, Parque Metropolitano).

> In the north bank sector, especially in the Lo Curro traffic circle, there are retaining walls built along the highway; there is no chance to build green spaces (E8, Municipality of Vitacura).

Most of the stakeholders did not regard this situation as a problem, and even in certain cases the direct access to streams from riparian parks was visualized as a source of potential insecurity and sanitary problems.

Thirdly, urban highways triggered the expulsion of population from riparian zones. This was initially due to the demolition of residential areas as the result of an expropriation process; then, there was an exodus of people living in the remaining residential areas as new highways involve changing the land-use denomination from residential to commercial.

> A highway that passes near properties that used to be located in front of the river. Then this group of people wants the master plan to move to a highly dense place suited for construction in order to increase profits (E8, Municipality of Vitacura).

Finally, on the one hand, riparian urban highways connect distant points of the city along watercourses, and on the other hand, urban highways prevent access to the banks of these bodies of water and reinforce the deficit of a secondary road network for short distance mobilization. In addition, road junctions between riparian highways and other urban highways are substantial barriers for pedestrian traffic and cycling.

> You are not allowed to park or stop by, you have to drive fast and you do not have any space to park your car (E8, Municipality of Vitacura).

> There are continuous corridor and there will be problems related to connecting lands and roads… if you examine in detail you will realize these are difficult road problems (E5, GORE).

Stakeholders pointed out that property rights are important aspects that define the social status, conditions and possibilities of urban riparian zones in Santiago. As mentioned, highways have been built immediately next to watercourses by using the public land strip; as a result, the most distant band of riparian zones, which usually is private land, remain available.

All stakeholders visualized this second and distant strip as the only land available for the intervention and development of riparian greenways; as a consequence, private land and eventual expropriation processes—including the costs of public resistance—are regarded as potential barriers and challenges.

> Transforming private lands into public lands, there are more and more restrictions on expropriation (E1, SEREMI-MINVU).

8.5.2 Regulations versus real estate

Despite the designation of public green areas along urban watercourses carried out by the PRMS, most of them have not been implemented. This situation is particularly severe along the western section of the Mapocho River.

Stakeholders suggested that some segments of watercourses are characterized by the existence of large areas of vacant land associated with undeveloped green areas, especially in low-income and vulnerable neighborhoods, which are normally used for illegal dumping, crime and drug trafficking.

> In many cases, these linear parks have little economic value. They are highly deteriorated; they have become waste dumps, etc... Green spaces are risky areas for young people and children, mostly because of drug trafficking and criminals (E1, SEREMI-MINVU).

Stakeholders believe that the situation of riparian parks located along the Mapocho River is quite exceptional for urban riparian zones in Santiago as these parks enhance the attributes of riversides. Parks such as Los Reyes, Forestal, Balmaceda, Uruguay and Bicentenario form a relatively well connected strip of public green spaces in the southern riverside of central and eastern sections of the Mapocho River.

Unexpectedly, stakeholders did not acknowledge a relevant feature that defines the character of riparian parks in Santiago, which is that most parks located in riparian zones are not adjacent to watercourses. This could call into question the use of the term ”riparian park” to refer to these spaces and the use of the word ”riparian” by stakeholders.

> Question: do you think that Parque Bicentenario is a riparian park? Yes, absolutely. This park does not touch the river because of the Costanera road. What could have been built instead of the Costanera road? Only grass that would extend to the retaining walls (E8, Municipality of Vitacura).

Finally, stakeholders mentioned that despite the fact that official flood hazard protection buffers along watercourses are excluded from urban development, there are residential areas, hospitals and resorts located in riparian areas. According to them, the protection buffer has been repeatedly reduced through administrative procedures (described in section 7.1) for urban development purposes.

> People want to build and these sectors located near watercourses are highly valued; sometimes people are not aware of the lack of security in these areas (E4, DOH).

> They carried out a survey and apart from green spaces there were deserted lands and anything but green spaces; clinics and first aid posts have amenities, and there is the tennis club located in Recoleta—which is a green space (E5, GORE).

8.5.3 Water quality and water needs

In Santiago, urban green spaces require intensive irrigation as the result of a dry and hot climate, and problems related to the selection of species. Consequently, stakeholders regarded the lack of irrigation water as a characteristic of Santiago that is also found in urban riparian environments, which becomes a barrier for the development of riparian green corridors.

> Acknowledging the shortage of water in the region and establishing exclusive criteria for vegetal selection (E5, GORE).

> You have to know what trees you want to plant; these trees should be sustainable, in the sense of not requiring irrigation; this is what E5 was talking about, she referred to maintenance and water (E5, GORE).

None of the interviewees noted the contradiction behind the scarcity of water in the banks of water bodies and how irrigation provision problems can be solved by reestablishing the hydrological connection between the streambed and the surrounding land.

According to stakeholders, the Mapocho Limpio sanitation project has had a major effect on the quality of water as well as on the riparian environmental status. As the result of the implementation of this project, the Mapocho River has not received sewage discharges since 2010.

> Mapocho Limpio is a significant step forward as that image of a heavily polluted river is being removed; humans are the only ones to blame for such a situation; the issues related to organic waste are being resolved (E9, USACH).

On the one hand, the decontamination of the Mapocho River has meant the almost complete control of odors and disease vectors; and on the other hand, there has been an increase in the attractiveness of the riparian environment and, consequently, an increase in their potential for social use and recreation. However, Mapocho Limpio is a unique sanitation project in Santiago and therefore the Zanjón de la Aguada and the rest of urban watercourses still may suffer from the abovementioned problems.

8.6 Synthesis of opportunities and challenges for urban riparian greenways in Santiago

This section presents a summary of challenges and opportunities for urban riparian development in Santiago according to the analyses presented in this chapter.

In general, it is possible to observe that there are more challenges (23) than opportunities (13) in relation to the development of urban riparian greenways in Santiago. Likewise, opportunities fail to balance (or compensate) challenges either in number and importance in almost every category; the only exception is the Social and Political Importance category, which shows some balance between both dimensions.

In quantitative terms, challenges are equally distributed among the different issues, with the exception of funding, in which challenges (2) and opportunities (1) are more or less clear and easy to measure by relevant actors.

The challenges and opportunities presented in this research differ in their nature, magnitude and complexity.

As for their nature, they were divided into five groups:

1. Regional Government
2. Funding
3. Social and Political Importance
4. Intergovernmental Coordination
5. Socio-Ecological Status

While most of opportunities and challenges perfectly match their respective categories, there is a group that is difficult to classify as it may be associated with more than one area.

There are challenges and opportunities that may be addressed in different terms (short, medium and long) and with different instruments (projects, plans and programs). For instance, there is the case of several undeveloped riparian parks compared with a weak regional government.

Another important aspect has to do with the possible causal relationships (either simple or multiple) among different challenges, in which some of them may be regarded as the cause of even more complex problems.

Finally, the analysis shows the current unfavorable conditions for the development of urban riparian greenways. However, Table 8.2 offers alternative forms of action to clearly demonstrate which are the main challenges to be addressed and the opportunities that must be taken advantage of.

Instead of understanding challenges as problems, they should be regarded as barrier hurdles to be overcome; therefore, there is the need to design a series of systemic actions to achieve such an objective, including short, medium and long-term measures and the participation of all relevant actors.

Table 8.2: Synthesis of opportunities and challenges.

Issue	Challenges	Opportunities
Regional Government	PRMS is highly influenced by the sectorial interests and visions of SEREMI-MINVU	The integral vision of GOREs beyond sectorial and municipal boundaries
	Laxity of the PRMS	
	Free market-oriented urban planning	
	Weak regional government	
	Lack of political and financial power	
Funding	Exiguous municipal budget for public green areas	Incorporation of private resources and actors
	Maintenance costs	
Social and Political Importance	Low social and political importance	New interested social actors
	Public green spaces under urban development pressure	High social demand for public green spaces in vulnerable municipalities
	Responsible units with lower institutional authority	Increase in the interest and value of public green areas
	Secondary task of SEREMI-MINVU	Increasing political importance
	Multiple unsatisfied needs in low-income municipalities	Regional Policy of Green Areas
	Unawareness about the variety of socio-ecological benefits of urban green spaces	Increase in the number of NGOs concerned about urban sustainable development

Intergovernmental Coordination	Highly fragmented national and regional institutional and regulatory framework	Experiences on intersectorial work for the development of riparian parks
	Low levels of coordination and association among territorial jurisdictions	Intersectorial vision of the MMA and GORE
	Lack of coordination between different—sometimes extremely different—municipalities	
	Sectorial policy and regulations have narrow sectorial targets	
	SEREMI-MINVU conflicting goals	
Socio-Ecological Status	Urban highways constructed and planned along watercourses	Mapocho River sanitation project
	Property rights	Large areas of vacant land
	High irrigation needs	Riparian parks along the Mapocho River
	Reduction of the flood hazard protection buffer	
	Existence of several undeveloped riparian parks	

Source: Author's own elaboration.

This chapter identifies the main opportunities and challenges for the development of a greenway in the Mapocho River from a qualitative approach. It focuses on the possibilities observed by actors for the occurrence of changes that lead to the planning and implementation of a greenway within the existing political and institutional context in Santiago.

The conjunction of the greatest opportunities and challenges with the highest suitability identified in Chapter 7, contributes to the identification of the main potential of the riparian zone of the Mapocho to transform into a greenway in Chapter 9.

Chapter 9

Discussion on urban riparian greenway potential

This chapter presents the main potentialities of Mapocho River's riparian zones for developing a multifunctional greenway. These potentialities emerges from a positive interaction between the priority ES's, segments of the riparian zone with greater suitability and main opportunities. For identification the proposed model in Section 3.2 and its adaptation to this study presented in Section 5.4. were used.In the following, the three identified main potentialities are elaborated for the development of a riparian greenway associated with the Mapocho River.

9.1 Potential political and social support of a multifunctional greenway

The results show that the most important ESs correspond to a wind corridor, routes for non-motorized transport and spaces for recreation.

Local actors have an interest not only for cultural ESs, but that their interests expand to ESs of regulation and support. This involves a broader and more complex view from actors than the traditional view focused on the aesthetic and recreational benefits of urban green areas. However, this may have been influenced by the fact that in a riparian green area the ecological functions may be more evident for actors than in other types of green spaces.

In this sense, it's remarkable that compared with other actors, the municipal officials recognise and value a diversity of ESs potentially provided by a riparian greenway (see Section 7.1). This is important given that the development of a greenway along the Mapocho River requires municipal management and planning, since municipalities are a public institution with direct influence at a local level on what occurs in the riparian zones.

Recognition from actors of a wide variety of ESs potentially provided by green spaces may be associated to the growing political importance of green spaces in Santiago identified by interviewees. The issue of urban green areas has recently become more important in the debate on the quality of life of inhabitants and the development of a sustainable city (Bachellet, 2014; Opazo and Jaque, October 18 2014).

In this way, as it is recognised that a riparian greenway in Santiago may contribute to improve air quality (wind corridor - non-motorized transport), thermal comfort (cooling effect), sustainable transport (non-motorized transport), protecting people and infrastructure from flooding, and recreation of the community, the idea of developing a multifunctional riparian greenway can achieve broader political and social support.

Another important aspect is that the idea of a multifunctional riparian greenway articulates well with the emergence of new social actors interested in the development of green spaces in Santiago. These groups have diverse interests that range from pro urban cycling and interest in building more cycle lanes (e.g. MapochoPedaleable, Bicicultura), to those who look to promote the historical-cultural heritage of the river and its riparian neighbourhoods (e.g. Cultura Mapocho, BiciPaseosPatrimoniales).

These groups of organised citizens can transform into important supporters for developing a multifunctional greenway in the Mapocho River that provides them opportunities to meet their demands.

9.2 Potential to provide green spaces and connections where needed

Today, there is a greater demand for green spaces from the most vulnerable sectors of the population located in the western section of the river.

This demand has increased in recent years and continues to grow. Although the initial concern was to meet the housing demand of the poorest population, once this was nearly satisfied in quantitative terms, the inhabitants currently have begun to be concerned for the quality of housing and the neighbourhood.

In addition, over the years the model to produce social housing and neighbourhoods of low standard - high density, small dwellings and few green areas - has produced an enormous need for green areas in the poorest sectors, such as space for recreation, social interaction and community cohesion.

This high demand for green spaces in the municipalities to the west of the river coincide with the section of the riparian zone where there is a greater availability of vacant land. Downstream of the municipality of Santiago are extensive patches of vacant land localized on the banks of the Mapocho River, which provides an opportunity for the development of riparian parks in this section that integrates with those existing in the central and eastern zone of the river.

The existence of a number of parks on the south riverside in the municipalities of Santiago, Providencia and Vitacura offer a favorable context for the integration of future riparian parks developed in existing vacant land in the municipality of Cerro Navia, Quinta Normal and Pudahuel.

The configuration of a future system of parks along the south riverside of the Mapocho River constitutes the potential development of a metropolitan riparian park. This large park would permit (1) valuing the river as a major urban component in Santiago, (2) taking advantage of the aesthetic and recreational potential of the river in the city, (3) the provision of public green spaces in areas that lack them, and (4) establishing a non-motorised transport route that connects the western municipalities with Santiago and Providencia.

Regarding this last point, it should be noted that the ES of non-motorised transport is the second most important for the actors and in the western section of the riparian zone the modelling resulted in a path that runs along the southern riverside.

The establishment of a system of riparian parks as the one described, would provide an attractive and safe non-motorised transport route for low-income people who live in the western municipalities and travel daily towards sectors (central and eastern) where most employment, education and services are concentrated (Ortiz & Escolano, 2005).

There are two other additional aspects that reinforce the potential for the development of a greenway to the west of Santiago. Firstly, the emergence of social organisation in the poorest sectors demanding the construction and maintenance of public green areas constitutes a favorable condition for the possible development of a greenway in the western section of the river. Secondly, the western section of the riparian zone presents a high suitability to serve a role in cooling the local climate, which is why the development of a greenway in these municipalities could also contribute to the thermal comfort of the population.

In summary, the development of a greenway in the western section of the city could contribute importantly to meet some of the social demands for green spaces and improve the quality of life of the population, mainly contributing in three aspects (1) offering greater access to recreational spaces given its linear shape, (2) decrease extreme high temperatures characteristic of high density urban sectors and scarce green spaces, and finally (3) offer an attractive and safe non-motorised transport route to the central-eastern part of the city.

9.3 Integrative vision and increasing importance of GORE

The multi-functionality and interjurisdictionality associated with the development of a greenway in the Mapocho River pose a challenge to sectorial visions, but that may be understood and addressed from the integrative vision of GORE.

The above is reinforced by two aspects. In first place, GORE has demonstrated a growing concern for issues related to the development of metropolitan green spaces, such as the case of the elaboration in 2014 of the first Regional Policy on Green Areas for the Metropolitan Region (GORE, 2014) and put into tender to convert a Cerro Isla in Santiago into a metropolitan park (GORE, 2014). In second place, there is the possibility that GORE will have a stronger political position in the future.

Despite the limitations of its political scope and current resource availability, GORE has been increasing its influence in these matters, which may benefit from the recently introduced modifications in its conformation.

For the first time in 2013, the Regional Council members (CORES) were elected by popular vote (Ley N°20,678) and perhaps soon the same will occur with the Regional Governor (Álvarez & Campos, 31 December 2014). This should facilitate a greater representation of the citizens' demands in regional decisions, with the consequent increase of the social and political influence and validation of GORE.

The current integrative vision of GORE together with a potentially stronger political position, can improve its role in the coordination between the different municipalities and competent state agencies for the development of greenways in Santiago. For example, coordinating the diverse actions of the municipalities and ministries on the riparian zone and diverse actions priorities regarding to the socio-ecological benefits that a greenway in the Mapocho River can provide.

Regarding the above, the suitability analysis (OR) demonstrates there is high suitability along the river for the development of a greenway, if a strategy is favoured which is based on the spatial integration of mono-functional zones within the multifunctional mosaic along the riparian zone. This provides the opportunity to incorporate in a plan for development of a greenway, the diversity of municipal priorities in the development of green spaces and the provision of specific ESs.

Another positive aspect is the high diversity of highly suitable green spaces that can be found along the river that contribute to the structural and functional diversity of a potential corridor.

The areas with the highest suitability to provide multiple ESs are associated with spaces of diverse nature. From east to west it's possible to find that these sectors of high suitability vary from golf courses to agricultural land.

For example, in the east there are important semi-natural zones and golf courses, riparian parks in the center, and vacant land and semi-natural riparian sectors in the west.

This diversity of green spaces in addition to the diverse ESs of interest are committed to many and diverse public agencies. GORE may act as the state agency that leads the intersectoral and inter-jurisdictional coordination and cooperation for the development of a greenway. This role may eventually be supported by the SEREMI MMA.

Likewise, the SEREMI MMA together with GORE could coordinate a system to address the compensations of green areas derived from the SEIA to consolidate designated but not yet implemented green areas, as well as the construction of new green areas in the riparian zone.

Chapter 10

Discussion and conclusions

The discussion chapter details the limitations of the research and methodological shortcomings. The meaning of the results is discussed in light of the research questions. In addition, this chapter outlines the main conclusions of the study, integrating and summarizing the main findings and contributions of the research. Finally, the academic and practical implications of the results are presented.

10.1 Discussion

10.1.1 Conceptual and methodological framework

The proposed conceptual-methodological framework developed in this research means progress on existing approaches for assessing the potential of a multifunctional greenway and its planning. The proposed structure articulates the two approaches that exist today: those based on suitability analysis and those based on the identification of opportunities and challenges. This in itself involves an advance in the integration of spatial-quantitative information with non spatial-quantitative information that supports the planning of greenways.

Today, it's common to find the concept of potential and suitability used synonymously in literature regarding the green infrastructure and specifically greenways (Miller et al., 1998, Gül et al., 2006; Du et al., 2011). Nevertheless, this research suggests that the potential for the development of a greenway is given by the suitability, or degree to which an area meets certain characteristics (especially physical), and the institutional and regulatory conditions interpreted by actors as opportunities for that purpose. This conception of potential and its distinction regarding the concept of suitability should permit a more complete and complex assessment of the potential of riparian zone to transform into a greenway.

The proposed conceptual-methodological framework also differs with respect to the mainstream followed by work on the evaluation of greenway potential, since this work focuses its attention on delineating greenways to link certain previously defined areas or nodes (Conine et al., 2004; Zhang & Wang, 2006; Teng et al., 2011). These studies searche for paths with the greatest potential as greenways, without restricting the assessment to specific linear components of the landscape, but in many cases providing greater value to the areas near watercourses. In the case of this research analyzed sectors are exclusively restricted to the riparian zone of the Mapocho River, and therefore, only this area is eligible as a greenway. Accordingly, there may be locations with greater potential in the city but are unexplored in this work.

In this sense, the research is based on the idea presented by Fábos & Ryan (2006) that the sectors with the greatest potential for the development of greenways are those associated with watercourses, the reason for why the riparian greenways are the most common worldwide. This initial prioritisation of watercourses follows the same line of increasingly frequent studies that explore the potential of urban riparian zones for the development of greenways and restoration projects and urban renewal (Che et al., 2012; Faggi et al., 2013; Liu, 2014).

The proposed conceptual-methodological framework integrates the functional classification of the components of a green infrastructure system (Benedict & McMahon, 2006; Hellmund & Smith, 2006) with proposals from Hansen & Pauleit (2014) to consider the multifunctionality as the provision of multiple ecosystem services, creating for the first time a classification of the ecosystem services more connected to greenways. This classification provides a framework for prioritising ESs when evaluating and planning greenways, while at the same time orienting what type of analysis is performed to evaluate the suitability to provide a given ES.

As a consequence of this, the notion of suitability used in this type of analysis is reformulated from one based exclusively in the application of multi criteria analysis (MCA), to one that also includes the analysis of least cost path (LCP). According to Teng et al. (2011) these two types of analysis correspond to two different approaches, where the LCP is classified as process-based and not on suitability. However, when considering a broader definition of suitability analysis as an assessment of spatial unit suitability for a given purpose based on the degree that it satisfies a set of criteria (Malczewski, 2004), it's possible to also consider the LCP analysis as a way to determine suitability. In the case of LCP, suitability is given by its capacity to permit movement through it and its relationship with spatial units around it.

In this sense, LCP, as proposed, must be used for the assessment of Primary ESs as those involve flow and therefore, require a continuous path to meet that objective. In contrast MCA may be used in the suitability assessment for the provision of Secondary and Tertiary ESs.

Another characteristic of the proposed conceptual-methodological model is that it is capable of being applied in different urban contexts, so that it may be transferable to the study and planning of greenways in other cities. However, this transfer process should consider operational adjustments to the amount and quality of available information for the socio-ecological analysis and suitability.

The application of the proposed conceptual-methodological framework to the Mapocho River identified the scope and limitation of the model.

The first strength of the proposed methodological framework is the sequential order of the three main stages which allow gradual gaining of knowledge of the riparian zones status and their potential as a greenway.

This begins with an analysis of their physical characteristics in social and ecological terms and how they can support some functions, proceeding with an analysis of its suitability to provide ecosystem services and concludes by identifying opportunities and challenges for the development of a riparian greenway in the Mapocho River perceived by the actors. This sequence highlights aspects of the general approach proposed by Hellmund & Smith (2006) for the design and planning of greenways and integrates analytical and evaluation instruments present in the relevant scientific literature.

The second strength is associated to the improvement of specific methods used in each of these three stages, base on expanding them and proposing improved versions to overcome some of the problems described in the Section 2.3 and Chapter 3.

Thirdly, this integrated approach gives a better account of the complexity of the concept of potential elaborated here, to provide a background of the two dimensions that compose it. Today, it is possible to find work that proposes paths of greenways based solely on suitability analysis (Miller et al., 1998; Giordano & Riedel, 2008; Du et al., 2012) and others only in the analysis of the legal institutional framework and the opinion of the actors (Erickson & Louisse, 1997; Ryan et al., 2006), thus this work progresses in its integration.

As for the weaknesses of the proposal, the most important relates to how it intends to integrate these two dimensions, that is to say, integrate the results from the suitability analysis with the results of the analysis of opportunities and challenges.

The integration is performed through a discussion that links the main findings of each one of these two analysis, however, this form of integration offers greater challenges. First, it is at the discretion of the researcher to choose which combination of levels of suitability and opportunities will be integrated and presented in the final evaluation. In this research only the greatest potentialities were presented, which resulted from a coincidence between the most important opportunities and the highest suitability. Nevertheless, other combinations of opportunity and suitability exist (different than the maximum) valuable for analysis as far as orienting action strategies (planning and management) either in opportunities (and challenges) or on which suitability to improve and how, in order to produce new potential.

The second challenge relates to the integration of the units of analysis used in the analysis of suitability and opportunities. First, for the suitability analysis the analysis units correspond to spatial units (polygons, municipalities, riverbanks) and ecosystem services, second, the results of the opportunities analysis correspond mainly to topics that offer opportunities. While it is true the conceptual model offered here (Chapter 3) facilitates a sequential analysis and integration of partial results to identify the potential of a greenway, it is necessary to find more appropriate ways to face the remaining challenges.

10.1.2 Status and functionality of the riparian zone

The riparian zone of the Mapocho River has a certain east-west longitudinal gradient in respect to its ecological and social characteristics, reflecting the pattern of urban disparities characteristic of the city of Santiago at a global level.

The eastern sector is principally occupied by a population of high socio-economic status, with the exception of some neighbourhoods in the municipality of Lo Barnechea, and is well provided with public green spaces. In the central sector, the riparian zone is occupied by a population of middle-high socio-economic level, multifamily high-rise housing and a good provision of green spaces. Finally, the western section of the river is occupied by high density and low-rise residential sectors intended for a population of middle and low socio-economic level, where families are more numerous and there is a greater presence of children. In these sectors there are very few green areas and many of them formally designated as such remain as vacant land.

Therefore, in general it is possible to divide the riparian zone of the Mapocho into three sections regarding their socio-ecological state: eastern (Lo Barnechea, Las Condes and Vitacura), central (Providencia and Santiago) and western (Recoleta, Independencia, Cerro Navia, Renca and Pudahuel).

In certain sectors there are notable differences in the socio-ecological state of the riverbank that are associated with municipal boundaries. The municipal administration and the difference in their interests, resources and capacity for action, have had unequal impacts in the development and state of the riverbank. For example, while both the municipality of Santiago and Recoleta are located in the center of Santiago, their riparian zones present enormous differences with respect to their socio-ecological status. Meanwhile in Recoleta, the riparian zone is characterised by a greater presence of roads and residential towers and comercial sectors, in Santiago there are important riparian parks that allow walking and biking along the river.

These results fit quite well with the typical and marked east-west socio-economic gradient characteristic of Santiago in the stages of a sectoral and polarised city according to the model proposed by Borsdorf & Coy (2009). However, according to Borsdorf & Coy (2009) today, Latin American cities like Santiago have converted into fragmented type cities, dominated by more complex and insular spatial patterns. In the riparian zone of the Mapocho, patterns of high spatial heterogeneity of the urban and social characteristics are not clearly observed at an intra-communal scale characteristic, on the contrary there is a relatively clear east-west gradient.

It seems until now the processes of functional and morphological transformation characteristic of fragmented cities is not clearly evident in the zone around the Mapocho

River, which could be explained because this zone has a rather old urban consolidation and a buffer in existence from the 60's that excludes urban development (Pavez, 2008).

The longitudinal pattern of the socio-ecological status described above can be understood as a reflection of the global situation of the city regarding the unequal distribution of income and environmental conditions that have not been properly buffered or compensated by institutional and regulatory arrangements that act on planning and intervention in the Mapocho River and the riparian zone. For example, the intention of developing a metropolitan park along the Mapocho expressed by the SEREMI-MINVU in the PRMS, has constantly been challenged by the existing jurisdictional and sectorial fragmentation in urban planning in Santiago, which in practice has led to the imposition of sectorial interests in the development of urban highways in the riparian strip.

Some of the limitations of this study are derived from the data used for the socio-ecological analysis. To explore patterns of air temperature and wind, and therefore, the possible cooling effect of riparian zone, two types of field measurements were used (1) mobile transects and (2) using stationary data loggers.

In both cases there are measurement limitations that may affect results. In the first case (1), the transects were performed one day in each season of the year, and although the subsequent analysis indicates that these days presented normal conditions, with such little data its possible that the results only represent the particular conditions of the measured days. Unlike measurements with data loggers, this type of mobile measurement allows for greater spatial representativeness with 16 transects along the river.

In addition to the mobile measurements and with the objective to increase the number of data to once per hour for one year, three transects with four instruments in each one were implemented. A major difficulty in this case was safeguarding the integrity of the instruments in public green areas. In this research various instruments were stolen on more than one occasion, consequently only one of the transects had sufficient data for developing the analysis required.

Regarding the data used in the analysis of the social and urban characteristics, it's important to highlight that several of the social and urban parameters used in the socio-ecological analysis were calculated using information from the 2002 census, given that the 2012 census was declared invalid because serious design and procedure flaws.

The results from these analyses were done using information from 13 years ago, therefore, the patterns found may be different today. However, it's feasible that in recent decades the social and urban conditions have not changed critically along the river given that, on one hand, the greatest physical expansion of the city occurs in the periphery (Romero et al., 2012), and on the other hand, there is a strip around the river where urbanization is restricted. An exception to this are changes due to the urban renovation process in the municipalities of Santiago and Recoleta, which has meant a social and urban transformation produced from the arrival of a higher income population and the construction of apartment buildings (Inzulza and Galleguillos, 2014; López et al., 2014).

This also points to a limitation of this study regarding the use of information from different years. The census data is from 2002, the Quickbird images are from the years 2006 and 2007, and the field campaigns were developed in 2011. Although as was previously mentioned, social changes from the year 2002 in the riparian zone causing the arrival of a new population or change in the resident population have not been important, the validity of certain associations between indicators calculated using information from these varied sources are influenced by the difference in years in which the information was collected.

10.1.3 The potential of a multifunctional riparian greenway of the Mapocho River

In general, there is a certain coincidence between the opportunities and challenges for the development of greenways identified in this study to those reported by previous research (Erickson & Louisse, 1997; Ryan et al., 2006). However, unlike the aforementioned work, this research uses five major topics or categories within which the challenges and opportunities are defined at the same time, without restricting a category directly and exclusively to opportunities and challenges.

For example, as opposed to Smaniotto et al. (2008) that proposes three categories of problems and three of opportunities, this research identifies opportunities and challenges within each one of those categories. For example, in the Financing category viewed by Smaniotto et al. (2008), Erickson & Louisse (1997) and Ryan et al. (2006) as only a barrier to the development of green spaces, in this research opportunities linked to this topic are also identified, such as the possibility of incorporating actors and private resources for the development and maintenance of green spaces.

In the analysis of opportunities and challenges the interviewees referred to the opportunities and challenges for the development and maintenance of green areas in general in Santiago, without specifically making reference to those associated to the development of a multifunctional riparian greenway. Only some of the interviewees were capable of making explicit and specific reference to the notion of a greenway. This may occur due to a low penetration of the greenway concept among the interviewed stakeholders, because this may remain still unknown to them in terms of its definition, functions and types.

At the interview a definition of a multifunctional greenway was given in order to situate the responses on specific aspects of this type of green infrastructure, however the limited knowledge of greenways by the interviewees produced a low specificity in the results of this stage. Despite this, the results of the research destined to identify challenges or barriers for the development of green spaces in general (Smaniotto et al., 2008) and those that do the same but only regarding greenways (Ryan et al., 2006; Haaland et al., 2010; Kim, 2011), tend to coincide, so in the case of Santiago it is expected that in general terms these are also closely related.

In this research the identified opportunities and challenges essentially reflect the vision of the actors and decision makers who work in government agencies. This means that the opinion of the other actors was not considered, thus additional research would be useful that also analyses the point of view and relationships of actors outside of the government, such as NGOs and private sectors. Despite this, it's possible to consider that the actors excluded from this study are not very important in number nor influence, since Reyes-Paecke (2014) studied the governance system of urban vegetation in Santiago, and point out that of the 43 organisations involved, 41 are public agencies.

In the suitability evaluation the most important ESs for actors were recreation, non-motorised transport route, wind corridor and cooling effect. The latter two are not commonly recognised as priority ESs in research about greenways but they were found to be the most important in Santiago. That may be explained by an increasing awareness of authorities and people in general about recent extreme heat waves (Romero et al., 2010b; Espinoza, April 22 2015; Gómez, March 09 2015) and chronic problems of air quality in the months of autumn and winter (Romero et al., 2010a).

On the contrary, the capacity of the river and its riverbanks as a biological corridor and buffer to protect the water quality of the main watercourse normally appear as important ES's provided by riparian corridors in the cities (Miller et al., 1998; Teng et al., 2011), but this was not relevant to the actors in the case of the Mapocho River in Santiago. This may be related to the general perception of the city as an ecological sacrifice zone (Gómez, 2009; Salinas, 2011), high levels of urbanisation in Santiago, or that there are no charismatic species in the city.

In this research it was not possible to clearly identify sectoral differences in assigning importance to the ecosystem services, which contrasts with reports from other studies (Agbenyega et al., 2009; Sanon et al., 2012) where different interest groups present significant differences when valuing different ES's. This may occur for two reasons, firstly, this study did not incorporate all actors involved but only those of the government, therefore, it is possible that this excludes more contrasting opinions, secondly, 31 questionnaires were used and distributed unevenly among the institutions which may impact the representativeness of the ecosystem services hierarchy.

The suitability of the Mapocho's riparian zone as a greenway is generally low, which is consistent with the findings from the socio-ecological analysis developed in this research and with those stated by Allard (2002), Pavez (2008) and Salinas (2011) that describe the Mapocho zone as highly degraded and poorly integrated into the city. However, these results are determined by a set of selected factors, membership functions and overlay methods used in the suitability analysis. Both the factors as the membership functions can be considered as a working hypothesis since there is not enough evidence to know for certain its influence over the suitability to provide a determined ES, nor at a general level or a local level in Santiago. Consequently, the suitability model is susceptible to continue changing as new research determine the nature of these relationships.

10.2 Conclusions

The research contributes to the field of knowledge on multifunctional urban greenways, mainly in two forms (1) proposing a transferable, comprehensive and innovative conceptual and methodological framework for assessing the potential of urban riparian zones for greenway development, (2) to particularly know the socio-ecological state of the urban riparian zones in Santiago, its suitability as a multifunctional greenway and the opportunities-challenges that exist for its development.

With regard to the first (1), it contributes to the discussion in progress regarding the development of analytical application-oriented frameworks to assess the potential for multifunctional green infrastructure development, especially those related to greenways and their characteristics. This is done by articulating and improving three analyses hitherto used in isolation: MCA, LCP and opportunities-challenges.

An integrated conceptual and methodological framework was developed to evaluate the potential of a greenway, which articulate existing approaches and proposes a new one that is comprehensive and innovative. This approach corresponds to a model of progressive integration of information into a base socio-ecological analysis, a suitability analysis and one of opportunities and challenges. This model also provides a conceptual framework for the integration of spatial-quantitative and qualitative-institutional information, to evaluate the potential of a riparian zone as a multifunctional greenway.

The model also highlights the concept of multifunctionality in the context of a linear green infrastructure, contributing to recognise ecosystem services more related to greenways, their trade-offs and possible spatial configurations. Stressing the complexity of doing this in linear spaces, which are in essence spatially restrained.

The suitability analysis applied is consistent with the proposed conceptual framework and uses different analysis models that depend on the type of ecosystem services (primary or others). It also improves, expands and integrates the two main existing methods for this: multi-criteria and least cost path.

The approach proposed in this study permits a more complex and comprehensive vision of the real potential of a riparian zone to develop a multifunctional greenway than the approaches existing thus far. However, additional research is necessary to test the scope and transferability of the proposed framework on other cities and other scales. In these subsequent implementations, the necessary adjustments and improvements should emerge for the development and evolution of the proposed framework.

With regard to the second (2), for the first time in Chile, a socio-ecological analysis of an urban riparian zone is conducted, giving recognition to the most relevant features and patterns that define the current state of the riparian zone and the possibilities of developing a greenway. Likewise, the suitability of the riparian zone is explicitly spatially modelled based on its physical conditions and identifies the opportunities-challenges that actors visualize in the institutional context and local regulations.

The socio-ecological status of the riparian zones is characterised by being highly altered in ecological terms, diverse in social terms, highly marked by metropolitan transport infrastructure and a concentration of green areas in a few municipalities.

This means that the riparian zones provide limited physical support for important social and ecological functions characteristic of these zones in urban environments: habitat, aesthetic, cooling, transport route and flood mitigation.

In some sectors, the riparian zone has been preferred as the location of the high-income population within a municipality, while in other municipalities these zones represent the poorest sectors at communal level. The same occurs with respect to the green areas, since the riparian zones generally concentrate green areas above municipal average.

The analyses revealed significant east-west gradient in the socio-ecological status of riparian zone of the Mapocho River, which gradually decrease from east to west.

Despite the differences in the state of the riparian zone between eastern, central and western sectors, there are interventions that have enormously affected the entire urban sector of the riparian zone of the Mapocho, affecting its socio-ecological state and the possibilities of developing a greenway.

One of the most important of these interventions is the almost complete channeling of the urban course of the River, which has meant the loss of its natural characteristics and dynamics and a major impact on its banks. However, there are two exceptions to this, the first corresponds to the existence of banks within the riverbed in various sectors, which have permitted the spontaneous development of plants and trees. The second corresponds to the western sectors (Pudahuel and Cerro Navia) where the river is channeled by gabions, allowing certain hydrological and biological connections of the main course with the surrounding land and thus sustaining plant communities with less need for irrigation and maintenance.

The other major intervention that almost equally affects the state and functioning of the entire riparian zone of the Mapocho corresponds to the construction of urban highways. The Costanera Norte and Sur have been planned and constructed along the entire urban section of the Mapocho River, greatly compromising the possibilities of developing riparian parks and at the same time isolating the River from the city. The latter is exacerbated given that the highways have been built in long sections immediately adjacent to the river, making it impossible for people and wildlife species to reach the riverbed.

The preferred ecosystem services by local actors are diverse and do not only refer to cultural ecosystem services. In addition to the classic recreation and transport, the wind corridor and cooling effect appear. Species habitat is the least important ecosystem service for actors. It is possible to identify a certain sectoral vision that affects the perception of the importance of the different ecosystem services.

The riparian zone of the Mapocho River in Santiago has good suitability as a wind corridor, cooling effect and to mitigate flood threats.

The multifunctional suitability depends on the shape it is modelled, if exchange is allowed between ecosystem services and therefore, is prepared to accept higher levels of risk in decisions, the multifunctional suitability (OR), is relatively high.

The main challenges for the development of a multifunctional urban greenway in the Mapocho River corresponds to low levels of inter-jurisdictional and inter-sectoral coordination and cooperation, maintenance costs and the existence of urban highways in the zone.

On the contrary, the main opportunities are the existence of important sectors of vacant land, increased political and social importance of urban green areas and the existence of a set of consolidated riparian parks.

In synthesis, the assessment developed in the Mapocho River identifies the most important aspects to be considered and the greatest potentialities to capitalize in planning a multifunctional greenway along the Mapocho River. This is key when thinking about a possible master plan for the Mapocho River that returns the river to the city and values it as an axis or pole for inclusion and integration.

The results of this evaluation can provide a basis for developing a structural intervention plan at a city level as was described above. Such a plan must be a concrete alternative to the sectorial interventions of minor magnitude that are currently considered, which essentially aimed at the creation of bikeways along the Mapocho River.

This is a major challenge in the case of Santiago, due to the characteristics and complexities of a megacity in Latin-American. In this sense, the assessment presented in this study regarding a riparian greenway in Santiago can give light on how to plan and implement riparian greenways in other major cities in the region.

Finally, the development of a multifunctional greenway in Santiago can considerably contribute to the social and ecological connectivity and thereby mitigate the socio-ecological segregation and disconnection characteristic of cities in the region. It may also contribute significantly to reconcile urban growth with ecological health and people′s quality of life, maintaining functions and key ecosystem services and mitigating the negative effects of urbanization.

The development of a greenway in the Mapocho River could be seen as a major step in the consolidation of a green infrastructure system at a city level, integrating other types of green infrastructure like metropolitan and municipal parks, plazas and other greenways. The establishment of a green infrastructure system can be converted into a key aspect to ensure long-term environmental sustainability of the city of Santiago.

Chapter 11

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Appendix A

Consultation with stakeholders and experts

Table A.1: Focus group participants.

	Name	Institución
1	Francisco Ferrando	Universidad de Chile Departamento de Geografía
2	María Isabel Pavez	Universidad de Chile Depratamento de Urbanismo
3	E8 Ubilla	Gobierno Regional Diplade
4	Annie Luypaert	Red Defensa Pre-Cordillera (ONG)
5	E8 Rojas	Municipalidad de Vitacura Departamento de Medioambiente
6	Fabiola Zamora	Gobierno Regional Diplade
7	Robinson Sandoval	PROTEGE Gerente Área Técnica
8	Karen Sepúlveda	Dirección General de Aguas Departamento de Medio Ambiente y Territorio
9	Juana Zunino	Geopaisaje
10	Patricio Escobar	Municipalidad de Peñalolén SECPLAC
11	Ramón del Piano	Defendamos la Ciudad (ONG)
	Joel E7ez	La Bicicleta Verde
12	Paloma Valenzuela	Municipalidad de Providencia
13	Javier Inostroza	Municipalidad de Recoleta
14	Cristián Villalobos	Consultor
15	Amarilis Horta	Centro de Bicicultura (ONG)
16	Hernán Larraín	Defendamos la Ciudad (ONG)
17	Claudio Aldunate	Municipalidad de Renca

Table A.2: Focus group structure and topics.

	Activity/Topic
1	Introduction of the facilitator (lead researcher)
2	Definition of length and objectives of the focus group
3	Introduction of participants
4	Presentation of doctoral research (context)
5	Discussion of Topic 1: Important ecosystem services in Santiago related to riparian areas
6	Break
7	Discussion of Topic 2: Valuable zones in ecological and social terms located in the urban riparian areas of Santiago
8	Final thoughts of participants
9	Close remarks and handing out of gifts

Table A.3: Stakeholders for questionnaires on ESs.

	Name	Institution
1	Alberto Carvacho	MINVU
2	Andrea Rojas Castro	MINVU
3	Augusto Gonzalez	MOP
4	Barbara Rodriguez	IDIEM
5	Carlos kossack	Municipalidad
6	Carolina Infante	GORE
7	Cristian Henriquez	PUC
8	Francisco de la Barrera	PUC
9	Francisco Ferrando	UCH
10	Gerardo Rojas	Municipalidad
11	Gerardo Ubilla	GORE
12	Gino Sandoval	UCH
13	Jaime Rovira	MMA
14	Jorge Inzulza	UCH
15	Luigi Brignardello	Municipalidad
16	Manuel Jose Diaz	Municipalidad
17	Marcela Salgado	UCH
18	Marianne Katunaric	MMA
19	Matín Moraga	Municipalidad
20	Mathias Koch	MINVU
21	Miguel E7ez	Municipalidad
22	Miguel Nanjari	Municipalidad
23	Natalia Garay	GORE
24	Pablo Fuentes	GORE
25	Pamela Smith	UCH
26	Paulina Ahumada	Municipalidad
27	Rodrigo Robles Vargas	GORE
28	Romina Aranda	MOP
29	Sonia Reyes	PUC
30	Tatiana Acuña	MINVU
31	Vivian Cena	Municipalidad

Figure A.1: Screen capture of the online questionnaire on ESs for stakeholders.

Evaluación ambiental de zonas ribereñas urbanas en Santiago de Chile: Oportunidades para el desarrollo de corredores verdes multi-funcionales?

PROYECTO DE INVESTIGACIÓN DOCTORAL / PROYECTO DE INVESTIGACIÓN FAU

DEPARTAMENTO DE GEOGRAFÍA
UNIVERSIDAD DE CHILE

CUESTIONARIO SERVICIOS AMBIENTALES

Este cuestionario pretende evaluar los diferentes intereses, prioridades y pertinencias de expertos y tomadores de decisiones respecto al problema de investigación.

Entre otras cosas, esta información permitirá el desarrollo de evaluaciones multicriterio para estimar la aptitud de las zonas en estudio para proveer múltiples funciones ecológicas y sociales. Además del uso de escenarios para evaluar el potencial como corredor verde multi-funcional bajo diferentes alternativas de gestión.

*Obligatorio

1. Identificación del experto

1.1 Nombre y apellido

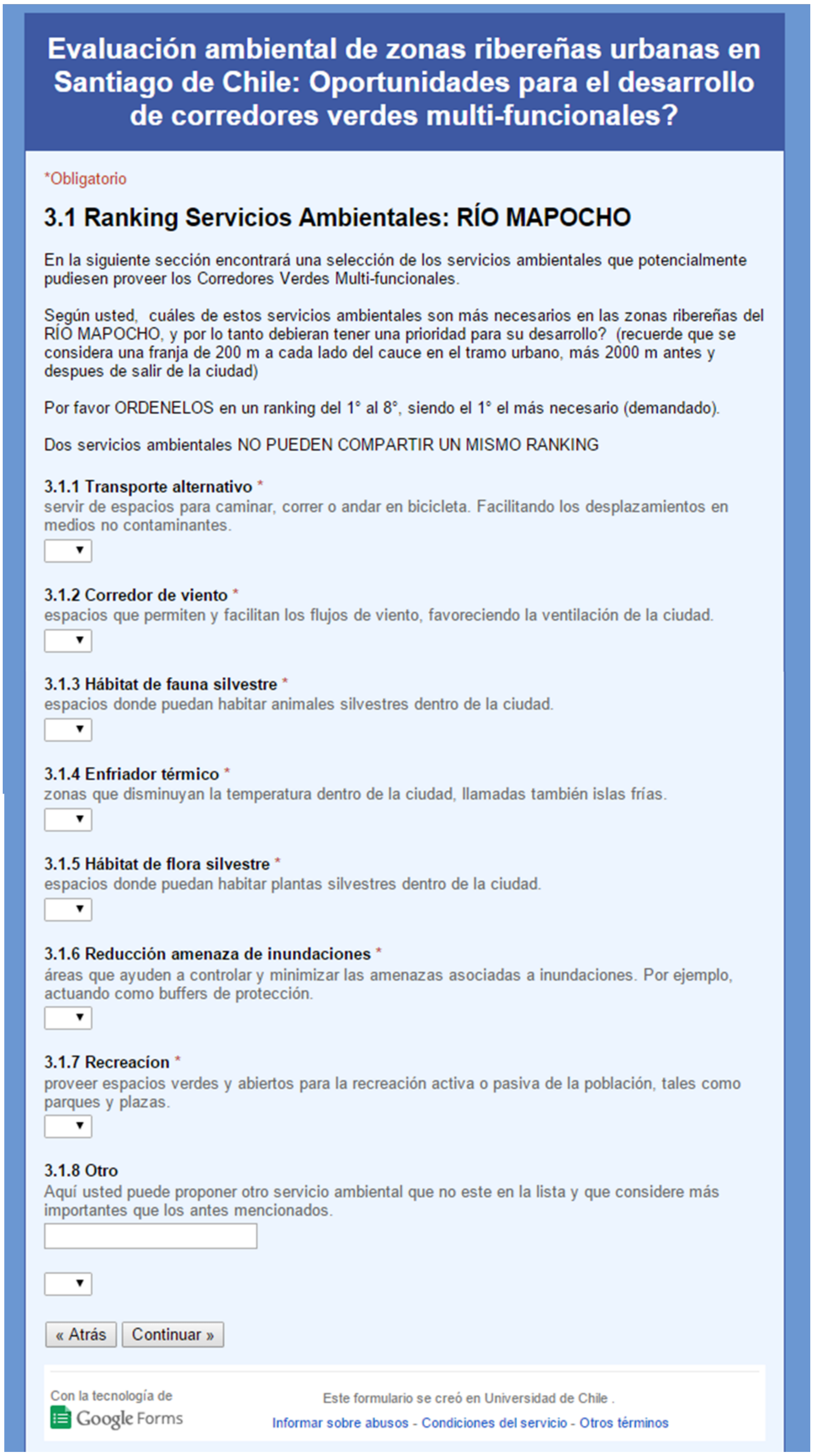
1.2 Área de especilidad *
área de expertis o desempeño

1.3 Institución *
lugar(es) donde trabaja

Continuar »

Con la tecnología de   Este formulario se creó en Universidad de Chile

Figure A.2: Screen capture of the online questionnarie on ESs for stakeholders.



Evaluación ambiental de zonas ribereñas urbanas en Santiago de Chile: Oportunidades para el desarrollo de corredores verdes multi-funcionales?

*Obligatorio

3.1 Ranking Servicios Ambientales: RÍO MAPOCHO

En la siguiente sección encontrará una selección de los servicios ambientales que potencialmente pudiesen proveer los Corredores Verdes Multi-funcionales.

Según usted, cuáles de estos servicios ambientales son más necesarios en las zonas ribereñas del RÍO MAPOCHO, y por lo tanto debieran tener una prioridad para su desarrollo? (recuerde que se considera una franja de 200 m a cada lado del cauce en el tramo urbano, más 2000 m antes y despues de salir de la ciudad)

Por favor ORDENELOS en un ranking del 1° al 8°, siendo el 1° el más necesario (demandado).

Dos servicios ambientales NO PUEDEN COMPARTIR UN MISMO RANKING

3.1.1 Transporte alternativo *
servir de espacios para caminar, correr o andar en bicicleta. Facilitando los desplazamientos en medios no contaminantes.

3.1.2 Corredor de viento *
espacios que permiten y facilitan los flujos de viento, favoreciendo la ventilación de la ciudad.

3.1.3 Hábitat de fauna silvestre *
espacios donde puedan habitar animales silvestres dentro de la ciudad.

3.1.4 Enfriador térmico *
zonas que disminuyan la temperatura dentro de la ciudad, llamadas también islas frías.

3.1.5 Hábitat de flora silvestre *
espacios donde puedan habitar plantas silvestres dentro de la ciudad.

3.1.6 Reducción amenaza de inundaciones *
áreas que ayuden a controlar y minimizar las amenazas asociadas a inundaciones. Por ejemplo, actuando como buffers de protección.

3.1.7 Recreacion *
proveer espacios verdes y abiertos para la recreación activa o pasiva de la población, tales como parques y plazas.

3.1.8 Otro
Aquí usted puede proponer otro servicio ambiental que no este en la lista y que considere más importantes que los antes mencionados.

« Atrás | Continuar »

Con la tecnología de Google Forms

Este formulario se creó en Universidad de Chile.

Informar sobre abusos - Condiciones del servicio - Otros términos

Table A.4: Stakeholders for questionnaires on suitability factors.

Priority ecosystem services	Expert
Recreation	Dr. Sonia Reyes. Pontificia Universidad Católica de Chile, Instituto de Estudios Urbanos.
	MSc. Isabel Figueroa. Ministerio de Obras Públicas.
Non-motorized transport	MSc. Tomás Echiburú. MapochoPedaleable – pedaleable.org
	MSc. Osvaldo Larraín. MapochoPedaleable.
Wind corridor	Dr. Cristian Henriquez. Pontificia Universidad Católica de Chile, Deparatamento de Geografía.
	Dr(c) Pamela Smith. Universidad de Chile, Departamento de Geografía.
Flood hazard mitigation	Dr. Francisco Ferrando. Universidad de Chile, Departamento de Geografía.
	Dr. Annemarie Müller. Helmholtz Centre for Environmental Research (UFZ).
Cooling effect	Dr. Cristian Henriquez. Pontificia Universidad Católica de Chile, Deparatamento de Geografía
	Dr(c) Pamela Smith. Universidad de Chile, Departamento de Geografía.
Habitat for native flora	Dr. Francisco de la Barrera. Pontificia Universidad Católica de Chile, Deparatamento de Geografía
	Dr(c) Carlos Garín. Pontificia Universidad Católica de Chile, Departamento de Ecología.
Habitat for native fauna	Dr. Hernán Cofré. Pontificia Universidad Católica de Valparaíso, Instituto de Biología.

Table A.5: Partners for the stakeholders interviews regarding the opportunities and challenges.

Interview number	Profesion/position	Institución
E1	Architect Head of Planning Unit	MINVU/SEREMI Departamento de Desarrollo Urbano
E2	Agricultural Engineer Head of Biodiversity and Natural Resources Unit	MMA/SEREMI Departamento de Biodiversidad y Recursos Naturales
E3	Architect Head of Regional Planning Department	GORE-DIPLADE División Planificación y Desarrollo Regional
E4	Civil Engineer	MOP-DOH Deparatamento de Obras Fluviales
E5	Architect	GORE-DIPLADE División Planificación y Desarrollo Regional
E6	Natural resources engineer	GORE-DIPLADE División Planificación y Desarrollo Regional
E7	Architect Head of Urban Parks Department	MINVU Parque Metropolitano
E8	Head of Urban Parks Department	Municipalidad de Providencia
E9	Architect	Universidad de Santiago de Chile Departamento de Arquitectura.

Figure A.3: Semi-structured interview conducted in order to obtain information regarding the opportunities and challenges.

Alexis Vásquez / Depto. de Geografía / U. de Chile / alexvasq@u.uchile.cl

Investigador responsable: Alexis Vásquez
Institución: Departamento de Geografía, Universidad de Chile
Instituto de Geografía, Universidad de Leipzig

Tópico: Desarrollo de corredores verdes ribereños multifuncionales en Santiago
Fecha:
Entrevistado:

Entrevista

¿Quién(es) tiene competencia sobre este tema y/o área?
¿Cuáles son los más importantes?

¿Quién(es) tiene interés en este tema y/o área?
¿Cuáles son los más importantes?

¿A su juicio cuáles son los mayores desafíos para el desarrollo de CVRM en Santiago y el Mapocho?

¿A su juicio cuáles son las mayores oportunidades para el desarrollo de CVRM en Santiago y el Mapocho?

¿Conoce planes o programas relacionados con esta idea en Santiago?

Appendix B

Maps of the most suitable areas for the provision of ESs

Figure B.1: Most suitable areas for recreation and flood mitigation.

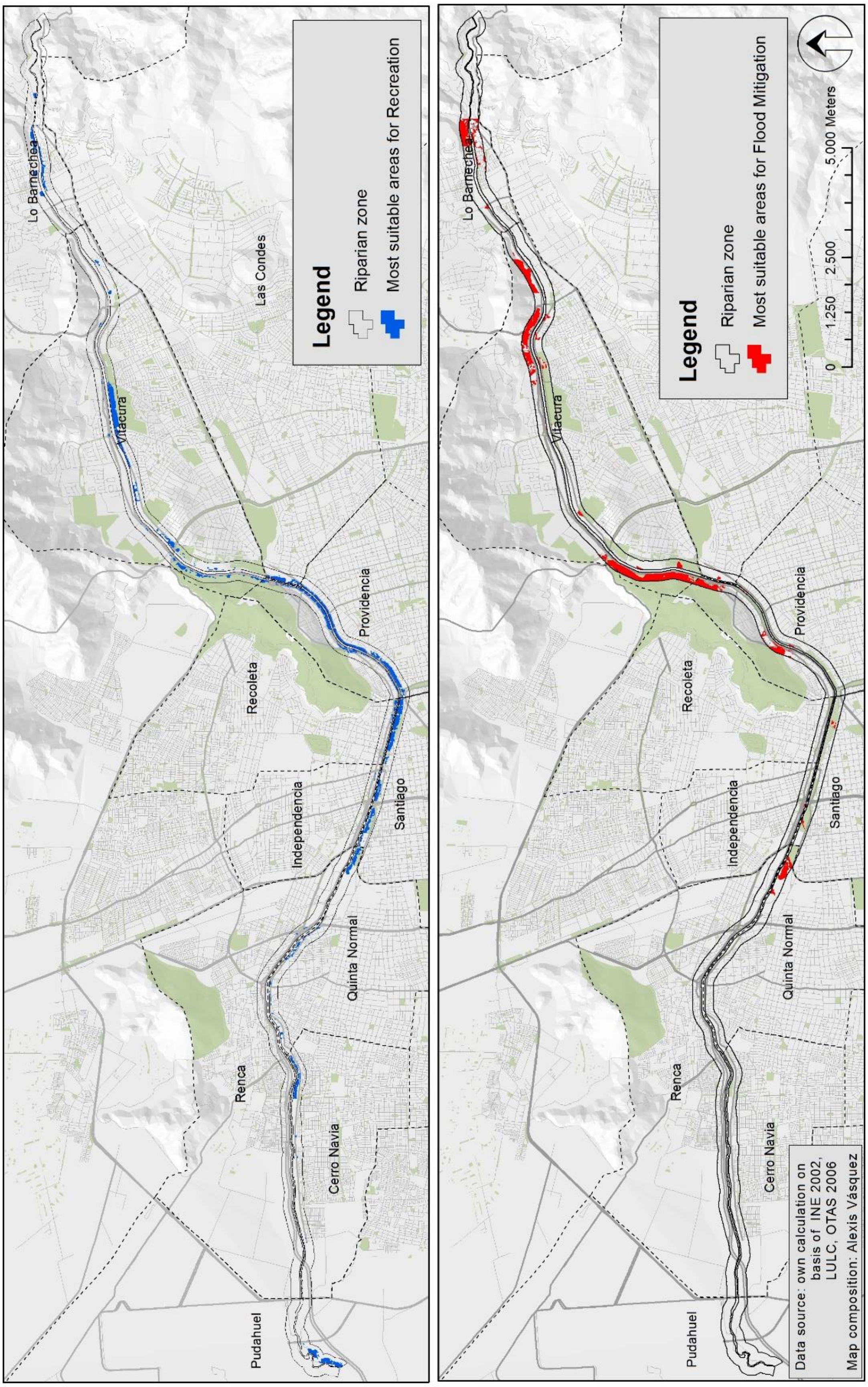
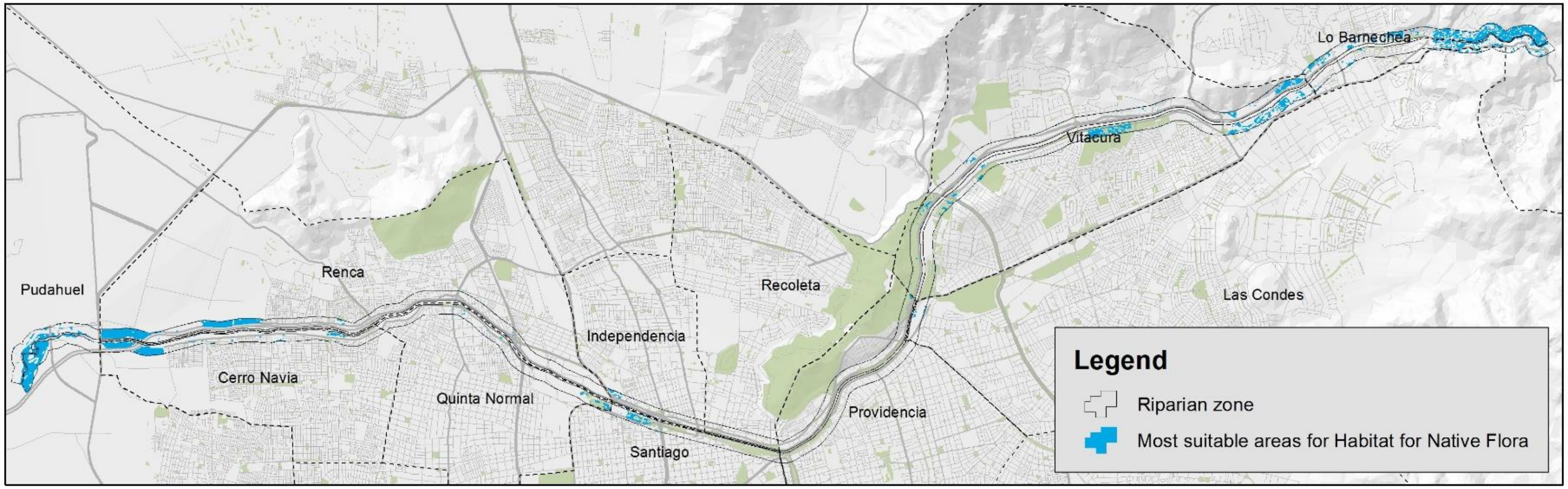
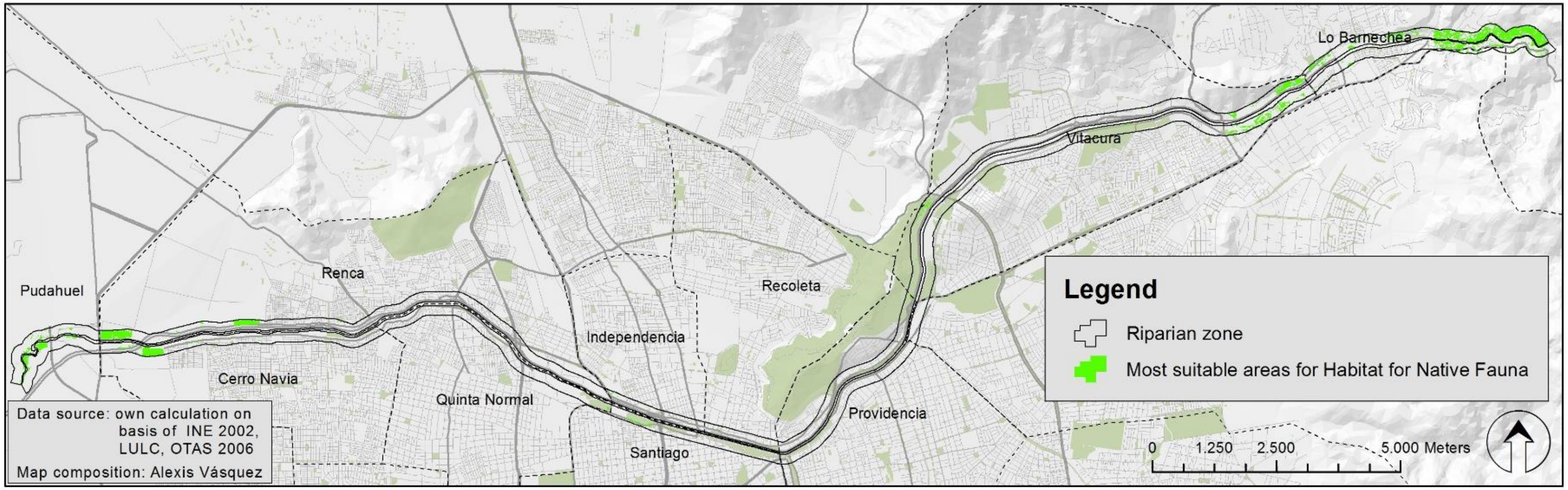


Figure B.2: Most suitable areas for habitat for native flora and fauna.





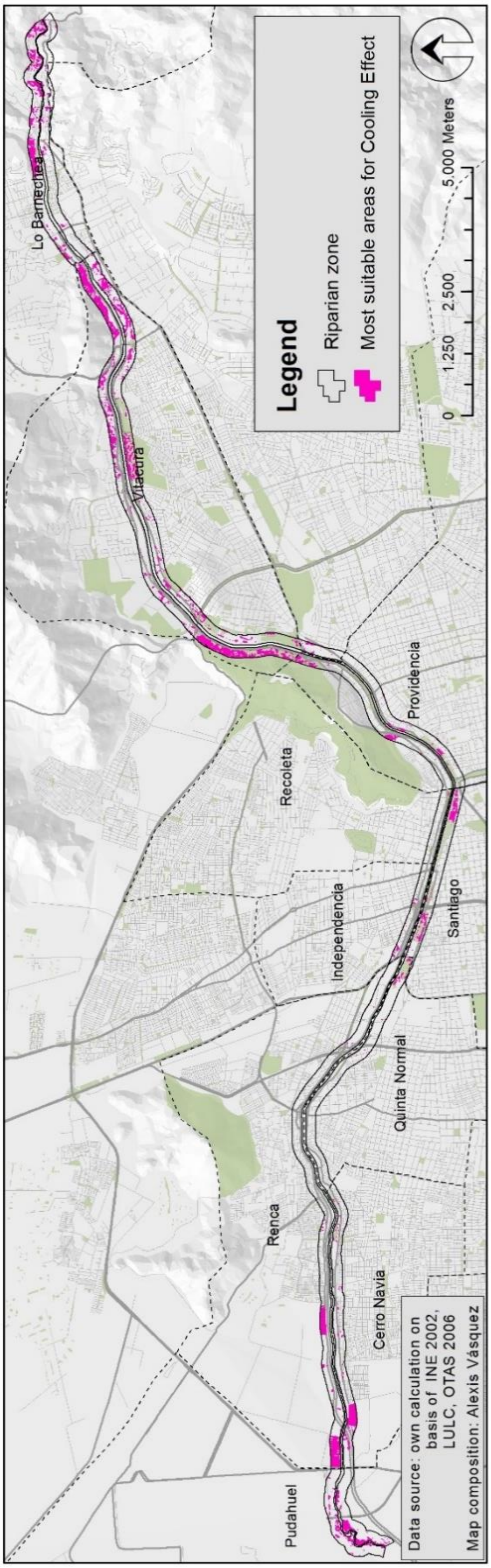


Figure B.3: Most suitable areas for cooling effect.

Bibliographische Beschreibung

Vásquez, Alexis

An integrative approach to assess urban riparian greenways potential: The case of Mapocho River in Santiago de Chile

Universität Leipzig, Dissertation

225 S.*, 214 Lit.*, 66 Abbildungen, 37 Tabellen, 11 Anlagen

Referat:

The research dedicates to develop a transferable conceptual and methodological framework for assessing the potential for multifunctional riparian greenway development in cities. This addresses the lack of application-oriented frameworks in the field of urban green infrastructure planning, articulating and integrating ecosystem service concepts and methodological approaches. This is specially true for linear open spaces such as greenways.

Later, the elaborated conceptual-methodological framework is applied to the Mapocho River in Santiago de Chile as a study case in order to explore its scope and applicability in a city representative of the structure and processes of megacities in Latin America.

In this research, a combination of quantitative, qualitative and geospatial analyses is used, including focus groups, questionnaires, interviews, multicriteria analysis and least cost path modelling.

The socio-ecological status of the riparian zone of the Mapocho River has an important east-west gradient, which gradually decreases from east to west. The riparian zone has good suitability as a wind corridor, cooling effect and to mitigate flood threats.

Low levels of inter-jurisdictional and inter-sectoral coordination and cooperation, maintenance costs and the existence of urban highways in the zone are the most important challenges for the development of a multifunctional urban greenway in the Mapocho River. On the contrary, the main opportunities are the existence of important sectors of vacant land, increased political and social importance of urban green areas and the existence of a set of consolidated riparian parks.

The research identifies the most important potentialities to capitalize in planning a multifunctional greenway along the Mapocho River. The development of a multifunctional greenway in Santiago can considerably contribute to the social and ecological connectivity and thereby mitigate the socio-ecological segregation and disconnection characteristic of cities in the region. It may also contribute significantly to reconcile urban growth with ecological health and people's quality of life, maintaining functions and key ecosystem services and mitigating the negative effects of urbanization.

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*S. (Seitenzahl insgesamt)
*Lit. (Anzahl der im Literaturverzeichnis ausgewiesenen Literaturangaben)