Urban Parks, Environmental Sustainability and Design Strategies: A Comparative Study of Fuenlabrada (Spain) and Porto Alegre (Brazil)

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3. ABSTRACT

Urban parks provide many benefits that improve the quality of life of the citizens. This capstone research project focuses on the contribution of parks to environmental sustainability. The condition of the three biggest urban parks was analyzed and compared in two cities: Fuenlabrada (Spain) and Porto Alegre (Brazil).

Contribution to sustainability was studied in terms biodiversity, accessibility, connectivity, and water and soil resources protection, using sustainability indicators from Agenda 21 and the Montreal Process. Green structure vitality, carbon storage and air quality improvement were also addressed by applying the UFORE Model from the USDA Forest Service. The design qualities of the parks and their functions were evaluated as well. Primary data was collected in 15 random plots in each park, and later translated into a rating scale for comparison purposes.

As a result of the study, accessibility to parks was found to be superior in the city of Porto Alegre, while universal access within parks was greater in Fuenlabrada. Biodiversity rated higher in parks containing remnant or protected ecosystems. Regarding vitality, parks with a larger percentage of native species were in better condition. Green structure connectivity and carbon storage were superior for the oldest parks. While in Porto Alegre urban parks protect water bodies, in Fuenlabrada soil protection from erosion and compaction was greater. On air quality improvement, urban parks' removal rates were higher for ozone and nitrogen dioxide in Fuenlabrada, while in Porto Alegre rates were higher for removal of carbon monoxide and sulfur dioxide. Design qualities were comparable. Brazilian parks had greater ratings regarding identity and relation to context, while the Spanish had better ratings on variety of forms, textures and colors. In relation to functions: aesthetics, passive recreation and protection were predominant in both cities. Active recreation was essential in Porto Alegre, while preservation was more important in Fuenlabrada.

Sustainable management practices were identified for every park and design strategies were suggested. Specific recommendations were made to influence city planners and decision-makers to support actions that maximize the environmental benefits of urban parks.

4. INTRODUCTION

4.1. PROBLEM STATEMENT

Urban parks provide environmental and social benefits that contribute to the quality of life of the citizens. While there is a considerable interest in researching the psychological and social improvements of natural areas for citizens′ well being, less attention has been paid to the environmental benefits of urban parks. Fewer research studies have investigated the design and planning implications those benefits may have.

Since the United Nations Conference on Sustainable Development in Rio de Janeiro in 1992, many countries have adopted sustainability as a framework to guide land planning and policy making. Park design is already being influenced by these tendencies and some authors have began to talk about the "ecological park" as the new park type for the beginning of the 21st century (Cranz et al., 2003). Given that urban areas are continuously increasing in size and population, so does the need for urban parks. These green areas are already a scarce resource for an increasing number of users. In this context, it seems necessary to employ a sustainable development approach when designing, planning and managing urban parks for present and future generations. That approach requires understanding and measuring, how urban parks contribute to urban sustainability, that is, what benefits the environment and citizens gain from parks and how they can be maximized.

Urban parks contribute to urban sustainability in several ways. Well-managed urban forests can reduce the demand for natural resources by producing food and conserving energy, water and carbon monoxide. Also, they can mitigate the impact of urban development by moderating urban climate, improving air quality, controlling rainfall runoff and flooding, lowering noise levels, harboring wildlife, reducing human stress levels and enhancing the attractiveness of cities (McPherson, 1992).

Analyzing the condition of urban parks and presenting their benefits in a simple and understandable way will influence city planners and decision-makers to include them in the community development process.

The research question for this capstone project can be then summarized as follows:

How can urban parks management, planning and design be improved to maximize their contribution to environmental sustainability?

4.2. SCOPE OF THE PROJECT

Some context clarifications and term definitions will be needed to understand the concepts implicit in this capstone project. For definitions of terms such as environmental sustainability or sustainability indicators and criteria refer to the literature review section.

Sustainability can be addressed at global, regional, rural, urban, and neighborhood levels. This project takes place in two cities so the scale can be defined as urban.

Although there are many disciplines and perspectives that examine sustainability, the emphasis of this project is on the environmental sustainability aspects of the urban forest from both forestry and landscape architecture perspectives. A forestry perspective is needed to understand and analyze how the urban forest structure functions and how its environmental benefits contribute to urban sustainability. A landscape architecture perspective will facilitate finding design solutions and planning strategies to use urban vegetation for increasing urban sustainability in terms of ecology, aesthetics, economics and social functions.

4.3. ORIENTATION TO THE REPORT

This report is a research study on the contribution to environmental sustainability in six urban parks: La Solidaridad, El Olivar and La Paz Park in Fuenlabrada (Spain) and Farroupilha, Harmonia and Marinha Park in Porto Alegre (Brazil). By extrapolating the study results of the three parks in each city, a comparative study was also made between Fuenlabrada and Porto Alegre.

The environmental sustainability themes covered in the research were:

- Species diversity (number, native and protected)
- Ecosystem diversity (ecosystem types, native and protected)
- Accessibility (access to parks from the city and universal access within parks)
- Connectivity (of the green structure)
- Vitality (condition of the trees)
- Water and soil resources (protection of water, soil compaction and erosion)
- Air quality (tree pollution removal for O_3, SO_2, NO_2, PM10 and CO)
- C storage (tree carbon storage, gross sequestration and net sequestration)

The results, discussion and conclusions are explained individually for each theme. They are first presented for the two cities in chapter 8, and later explained in detailed for every park in chapter 9. Air quality improvement is discussed at city scale, as pollution data is representative the city level. For each city and park the results are shown first, followed by a discussion using the best and worst examples found, and finally, conclusions are drawn and design strategies are made for every case.

The results presentation is the summary of the data collected during 9 months in the parks. Most of the data was collected to be used with indicators, a tool that measures how sustainability is being achieved and presents it in a simple way. Indicators are explained in the methods chapter.

The discussion is the interpretation of the indicators results. As every park was analyzed through 15 plots, the discussion uses the plots with best results to illustrate good examples of contribution to sustainability, and plots with worst results to show examples of what should not be done.

The conclusions are a collection of strategies for designing and planning urban parks that should be followed if the sustainability themes are to be achieved. Some of them are general and some are specific recommendations for each park and city.

A reader with little time can learn about the cities' overall results in chapter 9 to understand the research and the findings. Those with more interest in every park's characteristics and contribution can read chapter 8 as well.

Finally, in chapter 10, general conclusions are summarized from the research experience.

4.4. OBJECTIVES

This capstone research project compared the conditions of urban parks and their contribution to sustainability in two cities: Fuenlabrada (Spain) and Porto Alegre (Brazil). The project main goal was to find planning strategies and design implications that will help city decision-makers manage urban parks in such a way as to contribute to environmental sustainability.

The goals and objectives for this capstone research project were:

- **Goal 1: To determine the current condition of the three biggest urban parks in the cities of Fuenlabrada (Spain) and Porto Alegre (Brazil)**
  Objectives
  - To analyze the structure of the urban parks' vegetation
  - To study their accessibility to and within parks
  - To estimate their vitality
  - To analyze their connectivity

- **Goal 2: To estimate to what degree urban parks contribute to the city's environmental sustainability**
  Objectives
  - To measure to what degree they preserve biodiversity
  - To calculate how they improve air quality
  - To estimate how they contribute to carbon storage
  - To evaluate how they protect soil and water resources

- **Goal 3: To find planning, management and design strategies that maximize the contribution of urban parks to environmental sustainability**
  Objectives
  - To evaluate urban parks management practices
  - To find most and least sustainable urban parks spaces

- To find best and worst designed urban parks spaces
- To find best and worst sustainability strategies
- To develop management, planning and design recommendations and strategies for each park
- To develop management, planning and design recommendations and strategies for each park both cities

5. LITERATURE REVIEW

Papers and books on sustainability, urban forest and green space analysis were examined for this literature review. Due to the empirical character of this capstone project, more importance was given to scientific papers addressing similar studies. Definitions of key terms are included in this section.

5.1. **SUSTAINABILITY**

There have been many definitions, theories and classifications of sustainability since the term become popular during the 80's. The term "sustainable development" appeared originally as a microeconomic concept in forestry, meaning a strategy aimed at providing wood without wiping the forest. During the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro (the "Earth Summit") the concept played a central role and more than 300 pages of recommendations for sustainable development were collected and published as Agenda 21. (Renn et al., 1998)

As the term gained recognition different disciplines began to apply the sustainability concept to their fields. Nowadays sustainability is not simply an economic or ecological concept, but it is considered a theory or a framework of ideas that can be applied to different scenarios. "Sustainability has broadened its scope, but the core concept is constant: a system must be able to remain essentially intact while enduring the stresses of extraction, disease, destruction and metamorphosis". (Carter, 2003)

The following definitions will hopefully help to understand some of the complexities of sustainability.

5.1.1. SUSTAINABILITY DEFINITIONS

One of the most accepted definitions of sustainability, probably because of its simplicity, is the one presented in the "Bruntland Report" in 1987. This document, also known as *Our Common Future*, was prepared by the World Commission on Environment and Development and first defined the concept of sustainable development as:

> "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland Report, 1987)

This expression of caring for the welfare of the future generations is considered a valid definition by most of the authors reviewed for this capstone project. Almost every paper on sustainability contains the "Bruntland Report" definition. Authors like Ortwin

Renn, however, find it broad and problematic, as it promotes agreement but provide little practical guidance. Nevertheless, his considerations of what ingredients a sustainable development definition must have in the recipe show some concordance with the former:

> "The fundamental concerns that must be on the table in any discussion of sustainable development are human welfare, the environment and the future. The ultimate goal must be to maintain both the productivity of nature and the environment, as well as immaterial gains in their utility". (Renn et al., 1998, p.65)

Another keystone in sustainability definitions is the concept of carrying capacity. This concept comes from Malthu's population theory and it is defined as the maximum number of individuals of a defined species that a given environment can support over the long term. During the 70's the term came back when discussions about the population growth initiated an environmental awareness. The concept is used in sustainability to explain that the world resources are limited and they must be used within their capacity to be renewed. P. Upham (2000) highlighted this fact in the paper "Scientific consensus on sustainability". When comparing six sets of different sustainability principles he found some common organizing rationales among them. They were basically:

> "(i) That waste emissions be within the absorptive capacity of the receiving environment and
> (ii) That the use of renewable resources be within their renewal capacity" (Upham, 2000, p.181)

More recent authors and organizations include the carrying capacity concept in their definitions of sustainability. An example of the later was found in the paper "Evaluation of urban sustainability in specific sectors in Latvia" (2002), where Kristine Abolina and Andis Zilans used the World Conservation Union definition, giving consideration to the environmental, economic and social context.

> "The new paradigm of sustainable development has been formulated in an attempt to reorient and focus thinking towards a style of individual and community living, resource consumption and economic development that allows for a balanced co-evolution of the economic, physical and social environments while living within the carrying limits of the supporting ecosystems (World Conservation Union/UNEP/WWF, 1991)"(Abolina and Zilans, 2002, p.299)

The authors affirm that one of the difficulties defining sustainability is that there is not as a model for it. They used that fact to argue for flexibility in any policy related to sustainable development:

> -"Sustainability is a general idea that must be interpreted in specific contexts;
> - Sustainability cannot be achieved by a command or a control approach since there are no adequate causal models;
> - Sustainability can only be approached through a practical management process that includes permanent learning' (Schleider-Tappeser and Strati, 1999: 49)" (Abolina and Zilans, 2002, p.300)

For the purpose of this project we relied rely on the definition of environmental sustainability included by J.H. Spangenberg (2002) in his review paper of sustainability indicators:

> "Sustainability is understood to comprise four dimensions: the social, economic, environmental and institutional ones. Whereas the environmental dimension can be defined to be the sum of all bio-

geological processes and the elements involved in them (referred to as 'environmental capital' by economists), the social dimension ('human capital') consists in the intra-personal qualities of human beings: their skills, dedication and experiences. Institutions (confusingly called 'social capital') are the result of interpersonal processes...The economic dimension ('man-made capital') includes not only the formal economy, but as well all kinds of informal activity that provide services to individuals and groups and thus increase the standard of living beyond the monetary income (Spangenberg and Lorek, 2002)" (Spangenber, 2002, p.104)

This definition should not be understood as separating societies into four discrete subsystems. There is a permanent interaction of the economic, social, institutional and environmental subsystems. These interactions constitute the linkages of the four dimensions. (Spangenberg, 2002, p.105). The *prism of sustainability* illustrates this idea **(Fig.5.a)**.

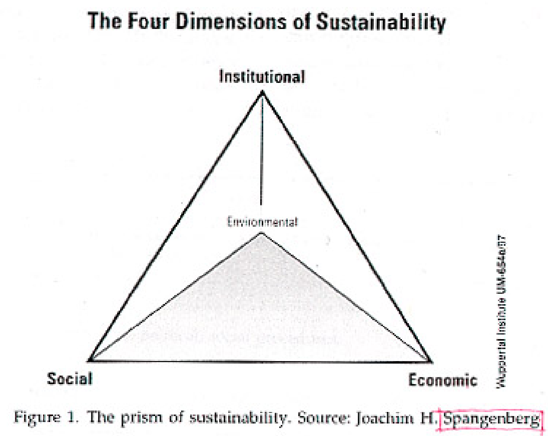


Fig.5.a. The prism of sustainability. Source: Spangenberg, 2002.

5.1.2. URBAN SUSTAINABILITY

There is a consensus on the central role cities play on the global agenda of sustainability. Among the reasons are that cities have sizeable ecological footprints, meaning that they use in resources and emit wastes. As Timothy Beatley explains in *Green Urbanism* (2002) "Any effective agenda for confronting global climate change, biodiversity loss, and a host of other challenges must necessarily include cities as a key, indeed, *the* key, element" (page. 4).

In a broad sense, urban sustainability refers to the sustainable development that takes place in an urban context, in a city. While revising networks and theories on urban sustainability a great discrepancy appeared between how different countries address it. For instance, the United States does not have an official document on sustainability strategies. North American cities and local governments work more or less on an independent basis. That is the case of organizations such as "Sustainable Seattle" or the "Sustainable Communities Network". In the case of Europe, "the European Union has been working since they agreed on the Agenda 21 document to prepare national, regional and local sustainability strategies and seriously incorporate them into the planning processes". (Beatley, 2000)

An example of the latter would be the report *European Sustainable Communities* prepared by the Expert Group in Urban Environment in 1996. The report includes four Principles of Urban Sustainability that will help to better understand the concept. The definition is included here, as the capstone project takes place, in part, within the European Union context and sustainability strategies. The European Union approach to urban sustainability is to understand the city as an ecosystem.

“Principles of Urban Sustainability

1. The principle of urban management.

Management for sustainability is a political process that requires planning and has an impact on urban governance…The management requires a range of tools to address environment, social and economic concerns…

2. The principle of policy integration

Integration should be achieved both horizontally, to stimulate synergetic effects of social, environmental and economic dimensions of sustainability, and vertically, between all levels of the European Union (state, regional and local levels)

3. The principle of ecosystem thinking

Ecosystem thinking emphasizes the city as a complex system that is characterized by flows as continuous processes of change and development... Energy, natural resources and waste production require maintenance, restoration, stimulation and closure in order to contribute to sustainable development…

4. The principle of cooperation and partnership

…Sustainability is a shared responsibility between different levels, organizations and interests…” (EC, European Sustainable Cities, 1996)

While there has been a great number of institutional work on urban sustainability, when revising different empirical studies, it is becomes clear that all the researches narrow the spectrum of the study to focus on one or two aspects of sustainability.

For instance Abolina and Zilans (2002), on their evaluation of on urban sustainability in five different cities of Latvia, focused mainly on the planning and decision-making processes. For their study methods they decided to analyze Development Plan implementation reports and indicators published by municipal departments to see how much of the proposed plans were really implemented. The sustainability issues they looked at where only transportation and green space. In transportation, they found contradictory policies in relation to urban sustainability; on green spaces, policy proposals were not anything more than general statements of intent.

For this capstone project the focus was on the environmental issues of urban sustainability.

5.1.3. ENVIRONMENTAL URBAN SUSTAINABILITY

Based on Spangenberg’s definition, the environmental dimension of urban sustainability would be defined as the sum of all bio-geological processes and the elements involved in them that take place in a city.

This capstone project studied how the green areas contribute to environmental urban sustainability and how those contributions can be maximized by urban design and planning strategies. As stated earlier, the dimensions of sustainability are linked one with each other. The recommendations expected from this capstone project would have an impact on social, economic and institutional urban sustainability as well.

Within the urban environment this capstone project focused on analyzing the urban forest and its effects. A main definition is necessary to provide a basis for the discussion throughout the study. John F. Dwyer, David J. Nowak and Mary Heather Noble used the following definition for their paper "Sustaining urban forests" (2003). This is also the main sustainability definition for the purposes of this capstone project.

"**Urban forest sustainability is defined in terms of maintaining healthy and functional vegetation and associated systems that provide long-term benefits desired by the community**"

Urban forest is defined later in this section.

5.2. SUSTAINABILITY CRITERIA AND INDICATORS

The international agreement Agenda 21 calls specifically for the preparation of sustainability action plans at different levels. To understand and assess the extent to which nations, regions or cities are sustainable a set of criteria and indicators should be implemented to measure and communicate sustainability achievements. As a consequence a number of efforts have been taken from global to local levels.

Among these efforts are European initiatives such as the Sustainability Index project, which included 12 European cities in developing a common set of indicators to measure and communicate how cities are leading towards sustainability. A most recent set of indicators was prepared by the Dobris Assesment in "Europe's Environment" (56 indicators) falling under three broad types: indicators of urban patterns, urban flows and urban environmental quality.

On the other side of the Atlantic, the United States with another 11 countries has developed a set of indicators to measure and communicate how forest management is sustainable or not. This set is known as the Montreal Process criteria and indicators. There is also urban sustainability initiatives developed independently by cities, but there is not such a thing as a national sustainability strategy.

In order to measure the sustainability of the green areas in the cities to be studied in this capstone project, European Union, Agenda 21 and Montreal Process indicators were revised to find and adapt a set of indicators for the purpose of this capstone.

5.2.1. AGENDA 21 CRITERIA AND INDICATORS

The international agreement of Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, governments, and other groups in every area in which human impact the environment. More than 178 governments at the "Earth Summit" in Rio de Janeiro on June of 1992 signed it.

A Commission on Sustainable Development (CSD) was created in December 1992 to monitor and report on implementation of the agreements at the local, national, regional and international levels. Since then Agenda 21 has been strongly reaffirmed in the following World Summits that take place every five years.

The CSD undertook in 1995 to develop a set of sustainability indicators as a tool for assessing the progress towards sustainability and to communicate achievements (UNDPCSD, 1995). A preliminary set of 134 indicators with their methodologies was selected but after a test phase of four years they were reduced to 58. This later selection was based on well-founded, consensus-based indicators for which data was available. (Spangenberg, 202, p.104)

The nations that signed Agenda 21 have been working since 1992 to implement national, regional and local strategies to meet the implicit obligations from the document. An important consequence is that Agenda 21 has a great influence on planning in those countries. David Jones, in his article "Sustainability and Agenda 21" mentioned for the case of Australia:

> "...the concept of Agenda 21 has become a central philosophical planning objective in the preparation of strategic and development plans...Several municipalities are starting to link Agenda 21 documents to development plans directly to make them formal parts of their development, planning or design process and evaluation mechanisms"

Although Agenda 21 concepts are applicable for planning and design process some authors criticize that local governments use them as way to camouflage and publicize their development plans as ecological without really understanding the term sustainability. For instance, Abolina and Zilans found in their study that many development plans supposed to promote integration of green space and to enhance biological diversity were in fact nothing more than general statements of intent with no real consequences.

In the same way, Jones found through different landscape sustainability projects with Landscape Architecture students in rural communities, that in many cases the concepts of Agenda 21 were not really understood by the town officials:

> "The project's findings are that both the community and the local government entities it has worked with, still do not understand Agenda 21 and mainly see it as a jargon phrase to appropriate for the purposes of grant applications or government hand-outs"

In my opinion, the same critique would be applicable to his article, that with the attractive title of "Sustainability and Agenda 21" does not address in detail those issues and simply covered the projects students did within that context.

An interesting fact is that Agenda 21 did provide a way to avoid this misunderstanding of sustainability. A set of criteria and indicators were explicitly chosen to measure, qualitatively and quantitatively, how nations, regions and cities were achieving sustainability. By using those as an analytical tool no confusion on what is sustainable and what is not should occur.

5.2.2. INDICATORS DEFINITIONS

As with sustainability, there is no unanimous consent on a definition of indicators. There are several discussions on what characteristics a good indicator should have. In most of them, these characteristics are the same under different names. Some differences appear when the definitions depend on the scale of sustainability they are assessing. Spangenberg provided probably one of the best discussions of the characteristics of a good indicator in "Institutional sustainability indicators" (2002, p.105).

> "The purpose of sustainability indicators in general is to serve as simplifying communication tools helping to guide political decision-making towards sustainable development. To serve for communication purposes, they should reduce complexity, be easily understandable and limited in number. To provide a sound basis for decision-making they have to be:
> (i) general, i.e. not dependent on a specific situation, culture or society;
> (ii) indicative, i.e. truly representative of the phenomenon they are intended to characterize;
> (iii) sensitive, i.e. they have to react early and sensible to changes in what they are monitoring, in order to permit monitoring of trends or the successes of policies, and
> (iv) robust, i.e. directionally safe with no significant changes in case of minor changes in the methodology or improvements in the data base."

Another definition of indicators, by Kristine Abolina and Andis Zilans, emphasizes their communication role and the horizontality of sustainability:

> "Indicators are pieces of information that highlight what is happening in a large system. They are small windows that provide a glimpse of the "big picture". Indicators should simplify complex phenomena into quantifiable measures that can be readily communicated (Delft van, 1998). Sustainability indicators combine environmental, economic and social indicators and their mutual relationships."(p.307)

For the use of indicators it is necessary to collect and have access to a great amount of information. Some critiques have been made in this sense of the difficulty of applying them in underdeveloped countries. Abolina and Zilans highlight in their paper this need of gathering data when using indicators to evaluate sustainability:

> "To create indicators data must be collected as part of a monitoring process in which repetitive measurements of coherent parameters yields information on changes in time. The data must be collected by comparable methods, according to previously set time schedules and places"(p.307)

Abolina and Zilans did also recognize in their study the importance of using the indicators as a tool for evaluating sustainability. They set a precedent that justifies the inclusion of sustainability criteria and indicators in this capstone project as a method for evaluating the sustainable management of green spaces in a city:

> "Sustainability indicators can be an effective management tool for creating greater accountability in urban planning decision-making and for enlivening sustainable development" (p.300)
> "Planners need indicators in order to learn about and to assess the existing development trends and to be able to quantify arguments for planning and development policies and development proposals."(p.307)

7.b.c. Montreal Process criteria and indicators

During the "Earth Summit" in Rio de Janeiro in 1992, special attention was paid to the sustainable management of all types of forests. Over 144 nations recognized its importance and adopted a nonbinding Statement of Forest Principles. (Sitarz, 1994, from USDA 2002).

The Montreal Process developed as result of efforts following the “Earth Summit”. The UN sponsored an international seminar in Montreal, Canada, on sustainable development of temperate and boreal forests. This forum for discussions provided a conceptual basis for international initiatives to develop criteria, which provide a large-scale reflection of public values, and indicators, which provide a means of measuring forest conditions and tracking changes in ecological, social and economic conditions. (USDA, 2002)

As with Agenda 21 indicators, the goal was to have a tool to measure and track progress towards sustainability of the forests.

In 1995, the United States, Canada, China and other countries signed the “Santiago Declaration” a statement including a comprehensive set of 7 criteria and 67 indicators for the conservation and sustainable management of temperate and boreal forests. The 12 signing countries contain 90 percent of the world’s temperate and boreal forests, which account for more than 60 percent of all forest on the globe. They also account for 35% of the world’s population.

The Montreal Process and Agenda 21 share some common themes. For instance, they both include specific criteria and indicators to measure biological diversity, global carbon cycles or the sustainability of soil and water resources.

For the purposes of this capstone project, criteria and indicators from the Montreal Process were be revised to use them as a tool for evaluating urban forest sustainability. This approach also implies looking at the urban environment as an ecosystem and the green areas as a forest within that particular ecosystem.

5.3. URBAN VEGETATION STUDIES

In this literature review several scientific articles were found that showed different approaches for studying the green spaces or urban forest of a city. Three of them put the emphasis on the sustainable issues of the green spaces, while another paper gives a good explanation of choosing the right scale when doing this type of analysis. In almost every one, biodiversity, access to green spaces and connections among them were mentioned as important factors to be evaluated when studying urban green areas.

5.3.1. DEFINITIONS

Urban forest, green areas, green spaces, urban vegetation, green lungs, open space and urban parks are just an example of how different authors refer to the same thing. Some definitions are needed to state clearly what is the extent of the study proposed in this capstone project. In the article “Urban tree cover: an ecological perspective” Wayne C. Zipperer and others made a clear explanation of defining urban vegetation.

> "Urban vegetation can be defined in two ways. First, it is defined as an assemblage of plant material above, on, and below the ground surface within an urban landscape (Sanders, 1984). This definition includes measurements of species structure, composition, and age; forest health; density; biomass; and leaf area. The second definition focuses on process and identifies those plant assemblages that are regularly subjected to urban influences as urban vegetation (Sanders, 1984; McDonald and Pickett, 1990). The process definition includes structural components and processes within urban areas as well as areas adjacent to or neighboring urban landscapes" (Zipperer, W.C. et al., 1997)

The distinction made above implies two different approaches when studying urban vegetation. The first one is more relevant when analyzing functions and values of the urban vegetation within the city, which is the case of this capstone project. The second approach is suitable for landscape ecology and process analysis such as evaluating urban rural gradients.

Urban vegetation is defined depending on the type of study to be taken. In the paper "The green poster, a method to evaluate the sustainability of the urban green structure" Kine Halvorsen Thorén gives a broader definition of green structures.

> "The green structure consists of all green areas of a city, private as well as public, gardens as much as areas of meadowland, woodland as much as parks or church yards, and even rivers, wetlands, ponds, etc." (Thorén, K.H. 2000)

This project studied the green areas by focusing on the three largest parks of each city, understanding parks as vegetated public places for passive recreation. As one of the goals of this capstone project is to find design and planning implications for the urban vegetation in these parks, they should be also understood as an identifiable management unit or urban planning unit.

5.3.2. SCALE OF THE ANALYSIS

In the paper "Urban tree cover: an ecological perspective" a discussion is presented about the appropriate scale of the study needed when analyzing urban vegetation. The scale depends, among other things, on the goals of the study, ranging from broad scale (studies based on aerial and remote sensing data) to a fine scale (studies based on individual trees data).

> "Analysis of vegetation in urban and suburbanizing landscapes has been conducted at broad (Schmid, 1975; Dorney, 1977; Brady et al., 1979; Rowntree, 1984; Sukkop and Weiler, 1988; Nowak, 1994) and fine (Lefkowitz and Greller, 1973; Stalter, 1981; Profous and Loeb, 1984; Rudnicky and McDonell, 1989) scales. At each scale, sampling is done by political or management units rather than ecological units. Broad-scale analysis focus on either the land use or the city-wide level and include descriptions and measurements of vegetation structure that relate to species

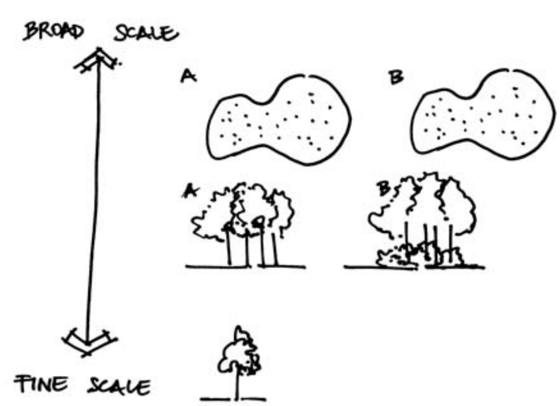


Fig. 5.b. Broad and fine scale urban tree cover analysis

> composition, percent canopy cover, tree density, diameter distribution and leaf surface area. Although this approach often assumes a homogeneity across a typology class (e.g. land use), it provides insights into tree management (e.g. Welch, 1994) or assessments or urban forest structure to improve air quality (Nowak, 1994)" (p.230)

When analyzing the sustainability of the urban vegetation the majority of the authors in this literature review use a citywide level approach. In some cases that was due to the methods used. For instance, Abolina and Zilans revised development plans to check how sustainability goals were implemented. That implies looking at urban vegetation from a local government perspective, a city level perspective.

A different approach has been taken for years in Norway, where they use an analysis method called "the green poster" as an aspect of land planning. This method has its roots in a landscape ecology approach. It analyzes independently the different functions and values of the green structure (fine scale) that are later combined to get an overview "the green poster" (broad scale) and organize all the knowledge collected. (Thorén, 2000)

The scale to be used in this capstone project was also broad and fine. Aerial pictures served as the basis for locating the green areas in the city. In the case of Fuenlabrada, they were also used to categorize the land uses and land cover of the city to get the context for the whole city area. A fine scale approach was taken when those green areas were being visited on the ground and their components analyzed individually.

From the sustainable management point of view the green areas were seen as management units of the city over which decisions can be taken to meet the sustainability goals of the citizens.

5.3.3. TYPE OF STUDIES

When comparing studies that analyze green spaces sustainability some common themes began to appear and the scope of study usually focuses on two or three aspects of sustainability. This could mean that those aspects are probably the main issues to be studied. But it could also mean that previous studies and data are available for those themes. Green spaces land cover, their biodiversity, and connections are usually among them. A second similarity is that all of the studies focus only on two or three specific aspects of environmental sustainability. This fact highlights the complexity of any sustainability analysis and the great amount of time and data they require.

In "Evaluation of specific sectors in Latvia" (Abolina et al., 2002), the authors compared planning and management policies against urban sustainability in five cities in Latvia to find a great deal of ambiguity and contradictions. In their approach they included reviewing development plan implementation reports and indicators published in statistical bulletins or used by municipal departments. The sustainability issues they cover in their research were transportation and green space. In terms of evaluating how green spaces were managed in a sustainable way they analyzed the development plans against the following policy issues:

- Preservation of the green space
- Preservation of family garden
- Enhancement of biological diversity
- Integration of the green space structure through the creation of green corridors (p.303)

Through these aspects the authors provide an example of how green areas are fundamental parts of the city and contribute to its environmental sustainability. Three of those aspects (preservation of green space, creation of green corridors and biological diversity) were incorporated for the study of this capstone project. Their analysis can be done by the use of already existing sustainable criteria and indicators.
Thorén explains an interesting approach with more similarities with the goals of this study in his article "The green poster: A method to evaluate the sustainability of the urban green structure". As mentioned before, in many municipalities of Norway they analyze the multiple values and functions of the green areas of a city. Values can be esthetic (beauty) or ethical (taking care of biodiversity). Functions are the different opportunities they offer: walks, wildlife corridors, recreation, etc. Originated as a planning tool, Thorén proposes that this method could also be used as a way to indicate the sustainability of the green area although more investigation is needed. What is important is that among the values of the urban green area three aspects are again considered:

- The size of the areas
- The connections between them
- Their content (related to biodiversity) (p.365)

Finally, on the paper "Sustaining Urban Forests" by John F. Dwyer and others identified three key characteristics of the urban forest that have significant implications for urban forest sustainability:

- Diversity (urban forest belong to a complex landscape pattern that includes a wide range of tree species and sizes, ground covers, soil types, microclimates, wildlife, people, buildings and infrastructure)
- Connectedness (urban forests are connected to other elements or urban environments, including roads, homes, people, industrial parks and downtown centers)
- Dynamics (urban forest undergo significant change with the growth, development, and succession of their biological components over time)

In summary, the area of green spaces, their biodiversity and their connections seem to be always present in the discussion of their sustainability. Their evolution and dynamics are implicit in every sustainability study, as trends in time must be analyzed to track if progress towards sustainability is been achieved. The effect of green areas on air quality and the health of the citizens is mention in some papers as well, but as an assumed value associated with the "green lungs" overall benefits. Many studies have analyzed the relationship of urban forest and pollution removal but little attention has been paid to how that effect can be maximized by green spaces management or if municipal development plans takes that factor into account.

6. SITE DESCRIPTION

Fuenlabrada (Spain) and Porto Alegre (Brazil) are two cites where different design and planning strategies have been applied to urban parks through time.

Fuenlabrada is located in the center of Spain, about 20 Km to the south of the capital, Madrid. The first documentation of settlement dates from 1606. At the end of that century the population had reached one thousand but in 1881 the population decreased. The 1890's urban configuration lasted for almost 50 years. It was not until 1970 that Fuenlabrada experienced the greatest population growth in Spain and became a modern city. From 7,389 inhabitants in 1970 it went to 65,181 in 1980. The current population is about 195,000 people, 50,000 of those who are of school age. The city works as a bedroom community where people that work in the capital can commute everyday through an excellent public transportation system.

Fig.6.a. The three urban parks of Fuenlabrada.

During the unexpected growth rate of the 70's the urban pattern experienced what some authors called 'a chaotic urbanism'. Many developers built massive high-rise apartment complexes with small semiprivate green spaces among them. As a result, the few parks and green spaces the city has are located on the periphery and it is obvious the city lacked a green space plan for years.

The urban parks studied in Fuenlabrada were La Solidaridad, El Olivar and La Paz.

La Solidaridad Park **(Fig. 6.b.)** is the most recent park in Fuenlabrada dating from the 1990's. Located on the west edge of the city it acts like a barrier between the outer industrial areas and the inner residential neighborhoods. A highway runs parallel to it on the west edge. With an area of 12 hectares it is the biggest park in Fuenlabrada and it is divided in half by a road that connects the city with the surrounding highway.

El Olivar Park **(Fig. 6.c.)** is located in the southeast corner of the city and it has an area of approximately 10 hectares. It is a remnant landscape of olive trees that have been cultivated for ages for the olive oil industry. Nowadays, the olive grove has been transformed into a park and it has no production purpose.

Fig.6.b. La Solidaridad Park.

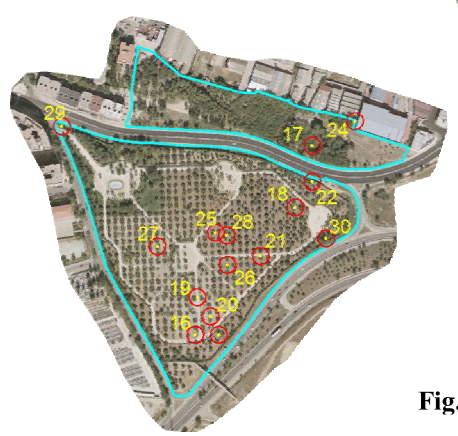


Fig.6.c. El Olivar Park.

La Paz Park **(Fig. 6.d.)** is the smallest park of the city with only 5 hectares, and it is located in the northwest corner of the city. Designed during the 1980's it contains many exotic species that were being experimented with by park managers at the time.

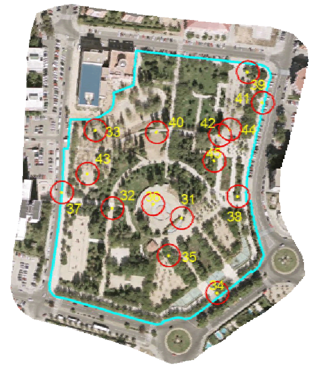


Fig.6.d. La Paz Park.

Porto Alegre is located in the South of Brazil where tropical and temperate climates meet. Settled in 1680 by people from the Azores, it experienced five clearly differentiated periods of urban evolution. From 1680 to 1772 is the settlement period and when the urban center was established. From 1772 to 1820 the city grew to 12,000 inhabitants due to the establishment of a commercial port for exporting wheat from the surrounding region. From 1820 to 1890 there is a period of German and Italian immigration that increased the population to 52,000 while the city consolidated its commercial, administrative and military functions. From 1890 to 1945 there was an industrial revolution related to commerce and agricultural production. The population reached 272,000 people. The last period of growth comprised the years from 1945 to the present and it is characterized by the urbanization of the region surrounding the city. It has a current population of about 1,500,000 inhabitants.

Fig.6.e. The three urban parks of Porto Alegre.

Many parks, *alleés* and green areas can be found within the city dating from different growth periods. The 30's and the 50's are famous for high rate of green space development. While the main purpose of green areas in the 30's was contemplation and circulation improvement, after 1950 green spaces were created for other functions like recreation. The first master plan of the city dates from 1954 and required that 10% of the land be used for public spaces. After the 70's there was a call for the implementation of green belts and the renewal of old parks. In recent years the use of native plant materials has been emphasized and specific legislation has been created for the forestation of the city. (Atlas Ambiental de Porto Alegre, 1999)

As the city of Porto Alegre is much larger than Fuenlabrada, the central district was selected to represent the city. This area is the oldest part of the town and it has the most similar area and conditions to Fuenlabrada.

The three parks studied in Porto Alegre were Farroupilha Park, Harmonia Park and Marinha Park.

Farroupilha Park, also known as “A Redenção”, is the oldest and most representative park of Porto Alegre. Designed by the French urbanist Alfred Agache in the 1930’s it has an area of 40 hectares. With a central pool, a pond, an amusement park, a small zoo and other amenities, it is divided into quarters with specific themes from the world (Oriental quarter, European quarter, Solar quarter and Alpine quarter). Located in the center of the “Centro” district it is surrounded by main transportation corridors. It has a great accessibility from distant districts of Porto Alegre and it is heavily used during the weekends. Flea markets and fresh produce markets happen on Saturday and Sunday mornings and it is a favorite destination for Portoalegrenses of all ages and economic class. The park is a symbol of the city. For more information you can visit http://www.parquefarroupilha.com.br

Fig.6.f. Farroupilha Park.

Harmonia Park, also known as Parque Mauricio Sirotski Sobrinho, has an area of 59 hectares and was inaugurated in 1982. It is located on the riverfront, where the city edge meets the Guaiba River. The park has many open areas that are used for big events, like the World Social Forum Youth Camp (Campamento da Juventude) or the Farroupilha Week (Semana Farroupilha) during the year. A new building is under construction to hold the Gaucho Cultural Center (Centro da Cultura Gaúcha) with the intention of celebrating the traditional cowboy (gaucho) culture. Areas are available for rodeos as well.

Fig.6.g. Harmonia Park.

Marinha Park, also known as Parque Marinha do Brasil, was inaugurated in 1978 and it is connected through a bridge with Harmonia Park. Mainly oriented for sports, it has a variety of courts including tennis courts, soccer fields, a skate park, an athletic field, gymnastic court and a cycling track. The park is also divided into thematic areas like the Farroupilha Park with a Solar quarter (for sun tanning), Adventure quarter (the playground), “Saudade” quarter and Gymnastics quarter. It also has a small amusement park and some vacant areas for visiting circuses. An important trail runs along the riverside connecting Harmonia Park and Marinha Park with the rest of the riverfront neighborhoods. During the weekends, another trail for biking connects these parks with Farroupilha Park and Moinhos de Vento Park forming a successful urban parks’ trail.

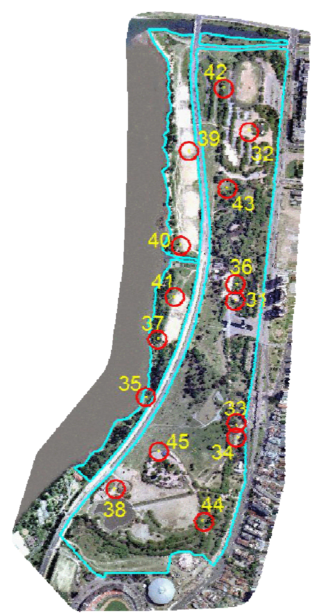


Fig.6.h. Marinha Park.

7. METHODS

Several methods were proposed in this project to study the conditions of the urban parks and their contribution to environmental sustainability. The application of the UFORE Model, a computer model developed by the USDA Forest Service Northeastern Research Station at Syracuse, provided information about the urban parks' forest structure, the amount of pollution removed and the carbon stored by them. Secondly, data was collected for a set of sustainability indicators to provide information about the accessibility, vitality, connectivity, biodiversity, and protection of water and soil resources of the urban parks. Thirdly, data was collected to rate the design qualities of the parks and record their functions. Finally, interviews with park mangers, review of the park system plans, notes and sketches from observation completed the gathering of information.

The same methods were applied for the urban parks of Fuenlabrada and Porto Alegre to be able to do a comparative study. Sampling in 15 randomly located plots for every park in each city were used to collect primary data, as explain later in detail.

7.1. UFORE MODEL

The Urban Forest Effects (UFORE) model is designed to use standardized field data from randomly located plots, and local hourly air pollution and meteorological data to quantify urban forest structure and numerous urban forest effects for cities. The model as applied in Fuenlabrada and Porto Alegre quantified:

- Urban forest structure in green space (e.g., species composition, tree density, tree health, leaf area, leaf and tree biomass, species diversity, etc.)
- Hourly amount of pollution removed by the urban forest, and its associated percent air quality improvement throughout the year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<10 microns)
- Hourly urban forest volatile organic compound emissions and the relative impact of tree species on net ozone and carbon monoxide formation throughout the year
- Total carbon stored and net carbon annually sequestered by the urban forest

The UFORE Model has four components for different calculations:

- UFORE-A: Anatomy of the Urban Forest
- UFORE-B: Biogenic Volatile Organic Compound (VOC) Emissions
- UFORE-C: Carbon Storage and Sequestration
- UFORE-D: Dry Deposition of Air Pollution

For the specific methods and equations used in each of the components, refer to the USDA publication Brooklyn's Urban Forest (Nowak et al., 2000)

7.1.1. FIELD DATA COLLECTION

For applying the UFORE Model in the urban of Fuenlabrada and Porto Alegre the three largest parks of each city were chosen. The reason for this rationale is that those parks have the green areas with the greatest influence on the city.

For each city, 15 randomly located field plots of approximately 0.04 ha were distributed within each of the three selected parks. A sample of the field form used to collect data is attached on Appendix 12.1. On every plot the following general data was estimated or recorded for the UFORE Model:

- Percent of tree cover
- Ground cover: percent of ground covered by the following types: buildings, cement, asphalt, other impervious, soil, rock, mulch, herbaceous (exclusive of grass or shrubs), maintained grass, unmaintained grass, water and shrubs.
- Tree species
- Number of stems
- d.b.h. (diameter at breast height, cm.)
- Tree height (m.)
- Height to base of live crown (m.)
- Crown width (m.)
- Tree condition:
- Street tree (y/n)

7.2. A SET OF SUSTAINABILITY INDICATORS

Agenda 21 and The Montreal Process are two international agreements that establish a framework of sustainability goals and criteria. Often stated, one of the complexities of achieving those goals in cities is how local managers translate them into real practices. In the case of green areas, many authors (Jensen et al., 2000; Dwyer et al., 2003) have highlighted the need for understanding the conditions of the local green structure in order to develop specific sustainability goals and strategies. The need for gathering information about it and presenting it in a comprehensive way is considered a keystone in this process.

To evaluate how urban parks contribute to the environmental sustainability of the city a set of indicators was created to be applied in green areas. The methodology of using sustainability indicators for measuring how sustainability is achieved was explained in the section Sustainability Indicators in the Literature Review.

Some indicators were taken from a set developed by the European Commission on Sustainable Development (CSD) as a consequence of the **Agenda 21** agreement. It is known as **Core Indicator Framework** and it has a chapter dedicated to indicators for measuring environmental sustainability.

One of the ambiguities of these indicators is that for their implementation, some definitions must be understood. As an example, an indicator of biodiversity in a city is the amount of protected area as a percent of the total area. Porto Alegre and Fuenlabrada may differently define "protected area", but that doe not mean that their percentages are not comparable. Some interviews were needed with the local Agenda 21 coordinators and Park Department employees to apply correctly the indicators. To complement the set, other local Agenda 21 Indicators were used from the Spanish cities of Vitoria-Gasteiz and Zaragoza.

The second main source for indicators was the **Montreal Process Criteria and Indicators set**. This group of indicators was developed to measure sustainable management of forests. As the green areas in the cities are urban forests some of the indicators from this set were applicable after minor modifications.

Finally, the author created some indicators to complete the set.

To every indicator selected a capital letter and a number was assigned. The letter indicates the theme they were measuring (for instance, B for biodiversity) and the number is just the ordinal. The letters are related to themes as follows:

- B. Biodiversity
- C. Connectivity
- D. Vitality
- E. Soil and water resources
- F. Accessibility

7.2.1. FROM INDICATORS TO RATINGS

As explained earlier, the contribution of urban parks to sustainability was measured through 45 randomly located plots inside the three biggest parks in the city (15 plots per park). In each one of these plots several quantitative parameters were estimated through indicators in relation to biodiversity, connectivity, vitality, soil and water resources and accessibility. In addition, two other issues were also studied in the plots: design quality and functions of the park.

In order to be able to compare the plots of the different parks almost all the indicators were translated into a value range of 1 to 5, 1 meaning the smallest contribution to sustainability on that theme and 5 the highest contribution. The sum of those numbers will give a final numerical value for each plot, revealing how much they contribute to sustainability in relation to the others. Design quality and functions were also translated to a numerical range following the same scheme. For each plot there is a final sustainability value and a final design quality value. The sum of all the plot values for a park will give a value for each park on sustainability and design quality that will allow comparison of one park with another. Contribution to air quality and carbon storage was discussed separately as the results came directly from the UFORE Model output files.

As any set of indicators, the list is flexible and open to review. Improvements can be made and some were introduced during the research. It is only through the use of the set that it can be tested and improved. The way indicators were translated to into values from 1 to 5 is also not definitive but was the approach chosen by the author and his committee. More important is that it was used consistently the same way each of the six parks during the research.

The following is an explanation of how the indicators were measured in the plots and the numerical values assigned. Plot number P19 of Fuenlabrada is chosen to illustrate this. The complete data entries can be consulted in the CD attached to this document under the file names Fuenlaparks_final.xls and Poaparks_final.xls. The rows in white contain the indicator measurements, and the rows in blue contain the 1 to 5 range values.

7.2.1.a. BIODIVERSITY

SUBTHEME: ECOSYSTEM DIVERSITY

				Plot 19	
		ECOSYSTEM DIVERSITY	Units		4
B1		**Protected ecosystem**	%	60	3
B2		**Succession stage**			3
		Remnant	%	*60*	
		Emergent	%	*0*	
		Planted	%	*40*	
B3		**Ecosystem type**			4
		Bare soil/Path	%	*0*	
		Grass/Prairie	%	*0*	
	Barrier	*Shrub/Park like (G&S)*	%	*0*	
	Hort	*Park like (G&T)*	%	*0*	
	Water	*Park like (S&T)*	%	*40*	
		Park like (G&S&T)	%	*0*	
		Forest	%	*0*	
		Wetland/Riparian	%	*0*	
		Dehesa (trad. to Spain)	%	*60*	
		Native to Brazil	%	*0*	

Indicator B1: Protected ecosystem
Explanation: a park containing a protected ecosystem is contributing to sustainability by preserving that unique ecosystem diversity.
Measurement: The percent of plot area containing a protected ecosystem (%).
Range value: translate the 100% area scale to a 1 to 5 scale (a 100% of area containing a protected ecosystem will give a 5 value)
Source: Montreal Process Criteria and Indicators. (USDA, 2002)
In this case 60% of this plot is a "dehesa", a protected ecosystem in Madrid. The plot gets a value of 3 in the range value.

<u>Indicator B2:</u> Succession stage
<u>Explanation:</u> the closer the succession stage the park vegetation is to climax, the higher its ecological. In this indicator the stage category with more ecological value would be the remnant stage (former vegetation), followed by the emergent stage (pioneer species) and finally, with the lowest value, the planted stage (artificially established).
<u>Measurement</u>: The percent of plot area containing each succession stage. (%)
<u>Range value:</u> giving the values of 5 to the remnant stage, 3 to emergent and 1 to planted the percents are weighted on a scale of 1 to 5.
<u>Source:</u> author, based on (Zipperer et al., 1997)
In this case 60% of the plot is in a remnant stage (the Dehesa is over 200 years old) and 40% is planted. The plot gets another 3 in the range value.

<u>Indicator B3:</u> Ecosystem type
<u>Explanation:</u> as each ecosystem has a different level of associated biodiversity, the type of ecosystem was taken into account.
<u>Measurement</u>: The percent of plot area containing each ecosystem type. (%)
<u>Range value:</u> a number between 1 and 5 is given to each ecosystem category in accordance to their level of biodiversity. Man-made surfaces were not considered as ecosystem. The values assigned are: Path/soil (1), Grass/Prairie (2), Grass with shrubs (2,5), Grass with trees (3), Shrubs with trees (3,5), Grass with shrubs and trees (4), Forest (4), Riparian or Wetland (4,5), Protected ecosystem in Spain or Brazil (5). The final value comes from the sum of the values weighted by the percentage.
<u>Source:</u> author, based on CSD Core Indicator Framework (UN/CSD, 1996)
In this case 40% of Shrubs and Trees (3,5) and 60% of Dehesa (4) gives a final value of 4.

Finally a unique value is given to Plot 19 on Ecosystem diversity by averaging the values for B1, B2 and B3.

SUBTHEME: SPECIES DIVERSITY

				Plot 19
	SPECIES DIVERSITY			2
B4	**Different tree species**	#	3	3
B5	**Protected species (locally)**	%	0	0
B6	**Native species (country)**	%	40	2

<u>Indicator B4:</u> Different tree species
<u>Explanation:</u> the number of different species in the plot is an indicator of diversity.
<u>Measurement</u>: number of different tree species (#)
<u>Range value:</u> the number itself.
<u>Source:</u> Montreal Process Criteria and Indicators. (USDA, 2002)
For plot 19 there are 3 tree species that gives a value of 3.

<u>Indicator B5:</u> Protected species
<u>Explanation:</u> the percentage of protected species is an indicator of the ecological value of the plot on species diversity.
<u>Measurement</u>: percentage of protected species within the species found in the plot
<u>Range value:</u> 100% scale translated to a 1 to 5 scale.
<u>Source:</u> based on Montreal Process Criteria and Indicators. (USDA, 2002)
For plot 19, there is 0 protected trees that gives a value of 0.

<u>Indicator B6:</u> Native species
<u>Explanation:</u> the percentage of native species is an indicator of the ecological value of the plot on species diversity.
<u>Measurement</u>: percentage of native species within the species found in the plot
<u>Range value:</u> 100% scale translated to a 1 to 5 scale
<u>Source:</u> based on Montreal Process Criteria and Indicators. (USDA, 2002)
For plot 19, 40% of the trees are native to Spain that gives a value of 2.

A unique value is given to Plot 19 on Species diversity by averaging the values for B4, B5 and B6 as follows: Species diversity= (B4x30+B5x40+B6x30)/100. (Indicator B5 was considered a bit more important than B4 and B6)

	Plot 19
BIODIVERSITY	**3**
ECOSYSTEM DIVERSITY	4
SPECIES DIVERSITY	2

Finally, a unique value is given to each plot on the theme of BIODIVERSITY by averaging the final values of the Ecosystem Diversity and Species Diversity.

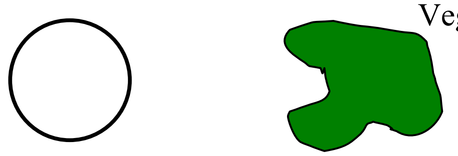
7.2.1.b. CONNECTIVITY

Two indicators were used to measure the connectivity of the green structure within the parks through plots data. Connectivity of parks within the city was analyzed on the accessibility theme. This table shows the values for plot 19.

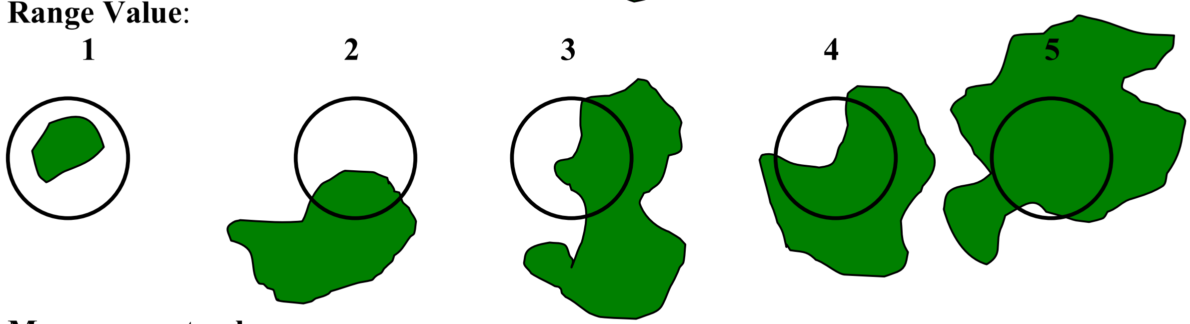
CONNECTIVITY				**3**
C1	Connectivity of main ecosystem	#	2	3
C2	Fragmented ecosystem	%	40	3

<u>Indicator C1:</u> connectivity of main ecosystem
<u>Explanation:</u> green structure is usually found in nature forming a continuous system that allows for interaction and succession with other natural systems. Lack of continuity was understood as an unsustainable condition in urban parks.
<u>Measurement</u>: connectivity was estimated by a subjective index applied to the main ecosystem of the plot (the ecosystem with the larger percent of area). See the following graphic.
<u>Range value:</u> from 0 to 5.
<u>Source:</u> author

Plot Vegetation patch



C1 Range Value:
1 2 3 4 5



C2 Measurement value:
70% 80% 45% 25% 2%

<u>Indicator C2:</u> fragmented ecosystem
<u>Explanation:</u> fragmentation of ecosystems was considered unsustainable as it isolates vegetal and animal species, reduces habitats and decreases diversity in reproduction.
<u>Measurement</u>: the percentage of plot fragmented, meaning area not covered by the predominant or main ecosystem type.
<u>Range value:</u> (100-area fragmented)/100 x 5
<u>Source:</u> author.

The final CONNECTIVITY value is the average of C1 and C2

7.2.1.c. VITALITY

				Plot 19
VITALITY				**3**
D2	**Trees below good condition**	%	40	3

<u>Indicator D2:</u> trees below good condition
Explanation: the percentage of trees below good condition (with more than 11% of dieback) is an estimation of the vegetation vitality in the plot. It is actually an estimation of mortality.
Measurement: the tree condition was recorded in the UFORE field forms for each plot.
Range value: to estimate vitality in a 1 to 5 scale the formula used was: (100-% trees below good condition)/100 x 5
Source: author, based on UFORE Model.

7.2.1.d. SOIL AND WATER RESOURCES

			Plot 19
SOIL & WATER RESOURCES			**2**
E1 Land w/ erosion problems protected by vegetation	%		0
E2 Land w/ water resources (or water resources <150 m.) protected by vegetation	%		0
E3 Land w/ compaction or flooding problems protected by vegetation	%	60	3
E4 Land w/ watering management			4
No watering needed - Adapted vegetation (I.e., xerophytes in Mediterranean)	*%*	*60*	
Seldom permanent watering	*%*	*0*	
Daily permanent watering	*%*	*0*	
Daily moving watering	*%*	*40*	
Watering needed	*%*	*0*	

<u>Indicator E1:</u> land with erosion problems protected by vegetation
Explanation: vegetation roots retain soil particles and reduces erosion problems. The presence of green structure in a plot contributes to environmental sustainability by preserving the soil resources.
Measurement: percentage of plot area with vegetation on soil with erosion problems.
Range value: translate a % scale to a 1 to 5 scale
Source: based on Montreal Process Criteria and Indicators. (USDA, 2002)

<u>Indicator E2:</u> land with water resources protected by vegetation
Explanation: vegetation adjacent to water resources or near water bodies (less than 150 m from a river o a lake) helps to protect those resources by reducing evaporation, increasing infiltration, etc. The green structure in that plot contributes to environmental sustainability by preserving the water resources.
Measurement: percentage of vegetated plot area with water resources or near water bodies.

Range value: translate a % scale to a 1 to 5 scale
Source: based on Montreal Process Criteria and Indicators. (USDA, 2002)

Indicator E3: land with compaction/flooding problems protected by vegetation
Explanation: the presence of vegetation located in a land with compaction or occasional flooding helps to reduce those problems. The green structure in that plot contributes to environmental sustainability by protecting the soil resources.
Measurement: percentage of vegetated plot area with compaction/flooding problems.
Range value: translate a % scale to a 1 to 5 scale
Source: based on Montreal Process Criteria and Indicators. (USDA, 2002)

Indicator E4: watering management
Explanation: the waste of water for irrigation purposes in a park is directly related to sustainability, as water is a scarce resource, especially in Mediterranean climates. Recording the watering condition for each plot is an estimation of the water consumption management.
Measurement: percentage of plot area with a specific watering management
Range value: for each watering management a value is assigned from 1 to 5 and the final value is weighted by the percentage of plot under each situation

No watering needed or Use of vegetation adapted to the climate (I.e., xerophytes in Mediterranean).	*5*
Seldom watering, approximately once a week	*4*
Almost daily permanent watering, but less than 3 days a week.	*3*
Daily watering or at least 5 days a week.	*2*
Watering needed	*1*

Source: author.

The final WATER AND SOIL RESOURCES range value is an average of E1, E2, E3 and E4 indicators.

7.2.1.e. ACCESIBILITY

The accessibility to parks was addressed by recording for each plot the distance to public transportation (buses stops, subway or train stations) and the possibility for accessibility.

				Plot 19
ACCESIBILITY				**2**
F1	**Public transportation** (<500 m.)	y/n	y	
	Distance	m	350	2
F2	**ADA accesible**	y/n	n	0

Indicator F1: distance to public transportation
Explanation: for pedestrian circulation, 500 m. is usually considered the walking distance limit. Pedestrian accessibility to parks is an important issue for sustainability

as the lack of it will encourage the use of individual transportation (with associated pollution) or will reduce the number of users benefited by the park.
Measurement: distance to public transportation (through use of GIS)
Range value: 0-100m. (5), 100-200m (4), 200-300m (3), 300-400m (2), 400-500m (1), >500m (0)
Source: based on CSD Core Indicator Framework (UN/CSD, 1996)

Indicator F2: ADA accessibility
Explanation: the park accessibility for people with disabilities was addressed by checking universal access in each plot. Inaccessible plots would reduce the number of park users.
Measurement: being accessible (y) or not (n)
Range value: in this case the value given was (n)=0, (y)=1
Source: author.

The final ACCESSIBILITY value was calculated as F1 + F2

7.2.1.f. FINAL SUSTAINABILITY VALUE

A FINAL SUSTAINABILITY VALUE was calculated for each plot by adding all the final values for each theme. For instance, plot P19 got a final value of 12 on sustainability, which allows comparing with other plots. By adding the final values of the plots it allows for comparison between parks. By adding the parks values it allows for comparison between cities.

PLOT IDs	*final values*	Plot 19
	SUSTAINABILITY	*12*
Indicators THEME		
BIODIVERSITY		**3**
CONNECTIVITY		**3**
VITALITY		**3**
SOIL & WATER RESOURCES		**2**
ACCESIBILITY		**2**

7.2.2. AIR QUALITY AND CARBON STORAGE

Park trees contribution to air quality improvement and carbon storage was estimated by the UFORE Model from the USDA Forest Service explained in chapter 7.1. Module C and D are explained more in the following sections.

7.2.2.a. Carbon storage

Increasing levels of atmospheric CO_2 and other greenhouse gasses are thought to contribute to an increase in atmospheric temperatures. Through growth processes, trees remove atmospheric CO_2 and store C in their biomass.

Biomass for each tree was calculated through the UFORE Model, Module C, using allometric equations already inserted for different species in the Model. When there was no valid species-specific allometric equation, equations from the same genus was used. Similarly, if no genus equations were found, biomass was computed separately for each hardwood and conifer equation, and the group average was used.

As deciduous trees drop their leaves annually, only C stored in wood biomass was calculated. For evergreen trees, leaf biomass was calculated and added to the estimate of total wood biomass to yield total tree biomass.

Average diameter growth from the appropriate diameter class was added to the existing tree diameter (year *x*) to estimate tree diameter in year *x+1.* For the land use of this project, parks, the average diameter growth was 0.61 cm/yr. Average height growth was calculated through formulas in the literature using adjustment factors based on tree condition.

Tree death leads to the eventual release of stored carbon. In estimating the net amount of C sequestered by the park trees, C emissions due to decomposition after tree death must be considered. To calculate the potential release of carbon due to tree death, estimates of annual mortality were used. In urban areas, removed trees usually are not developed into wood products for long C storage, so the release of carbon was considered to happen relatively soon after removal.

Results were presented for each park in terms of carbon storage (tons of carbon stored in the trees through the years), gross carbon sequestration (tons of carbon stored every year) and net carbon sequestration (tons of carbon stored every year based on estimated mortality and tree removal). Results will be shown as tons of carbon and as tons of carbon per hectare.

7.2.2.b. Pollution removal

Module D of the UFORE Model was used to estimate dry deposition of air pollution (i.e., pollution removal during non precipitation periods) to trees in the parks of each city. This module calculates the hourly dry deposition of O_3, SO_2, NO_2, CO, and PM10 to tree canopies through the year based on tree cover data, hourly weather data and pollution concentration monitoring data. In this research, it was estimated for the year 2002.

In UFORE D, several formulas were used to calculate the pollution removal. Pollutant flux is calculated as the product of the deposition velocity and the pollutant concentration. O_3, SO_2, NO_2 removal are related to transpiration, while CO and PM10 removal are more dependant on deposition on the leaf surface. For details on the methods refer to (USDA, 2002). The model uses leaf area indexes making a difference between evergreens (leaf the year round) and hardwoods. It also limits deposition estimates to periods of dry deposition by setting deposition velocities to zero during periods of precipitation.

The average hourly pollutant flux (grams of pollutant per m^2 of tree canopy coverage) was multiplied by the parks tree canopy coverage (m^2) to estimate total hourly pollutant removal by trees across each park.

Results were presented for each park for every pollutant as the pollution removal rate (grams of pollutant removed by m^2 of tree canopy cover) for the year 2002.

7.3. DESIGN QUALITY STUDY

The purpose of this capstone project is not only to estimate the parks' contribution to sustainability but also to find what implications that contribution may have on park design and planning. For that reason, a design quality study was done while the primary data for the indicators and the UFORE Model were being collected.

The study of the design quality or aesthetics was taken in terms of two perspectives, one quantitative and one qualitative. Three issues were covered: design qualities, function and patterns.

Under the quantitative study design qualities such as variety of colors, identity of place or relation to context were rated in each plot in a 1 to 5 scale. The functions of the park, such as passive recreation or preservation, were recorded in each plot as well. Notes for every rate were made, and sketches were drawn in those plots that were particularly interesting. Using the ratings obtained for design qualities and functions a final number was given to each plot regarding design quality.

Under the qualitative study in those plots with a unique sense of place landscape patterns were searched for and black and white pictures taken.

7.3.1. DESIGN QUALITIES

Giving ratings between 1 (poor) and 5 (excellent) to each plot, six aspects of aesthetics were covered and design qualities:

<u>G1:</u> textures and color variety
The variety of textures and colors achieved with the planting materials and other design elements (hardscape, water, decorative elements, lights, etc.) was observed. The lack of variety was considered as negative under design quality, but also variety of color or texture in the elements without relation among them was considered equally poor.

<u>G2:</u> shape and silhouette variety
The variety of shapes and silhouettes achieved with the vegetation and other design elements was observed. As before, variety was considered as positive in design quality when there was consistency among the elements. (Variety of elements with no relationship or apparent pattern among them was considered poor)

<u>G3:</u> identity of place
The uniqueness of a place revealed or created by the design was evaluated under identity of place. The more unique the place, or the higher the sense of place in it, the greater the rating was given under this aspect.

<u>G4:</u> topography variety
Taking advantage of the natural topography or the formation of landforms to create different places in a plot was considered as positive for this aspect of design quality.

<u>G5:</u> physical connections with surroundings
A common critique in design is isolation from the surroundings. Establishing physical connections with the outside and making the spaces part of a bigger system was considered positive under this aspect of design quality.

<u>G6:</u> links with the context or the past
Designs that revealed the relationship of the place with its context or explain the history of the place, were considered to be more successful than those that did not. These links help people understand the place they live in and increase their sense of place.

These were the issues selected to analyze the quality of the design. They were evaluated qualitatively through the recording of personal comments in each plot, and quantitatively through the translation of those comments into the 1 to 5 rating scale, 5 meaning best quality achieved under an aspect and 1 meaning the worst quality.

The following is the example for Plot 20. A final value was averaged from G1 to G6 for each plot

DESIGN QUALITY		comments	**3**
G1	Textures & colors variety	contrast between brown soil and yellow grassland, gray bark and olive green leaves	5
G2	Shape & silhouette variety	great richness	5
G3	Identity of place	“dehesa” identity lessen by park-like proximity	4
G4	Topography variety	plain topography, flatness	1
G5	Physical connections w/ surroundings	no	1
G6	Links with context & past	Traditional agricultural and forest cultivation but not emphasized	3

7.3.2. FUNCTIONS

Under this theme of design quality each plot was evaluated in terms of function. It is implied that the more functions a space provides, the better the design quality is. The functions analyzed were:

Aesthetics: when the intention of the design was to provide an aesthetically pleasant experience.

Active recreation: when the design provided an opportunity for users to practice sports activities (running, jogging, biking, skating, etc)

Passive recreation: when the design provided an opportunity for users to recreate passively (strolling, walking the dog, sitting on a bench, reading, resting…)

Preservation: when the intention of the design was to preserve ecological values (protected species, remnant ecosystems, wildlife reserve, etc.), but also cultural values (historical monuments, etc).

Protection: when the intention of the design was to protect the environment from disturbing agents (noise, air pollution, etc), erosion or other harm.

Production: when it is intended to obtain products (wood, fruits, grass for cattle, etc.)

This is an example for plot 20. This plot is aesthetically pleasant, preserves a protected ecosystem and its trees protect the soil from compaction.

G7	Functions				**3**
		Aesthetic	y/n	y	1
		Active	y/n	n	0
		Passive	y/n	n	0
		Preservation	y/n	y	1
		Protection	y/n	y	1
		Production	y/n	n	0

In the quantitative study a value of 1 is given for each function the plot has. The final value for Functions is the sum.

A final DESIGN QUALITY value is obtained by adding this Functions value to the previous one.

Plot 20		*DESIGN QUALITY*	*6*
DESIGN QUALITY			**3**
G7	Functions		**3**

7.3.3. PATTERNS

The previous methods have covered the urban parks design qualities analysis primarily through quantitative means. Parks have qualities related to design that are hard to measure by numbers or categories but that are essential to the park character. The research for patterns in the park was included in the study, as a qualitative method to account for those park design qualities related to personal perception and subjective experience.

This area of the study relates to the theory of phenomenology, a philosophical method originated by Edmund Husserl that looks for "a descriptive account of the essential structures of the directly given". Phenomenology emphasizes the immediacy of experience, uncontaminated by any theory or assumption. The author Christopher Alexander and his language pattern theory were chosen for the qualitative analysis of the park design qualities.

Christopher Alexander, in his book "The Timeless Way of Building" (1979), argues that some places (such as cities, buildings, and in this case parks) have a central quality that makes them unique and attractive. This quality is objective and precise, but it has no name, and that is why is so hard to be described or measured. "Places are given their character by certain patterns of events that keep on happening there". "These patterns of events are always interlocked with certain geometric patterns in the space" (Alexander, 1979).

In Alexander's view, living patterns (patterns that evolve in time, that can be used endless times but always with a slight difference) are responsible for the quality of the place. Patterns form a language that can be learned, and like words are use to make a phrase, patterns can be used to make places. The quality without a name appears when a place is made considering such a system of patterns. Alexander gives several examples of patterns, from a large to a small scale, which can be searched in places.

In this capstone research, patterns were recorded in those plots of the park with special character. Some patterns were borrowed from Alexander's book "A Pattern Language"; others were adaptation of those patterns to parks and the author found others. They are referred as landscape patterns. The idea is that the living patterns are a qualitative measure of the park design quality. For clarification some examples of landscape patterns used are shown:

- Access to water (Alexander)
- Grid of paths (Alexander)
- The magic of the forest (Alexander)
- Nodes of activity (Alexander)
- Street vendors (Alexander)
- The edge of the forest (author)
- Benches in the shade (author)
- Roots on earth (author)
- Novel tree (author)
- Room for birds (author)

7.3.4. OTHER INFORMATION

Beyond the data mentioned above, the following questions were also addressed for every plot:

- Are there any unique elements of design?
- Is there any major critique to the design?
- Is there any major idea for a recommendation?
- Is the plot design successful?
- Does the people use it?

Finally, interviews with the head of the park department in every city and with the park managers in every park were made. A copy the interview form is attached in Appendix 12.2. The purpose of the interviews were several, among them:

- To double check if some assumptions made during the research were true (such as the more functions for the park the better, native species are preferred to exotics or what areas considered under protection)
- To find major problems on park maintenance and management for later recommendations
- To find what planning strategies were more successful in every park
- To gather additional information (such as community programs involved with the park or watering frequency)

City master plans were also reviewed to find large-scale strategies. The Department of Parks and Gardens in Fuenlabrada provided had little documentation published and more information was gathered through personal visits. The Department of Parks in city of Porto Alegre had more documentation and that was available for the research. In Porto Alegre, every park has a small administration office where more data such as maps and inventories was available.

Sketches, pictures and other notes were also taken in every plot and in different interesting areas of the park to complete the study.

7.4. RELATING SUSTAINABILITY WITH DESIGN

To find design strategies for sustainability, the best and worst plots on sustainability and designed qualities were reviewed in depth. From the methodology used, there is a rating on sustainability and design quality for the 45 plots evaluated in each city that allows the comparison among them.

Adding plot ratings for each park allows for a comparative study of sustainability and design quality among parks. Adding park ratings allows for a comparative study between the two cities. In the following example from Fuenlabrada, La Solidaridad Park (P1), El Olivar Park (P2), La Paz Park (P3) and plots P19 and P20 are shown.

PLOT IDs	*final values*	P1	P2	P3	Plot 19	Plot 20
	SUSTAINABILITY	181	194	175	*12*	*13*
	DESIGN QUALITY	72	87	62	*6*	*6*
	sum	**254**	**281**	**237**	***18***	***19***

Design strategies were found for each sustainability theme. First, plots with highest values on each theme were appraised. If the designed had influenced the good results obtained, successful design strategies could be taken. Secondly, plots with the lowest ratings were examined as well to find unsuccessful design strategies for sustainability.

Finally, for every sustainability theme, landscape patterns that had been collected in the best plots were reviewed as well. Those found more repeatedly in different plots and parks under a specific theme are thought to be related. In other words, plots contributing the most to an aspect of sustainability tend to have patterns in common that can be related to the design strategies behind them. As an example, proximity to water was a pattern found in most of the best plots contributing to biodiversity. Locating green areas near existing water bodies is a planning strategy for parks that increases the contribution to diversity, as the number of different ecosystems, plants and animals is usually higher in areas with water.

While design strategies and sustainability have a clear relation, patterns are less obvious. If applying the design strategies found for each sustainability theme (i.e., species diversity), the contribution of parks will increase towards that theme (species diversity). Patterns found to be associated with that theme (i.e., novel trees) will likely appear in time as well and give quality to the place, but that relation depends on more factors and is not direct.

Patterns were used to identify design qualities in the existing parks and to give an idea of some qualities that can be achieved when using the sustainability design strategies.

8. RESULTS, DISCUSSION AND CONCLUSIONS FOR EACH PARK

8.1. ACCESIBILITY

8.1.1. FUENLABRADA PARKS – LA SOLIDARIDAD

8.1.1.a. RESULTS

La Solidaridad is a park with great accessibility. It has 1750 m. of biking and running trails (in red in **Fig. 8.1.a**) bridging the two halves of the park divided by a main traffic road. The average distance to public transportation is 237 m. and only two plots are further than walking distance (500m.). 10 of 15 plots were accessible for people with disabilities.

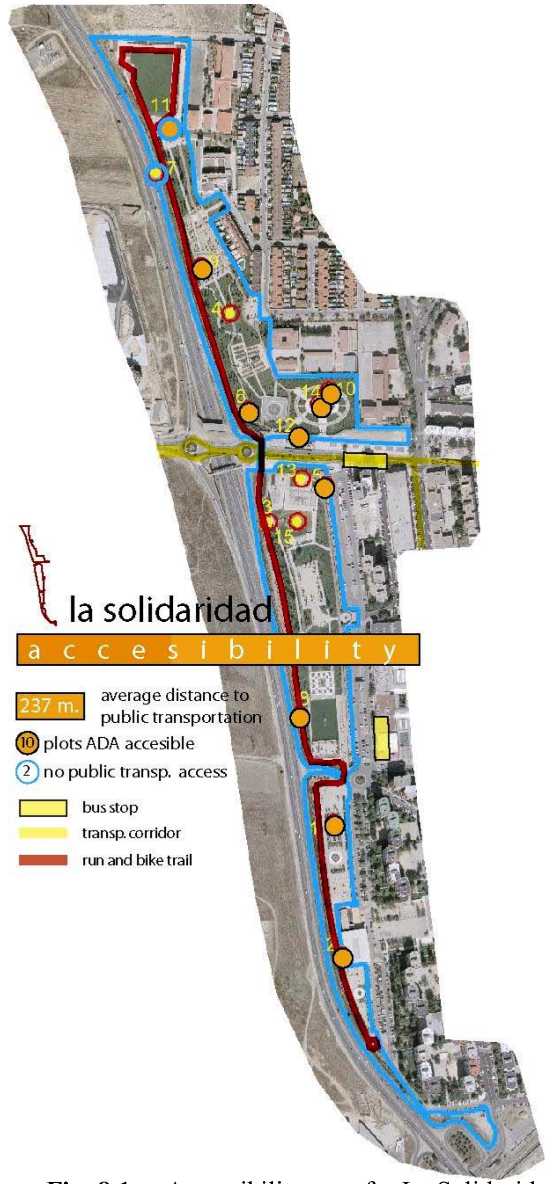


Fig. 8.1.a. Accessibility map for La Solidaridad.

8.1.1.b. DISCUSSION

Although this park is located in the limits of the city, it has good accessibility, as there are bus stops near the main entrance and a secondary entrance. It is also the most recently built park and more attention was paid to providing ramps and hard surfaces for wheelchair accessibility. Young and old people successfully use the trail, mainly for running and taking walks.

8.1.1.c. CONCLUSIONS – DESIGN STRATEGIES

1. A general strategy that applies for all parks is that, if possible, public transportation points (bus stops, subway) should be located within 500 meters from the park areas, not just the entries.

2. Bike and running trails not only offer a recreational value but also can be used to connect areas of the park and increase the number of users. The type of trail design used in La Solidaridad is suitable for linear parks. Located at higher elevation along the edge, it has a continuous vegetation buffer toward the highway and scattered trees that allow views to the park interior. (Picture on the right).

8.1.2. FUENLABRADA PARKS – EL OLIVAR

8.1.2.a. RESULTS

El Olivar is the park in Fuenlabrada that is least accessible. The average distance to public transportation is 346 m although there is a stop bus next to the only entrance.

Access for people with disabilities was reduced to only 1 plot out of the 15 analysed.

8.1.2.b. DISCUSSION

The majority of the park is old agricultural land (an olive grove) transformed into a park. The ground cover is mainly bare sandy soil and grass. Providing hard surface paths through the olive grove could increase accessibility, but that will create a conflict with the naturalistic view of the park, one of its main assets. A solution could be the use of compacted soil paths.

Fig. 8.1.b. Accessibility map for El Olivar.

8.1.2.c. CONCLUSIONS – DESIGN STRATEGIES

The analysis of El Olivar revealed some design problems to be avoided.

1. If a park needs to be fenced, it should have more than one entrance. In the case of El Olivar, the accessibility of the park is reduced as the only entry and exit is located in the northwest corner. The result is the anonymous creation of holes in the fence that reveal the users' need for a shortcut. There is not even a direct connection with the segregated part on the north as can be seen in **Fig.8.1.b.**

2. Special attention to accessibility for people with disabilities must be paid when agricultural lands or woodlands are intended to be part of a park system. As they were not artificially designed, they need to address universal access. Compacted soil or wooden platforms could be some options that do not compromise the naturalistic feeling of those areas.

8.1.3. FUENLABRADA PARKS – LA PAZ

8.1.3.a. RESULTS

La Paz is the park in Fuenlabrada that rated highest in accessibility. Although there was no trails inside the park, the average distance to bus stops was 146 m and all plots fell within walking distance.

Fig. 8.1.c. Accessibility map for La Paz.

8.1.3.b. DISCUSSION

This is the smallest park of the six analysed in this study with only 5 ha. Its size and location in the canter of the city makes it very easy to access. The amount of hard surfaces on the ground is considerable and most of the plots are accessible for people with disabilities.

There is also an important transportation corridor with bus stops near the park (see **Fig. 8.1.c**.). Once a week this street is closed during the morning for a fresh produce market, but this fact did not seem to have an impact on park users or park management.

8.1.3.c. CONCLUSIONS – DESIGN STRATEGIES

1. Parks located in the centre of the cities have more accessibility. They have more chances to be close to transportation corridors, bus stops or subway stations.

2. The size of the park has an influence as well. It is easier to get within walking distance (500 m.) to more areas in a small park like La Paz than in a bigger one.

8.1.4. PORTO ALEGRE PARKS – FARROUPILHA

8.1.4.a. RESULTS

In Porto Alegre, Farroupilha Park got good ratings on accessibility as it is located in the city centre and is surrounded by important transportation corridors (see Fig.8.1.d.). The average distance to the park areas was 226 m.

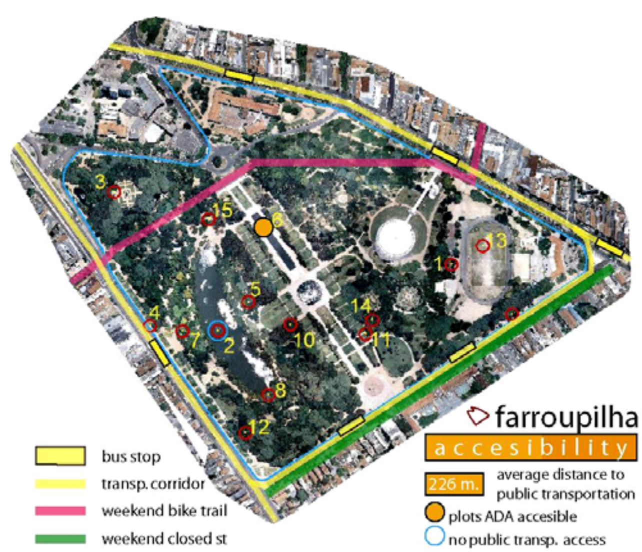


Fig. 8.1.d. Accessibility map for Farroupilha.

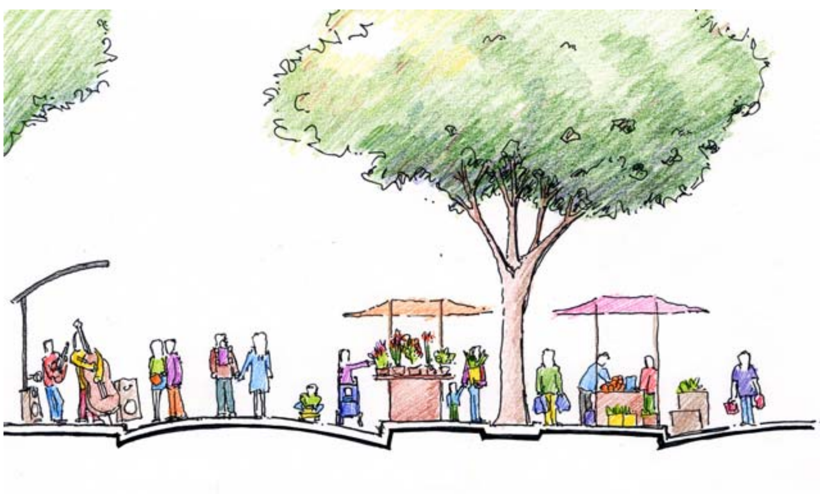
Universal access was not high in

Porto Alegre in general, as most of the ground cover is compacted sand. Only one plot was accessible in this case.

8.1.4.b. DISCUSSION

Two interesting accessibility strategies are used in this park. A weekend bike trail that connects the city parks system goes through Farroupilha Park, increasing its exterior links (purple line shows in the **Fig.8.1.d**.).

A second successful idea is the Avenida José Bonifacio, a street closed during the weekends for different activities. Organic food markets, crafts and flea markets take place during those days and are visited by an incredible amount of people (pictures below). This area works as an extension of the park and people spend time in it after strolling in the markets. The layout is a successful design that functions the whole week (see sketch).



8.1.4.c. CONCLUSIONS – DESIGN STRATEGIES

1. Transportation corridors surrounding the parks give the greatest accessibility to them. Farroupilha Park is known for the affluence of people from adjacent areas during the weekdays to people from nearby suburbs during the weekends. Once a month, a free bus ride day brings more users from impoverished areas surrounding the city. The mix of social classes in this park is related to these facts.

2. Closing streets adjacent to parks is a successful strategy to bring users to the park, reducing the car access, extending the park area and providing recreational activities for citizens. Weekend days proved to be more popular than weekdays as the comparison between Farroupilha and La Paz showed. Craft and organic produce markets also contribute to local sustainability, both economically and socially.

3. The design of the street to be closed plays a fundamental role. Providing a central pedestrian space makes the area function the whole week.

8.1.5. PORTO ALEGRE PARKS – HARMONIA

8.1.5.a. RESULTS

Harmonia Park has moderate accessibility as it is located adjacent to the river and there is only one bust stop in its vicinity. The average distance to that point from the surrounding street was 314 m., and two plots located in the riverside, were further from walking distance.

There is an important bike trail that connects with Marinha Park to the south, and parallels the coast line of approximately 4.5 Km., being 2 Km. in Harmonia Park (see **Fig. 8.1.e.**)

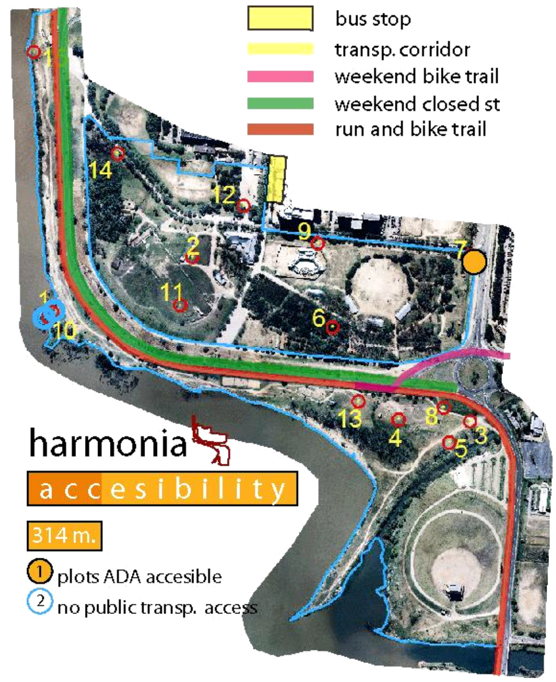


Fig. 8.1.e. Accessibility map for Harmonia.

8.1.5.b. DISCUSSION

Although the park is located in a natural limit of the city its exterior connections are very well resolved. The trail that connects with Marinha Park is heavily used and continues along the coast beyond park limits. During the weekends, the bike trail links Harmonia with the two other parks of Porto Alegre: Farroupilha and Moinhos de Vento via a 4.42 Km. path. The road that divides the park in two is closed during the weekends for strollers, bikers and skaters.

Despite of all these connections, the interior accessibility of the park is poor, as paths are not paved and there is a general lack of maintenance.

8.1.5.c. CONCLUSIONS – DESIGN STRATEGIES

1. This park benefits from the strategy of increasing the park area during the weekends by closing a street. Less successful than in Farroupilha Park, the road is mostly used for active sports such as skating or bicycling. It also brings together the two parts of the park that during the week are segregated.

2. As the riverfront is facing west, the northern corner is a favourite spot in the city to watch the sunset. The city has allowed street vendors along the running and bike trail in that area. The sportsmen visit the variety of carts selling drinks and snacks.

3. Marinha Park contains several areas that are temporarily occupied with festival activities (camps, circus, rodeos). The rest of the year they remain vacant, inactive and sometimes vandalized. An alternative use for those periods would be a convenient strategy to keep the park used and maintained. The southwest corner reflects that case.

8.1.6. PORTO ALEGRE PARKS – MARINHA

8.1.6.a. RESULTS

Marinha Park has the longest average distance to public transportation points, 320 m. It also has the longest bike and run trail (red line in Fig.8.1.f.) with 3.4 Km inside the park limits. As with the rest of the parks in Porto Alegre, the ground cover type makes it difficult for universal accessibility, only 1 plot out of 15 accessible.

8.1.6.b. DISCUSSION

The main problem in Marinha Park is similar to the previous park: there is a road cutting the park in two parts without connections. While the eastern part is next to a main transportation corridor (yellow line in **Fig.8.1.f**) there are no bus stops next to the western part.

The western part has less accessibility, less maintenance and room for activities. Some people don't even perceive it as part of the park. There are some well kept areas and the run and bike trail is included here, but the majority is vacant land and unused soccer fields. Connecting these two parts should be a priority.

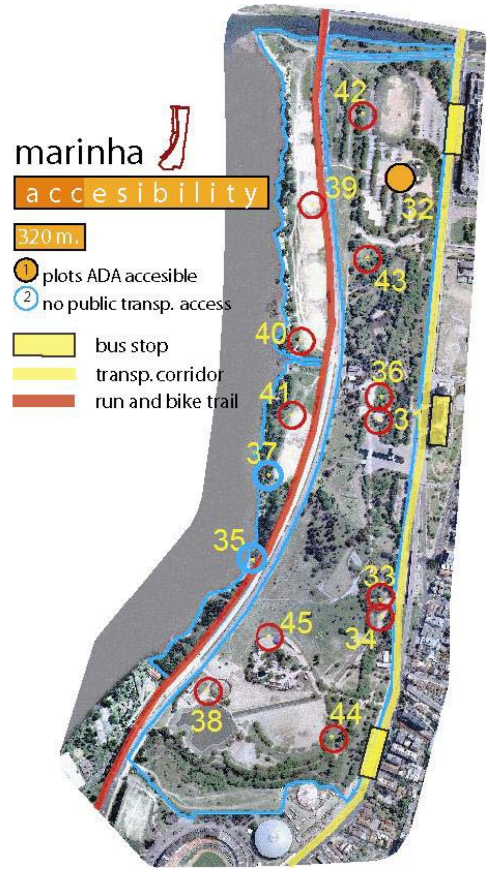


Fig. 8.1.f. Accessibility map for Marinha.

8.1.6.c. CONCLUSIONS – DESIGN STRATEGIES

1. Main transportation corridors running along the park provide numerous access points (bus stops) and bring opportunities to use the park to citizens from longer distances. Again, a free ride bus day opens the park to more public with fewer resources.

2. Any road segregating areas of the park should be carefully considered. The separated areas may easily be perceived as not being part of the park, becoming unused in time and vandalized. If a road is inevitable, solutions for pedestrian connections must provided and attracting activities should take place in those areas to avoid abandonment.

8.2. ECOSYSTEM BIODIVERSITY

8.2.1. FUENLABRADA PARKS – LA SOLIDARIDAD

8.2.1.a. RESULTS

The Park of La Solidaridad in Fuenlabrada had relatively low ratings for ecosystem diversity (**Fig. 8.2.a)**. Only two plots can be considered to contribute positively to this theme, plots P04 and P15. Both of these plots contained water features.

Plots P10, P11 and P12 had lower ecosystem diversity; value and ratings were poor compared to other parks. These plots were composed of 75% park-like ecotypes (trees and grass) and 25% paths, with no protected areas as all plots were artificially created.

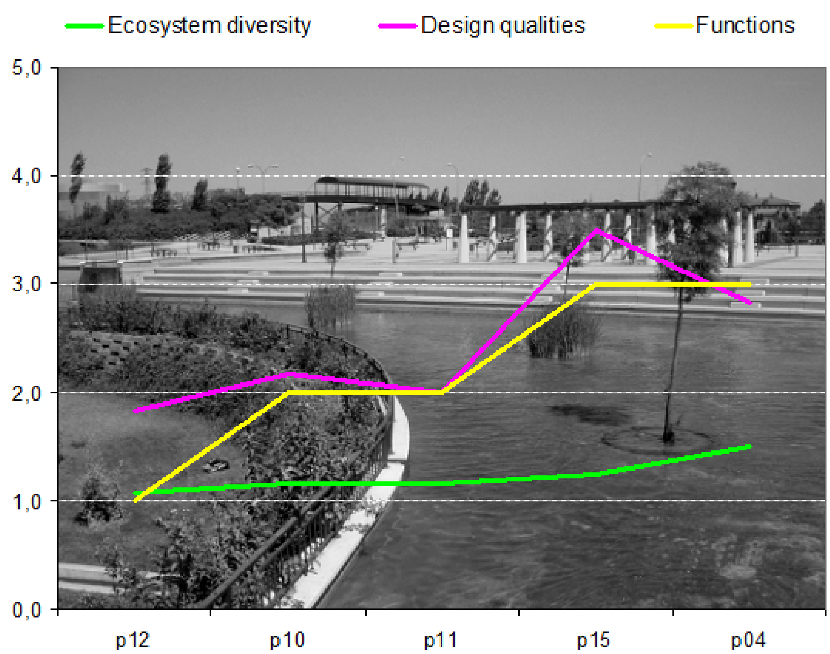


Fig. 8.2.a. Ratings (from 0 to 5) of best plot in La Solidaridad on ecosystem diversity, design qualities, and functions. Ratings were low for biodiversity.

8.2.1.b. DISCUSSION

Plot **P04** (right) is located near an artificial pond with two channels of water, one arriving and one leaving. This water system starts in a water reservoir on the north end of the park and ends in a water pool at the south end. It is intended to be a closed cycle that recycles water and helps with irrigation.

The vegetation in plot **P04** was particularly chosen to match the riparian character and design of the area. Birch, poplars, and other species mimic what riparian vegetation looks like in nature. The water link establishes a connection with the rest of the park that brings a sense of continuity to the user. The ecosystem types were water (40%), paths and riparian vegetation (40%).

Plot P15 is only 50% planted but has a variety of plant forms: trees adapted to live near water, vines in retaining walls, grass on plain terrain, and trees and grass on the rest. Water is again an important aesthetic element, and vegetation is related to its local ecology. Water sounds and waterfalls give this plot a particularly high rating on design quality. Similar to plot P04, this plot has a water protection function in addition to aesthetic and passive recreational functions.

Plots P02 and **P14** (right) have no vegetation and rated the lowest on ecosystem diversity. They are corridors and nodal spaces made out of concrete, with no specific use other than connecting spaces or being gathering places. They may have a good design, but they do not contribute much to biodiversity.

8.2.1.c. CONCLUSIONS – DESIGN STRATEGIES

1. When creating an artificial water system through a park, provide enough diversity of water features: channels, ponds, waterfalls, creeks, etc. to provide ecosystem diversity as well. This will increase the different opportunities for plant and animal species to establish.

2. Use species that are adapted to the type of water ecosystem created: riparian vegetation for creeks, wetland species for ponds, ferns and vines for waterfalls, and so on. One good example in La Solidaridad is the use of *Taxodium mucronatum*, a species specially adapted to live with their roots under water.

3. Protection of soil and water is the main function for these areas. As they are artificially created they can have a pleasant design and paths running through them, so aesthetic and recreation functions can be easily added.

4. Use the water channels and small streams as a way to connect the whole park and provide a sense of unity. This was very well done in La Solidaridad, where the water plays an important role in the identity of the park. Waterfalls, giant water jets, reservoirs and little canals give different senses of place where they are located without losing the picture of the whole.

8.2.2. FUENLABRADA PARKS – EL OLIVAR

8.2.2.a. RESULTS

El Olivar is the park among all parks studied that rated the highest on ecosystem biodiversity. This is because the major area of the park consists of a *dehesa*, a man made traditional ecosystem typical of Mediterranean regions that has excellent ecological values and is considered protected in the Madrid region, where Fuenlabrada is located.

Plots P27, P28, P25, P18 and P20 received the highest value (5), as they all fell in the *dehesa* area. These plots also have good design qualities and a high number of functions (**Fig.8.2.b**). The plot with the lowest rating the functions was P24, a residual space at the entrance of the park.

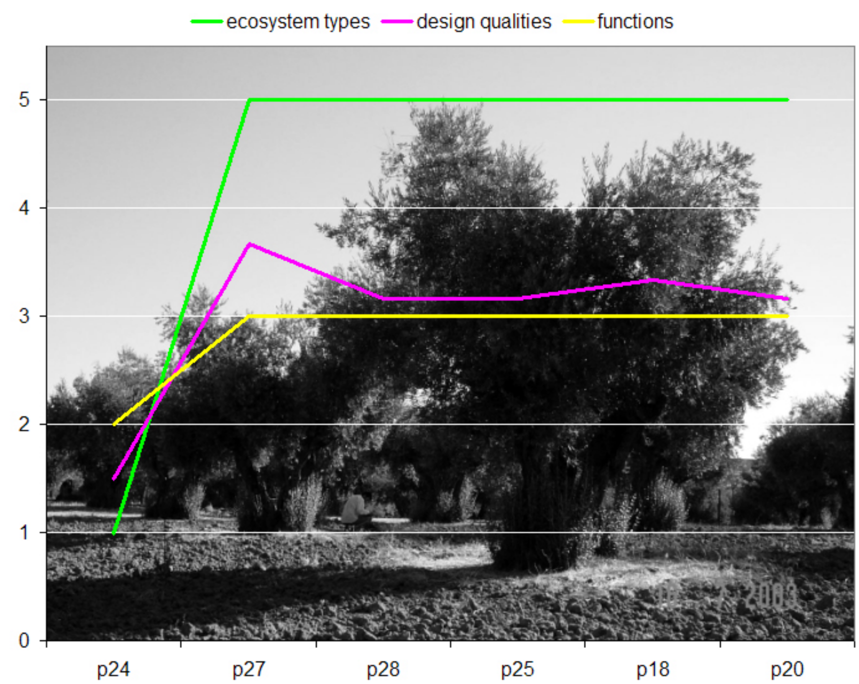


Fig. 8.2.b. Ratings of El Olivar most significant plots on ecosystem diversity, design qualities and functions. Ratings were the highest for biodiversity. Olive trees form the *dehesa* landscape in the background.

8.2.2.b. DISCUSSION

There are several reasons for that all the plots within the *dehesa* rated the highest for ecosystem diversity. First of all, the *dehesa* is a type of ecosystem associated with antique agricultural areas, so in the region of Madrid they are protected. Therefore all the plots have an important preservation role as the *dehesa* is becoming scarce in the region.

The *dehesa* is a working landscape that combines silviculture with pasturelands, and sometimes agriculture as well. It is managed to obtain products from the trees (wood, cork, or fruits) for animals and/or people, grass to feed the cattle, and sometimes other agricultural products. In this case, the products to obtain were olives for the olive oil pressing industry, which was not located in the city. Even today some neighbors come to the park to pick the olives, although they are not the type intended for the table.

As the city grew over surrounding agricultural lands, the olive grove was incorporated into the city and was later transformed into a park. The distribution of trees in a *dehesa* is usually in a grid, to let cattle move around the trees, and trees are pruned to round shape to facilitate the fruit harvesting. As the olive grove was transformed into a park, the production function was soon forgotten and the trees are no longer pruned. As it is a system adapted to the local climate, it does not need irrigation like the other parks.

High values on ecosystem diversity are not only due to being a protected ecosystem. Plots are also 100% remnant vegetation, as the olive grove is over 200 years old. Finally, they are 100% in the *dehesa,* as it is a continuous landscape covering more than 80% of the park area. As the picture taken in plot P27 (right) shows, this continuity is one of El Olivar's main characteristics that give it a strong sense of place. The image also relates to the broader context of a Mediterranean classic landscape that anybody who has traveled in the South of Spain will remember.

Finally, the design qualities of the *dehesa* rated very high as well. Color contrast between the brown dry soil, the yellow grass in the summer, the grayish olive green on the leaves, and the dark barks were astonishing, as can be seen in the picture from plot P20 (right). The strong relationships with the context and grove's past gave high ratings on identity. The horizontality and the geometric lines of the grid were other aesthetic qualities considered.

8.2.2.c. CONCLUSIONS – DESIGN STRATEGIES

1. Existing agricultural areas within or surrounding the city can be successfully incorporated into a park system. The production function may or may not be necessary in the new situation, but other functions can be easily aggregated, such as aesthetic and passive recreation values, that were not originally intended.

2. Old working landscapes have a history that relates to the context of the region. Although the context may have evolved over time, those landscapes preserve in their essence the past of the place and can be used to understand its present and imagine its future. Relation to past and context gives strong identity to those landscapes, and those values should be incorporated while designing the park.

3. When designing green spaces with a considerable amount of space available, an ecosystem could be planned with enough dimensions so the observer will lose any sense of artificiality. While parks are typically designed with small patches of vegetation types inside them, El Olivar is an example of a park with one main large ecosystem, the *dehesa*. One of the most important aesthetic values considered was the fact of being a continuous landscape that sometimes goes further than the eye. This could be a design strategy for large-scale parks to follow.

4. Parks can be used to preserve protected ecosystems. Although preservation may be incompatible with active recreation functions: aesthetics, protection, and passive recreation are compatible. Actually, in this case, the creation of a park led to the preservation of a protected landscape that otherwise may have been lost to urbanization.

8.2.3. FUENLABRADA PARKS – LA PAZ

8.2.3.a. RESULTS

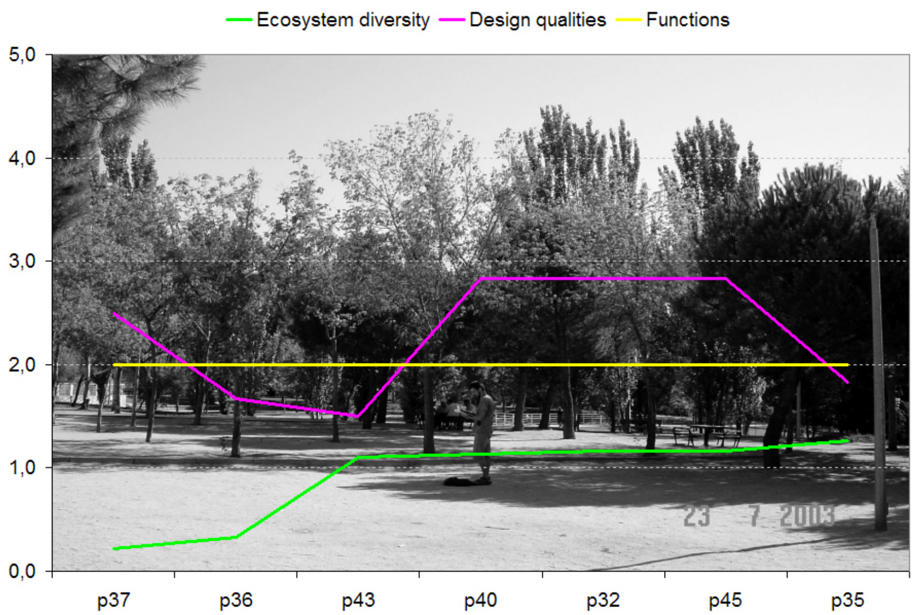


Fig. 8.2.c. Ratings for best and worst plots in La Paz Park. There is no significant relationship between the three variables rated.

La Paz Park did not have high ratings on ecosystem diversity, as shown in **Fig.8.2.c.** The entire area of the park is planted, and there are no emergent, remnant, or protected ecosystems. This was a park established in the 1980's with some variety of species but without attention paid to creating different environments or habitats. Clusters of trees and grass and, intermittently, shrubs compose most of the park.

In almost all plots with good ratings about 40% of the area was bare soil or paths, that is, no green structure. This park had a very hardscape design and some of those concrete areas have remained unused. The remainder of those plots is formed by grass and trees (from 30 to 60% of the area), followed by the grass, shrubs, and trees type of ecosystem (from 15 to 30% of the area).

8.2.3.b. DISCUSSION

Plot P45, P35 and P32 received the best ratings. They all have a good mixture of species that combine hardwoods with shrubs in the background. In plot **P45** (right) trees were planted in parallel lines. This *alleé* works well as a transitional space. It also hides the retaining walls in the background planted with shrubs and conifers and allows for views of the rest of the park.

An unsuccessful example is plot **P36** (right). The ecosystem is nonexistent, as all the area is covered by concrete and bare soil. It is supposed to work as a nodal space for gathering, but it was not being used and therefore had no function. In this case, the lack of vegetation could have been avoided, and the water feature could have been designed to interact with the vegetation. Signs of vandalism were present and reveal the lack of use.

8.2.3.c. CONCLUSIONS – DESIGN STRATEGIES

1. Transitional spaces for pedestrian movement can be designed in combination with tree *alleés*. Trees can be the same in parallel lines or, as in this case, different by rows, leaving usually the denser or bigger trees toward the background.

2. Retaining walls provide opportunities for establishing shrubs on their edges. Usually concrete walls are not aesthetically pleasant, and shrubs can lessen their visual impact on the park landscape. Here they were vandalized (*graffiti*) a situation that could have been avoided by planting shrubs in front of the wall.

8.2.4. PORTO ALEGRE PARKS – FARROUPILHA

8.2.4.a. RESULTS

The plots that rated the highest in relation to ecosystem diversity in Farroupilha were p11, p08 and (**Fig. 8.2.d.).** They also received good design quality ratings, except for p05, a plot located in a corner without use. Plots with low ecosystem diversity also rated low on functions and design quality (p13 and p01).

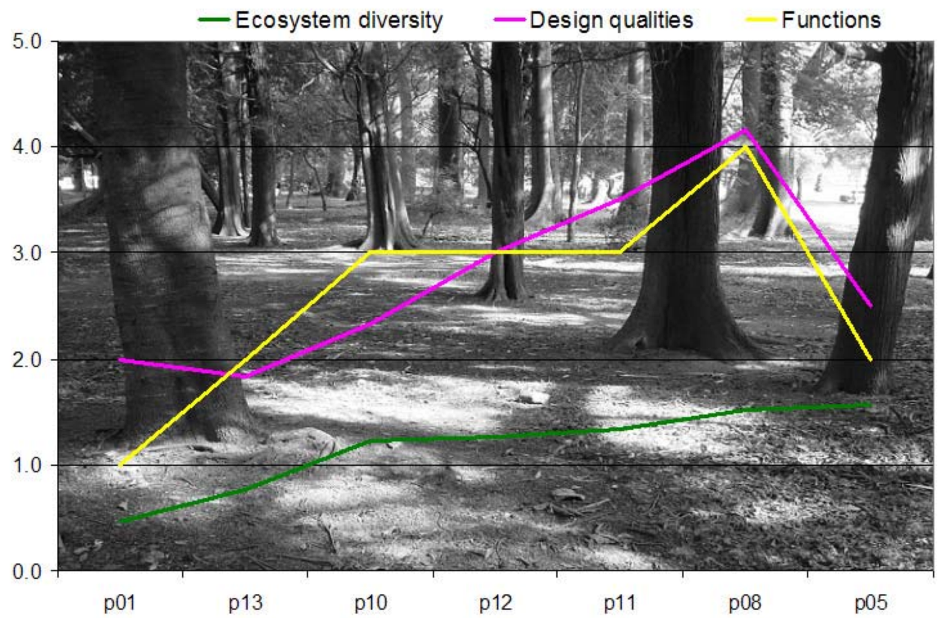


Fig.8.2.d. Ratings for best and worst plots in Farroupilha Park, Porto Alegre, Brazil. There is a relationship between the variables measured except for plot p05.

8.2.4.b. DISCUSSION

Plots with good ratings have almost 100% of the area filled with some kind of green structure. They all have trees and grass, having the best two plots from 50 to 60% of trees combined with shrubs. Plots **p05** (right) and p08 also have emergent vegetation within their boundaries. In this case this is due to management practices in the park: natural regeneration is allowed to happen. Seeds from planted trees are growing, creating shrubbery strata underneath the trees and allowing for a new ecosystem type in the park.

Soccer fields, such as plot **p13** (right) and other sport facilities areas have the lowest ratings on ecosystem biodiversity, as grass would be the only vegetation on them. They also have high maintenance needs and require the use of chemicals and pesticides. It is questionable that the urban park is the best place for locating such activities. A discussion could take place about whether active recreation is important enough to make the place incompatible with other uses.

8.2.4.c. CONCLUSIONS – DESIGN STRATEGIES

1. Allowing natural regeneration to occur in some locations of the park provides green spaces that are rich in ecosystem diversity. Shrubs and small trees grow and will eventually substitute for the decaying ones. This is a more passive than an active planting strategy that replicates how forests behave in nature.

2. Leaving room in the parks for emergent ecosystems is another strategy to follow. This emergent vegetation usually appears in those places under less use, such as interiors of forest, water edges without accessibility or rights of way. It would be a good idea to let native vegetation reach and begin to colonize those places.

3. The ideal function for these areas would be protection as those rich ecosystems would best protect soil and water resources. An aesthetic function could be possible if native landscapes are to be appreciated. Finally, passive and active recreation can take place in the form of a running or strolling path in some areas. Much more than that would compete with the other functions.

4. The presence of water is also common in plots that contribute more to ecosystem biodiversity. This is because water bodies (rivers, ponds, etc) provide rich biotopes for different species, from different plant communities to bird species among other wildlife, to live.

8.2.5. PORTO ALEGRE PARKS – HARMONIA

8.2.5.a. RESULTS

The areas of this park with higher ecosystem diversity also rated the highest for the city of Porto Alegre. They were located near natural water bodies, such as the Guaiba River (plots p16 and p25) and next to a wetland area (plot p29). **(Fig.8.2.e.).**

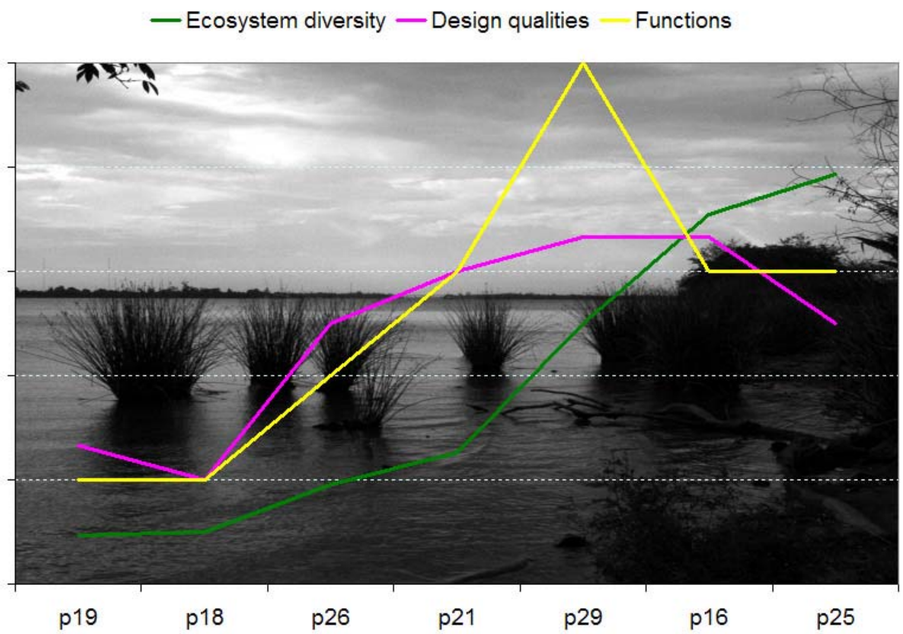


Fig.8.2.e. Ratings for best and worst plots on ecosystem diversity at Harmonia Park, Porto Alegre, Brazil. As ecosystem diversity increases so do the other variables.

8.2.5.b. DISCUSSION

Areas located near rivers or wetlands are higher in ecosystem diversity, and if within 30 m. from the water body they are protected by law. This is the case in plot **p16** and **p25** (right). These areas contain 60 to 100% of emergent vegetation, usually native species whose seeds traveled through water and settled naturally.

The relationship of the park with the water brings enormous design qualities like relaxing views of water, water sounds, associated wildlife, or connections with regional geography and ecology of the river.

Harmonia Park contains some areas that have been left without management, such as plot **p18** (right). Usually they were located close to but not adjacent to the river, in areas with less accessibility across the road that divides the park. These areas of land have no apparent use other than walking through them. During certain times of the year the city rents these spaces for circus and other entertainment shows. They all lack basic design, maintenance, and infrastructure.

8.2.5.c. CONCLUSIONS – DESIGN STRATEGIES

1. If planning for ecosystem diversity, all water bodies should be considered as the prime areas to work with. The interface between water and earth hold a great variety of conditions for different plant and animal communities to live in.

2. The edge of the water is usually a favorite place for passive and active recreation. Bike trails and strolling paths happen spontaneously along these lineal corridors and can be used to connect different areas.

3. Views of the water are usually appreciated, as they offer a relaxing experience to observers. Benches and other street furniture can be located in those spots with better landscape views.

4. Tree planting is better combined here with other elements such as grass mounds or shrubs. Trees entering the water will increase the aesthetic quality of the place. They occur naturally from the seeds carried on the water, but this aspect can be incorporated as a planting strategy.

5. Protection of the water edge is fundamental to the conservation of these areas. Access to water is an important asset to be addressed but should be allowed only in certain locations, leaving room for vegetation and wildlife to behave naturally on the rest.

8.2.6. PORTO ALEGRE PARKS – MARINHA

8.2.6.a. RESULTS

In Marinha Park areas located near the riverfront had high values of ecosystem diversity (plots p35 and p37), as they contain emergent vegetation, riparian vegetation and some protected land. In comparison with Harmonia Park (to which this park is linked trough a bridge), it rated very low on design qualities. Plots p36 and p33 rated high in ecosystem diversity, with the novelty that these are completely artificially established areas. These plots had good ratings in design quality, as trees were meticulously chosen for their aesthetics. The graphic in **Fig. 8.2.f.** shows no direct relation between the three variables studied.

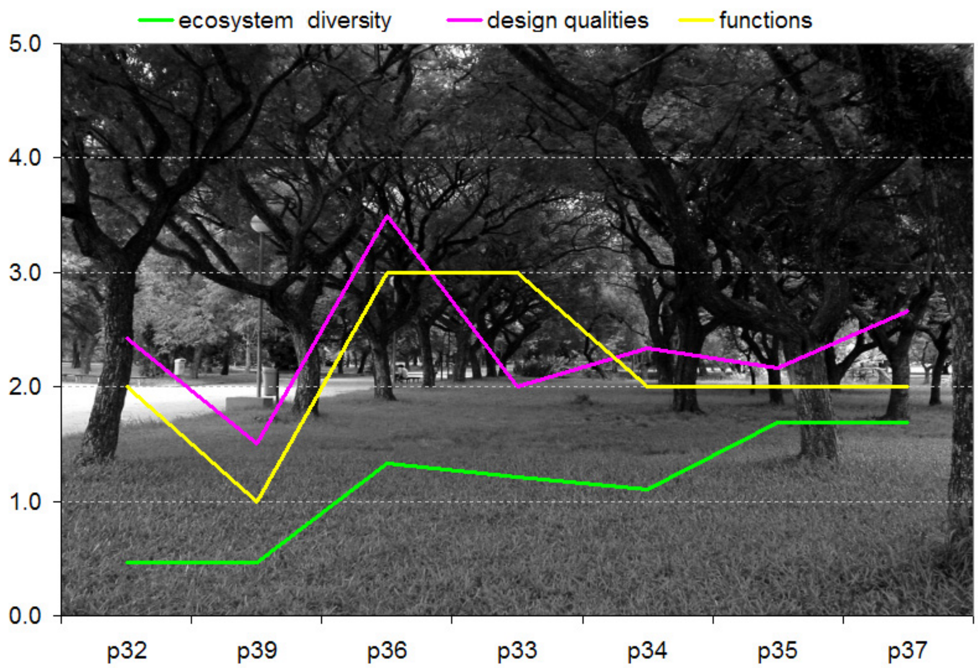


Fig. 8.2.f. Ratings for best and worst plots on ecosystem diversity at Marinha Park, Porto Alegre, Brazil. A clear relation is not apparent.

8.2.6.b. DISCUSSION

Although the results do not follow a trend there are some good design examples in Marinha Park that may be applied in other situations. Low ratings in ecosystem diversity may be explained the fact that few plots fell within protected or completely native vegetation areas. The riverfront areas in Marinha Park, such as plot p35 (right), rated low on design quality as they were isolated from the rest of the park, poorly maintained and dirty. Although they related to the regional

ecology they contained fewer native species than Harmonia Park. Percent of emergent vegetation was also low but riparian vegetation presence was high.

Some planted plots rated high on diversity due to a good selection of species and tree location. One example is plot 36 (right) that fell into a nice artificially created *Tipuana tipu* corridor. Over time the shape and size of the tree creates beautiful shaded corridors of grass for people to rest, run or walk. The gradient of shadow and light created is also excellent and gives the place a strong sense of identity. Other planted areas rated high on design quality due to novel old trees such as in plot p33.

The poorest examples of ecosystem biodiversity in Marinha Park were found in plots p32 and p39. One of these is located on a soccer field, as the case explained for Harmonia Park. The other is an area located in front of the administration building. In this case, the area was planted with exotic ornamental trees and grasses, providing low levels of ecosystem richness but some design quality, as they were arranged in a formal display.

8.2.6.c. CONCLUSIONS – DESIGN STRATEGIES

1. The *Tipuana tipu* corridor is an excellent combination of the right tree fitting in a formally designed promenade. The tree grows in a peculiar way creating a dense canopy that protects from the direct rays of the sun. At the same time it allows enough light and air to go through, as the crowns don't start growing until some considerable height. Although this is not a very varied ecosystem type (just one tree species and grass on the ground) it is very successfully used in the city of Porto Alegre and it is well adapted to the subtropical climate. The lessons to be learned here would be to choose the right tree to form promenades (right shape, water needs, etc) and locate those corridors in transitional areas of the park where circulation is linear (i.e.: along street main corridors, connecting nodal spaces)

2. Protection of the riverfront would be the main function for the areas located adjacent to the river. Preservation of the riparian vegetation would be a consequent function that in the case of Marinha Park was missing due to the artificially established vegetation in most of that area.

3. Make sure that isolated areas without accessibility are also included in the park visually or physically so they don't get abandoned and vandalized with time.

8.3. SPECIES DIVERSITY

The following table summarizes the results for Fuenlabrada parks:

City of Fuenlabrada	Park Area (ha)	Sampled area (ha)	Sampled trees	Sampled species	Species per ha	Shannon diversity index	Menhinick diversity index	Simpson diversity index	Evenness
Solidaridad	12	0.61	101	29	47.8	2.99	2.88	15.40	0.89
El Olivar	10	0.61	158	16	26.4	1.96	1.27	4.27	0.71
La Paz	5	0.61	126	26	42.8	2.92	2.31	16.01	0.90

Table 8.3.a. Species diversity for Fuenlabrada parks.

In general, the more different species planted the higher the diversity of the park. But variety itself is not a value. In terms of design quality and functions, a combination of species works best when relationships among them and with the environment can be established (as it happens in natural ecosystems). It is also desirable the use of native and protected species if possible so the park will have a species preservation function as well.

8.3.1. FUENLABRADA PARKS - LA SOLIDARIDAD

8.3.1.a. RESULTS

The Park of La Solidaridad has the highest species diversity in the city of Fuenlabrada, with almost 48 different species per ha. It is not the park with more trees per area but it has the highest values for species richness, indicated by the Shannon and Menhinick diversity indexes.

Individual plots inside the park were rated considering species diversity but also if they were native and protected. Plots that rated the highest were P07, P03 and P08. The lowest were plots P14 and P02 that had no vegetal species.

8.3.1.b. DISCUSSION

La Solidaridad is the most recent park built in Fuenlabrada, and more attention was paid to species diversity than in other parks. The best plots have from 60 to 100% native species, which were also chosen by the adaptability to the location needed.

Examples of this adaptation to function are the varieties of *Cupressus sempervirens* used on plot **P07** (right). These conifers were chosen for their fine texture, dense and permanent foliage to act as a traffic barrier. Densely planted in three parallel lines, they reduce the noise from the highway and capture pollutants and dust from the cars and surrounding industrial area. See sketch on next page.

Other native species used were *Celtis australis* and *Pinus halepensis*. They were planted with other exotics in a slope with paths on the top and the bottom (plot P03). This design created a nice mix of hardwoods and softwoods with enough distance between them so their silhouettes are perceived individually and allowing views of the rest of the park as well.

8.3.1.c. CONCLUSIONS – DESIGN STRATEGIES

1. Dense foliage conifers such as cypress can be densely planted in rows to create traffic buffers. Their conical shape is suitable to create vegetation walls that stop dust and pollutants from combustion and reduce the "white noise".

2. Another strategy to be followed from La Solidaridad was the creation of an orchard for the elderly with fruit species. Although the orchard trees are in good shape they are not functioning as an orchard due to a lack of agreement with park mangers.

3. In transitional areas such as slopes with paths with the functions of aesthetics and passive recreation, a combination of well-adapted hardwoods and softwoods can be planted at intervals of 5 to 10 m. This allows for perceiving their aesthetic values individually and to engage the rest of the scenery through them. Usually smaller trees are located near the top of the slope and bigger at the bottom.

Sketch showing the use of dense planted conifers on a slope as an effective barrier against traffic noise and pollution. Scattered hardwoods allow for park views on the other side.

8.3.2. FUENLABRADA PARKS – EL OLIVAR

8.3.2.a. RESULTS

City of Fuenlabrada	Park Area (ha)	Sampled area (Ha)	Sampled trees	Sampled species	Species per ha	Shannon diversity index	Menhinick diversity index	Simpson diversity index	Evenness
El Olivar	10	0.61	158	16	26.4	1.96	1.27	4.27	0.71

Table 8.3.b. Species diversity for El Olivar Park.

El Olivar is the park of Fuenlabrada that rated the lowest in species diversity. Although it is the park with more trees, it only has about 26 species per hectare. Plots with highest species diversity were P21, P23 and P30. Plots P29 and P24 rated the lowest.

8.3.2.b. DISCUSSION

El Olivar is a *dehesa* system, that is, a monoculture of olive trees. This is the reason why although it has more trees than any other park the diversity was the lowest. In this park no relationship was found between species diversity, design qualities and functions. There are plots with many species rating low on design quality and the opposite was found as well.

Plot **P23** (right) is an example of a plot with high diversity (5 different species 4 of them native) that rated low on aesthetics. This is because species were mixed without any criteria. Conifers, hardwoods and palms were planted in this edge area without any relation to each other or to the surrounding olive grove. Although variety exists, there is a lack of identity and sense of place.

In some plots, like **P22** (right), some pines (*Pinus pinea)* were introduced in the dehesa. Although diversity of species is increased, the aesthetics and identity was poorer. Those trees relate to the Mediterranean coast and not to the inland environment, the past of Fuenlabrada or the surrounding context.

Finally, there were plots with low diversity (such as plot P29) that rated high on aesthetics and functions.

8.3.2.c. CONCLUSIONS – DESIGN STRATEGIES

It can be concluded, at least from this park, that high diversity of species doesn't bring good design qualities. There must be criteria for choosing them so they are related to each other and the environment. These are some strategies.

1. When selecting different species to plant it is desirable that they share some characteristics. Studying the local plant communities may help the discovery of relationships among plants and with the surroundings. The case of El Olivar shows an intelligent re-use of *Olea europaea,* a productive species transformed here into ornamental.

2. An interesting combination of species can also happen over time. Opposite to what is being done in El Olivar. Conifer and other pioneer species can be planted first when a park is been built and no vegetation is installed yet. As they grow and shaded areas are created, shade species and others in the following steps of the natural succession can be introduced. The opposite was being done in El Olivar without apparent reason (planting pines in a ancient established olive grove).

3. In some places of Fuenlabrada, left over plants from the city's nursery were planted where room was available for them. That resulted in vegetated areas with low design qualities. This is another example not to be followed. Trees should be grouped in a way that they can be identifiable as individuals but as a plant community as well.

8.3.3. FUENLABRADA PARKS – LA PAZ

8.3.3.a. RESULTS

City of Fuenlabrada	Park Area (ha)	Sampled area (ha)	Sampled trees	Sampled species	Species per ha	Shannon diversity index	Menhinick diversity index	Simpson diversity index	Evenness
La Paz	5	0.61	126	26	42.8	2.92	2.31	16.01	0.90

Table 8.3.c. Species diversity for La Paz Park.

La Paz is the park in second place regarding species diversity for Fuenlabrada, with about 43 species per hectare. In La Paz Park there is a relationship between species diversity and design qualities, as the graphic shows in **Fig. 8.3.a.**

Plots P39 and P32 got the highest ratings for species diversity and P37 and P36 got the lowest (they were also the lowest on ecosystem diversity) as there is no vegetation on them. The functions were aesthetics and passive recreation for all plots.

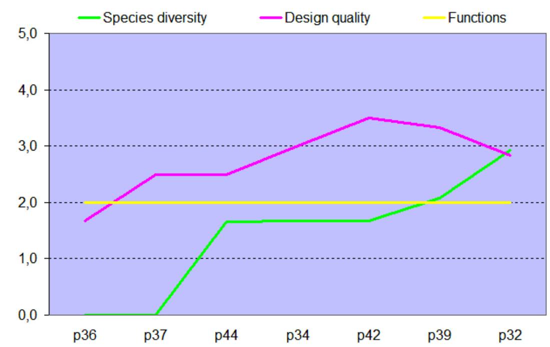


Fig. 8.3.a. Species diversity, design qualities and functions for La Paz Park.

9.3.3.b. DISCUSSION

When this park was built, managers where trying new species in the city so they experimented in this park with some species, mostly exotic, that were new in the nursery market to test their adaptability. In some areas, trees where grouped by genus, like a plaza of maples.

Plot **P39** (right) is a good example of 5 mixed species, 3 being native. In a corner location, conifers, palms and hardwoods are group in the following manner: conifers are lined defining one edge of the park; hardwoods are planted on a perpendicular line forming a dense wall that hides vehicular traffic, the native palms and *Ficus* are planted in the towards the interior. Finally shrubs complete the vegetation in the transitions between levels.

Plots with the lowest ratings were P36, without any vegetation, and P37, a plot in the edge of the park with only a line of one species, the exotic *Celtis occidentalis.*

9.2.3.c. CONCLUSIONS – DESIGN STRATEGIES

1. When planting trees from different families (conifers, hardwoods, palms) it seems to be more successful in terms of design qualities to group them under some criteria (in this case, the family taxon). If those groups can be linked to some geometrical layout the design is more aesthetically pleasant. Lines of trees of the same species help to establish a hierarchy in the place and can define the limits of different areas in the park.

2. An example of using species diversity in a design was found in La Paz. The maple square is a paved plaza with around 10 varieties of the maple genus. Exotics and natives are mixed here for an educational an aesthetic purpose.

8.3.4. PORTO ALEGRE PARKS – FARROUPILHA

8.3.4.a. RESULTS

City of Porto Alegre	Park Area (ha)	Sampled area (ha)	Sampled trees	Sampled species	Species per ha	Shannon diversity index	Menhinick diversity index	Simpson diversity index	Evenness
Farroupilha	40	0.61	147	39	64.3	3.09	3.22	13.83	0.84

Table 8.3.d. Species diversity, design qualities and functions for Farroupilha Park.

Farroupilha Park is the one with the highest diversity of species among the six studied in both cities. The diversity indexes show a great richness of species, approximately 64 species per hectare. Plots with highest ratings were p05, p07 and p08. Lowest ratings were for p14 and p06.

8.3.4.b. DISCUSSION

This park was designed in the early 1930's following a traditional European design style. The park was divided in sections by countries: the European quarter, the Alpine quarter, the Solar quarter and the Japanese quarter. Species were planted in relationship with those themes resulting on a great variety of plants, being exotics predominant over the natives.

An interesting practice, already mentioned in the ecosystem diversity chapter, is that park managers let natural succession happen in some areas. In those areas it is possible to find pioneer natives that are competing with the planted species. In the choice of species attention was paid for edible fruit plants such as *pitangueira (Eugenia uniflora)* and *cerejeira (Eugenia involucrate)*.

Plot **p08** is located on the edge of the main water pond; it includes 11 different species with 4 of them being native. Some are big native trees, such as *Rapanea umbellata, Chorisisa speciosa* or *Erythroxylum argentinum,* which give good aesthetic quality to the place. Patterns such as singular tree, reflections on the water, the silhouette over the lake and roots on the path are directly related to those trees. Towards the background, new trees of *Allophylus edulis* are growing spontaneously bringing a wilderness look to the whole area. Plot **p05** share the same characteristics although its location in a residual space lessens its aesthetic quality.

Plot **p05** is an example of a plot with low species diversity but good design qualities. It is located in the main axis of the park, where paved walks and some flowerbeds surround a rectangular water pond. As mentioned before, diversity of species was not directly related to design quality or functions in Farroupilha Park.

8.3.4.c. CONCLUSIONS –DESIGN STRATEGIES

1. Letting natural regeneration happen in the park will increase the variety of species, as new plants will appear from the existing bank seed in the soil and the seeds from surrounding species.

2. The use of natives is generally a good idea when trying to create a place with local character. Choosing those natives with particularly outstanding shapes, colours and forms will contribute to the overall aesthetic quality of the place. In the case of Porto Alegre, this has been achieved in Farroupilha Park with species such as *Rapanea umbellata, Chorisisa speciosa* or *Erythroxylum argentinum.*

3. Species that produce edible fruits can be also used to increase the design qualities and functions of the park. In this case, *pitangueira (Eugenia uniflora)* and *cerejeira (Eugenia involucrate)* were planted in accessible locations of the park, feeding not only people but animals as well.

8.3.5. PORTO ALEGRE PARKS – HARMONIA

8.3.5.a. RESULTS

City of Porto Alegre	Park Area (ha)	Sampled area (ha)	Sampled trees	Sampled species	Species per ha	Shannon diversity index	Menhinick diversity index	Simpson diversity index	Evenness
Harmonia	59	0.61	46	11	18.1	2.00	1.62	6.72	0.83

Table 8.3.e. Species diversity, design qualities and functions for Harmonia Park.

Harmonia Park is the park with the least species diversity of the six with only 18 species per hectare approximately. Plots with high diversity and low diversity are shown in the graph on the right. Although there is not a linear relation between the variables measured, design quality and function were higher where species diversity was higher as well, a low in those plots without tree species.

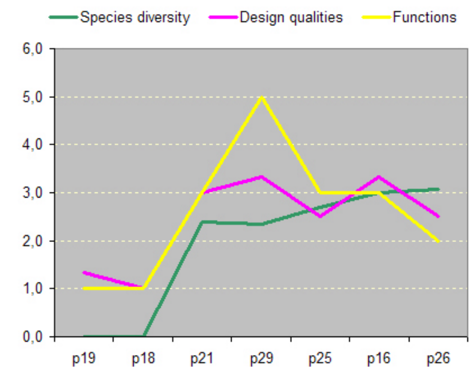


Fig. 8.3.b. Species diversity, design qualities and functions for Harmonia Park.

8.3.5.b. DICUSSION

Plots with low diversity, p19 and p18, were the same for low ecosystem diversity. They are vacant areas of the park without any management that are used for temporary activities (like a circus).

Plot **p29** (right) had only 2 species, but one is a native with protected status, *Erythrina crita-galli*, whose red flowers, shape and adaptation to the wetland environment gave a high rating on design qualities and functions (all but production).

Plot p16 in the riverbank was mentioned already by having spontaneous emergent vegetation. It has 5 different species, all of them native as their seeds came from the river. Although it is not a designed space, design qualities are good due to the variety of plants, the fact of not being vandalized and an interesting relation to the river environment. In general, the percentage of native species in Harmonia Park was high.

8.3.5.c. CONCLUSIONS – DESIGN STRATEGIES

1. The use of protected species with good aesthetic qualities is the best option to increase diversity and augment overall design qualities. Protection and preservation functions are added as well. The use of *Erythrina crita-gallii,* (corticeira do banhado), is an excellent example for wetlands in Porto Alegre.

2. Emergent species in areas that are unmanaged can contribute to design quality as they relate to the surrounding ecology and can be used to interpret how natural processes can create landscapes. In the case of Porto Alegre, the riverbank is a rich source of information about native species and colonization.

8.3.6. PORTO ALEGRE PARKS – MARINHA

8.3.6.a. RESULTS

City of Porto Alegre	Park Area (ha)	Sampled area (ha)	Sampled trees	Sampled species	Species per ha	Shannon diversity index	Menhinick diversity index	Simpson diversity index	Evenness
Marinha	67	0.61	32	16	26.4	2.43	2.83	10.78	0.88

Table. 8.3.f. Species diversity for Marinha Park.

Marinha Park is the second best on species diversity for Porto Alegre, although it has the same number of species per hectare (26) as El Olivar, which was the less diverse park for Fuenlabrada. Best plots were p43, p33 and p37. Worst plots were p38 and p41.

8.3.6.b. DISCUSSION

Plot **P43** (right) is a plot located near several active recreation spots such as a skate park and a playground. Three different species, two natives, one of them protected (*Ficus enormis)*, fell in the plot. The area is designed with scattered trees over a grass field. The place is successfully used for resting, sitting or chatting by the young who use the sport facilities. The openness and view of the river makes it attractive as well.

Plot **37** (right) has similar diversity of species, 3 different natives, but the quality of the place lies in the presence of a splendid specimen of *Inga vera*, whose size and peculiar shape bring identity to the place. Its location in a difficult accessible area of the riverbank made this area dangerous and underused. It is adjacent to a soccer field rarely used for the same reason.

8.3.6.c. CONCLUSIONS – DESIGN STRATEGIES

1. Scattered trees planted over grass near sport facilities provide nice areas for resting and other passive recreation (reading, talking, sleeping, etc.)

2. Singular trees with peculiar shapes and sizes bring identity to a place and make it appealing for users.

8.4. CARBON STORAGE AND SEQUESTRATION

As trees grow, they remove atmospheric CO_2 through photosynthesis processes and store C in their tissues. CO_2 and other gases are thought to contribute to an increase in atmospheric temperatures by trapping certain wavelengths of radiation. By removing and storing atmospheric carbon park trees contribute to reduce the greenhouse effect.

The results from this chapter were calculated by applying UFORE Model C from the USDA Forest Service to the tree data collected in the parks. The model estimates the tree biomass, tree growth and death, to calculate carbon storage, carbon sequestration and net carbon sequestration. For more details refer to the methods chapter.

Carbon storage is the amount of carbon trees have incorporated in their biomass through the years. Carbon sequestration is the amount of atmospheric carbon the trees store every year. As trees die carbon could be eventually released by wood decomposition. Net carbon sequestration is calculated by subtracting from the total carbon sequestration, the potential release of carbon due to tree death.

The more tree cover a park has, the more carbon will be stored in the park. To be able to compare between parks, the results are first shown total and then in relation to area.

8.4.1. LA SOLIDARIDAD PARK

8.4.1.a. RESULTS

Parks	Trees (no.)	Carbon storage (kg)	Carbon seq (kg/yr)	Net carbon seq (kg/yr)
La Solidaridad	1,990	11,820	1,800	1,750

Table 8.4.a. Total C storage and sequestration for La Solidaridad Park.

Parks	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
La Solidaridad	**166.4**	**988.8**	**150.2**	**146.2**
Carolina poplar	8.2	146.6	16.3	15.9
White poplar	6.6	120.9	14.5	14.2
Atlas cedar	6.6	101.5	6.5	6.3
Italian cypress	32.9	83.1	12.1	11.8
Common pear	13.2	73.8	15.4	15.1
Chinaberry	14.8	47.0	12.2	12.0

Table 8.4.b. C storage and sequestration per area for La Solidaridad Park

8.4.1.b. DISCUSSION

La Solidaridad is the park in Fuenlabrada with the lowest amount of carbon stored (11,820 kg). This is because carbon storage is greater for large trees, and La Solidaridad is the park with the youngest tree population as it is the most recently built park.

Carolina poplar is the species with the highest amount of carbon stored, followed by White poplar. Poplars have one of the highest growth rates among trees, and as carbon is stored trouhg tree growth, carbon storage was the highest as well. Carolina poplar and common pear were the trees with the highest net carbon sequestration in La Solidaridad.

8.4.1.c. CONCLUSIONS – GENERAL AND SPECIFIC DESIGN STRATEGIES

If the purpose of a park was to store and sequester carbon from the atmosphere, the design and management strategies are going to be very similar for every park, with some difference depending of the park structure (species composition, age of the trees, maintenance practices, etc.). **General strategies** should be oriented to:

1. **Maintain the existing cover**

To keep the carbon already stored in the trees and maintain the current levels of carbon sequestration.

2. **Increase tree cover**

To augment the levels of carbon sequestration per year and total carbon storage.

3. **Select long-live species**

Carbon sequestration and storage rates are highest in trees with larger size. By selecting species that live long and develop large diameters carbon storage and sequestration will be maximized

4. **Avoid the use fuel based machinery**

Machinery is used quite often in parks for maintenance purposes. The machinery usually employs oil-based fuel and emits CO_2 as a product of combustion. These emissions reduce drastically the benefits obtain by tree removal and carbon storage. Management strategies should find ways to avoid the use of fuel. Increasing manual labor or searching for less polluting fuels may be an option.

5. For the case of La Solidaridad the strategies are also the mentioned above, although as a young park, the main recommendation is to maintain the existing tree cover in healthy conditions and introduce more long-live species to substitute the dying trees.

Poplars (picture on the right) are good trees for the first years of the park as they grow fast. They can establish quickly a canopy cover that allows for other species to be planted. But, although carbon sequestration is high in the first years for poplars, these trees have a short live and die faster than others. As dying trees may release the carbon in to the atmosphere through decomposition, long-live species are preferred as they store carbon for a longer period. If poplar wood from dying trees is used as a product, carbon can still be stored.

8.4.2. EL OLIVAR

9.4.2.a. RESULTS

Parks	Trees (no.)	Carbon storage (kg)	Carbon seq (kg/yr)	Net carbon seq (kg/yr)
El Olivar	2,665	682,650	19,250	17,240

Table 8.4.c. Total C storage and sequestration for El Olivar Park

Parks	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
El Olivar	**260**	**66,671.8**	**1,880.5**	**1,683.7**
Olive tree	117.0	60,757.8	1,517.5	1,352.6
Siberian elm	26.4	1,990.5	103.4	86.0
Italian stone pine	21.4	1,462.2	59.3	52.0
Carolina poplar	13.2	1,075.4	64.5	62.0
Black locust	28.0	437.7	57.5	55.8

Table 8.4.d. C storage and sequestration per area for El Olivar Park

9.4.2.b. DISCUSSION

The case of El Olivar is a great example of park contributing to carbon storage and sequestration. With only 2,665 trees it has 682,650 kg of C stored and sequesters 19,250 kg of C every year. This C stored accounts approximately for 92% of the total C stored by the three parks in Fuenlabrada.

The explanation for these outstanding results lays in the olive grove. The main area of El Olivar Park is composed of a remnant olive grove, with very old olive trees. These olive trees, as seen in **Table 8.4.d.**, store 66,671 kg of C per hectare in El Olivar Park (91% of the total in the park). These olive trees are very old and have great diameters (picture on the right); the amount carbon stored in their tissues reveals the importance of preserving remnant forests.

A remnant patch of Italian stone pine and Siberian elms also belongs to El Olivar Park. Their carbon storage and sequestration rates, although lower than the olive trees, is much higher than in La Solidaridad or La Paz. Those areas are worth preserving as well.

9.4.2.c. CONCLUSIONS – DESIGN STRATEGIES

1. General carbon strategies mentioned in 8.4.1.c.

2. Preserving the olive grove is essential for El Olivar Park. Being the olive grove so old, trees are more prone to suffer attacks from pests and diseases. Maintenance and supervision practices should be increased for this area.

3. Dead trees can release trees into the atmosphere through decomposition. If this happens, benefits from carbon storage may be lost or reduced. A way to keep the carbon stored is to use wood from trees for products. Olive tree wood is has very good characteristics and could be employed for new uses. Boardwalks, benches, planters, fences, trashcans and other street furniture could be made of dead trees. The reuse of wood will also keep some of the olive grove identity in place.

4. Using wood for burning is another alternative. Although this option does not maintain the carbon in the wood, it substitutes instead the use of polluting fuel for a renewable resource. Thinking about parks as renewable source of energy may be a new role for parks much more in accordance with the urban sustainability goals than aesthetics.

8.4.3. LA PAZ

8.4.3.a. RESULTS

Parks	Trees (no.)	Carbon storage (kg)	Carbon seq (kg/yr)	Net carbon seq (kg/yr)
La Paz	963	42,200	2,570	2,450

Table 8.4.e. Total C storage and sequestration for La Paz Park

Parks	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
La Paz	**207**	**9,091.3**	**554.4**	**527.3**
Chinese poplar	24.7	4,668.8	206.1	195.4
Northern hackberry	26.4	633.8	29.6	28.2
London planetree	4.9	531.3	32.6	31.3
Boxelder	13.2	445.3	39.3	35.7
Southern catalpa	13.2	313.4	34.1	33.2

Table 8.4.f. C storage and sequestration per area for La Paz Park

8.4.3.b. DISCUSSION

La Paz Park contributes to carbon storage by keeping 42,200 kg of C and sequestering 2,570 kg per year. Although it has the least number of trees, the carbon sequestration rate is higher than in La Solidaridad Park, as the trees are lager here. This park was built in the 1980's and La Solidaridad was built in the 1990's.

Chinese poplar is again the genus with the highest carbon stored followed by Northern hackberry and London planetree. On carbon sequestration Chinese poplar is the first followed by Boxelder and Southern Catalpa.

8.4.3.c. DESIGN STRATEGIES

1. General strategies described in 8.4.1.c. apply.

8.4.4. FARROUPILHA PARK

8.4.4.a. RESULTS

Parks	Trees (no.)	Carbon storage (kg)	Carbon seq (kg/yr)	Net carbon seq (kg/yr)
Farroupilha	9,774	2,793,390	103,960	92,370

Table 8.4.g. Total C storage and sequestration for Farroupilha Park

Parks	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
Farroupilha	242	69,210.6	2,575.8	2,288.7
Perfume eucalyptus	11.5	13,861.6	379.8	325.2
Beakpod eucalyptus	9.9	13,467.1	328.0	227.3
Paineira	9.9	11,582.1	316.2	279.8
Tipa	16.5	10,835.4	355.8	331.1

Table 8.4.h. Total C storage and sequestration for Farroupilha Park

8.4.4.b. DISCUSSION

Farroupilha Park is the oldest park in Porto Alegre, and the one with the greatest contribution to C storage and sequestration. Its 9,777 trees store approximately 2,793,000 kg of carbon and every year they sequester 93,370 kg.

This park has great similarities with El Olivar. The number of trees per hectare are alike (242 versus 260) and the carbon storage per area too (69,210 versus 60,757). It seems then that preserving existing parks is vital for carbon storage and sequestration, as they are both the oldest parks of the city and have the greatest contribution on this theme.

In terms of contribution by species, two exotic Eucalyptuses had the greatest amount of carbon stored (high rate growth species again), while in carbon sequestration Tipa and Paineira are the second best. Paineira (*Chorisia speciosa*) is a native species a singular morphology and could be used to give character to places (picture on the right).

8.4.4.c. DESIGN STRATEGIES – CONCLUSIONS

1. General strategies described in 8.4.1.c. apply.

2. In Farroupilha Park, fuel based machinery is used for maintenance. Some of this labor could have been done manually or using non-polluting sources. The picture on the right shows the trash removal truck.

3. As in the case of El Olivar, it is of great importance to think about later uses for wood in the park for dead trees, such as construction or landfill.

8.4.5. HARMONIA PARK

8.4.5.a. RESULTS

Parks	Trees (no.)	Carbon storage (kg)	Carbon seq (kg/yr)	Net carbon seq (kg/yr)
Harmonia	4,469	567,190	31,690	30,010

Table 8.4.i. Total C storage and sequestration for Harmonia Park

Parks	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
Harmonia	**76**	**9,616.5**	**537.2**	**508.8**
Salgueiro	16.5	5,734.2	221.7	204.8
Tipa	6.6	1,502.6	89.2	85.7
Inga banana	11.5	1,023.7	82.8	79.7
Timbauva	1.6	479.4	26.9	25.8
Sarandi	9.9	466.6	50.6	48.3

Table 8.4.j. C storage and sequestration per area for Harmonia Park

8.4.5.b. DISCUSSION

Harmonia Park has the lowest contribution to carbon storage and sequestration. With 76 trees per hectare, the storages 9,616 kg per hectare and sequesters annually 509 kg. Although the amount seems low for Porto Alegre and is obvious the necessity to increase the tree cover in this park, the results are much higher when compared to La Paz and La Solidaridad parks in Fuenlabrada.

The highest carbon storage and carbon sequestration rates are for Salgueiro (*Salix humboldtiana),* the native willow. Many of these trees belong to emergent patches located in the riverfront of the Guaiba and colonize the terrain naturally. All of the following species but Tipa are native trees to Brazil.

8.4.5.c. DISCUSSION – DESIGN STRATEGIES

1. General strategies described in 8.4.1.c. apply.

2. Preserving emergent patches may be vital for carbon storage and sequestration. Most of these naturally vegetated areas remained unmanaged by the city parks department. If in a park there are areas of less accessibility or unutilized, they may remain as land where natural succession can occur or native species can colonize. This strategy was mentioned before for biodiversity but applies as well for carbon storage and sequestration.

3. Long-live and low maintenance species should be selected for maximizing carbon storage benefits. In the case of Porto Alegre, the Timbauva and Inga banana have been very successful in the past.

8.4.6. MARINHA PARK

8.4.6.a. RESULTS

Parks	Trees (no.)	Carbon storage (kg)	Carbon seq (kg/yr)	Net carbon seq (kg/yr)
Marinha	53	12,840.7	582.7	540.6

Table 8.4.k. Total C storage and sequestration for Marinha Park

Parks	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
Marinha	**53**	**12,840.7**	**582.7**	**540.6**
Inga banana	13.2	4,246.1	150,4	138.2
Paineira	1.6	1,698.9	56.4	52.6
Canafistula	1.6	1,679.1	56.3	52.5
Australian pine	8.2	1,380.4	59.6	52.1
Brazilian pepper	6.6	697.3	55.3	52.4

Table 8.4.l. C storage and sequestration per area for Marinha Park

8.4.6.b. DISCUSSION

With the least number of trees per hectare (53 trees/ha), Marinha Park storages 12,840 kg per hectare and sequesters 540 kg per hectare. As explained before, these results are directly related with the size of the trees, being the rates highest for those threes with larger diameters and wider canopies.

The three species with highest rates in Marinha area native: Inga banana, Paineira and Canfistula. They all develop great forms and wide canopies and show good criteria for species selection among Marinha designers.

Another excellent idea found in this park was an area designated for treating the residues from the urban forest (picture on the right). Branches, leaves, dead trees and other woody residues from parks and streets are brought to this center for recycling. Most of them are chipped and left for making compost to be used later as natural fertilizer. Other bigger woody materials are employed for landfill and other uses.

8.4.6.c. CONCLUSIONS – DESIGN STRATEGIES

1. General strategies described in 8.4.1.c. apply.

2. Recycling woody materials from urban forest is an excellent sustainable strategy. A collection center allows for distributing those residues into several uses. Larger logs can be used for wood products, medium size for burning purposes and the smaller ones can be transformed into compost. Giving a use to residues does not only reduce the cost of eliminating them but increases the value of the urban forest as a useful resource.

8.5. WATER AND SOIL PROTECTION

Parks can contribute to the protection of water because vegetation, when located near water bodies, helps to increase infiltration and reduce evaporation. They also can contribute to the protection of soil resources when vegetation is planted on soils vulnerable to compaction or erosion by retaining the soil particles and allowing for aeration.

Following the same methodology as with biodiversity and accessibility, the assessment of water and soil protection in the parks was done through examining the plots with the best ratings on this theme to find design strategies. The percent of land protected is also shown in the results as well as the wasted watering for the parks. Impervious surfaces (paths, pavement, buildings) were excluded from wasted watering so the percents do not add up to 100.

In general, the plots rating highest in soil and water protection did not necessarily coincide with those rating best on design qualities and functions. Some plots that protect erosion were located on steep slopes where other functions, such as recreation, are difficult to locate. In some cases, plots with low ratings on water and soil protection rated high on design qualities. For instance, unsustainable practices like watering help to maintain a variety of exotic and water demanding species that had good aesthetic qualities.

8.5.1. FUENLABRADA PARKS – LA SOLIDARIDAD

8.5.1.a. RESULTS

Plots in La Solidaridad Park did not rate very high on water and soil protection. The plots with highest contribution were P04, P08 and p02. The plot with the lowest rating was P09. When matching water and soil protection ratings with design qualities and function ratings no apparent relationship was found for this park. The percent of land protected and wasted watering is shown in **Table 8.5.a.** Wasted watering was high for La Solidaridad as most of the area in this park is watered three times a week. Water resources were protected in 13% of the area.

% Of land protected from erosion	% Of land protected from compaction	% Of land protecting water resources	**Watering waste**				
			No water need	Seldom	<3 /week	Daily	Water needed
9%	0%	13%	13%	24%	40%	21%	0%

Table 8.5.a. Soil and water protection in La Solidaridad Park

8.5.1.b. DISCUSSION

Plot P04 (right) had the greatest ratings on water protection. Although it is an artificial pond with canals, trees are planted on its surroundings reducing evaporation and increasing water collection. This water is part of a larger supply system, that recycles water from a reservoir uses it for irrigation purposes.

A permanent irrigation system (automatically managed) was employed in this park, reducing wasted watering and maintenance costs.

8.5.1.c. CONCLUSIONS – DESIGN STRATEGIES

1. If creating artificial water systems, mimicking natural patterns helps to create a sense of living space. Riparian vegetation fits surrounding small ponds. Gentle slopes slow down water speed and gives a sense of tranquility.

2. When designing with water it is recommended to take advantage of changes in elevation. In this park, natural elevation changes were used to create cascades and water features like water jets. Those spaces were people's favorite and attracted numerous users to the park.

3. Utilize water systems to connect the elements of the park and give unity

4. A recommendation for La Solidaridad is to use the water canal that already exists for irrigation of more areas. For the existing orchard, watering needs are high so fruit trees adapted to local weather should be encouraged when selecting species.

8.5.2. **FUENLABRADA PARKS – EL OLIVAR**

8.5.2.a. RESULTS

The best plots for El Olivar were P24, P21, P26, P28 and P18. The worst plot was P29. P21 and P26 were both two *dehesa* plots with 100% of their area without watering needs and 95 of the area protected by the trees against compaction. P18 and P28 had similar conditions with 80% of the land protected from compaction. All of them got good ratings on design qualities and functions (aesthetics, preservation and protection).

% Of land protected from erosion	% Of land protected from compaction	% Of land protecting water resources	**Watering waste**				
			No water need	Seldom	<3 /week	Daily	Water needed
13%	54%	1%	70%	12%	3%	10%	0%

Table 8.5.b. Soil and water protection in El Olivar Park

Protection from compaction was very high in El Olivar with 54% of the land protected. Wasted watering was very low as 70% of the area has vegetation adapted to the local climate and no watering is needed.

8.5.2.b. DISCUSSION

It should be noted that plot P24 (right) with the highest contribution to soil and water protection got very low ratings on design qualities. A former old pine grove protects the soil and needs no watering. It is located on a corner of the park, in the top of a slope where it collects water coming from near roofs. It is not accessible nor it has other function rather than protection and maybe passive recreation.

P21 and P26 are two plots that fell in the *dehesa* and are rated very similar. As the olive grove is adapted to the local climate it has no need for watering. The soil in the *dehesa* is labored once a year as it used to be when it was an agricultural land. The breaking of the soil surface allows for water infiltration, let the olive roots breath and the trees protect the soil from erosion.

The worst plot was P29 the formal entry to the park. This plot had little vegetation and is mainly concrete pavement. The formal arrangement gave it good design qualities but its ratings on sustainability were low on most themes.

8.5.2.c. CONCLUSION – DESIGN STRATEGIES

1. Areas of the park with soil compaction problems could be labored to break soil surface and allow infiltration, let tree roots breath and protect from flooding.

2. Remnant woodlands are very efficient in wasted watering, as they are already adapted to local climate conditions and need no watering.

3. Some locations of the park were located near buildings. In some areas water was dropped into the park and used by the vegetation. Roof water collection could be used as a strategy to minimize water waste and reduce run-off.

4. A recommendation for El Olivar is the use of native grasses to create a pastureland in the *dehesa.* The soil is currently very exposed to weather elements and during the summer days it creates dust problems. Using adapted species to the Mediterranean climate will enhance the area without loosing the identity, as *dehesas* used to have pasturelands between the trees to feed the cattle.

8.5.3. **FUENLABRADA PARKS – LA PAZ**

8.5.3.a. RESULTS

In general, the ratings for the plots in El Olivar Park were lower than the other parks. The best plots on water and soil protection in La Paz Park were P37, P31, P43 and P35. The worst plots were p36 and P38.

% Of land protected from erosion	% Of land protected from compaction	% Of land protecting water resources	**Watering waste**				
			No water need	Seldom	<3 /week	Daily	Water needed
8%	24%	0%	13%	4%	0%	71%	5%

Table 8.5.c. Soil and water protection in La Paz Park

Protection from compaction was the highest for this park, with 24% of the park protected by vegetation. Wasted watering was the highest for the city, with 71% of the area being water daily (5 days a week) during the summer days.

8.5.3.b. DISCUSSION

In the best plots, the main protection function was for compaction problems. Sandy soil was used in this park and where no vegetation is present, soil was compacted and flooding occurred after it rained. Although the weather is very dry in this region, it could lead to accessibility and maintenance problems.

Exotic species are abundant in this park. That may be the reason for the high watering needs. They also use manual irrigation systems, which increase watering waste and maintenance costs. Plots that rated highest were those were watering was less needed. That was the case of Plot P31 where conifers adapted to the Mediterranean climate, such as *Cupressus sempervirens,* were used. Almost the rest of the park is watered daily.

8.5.3.c. CONCLUSIONS –DESIGN STRATEGIES

1. Use adapted species to avoid water waste. Conifers such as *Cupressus sempervirens* were successful in some parks and were suitable for controlling erosion problems on slopes as well.

2. A recommendation for La Paz is to establish a permanent irrigation system. As the actual species need daily watering during the summer, automatic watering will avoid manual labor and increase the efficiency of the watering.

8.5.4. **PORTO ALEGRE PARKS – FARROUPILHA**

8.5.4.a. RESULTS

For Farroupilha Park, the plots that rated the highest on soil and water protection were P05, P07, P08 and P10. Their major function was water bodies' protection and watering waste was very low. Plot P06 got the lowest ratings. The overall results for the park were:

% Of land protected from erosion	% Of land protected from compaction	% Of land protecting water resources	**Watering waste**				
			No water need	Seldom	<3 /week	Daily	Water needed
10%	11%	23%	9%	56%	0%	0%	0%

Table 8.5.d. Soil and water protection in Farroupilha Park

Water protection was the highest, occurring in 23% of the park area. Protection from compaction was second (11% of the area) and from erosion third (10%). Most of the park does not need watering regularly, being 56% of the areas seldom watered, only during high droughts in summer months (as explained by park managers).

8.5.4.b. DISCUSSION

Plots with the highest ratings had vegetation on more than 85% of the area protecting water bodies. Also, approximately 90% of the area did not need watering other than on seldom occasions. Plot 05 (right), with the highest ratings, is a densely vegetated plot where natural succession was allowed to occur. Tall trees, small trees, shrubs and vines retain the soil and reduce erosion. A surface cover of leaves and mulch protects and maintains the humidity of the soil and prevents water loses from evaporation. As the plot is located near the lake, it helps to feed its water table as well.

Native species were successfully employed in this park. As a consequence there are no areas in the park demanding water more frequently than during droughts (seldom). The vegetation density of the park is very high and the different strata maintain the humidity in the soil. In those areas without vegetation, soil compaction is very evident and some flooding problems were noticed.

8.5.4.c. CONCLUSIONS – DESIGN STRATEGIES

1. Increasing the vegetation density is beneficial for soil and water protection. Vegetation density can be increased by augmenting tree cover, but also through the use of vegetation on different strata: grass, herbs, vines and shrubs.

2. The use of native vegetation is the best strategy for reducing watering waste.

3. Another strategy to learn from this park is the recycling of water. Park managers use the water stored naturally in the pond as the water source for irrigation purposes.

8.5.5. **PORTO ALEGRE PARKS – HARMONIA**

8.5.5.a. RESULTS

Best ratings under this theme in Harmonia Park were for plots P16, P25, P29 and P21. Major protection was for water bodies and from soil erosion. Most of them have vegetated areas with no water needs in up to 100% of their area. Plots with worst ratings were P27 and P18, with no protection functions and some watering needs.

% Of land protected from erosion	% Of land protected from compaction	% Of land protecting water resources	**Watering waste**				
			No water need	Seldom	<3 /week	Daily	Water needed
13%	10%	19%	47%	19%	2%	0%	0%

Table 8.5.e. Soil and water protection in Harmonia Park

For the whole park, water bodies' protection was the main function (19% of the total area), followed by erosion control (13%) and protection from compaction (10%). Almost half of the park area did not need irrigation.

8.5.5.b. DISCUSSION

The best examples of soil and water protection in this park were found actually in unmanaged areas of the park were emerging vegetation is colonizing the terrain. Plots P16 and P25 are located in the shoreline of the Guaiba River, and vegetation provides an important function of water protection and soil erosion in that area. As native colonizing species they do not demand watering. Their roots help to clean the pollution in the river water as well. Vegetation density was also high in these plots as can be seen in the picture of plot 25 (right).

Other plots with good ratings in Harmonia Park were plots P21 and P29. In these cases they are located near a small creek and a wetland area that they help to protect. In the rest of the park, trees protect from compaction of the soil. Plot P18 is in a vacant area that has temporary activities such as circuses. The combination of absent vegetation and the activities that take place there lead to compaction and flooding problems. The high percent of native species allows for maintaining a healthy park with very low watering needs.

8.5.5.c. CONCLUSIONS – DESIGN STRATEGIES

1. Emergent patches in unmanaged areas have a great value for protecting soil and water resources. In the case of the riverfront, it would be ideal to have access to all areas

and maximize the use of vegetation. When this is not possible, as in the case of Harmonia Park, letting native species colonize the area is an acceptable strategy.

2. When designing for soil protection, areas vulnerable of soil losses should be identified in the first place. This can be steep slope terrain or shorelines of rivers or lakes. Vegetation on these sites retains the soil through their roots, facilitates water infiltration and helps other species to establish. In some cases they also act as pollutant removers.

8.5.6. **PORTO ALEGRE PARKS – MARINHA**

8.5.6.a. RESULTS

Plots with the highest ratings for Marinha Park were P41, P37, P36 and P42. Their major contribution was to protect water bodies and land from compaction problems. The worst ratings were for plots P45 and P38.

% Of land protected from erosion	% Of land protected from compaction	% Of land protecting water resources	**Watering waste**				
			No water need	Seldom	<3 /week	Daily	Water needed
7%	19%	29%	50%	8%	0%	0%	0%

Table 8.5.f. Soil and water protection in Marinha Park

Marinha Park is similar to Harmonia, but with protection functions that were more successful. Marinha Park is also located on the riverfront of the Guaiba, but the areas are under better management. The main protection function is also water protection (in a third of the land), followed by protection from compaction.

8.5.6.b. DISCUSSION

The plots with highest ratings where those located on the riverfront. As with Harmonia, there are some emergent patches but there are planted trees as well. Fewer unmanaged areas remain in Marinha Park and the overall ratings were higher. In both case the majority of the trees are native and do not require watering (almost 100% of the are without watering needs).

While examining the worst plots, a difference with Harmonia Park is that while in that park bare soil was predominant in Marinha Park they are at least covered by grass. Some were designated for soccer fields and some are used as running fields, like plot P45 (right). While a denser vegetation cover would do a better job on protection, at least the grass protects more from erosion than bare soil, and compaction problems were less frequent.

A wise use of native species led again to a great percent of area without watering needs (50%).

8.5.6.c. CONCLUSIONS – DESIGN STRATEGIES

1. Areas adjacent to water should be designed carefully. The presence of vegetation is extremely important in those areas, as their protection function reaches its peak. Remnant and emergent patches are beneficial, but planted vegetation can also maximize the benefits.

2. The use of native species is fundamental to avoid watering waste problems. Species with strong root systems are adequate for erosion control on slopes. In areas that suffer naturally from compaction problems, species adapted to hard soils can be used.

3. Areas without any vegetation cover should be avoided. In areas to remain vacant, native grasses can be used to reduce soil resources losses with modest maintenance costs.

8.6. VITALITY

For every park the vitality is explained through the percentage of trees by condition class. The healthier the trees are, the highest the parks contribution to sustainability. For every park, a list of species in best and worst condition is shown as well. Improvement of air quality, carbon storage, soil and water protection and other benefits are maximized when trees are in good condition.

As explained before, condition of the trees was estimated through missing canopy. Refer to the methods chapter for condition definitions.

8.6.1. FUENLABRADA PARKS – LA SOLIDARIDAD

8.6.1.a. RESULTS

	Excellent	Good	Fair	Poor	Critical	Dying	Dead
Park	%	%	%	%	%	%	%
La Solidaridad	48.5	38.6	6.9	2.0	1.0	3.0	0.0

Table 8.6.a. Tree condition for La Solidaridad

La Solidaridad is the park in Fuenlabrada with the highest percentage of healthy trees: almost 50% of the trees are in excellent condition and near 40% in good condition. Plots with the highest ratings on vitality were P15, P05, P06, P07 and P04. The plots with the lowest vitality were P02 and P14.

The following table summarizes those species that were 100% (unless noted) in best (excellent and good) and worst (critical to dead) condition in La Solidaridad.

Excellent	Good	Critical	Dying or Dead
Southern catalpa (*Catalpa bignonoides*)	Sycamore maple (*Acer pseudoplatanus*)	Arbol de Judea *(Cercis siliquastrum)* (25%)	Saucer magnolia *(Magnolia x soulangeana)*
Port orford cedar (*Chamaecyparis lawsoniana*)	Russian olive (*Olea europaea)*		Mimosa (*Albizia julibrissim)* (50%)
Atlas cedar (*Cedrus atlantica)*	Tulip tree (*Liriodendron tulipifera)*		European hackberry *(Celtis australis)* (50%)
Southern magnolia (*Magnolia grandiflora)*	London planetree (*Platanus hybrida)*		
Giant sequoia (*Sequoiadendrom giganteum*)			
Aleppo pine (*Pinus halepensis*)			
Montezuma cypress (*Taxodium mucronatum)*			

Table 8.6.b. Tree condition summary for La Solidaridad by species

In La Solidaridad seven species were in excellent condition, five of them being conifers, and four in good condition. Only three species had specimens in critical condition, none of them dying or dead.

8.6.1.b. DISCUSSION

Tree condition is very related to age. As park vegetation gets older, trees begin to die. La Solidaridad has the greatest vitality because it is also the most recent park in the city and its trees have not suffered as many hard conditions as those in other parks. But this is not the only reason.

Plots that rated the highest on vitality were also those with good ratings on ecosystem diversity. Species were well selected to suit the environment, like poplars and alders next to streams in plot P06, or like *Taxodium mucronatum* in plot P15, a tree than can live with its roots under the water (right).

In this park, the condition of the trees is also due to an excellent irrigation system. This system waters plants automatically, based on a schedule (early in the mornings and late at night) that otherwise would need the presence of maintenance personnel. This also allows for non-native species to be in good condition although some (like *Magnolia x soulangeana*) seem to have difficulties adapting to the environment.

Plots with the lowest ratings on vitality were those where no vegetation exists.

8.6.1.c. CONCLUSIONS – DESIGN STRATEGIES

1. Use of adapted vegetation. As seen in the plots P05 and P15, vegetation adapted to the local meteorology has more chances to be in healthy condition. Usually, exotic species require more maintenance than natives.

2. Use of automatic irrigation systems. These systems have been very successful in this park. Although they may be more expensive to begin with, in the long term they save maintenance costs and water waste.

3. Choice of species
   For La Solidaridad, best species were mentioned in the Table 8.7. b. Among those, Atlas cedar (*Cedrus atlantica*), Aleppo pine (*Pinus halepensis*) and Russian olive (*Olea europaea)* are very well adapted to the Mediterranean weather.

8.6.2. **FUENLABRADA PARKS - EL OLIVAR**

8.6.2.a. RESULTS

	Excellent	Good	Fair	Poor	Critical	Dying	Dead
Park	%	%	%	%	%	%	%
El Olivar	25.8	47.8	19.5	1.9	4.4	0.0	0.6

Table 8.6.c. Tree condition for El Olivar Park

El Olivar was the park with the least healthy condition. However, 26% of its trees were in excellent condition and 48% in good condition. The plots with the highest ratings for vitality were P23, P26, P29 and P28, most of them located in the *dehesa* ecosystem. P17 was the plot with the lowest ratings. Condition by species was the following:

Excellent	Good	Critical	Dying or Dead
Drácena (*Dracaena sp.)*	Japanese flowering crabapple (*Malus floribunda*) Norway maple (*Acer platanoides)* Aleppo pine (*Pinus halepensis)* London planetree (*Platanus hybrida)*	Syrcamore maple (*Acer pseudoplatanus)* (67%) Siberian elm (*Ulmus pumila)* (6%)	

Table 8.6.d. Tree condition summary for El Olivar Park by species

In El Olivar Park, few species were 100% in excellent or good condition. Most of the park area has no permanent irrigation so only those species located in few areas watered more often were in best condition.

8.6.2.b. DISCUSSION

El Olivar is the only park in Fuenlabrada without frequent irrigation. The impact on vitality is clear: fewer trees are in excellent condition. However, the majority of the trees are in good condition. Having fewer trees in excellent condition (less than 2% of canopy dieback) and more under good condition (2 to 10% dieback) is worth the savings in irrigation maintenance.

Plots with best ratings (higher percent of excellent and good trees together) were actually located in the remnant olive grove, where olive trees adapted to the local climate need no watering. The olive grove is an old ecosystem and decaying trees should be part of its natural evolution. The current conditions show that the *dehesa* vitality is still very good.

The worst plot P17 (right) was located on an area of the park with lack of management. In this case, the tree density is obviously too high. Competition for light is too strong, tree diameters are small for the age of the forest and canopies are not fully developed. Density should be reduced by some silvicutural interventions to allow natural growth.

8.6.2.c. CONCLUSIONS – DESIGN STRATEGIES

1. Reduce irrigation costs by the use of species adapted to the local weather. Having fewer trees in excellent conditions in favor of more trees in good condition has a small impact when compared to the costs of watering practices.

2. Remaining vegetation may need some silvicultural interventions to increase tree health. In the case of El Olivar Park, the planted forest outside the *dehesa* area has become too dense; tree canopies cannot develop and tree health has begun to decrease. Some clearance of the worst specimens is recommended.

8.6.3. **FUENLABRADA PARKS - LA PAZ**

8.6.3.a. RESULTS

	Excellent	Good	Fair	Poor	Critical	Dying	Dead
Parks	%	%	%	%	%	%	%
La Paz	29.4	53.2	12.7	2.4	2.4	0.0	0.0

Table 8.6.e. Tree condition for La Paz

Most of the trees in La Paz Park were in good condition (53%) and almost 30% in excellent condition. No dying or dead trees were found in the study. Plots with highest ratings were P35, P32, P38 and P41. These plots did not have outstanding design qualities and a relationship was not found between vitality and aesthetics. The plot with the lowest rating was P36, an area designed without vegetation.

Excellent	Good	Critical	Dying or Dead
Tree of heaven (*Ailanthus altissima*)	Chinaberry (*Melia azedarach)*	Italian cypress (*Cupressus sempervirens)(6%)*	
European mountain ash (*Sorbus aucuparia*)	London planetree (*Platanus hybrida)*	Mediterranean fan palm *(Chamaerops humilis) (33%)*	
Russian olive (*Olea europaea)*	European alder (*Alnus glutinosa)*	White poplar *(Populus alba)* (33%)	
	Juniper (*Juniper spp.)*		
	Laurel (*Laurus nobilis)*		
	Ligustro (*Ligustrum vulgare)*		

Table 8.6.f. Tree condition summary for La Paz Park by species

La Paz Park is the green area with the highest percentage of exotic species. Yet, some of the trees in better condition were native.

8.6.3.b. DISCUSSION

The areas with highest ratings on vitality in La Paz are very representative of the majority of the park: small clusters of trees and grass surrounded by concrete paths (see plot P41 on the right). Aesthetic qualities were not impressive but the conditions of the trees were good due to intense maintenance practices. They represent the prototype of small urban park in Spain for recnt decades: traditional design, high maintenance costs and small contribution to sustainability.

8.6.3.c. CONCLUSIONS – DESIGN STRATEGIES

1. Few strategies can be learned from La Paz in terms of vitality as it is maintained at a high cost of watering and management. It should be noted the majority of species representing better condition were native; *Sorbus aucuparia, Olea europaea, Alnus glutinosa, Juniper ssp., Laurus nobilis* are recommended for future plantings.

8.6.4. **PORTO ALEGRE - FARROUPILHA**

8.6.4.a. RESULTS

Parks	Excellent %	Good %	Fair %	Poor %	Critical %	Dying %	Dead %
Farroupilha	29.1	50.7	13.5	2.7	2.7	0.7	0.7

Table 8.6.g. Tree condition for Farroupilha Park

The healthiest park in Porto Alegre was Farroupilha with about 51% of the trees in good condition and 29% in excellent condition, but it is also the park with more trees below critical condition (4.1%). Plots with the highest vitality ratings were P04, P03, P01 and P14. There were several plots with low ratings like P13, P06, P12 and P15. No relation between vitality and design qualities was found.

Excellent	Good	Critical	Dying or Dead
Araçá *(Psidium cattleyanum)*	*Aegiphila sp.*	Manduirana (*Senna macranthera)*	Unknown
Ombú (*Phytolacca dioica*)	Canafistula *(Peltophorum dubium*)	Ginger-thomas (*Tecoma stans)* (50%)	Slash pine (*Pinus eliotii*)
Cabriuva *(Myrocarpus frondosus*)	Capororocao *(Myrsine umbellata)*	Cocao (*Erythroxylum argentinum)* (33%)	
Camboatá vermelho (*Cupania vernalis)*	Chinaberry *(Melia azedarach)*	Eucalipto perfumado *(Eucaliptus citriodora)* (14%)	
London planetree (*Platanus x acerifolia)*	Senegal date palm *(Phoenix reclinata)*		
Mexican fan palm (*Washingtonia robusta*)	Taruma de espinho (*Citharexylum montevidense*)		
Guapuruvú *(Schizolobium parahybum)*	Timbaúva (*Enterolobium contortilisquum)*		
Figueira (Ficus microcarpa)	Marica (*Mimosa bimucronata)*		
Palmeira (Phoenix sylvestris*)*			

Table 8.6.h. Tree condition summary for Farroupilha Park by species

8.6.4.b. DISCUSSION

Although maintenance budget was much lower in the parks of Porto Alegre, vitality of the trees was not very different. Farroupilha Park is the only park with irrigation practices, and the park with highest percent of trees in excellent condition in Porto Alegre. But it is also the oldest one, and some decaying trees appear as a result of a natural dying process. As they let natural succession occur in this park, there is a young population of trees growing that will substitute for the dying ones.

In Farroupilha Park, exotic and native species were used. While looking at the species in best condition, the percentage of native is much higher.

Plots with the highest ratings on vitality were not the best on design qualities. Most of them were areas with scattered trees and grass with high maintenance. Lowest ratings on vitality were usually on plots without vegetation. Some areas of the park that are more forest-like (shrubs, higher vegetation density) rated low on vitality as they contain decaying old trees; however, they also contain new trees. Plot P12 (right), located on a playground had good design qualities but few trees in good condition.

8.6.4.c. CONCLUSIONS – DESIGN STRATEGIES

1. Native species are recommended to keep parks in good health. In Farroupilha Park many natives were successful: *Myrocarpus frondosus, Cupania vernalis, Schizolobium parahybum, Syagrus romanzoffiana, Phytolacca dioica, Myrsine umbellata, Citharexylum montevidense,* and *Enterolobium contortilisquum*.

2. When letting natural succession occur, it needs to be understood that decaying trees are a natural process of vegetation. To maintain healthy parks, some interventions may be necessary on decaying and dead trees. In Farroupilha, trees were removed only when they represent danger for users. Sometimes, decaying trees are a focus of diseases and pests so they need to be supervised.

8.6.5. **PORTO ALEGRE - HARMONIA**

8.6.5.a. RESULTS

Parks	Excellent %	Good %	Fair %	Poor %	Critical %	Dying %	Dead %
Harmonia	28.3	41.3	26.1	4.3	0.0	0.0	0.0

Table 8.6.i. Tree condition for Harmonia Park

Harmonia Park had 28% of its trees in excellent condition and 41% in good. No trees were found below critical condition. The plots that rated the highest were P22, P27 and P29. Many plots rated low on vitality (9 out of 15) as in Harmonia Park. There are many plots without vegetation and some without trees above good condition. As for the other parks, vitality was not related to design quality ratings.

Excellent	Good	Critical	Dying or Dead
Canafistula (*Peltophorum dubium*) Arbol del coral *(Eritrina crista-galli*)	Figueira de folha miuda *(Ficus organensis)* Goabiroba miuda *(Campomanesia rhombea)* Timbaúva (*Enterolobium contortilisquum)*		

Table 8.6.j. Tree condition summary for Harmonia Park by species

8.6.5.b. DISCUSSION

Plots with highest vitality in Marinha Park correspond with locations where maintenance practices were easier to apply. All the species in better condition are native to Brazil and some of them, such as *Eritrina crista-galli,* were specially adapted to the site conditions (in this case plot P29, wetland areas).

There were many plots with low ratings, as there are many vacant lands in the parks that remain unmanaged due to bad accessibility and lack of enough resources. In the following pictures, plots P17, P18, P20, and P26 are shown as an example of areas designated for temporary activities (circus, rodeos, etc.) that remain without use during the rest of the year and reduce the park's overall vitality.




8.6.5.c. CONCLUSIONS – DESIGN STRATEGIES

1. Increase the canopy cover in vacant lands. Many of the vacant lands of Harmonia Park could be vegetated and still be compatible with the temporary uses. If park budget does not allow for new planting, natural succession can be favored.

2. Placing the temporary events in different times of the year could reduce those areas that remain unmanaged. Areas are left for circuses, festivals, rodeos etc. in different spaces. As the events happen in different seasons it seems reasonable to keep one unique location in the park for temporary activities.

8.6.6. **PORTO ALEGRE - HARMONIA**

8.6.6.a. RESULTS

Parks	Excellent %	Good %	Fair %	Poor %	Critical %	Dying %	Dead %
Marinha	28.1	43.8	21.9	6.3	0.0	0.0	0.0

Table 8.6.k. Tree condition for Marinha Park

Marinha Park was second in vitality among Proto Alegre parks with almost 44% of the trees in good condition and 28% excellent. Plots with highest ratings were P42, P40, P33 and P35. Six plots out of 15 got low ratings on vitality, some of them being areas without vegetation and others plots with vegetation below good condition. Seven species were identified to be successful in Marinha Park, five being native.

Excellent	Good	Critical	Dying or Dead
Paineira (*Chorisia speciosa)*	Angico vermelho *(Parapiptadenia rigida)*		
Canafistula (*Peltophorum dubium*)	Chinaberry *(Melia azedarach)*		
Common crapemyrtle *(Lagerstroemia indica)*	Jerusalem thorn *(Parkinsonia aculeata)*		
Cerejeira *(Eugenia involucrata)*			

Table 8.6.l. Tree condition summary for Marinha Park by species

8.6.6.b. DISCUSSION

Marinha Park is a similar situation to Harmonia, but areas hard to manage were given to active recreation functions. Several plots with low vitality are soccer fields or running fields. In this park, plots with high vitality got good aesthetic ratings as well. They contain individual trees in great conditions that give character to the place. Species like *Inga vera* or *Chorisia speciosa*, like the one shown in Plot P42 (right), were successfully used.

8.6.6.c. CONCLUSIONS – DESIGN STRATEGIES

1. As explained for the previous parks, using native species reduces costs on watering and maintenance. This is a sustainable approach because it preserves biodiversity, protects water and keeps a similar percent of trees above fair condition.

2. Lack of watering and low maintenance is common in Porto Alegre. Species selection becomes fundamental in this case. It is highly recommendable to put more effort then in the vegetation establishment, as later maintenance practices may not be available.

3. Native species from Tables 8.6.j. and 8.6.l. are recommended for Porto Alegre parks

8.7. CONNECTIVITY

Under the theme connectivity the continuity of the green structure was measured. As explained in the methods section, in each plot the connectivity was estimated for the main ecosystem type by two indicators: a subjective connectivity index from 1 to 5 (least to maximum connectivity) and the percent of area without the main ecosystem (% of fragmentation). Plots rating high in connectivity also rated high in design qualities for some of the parks.

Connected green areas help preserve the biodiversity of plant and animal species. Fragmentation of ecosystems leads to loss of diversity and allows invasive species, pests and diseases to penetrate easily in the green structure. Connected green areas provide a variety of habitats and migration corridors for animals to live and travel through the city.

8.7.1. **FUENLABRADA PARKS – LA SOLIDARIDAD**

8.7.1.a. RESULTS

La Solidaridad Park is a green area with low connectivity (2) and high percent of fragmented green cover (43%). Most of the fragmented area is composed of paths and hardscape. The best plots on connectivity were P04, P06, P09 and P11. Plot P14 rated the lowest.

8.7.1.b. DISCUSSION

Although green areas in La Solidaridad are quite fragmented, some continuity can be found along the water system. From a reservoir located on the north side of the park, two water channels run through the park to the south end. Vegetation was planted on either side of the creek creating a small green corridor inside the park.

Along this water system is where plots rating high on connectivity were located. These plots also rated high on design qualities and biodiversity. Plots rating lowest were those without vegetation. Poplars trees planted next to the water creek in plot P09 (right) mimic riparian vegetation and recreate a natural sensation.

The green structure in La Solidaridad is poorly connected with surrounding areas as the park is fenced and closes at night. Birds are the only wildlife entering and leaving the park.

8.7.1.c. CONCLUSIONS – DESIGN STRATEGIES

1. Water systems can be successfully used to connect green areas inside the park. Riparian vegetation can mimic green corridors in nature.

2. Fenced parks keep urban green areas fragmented. When vandalism makes fencing unavoidable, creative solutions for wildlife corridors through the park should be considered.

8.7.2. **FUENLABRADA PARKS – EL OLIVAR**

8.7.2.a. RESULTS

El Olivar is the park in Fuenlabrada with the highest degree of connection (4) and the least fragmentation (22%). Most of the park is a former olive grove that occupies a great area and is not interrupted by roads or hardscape. Plots in this olive grove (*dehesa*) rated the highest in continuity: P20, P18, P25 and P28 rated the maximum value. P17 also rated high but was located on a forested slope. The worst plot on connectivity was P29, located at the entrance of the park.

8.7.2.b. DISCUSSION

Connectivity was the highest in El Olivar as the remnant olive grove has maintained its continuity over the years. Adding paths and park furniture to the existing ecosystem created the park, and some new green areas were planned as well. Continuity and horizontality are two of the main aesthetic qualities of the park, as seen for plot P25 (right). These characteristics relate the park with a broader landscape: the working lands of Mediterranean Spain. Maintaining the continuity of the olive grove is vital for keeping the park identity alive.

El Olivar Park is also fenced. Fuenlabrada parks are not connected with each other nor with other green areas. Located in the periphery of the city, El Olivar has only one entrance and should be linked to the surroundings.

8.7.2.c. CONCLUSIONS – DESIGN STRATEGIES

1. Natural ecosystems have a great degree of connectivity. When urban parks incorporate surrounding green areas, continuity should be understood as an aesthetic quality and management practices should be encouraged for preserving it.

2. Parks located in the urban periphery should not be fenced. Wildlife from the surrounding areas could use peripheral parks to penetrate and migrate through the city.

8.7.3. **FUENLABRADA PARKS – LA PAZ**

8.7.3.a. RESULTS

La Paz had the lowest ratings for connectivity in Fuenlabrada. With a connection index value of 2, like La Solidaridad Park, the percent of fragmented area was higher (59%). Plot ratings on connectivity were low in general, being the highest for plots P43, P35, P32 and P37. P36, a small concrete plaza without vegetation, rated the lowest.

8.7.3.b. DISCUSSION

La Paz is a park from the 1980's located in the center of the city. It has many hardscape surfaces such as concrete paths, pavements, stairs, ramps, etc. Vegetation was planted in small groups and is fragmented by hardscape. Plots with the highest connectivity are areas with more vegetation planted, such as plot P43 (right), although they are not continuous on a 100%.

La Paz is the only park not fenced in Fuenlabrada, but there are no surrounding green areas to connect with. Due to the uncontrolled development of the city, the percent of impervious surfaces is very high and green connectors through the city are difficult to develop.

8.7.3.c. CONCLUSION – DESIGN STRATEGIES

1. Impervious surfaces were too dominant in the design of La Paz Park. New parks should consider reducing the amount of impervious surfaces. They not only fragment the green areas but also increase storm water run-off and erosion.

2. For all parks in Fuenlabrada, specific streets should be selected to become green connectors. Connectivity among parks and with the surroundings was very poor and should be improved.

8.7.4. **PORTO ALEGRE PARKS – FARROUPILHA**

8.7.4.a. RESULTS

In general, connectivity was lower within the parks of Porto Alegre. Farroupilha Park got the highest average connectivity index (3) and the lowest percent of fragmentation (40%). Plots with the highest ratings on connectivity had also good ratings on design qualities: P02, P07, P05 and P11. The plot with the lowest rating on connectivity was P13, a soccer field area.

8.7.4.b. DISCUSSION

Farroupilha Park is the oldest among the three parks studied in Porto Alegre and has the highest density of trees as well. Plots rating highest in connectivity were also those rating highest in biodiversity, with the exception of plot P02 (right) that was located on the lake. The rest are areas where natural succession occurs and have a continuous green cover of vines, shrubs and trees. Good aesthetic qualities were found in association with the wilderness look, the relation with the surrounding park, the sense of unity and the presence of some singular trees.

The park is located in the center of the city and traffic arteries surround it. Although connection of the green structure is difficult, the city has created a weekend bike trail along a road with old street trees.

8.7.4.c. CONCLUSIONS – DESIGN STRATEGIES

1. The strategy of letting natural succession occur inside the park was already mentioned for biodiversity and vitality. It has proved to be successful for connectivity as well.

2. Use vegetated streets as connectors between parks.

8.7.5. **PORTO ALEGRE PARKS – HARMONIA**

8.7.5.a. RESULTS

Harmonia had poor overall connectivity, with a low subjective index (2) and almost 50% of the area fragmented. Plots rating the highest on connectivity were P21, P26, P25, P20 and P28. The plot with the lowest connectivity rating was P24, located in the north edge of the park where a fence and a path divide the green cover.

8.7.5.b. DISCUSSION

There are many vacant areas in Harmonia Park that remain underutilized. They interrupt what could be a continuous green structure along the park. In some of those areas, the only green cover was grass. More interesting were the plots with continuous tree cover, as the case of plots P16, located in the riverfront, and P21 (right), near a small creek inside the park. They both rated high in design qualities.

8.7.5.c. CONCLUSION – DESIGN STRATEGIES

1. Increase vegetation cover in inaccessible areas by letting natural succession occur.

2. The riverfront is an excellent location to create a green corridor. A recommendation for Marinha Park would be to connect the existing emergent patches in the riverside through new plantings along the shoreline.

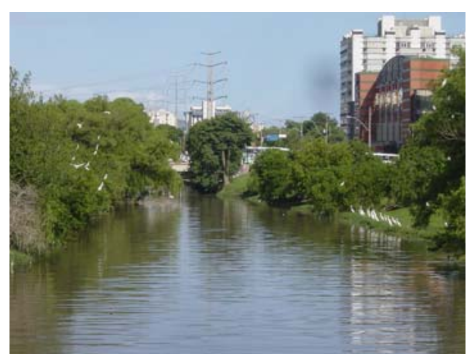
8.7.6. **ALEGRE PARKS – MARINHA**

8.7.6.a. RESULTS

When measuring connectivity, Marinha Park rated the lowest with a value of 2 on the subjective connectivity index and with 68% of the area fragmented. The best plots on connectivity were P36, P37 and P33. The worst results were for plots P41 and P45, areas of active recreation.

8.7.6.b. DISCUSSION

For Harmonia Park, some of the best plots on connectivity were the emergent patches in the Guaiba River shoreline already commented on for their good ratings on biodiversity and water and soil protection. Another plot, P36, was commented on already but should be noted again as it is the best example found in the study for a green corridor inside the park. The species *Tipuana tipu* creates a nice transitional space (right).



It is also interesting that Harmonia and Marinha parks are divided by a small river and connected through a bridge. The riversides of that creek are actually densely vegetated and used by the local fauna as the connection of the Guaiba River with the lands beside the city. (Birds can be appreciated in picture on the right).

8.7.6.c. CONCLUSION – DESIGN STRATEGIES

1. Rivers and riverfronts are natural connectors for the city, sometimes the only ones left. Increasing the vegetation cover in the riversides allows for more wildlife to travel through the green corridor and keeps the continuity of the green structure.

2. In transitional spaces within parks, some tree species can be successfully used to create “green tunnels” that protect against strong temperatures during the summer.

9. RESULTS, DISCUSSION AND CONCLUSIONS FOR EACH CITY

9.1. ACCESIBILITY

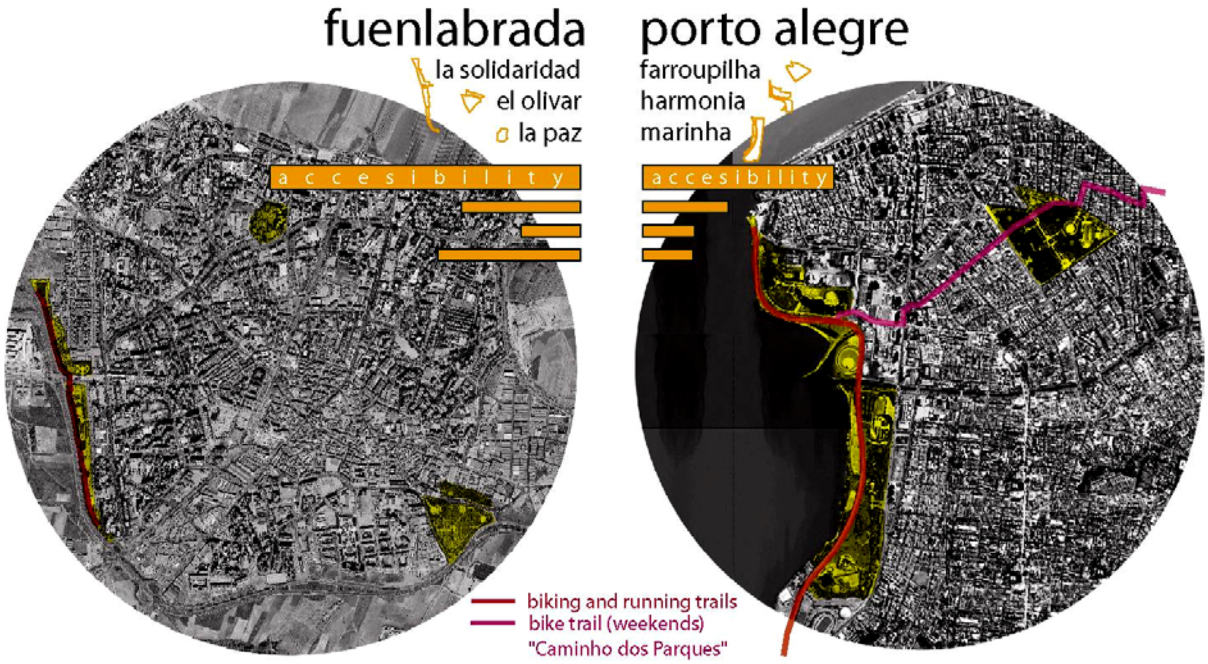


Fig. 9.1.a. Bike and running trails in the parks of Fuenlabrada and Porto Alegre. The orange bars show a measurement of accessibility inside the parks.

9.1.1. RESULTS

Accessibility to parks was greater in Fuenlabrada than in Porto Alegre, as shown in **Fig. 9.1.a**. While the number and length of running and bike trails was much higher in the Brazilian city, the average distance from parks to public transportation was a bit shorter in Fuenlabrada. The level of accessibility inside the parks was higher for Fuenlabrada as well. People with disabilities (ADA) could reach more areas if the ground has more hard surfaces, and fewer plots were outside the limit of walking distance to public transportation (500 m.).

On the other hand, the area of the parks in Porto Alegre increases during the weekend by the closing of adjacent streets that extend the park limits. As a final result, the overall accessibility was a little bit higher in Fuenlabrada. **Table 9.1.a**. summarizes the measurements mentioned above.

City	Km. of bike & running trail	Km. of weekend bike trail	Km. of weekend streets	Average distance (m.) to transportation	% of plots ADA accessible	% of plots without transportation
Fuenlabrada	1.750	-	-	253	47%	7%
Porto Alegre	5.450	4.420	2.475	287	7%	11%

Table 9.1.a. Accessibility summary for the cities of Porto Alegre and Fuenlabrada.

9.1.2. BRIEF DISCUSSION AND DESIGN STRATEGIES

9.1.2.a. FUENLABRADA

Parks	Km. of bike & running trail	Km. of weekend bike trail	Km. of weekend streets	Average distance (m.) to transportation	% of plots ADA accessible	% of plots without transportation
La Solidaridad	1.750	-	-	237	67%	13%
El Olivar	-	-	-	346	7%	7%
La Paz	-	-	-	176	67%	0%

Table 9.1.b. Accessibility summary for Fuenlabrada parks.

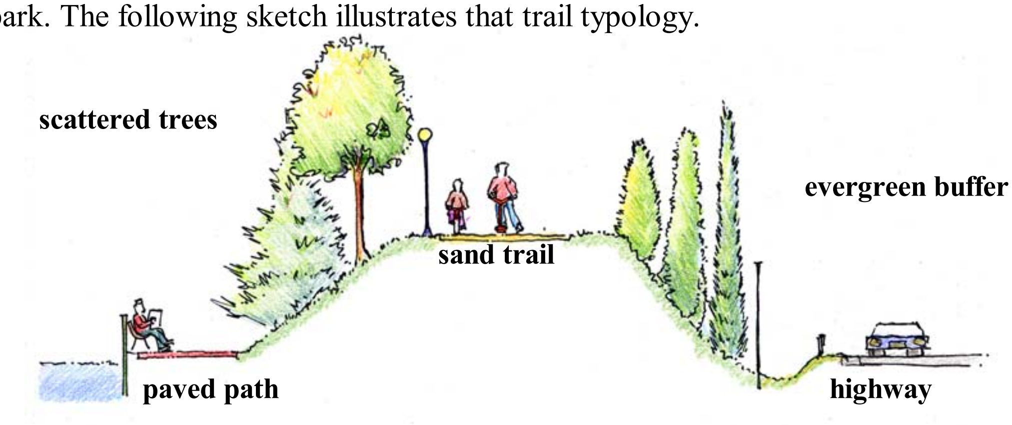
As **Table 9.1.b.** shows, La Paz is the park with greatest connectivity in Fuenlabrada as all plots were within walking distance to public transportation, with the average of 176 m, and 67% of the plots were ADA accessible. La Solidaridad has good accessibility as well, with its north and south parts connected by a successful bike and running trail. El Olivar, as an old agricultural ecosystem, has less ADA accessibility and it is located further from public transportation points.

The following is a summary of design strategies found in Fuenlabrada parks:

1. **Park areas located within walking distance.**
   In general, smaller parks (<5 ha.) located in the centre of the city will have the greatest accessibility. When planning bigger parks or parks located in the edge of the city, public transportation points should be located no further than 500 m. from the park areas. If the park is fenced it should have more than one entry.

2. **Bike and running trails to connect segregated areas.**
   Bike and running trails are an excellent way to connect different areas of a park or separated parts. Providing different activities in the areas connected will attract a wider range of users than just bikers and runners.

3. **Good trail design.**
   A good trail design is fundamental. In the case of Fuenlabrada a successful solution for an edge trail was to provide a vegetation buffer against the road on one side and scattered trees on the other side to allow physical and visual connections with the rest of the park. The following sketch illustrates that trail typology.



4. **Universal accessibility to unplanned areas.**
   Transforming existing lands to parks (woodlands, agricultural lands) has to be done carefully. As those areas are not intended to provide accessibility to people with disabilities design solutions will be needed. Compacted soil paths or wooden platforms are an example.

9.1.2.b. PORTO ALEGRE

Parks	Km. of bike & running trail	Km. of weekend bike trail	Km. of weekend streets	Average distance (m.) to transportation	% of plots ADA accessible	% of plots without transportation
Farroupilha	-	1.150	0.775	226	7%	7%
Harmonia	2.050	-	1.700	314	7%	13%
Marinha	3.400	-	-	320	7%	13%

Table 9.1.c. Accessibility summary for Porto Alegre parks.

The parks of Porto Alegre are very well connected with each other through running and bike trails and they are all within walking distance from public transportation points. In two of them adjacent streets are closed during the weekend for pedestrians, and they get filled with strollers and street vendors. As their main ground cover is sand or grass, people with disabilities may have problem entering most of the areas, as shown in **Table 9.1.c**. Some design strategies for accessibility are discussed from Porto Alegre parks:

1. **Transportation corridors along park edges. Free bus ride day.**
   When designing linear parks, it is extremely convenient if a main transportation corridor runs along the edge of the park. Bus stops located at several distances will provide enough access points to make the park accessible to citizens living beyond the park area. A free bus ride day will give accessibility to parks to a wider range of people.

2. **Closing adjacent streets on weekends to extend the park.**
   Closing adjacent streets to parks during the weekends was probed to be an excellent strategy. Providing activities in those gained areas (markets, festivals) will attract people to the park. These areas create a unique sense of place, and open the park to public participation. Their design should be carefully considered and a good example is explained in the case of Farroupilha Park.

3. **Avoid roads through the park without pedestrian crossings.**
   Roads dividing the parks into segregated areas should be avoided. They create unused spaces that are forgotten and vandalized in time. If a road is to be constructive, pedestrian connections should be created and attractive activities planned to keep the park connected.

4. **Provide uses in areas to be connected.** Bike and running trails are good park connectors but not sufficient. They have to be accompanied by a good design that provides different areas with different uses to be connected.

9.1.3. PATTERNS ASSOCIATED WITH ACCESSIBILITY

- ***Street vendors***
- ***Presence of walkers***
- ***Increased number of users***
- ***Old people talking***
- ***Hardscape***
- ***Commercial nodes***
- ***Traffic noise***
- ***Benches facing activities***
- ***People in groups***

9.2. ECOSYSTEM DIVERSITY

9.2.1. RESULTS

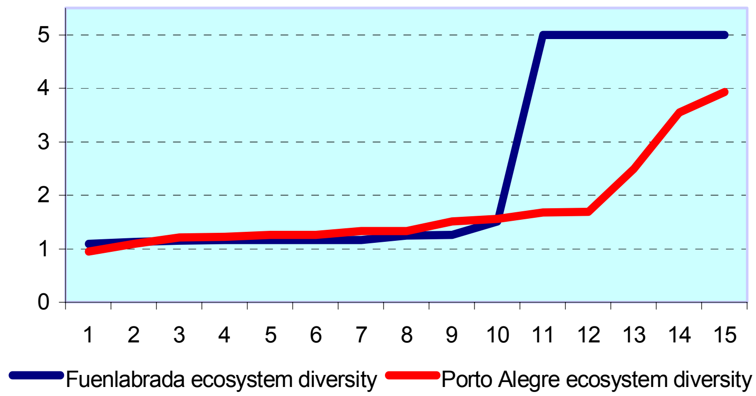


Fig. 9.2.a. Ecosystem diversity in Fuenlabrada and Porto Alegre.

The above graphic in **Fig.9.2.a** shows the ecosystem diversity ratings on the 5 best plots for each park in both cities. The diversity is very similar in two thirds of the parks, but the park with higher ratings in Fuenlabrada (El Olivar) was a native protected ecosystem so it rated much higher than the most diverse park of Porto Alegre (Farroupilha).

9.2.2. DESIGN STRATEGIES

The following list is a summary of the design strategies found when analyzing the ecosystem diversity, design qualities and functions of the six parks studied. These strategies are intended to increase the ecosystem diversity of the cities when applied.

9.1.2.a. FUENLABRADA

1. **Provide diversity of water features with suitable vegetation**
Different water bodies increase the diversity of habitats for plants and animals. Vegetation should be suitable for those types of ecosystems, such as riparian vegetation for creeks, wetland plants for ponds, ferns for cascades, etc.

2. **Use water systems to unify the park**
Creeks, channels, ponds, fountains and other water features can be connected through the park in a closed loop that recycles water (from storing rainwater to irrigation). This closed system gives a sense of unity to the park and makes it more self-sufficient.

3. **Surrounding landscapes can be incorporated successfully into parks**
Surrounding landscapes such as abandoned agricultural lands, old forests, orchards and other working landscapes can be successfully incorporated in the park. With the help of the design their function can be changed from production to recreation, preservation or protection, transforming these areas into parks that still preserve their past identity.

9.1.2.b. PORTO ALEGRE

1. **Locate green areas near or adjacent to water bodies**
Use rivers, creeks, ponds, wetlands, etc, or where water is stored naturally. The presence of water is not only an aesthetic asset; it provides a rich variety of biotopes for different animal and plant communities. Riparian vegetation and wetland plants often serve an important function protecting water and soil resources.

2. **Increase the green structure cover**
The areas with higher ecosystem diversity were fully covered by vegetation. A "trees with grass" ecosystem type should occupy from 40 to 90% of the area, with the remaining percentage being a combination of trees, shrubs, herbs, grass mounds and tall grasses. While a mix of types is best for diversity, novel trees (very old specimens, endangered species) are suitable in these places as well.

3. **Let natural succession occur**
From 15 to 50% of the area can be left for emergent patches to grow. This is recommended for those areas of the park with less accessibility. Letting natural succession occur doesn't mean not taking care of those green spaces. It means that new plants will grow from seeds coming from the soil bank and the surrounding trees. There could be a selective process to remove undesirable species and retain plants adapted to the conditions of the site, preferably natives.

4. **Protection as the main function**
As these areas are located in places susceptible to erosion and pollution (water bodies) it seems reasonable to propose that the main function of the green structure would be to protect the soil and water resources, as well as preserve the biodiversity itself. If the green space can be read more as a process than as an object, people will consider those functions as aesthetically valuable as well.

9.2.3. PATTERNS ASSOCIATED WITH ECOSYSTEM DIVERSITY

- ***Presence of water bodies, proximity to water, access to water***
- ***Connection with regional ecology***
- ***Trees on water, water related vegetation***
- ***Edge of forest***
- ***Noise reduction***
- ***Variety of birds***
- ***Water sound, water mirror***
- ***Native forest***
- ***Remnant landscape***
- ***Sense of natural ecosystems***
- ***Connection with regional ecology***
- ***Naturally aging trees***

9.3. SPECIES DIVERSITY

9.3.1. RESULTS

The results of species diversity indexes are shown for each city in the following **Table 9.3.a**. The list of the different species found in each park of each city is attached in the Appendix 12.3. The different diversity indexes were explained in the methods section. As can be seen, the overall species diversity is just a bit higher in Porto Alegre than in Fuenlabrada, although the latter had more trees in its parks.

City	Park area (ha)	Sampled area (ha)	Sampled trees	Sampled species	Species per ha	Shannon diversity index	Menhinick diversity index	Simpson diversity index	Evenness
Fuenlabrada	27	1.82	385	50	27.5	3.25	2.55	15.34	0.83
Porto Alegre	167	1.82	225	52	28.6	3.40	3.47	21.19	0.86

Table 9.3.a. Species diversity for the cities of Fuenlabrada and Porto Alegre.

9.3.2. BRIEF DISCUSSION AND DESIGN STRATEGIES

9.3.2.a. FUENLABRADA

The species diversity for Fuenlabrada was assessed by an average of species diversity in the three parks weighted by area. The following table summarizes the results for Fuenlabrada parks that were described in detail in chapter 7.3. La Solidaridad and La Paz have similar diversity of species while El Olivar, as being a monoculture of olive groves in the past, has less diversity.

City of Fuenlabrada	Park Area (ha)	Sampled area (ha)	Sampled trees	Sampled species	Species per ha	Shannon diversity index	Menhinick diversity index	Simpson diversity index	Evenness
Solidaridad	12	0.61	101	29	47.8	2.99	2.88	15.40	0.89
El Olivar	10	0.61	158	16	26.4	1.96	1.27	4.27	0.71
La Paz	5	0.61	126	26	42.8	2.92	2.31	16.01	0.90

Table 9.3.b. Species diversity for the parks of Fuenlabrada.

This is the summary of the design strategies for species diversity found in Fuenlabrada parks.

1. **Use of criteria to group species**
When mixing a variety of species, greater design quality is achieved when the plants are grouped by some criteria, such as genus or family. Contrast between groups and harmony within tree clusters rated higher on aesthetics than random mix. An example of a criterion to associate plants can be found by investigating local plant communities.

2. **Plant first pioneers species to create shade.**
When establishing a park in a vacant area, pioneer species can be introduced to create shade so that other shade species can be planted later. Variety throughout time is another way to understand species variety.

3. **Select species based upon the future use.**
Some species are better suited for certain uses. Dense conifers proved to be successful as traffic barriers (protection function). Fruit trees can create orchards within parks, and different groups can take care of them (production and education functions).

9.3.2.b. PORTO ALEGRE

In the city of Fuenlabrada are the parks with the highest species diversity per area (Farroupilha) and the lowest (Harmonia). The first is an old park designed to display different species and park styles from all over the world. The latter is a park with unmanaged vacant areas. In general, there were more native and emergent species in Porto Alegre.

City of Porto Alegre	Park Area (ha)	Sampled area (ha)	Sampled trees	Sampled species	Species per ha	Shannon diversity index	Menhinick diversity index	Simpson diversity index	Evenness
Farroupilha	40	0.61	147	39	64.3	3.09	3.22	13.83	0.84
Harmonia	59	0.61	46	11	18.1	2.00	1.62	6.72	0.83
Marinha	67	0.61	32	16	26.4	2.43	2.83	10.78	0.88

Table 9.3.c. Species diversity for the parks of Porto Alegre.

These are some design strategies:

1. **Use of protected and native species.**
Use of protected species and/or native species with good aesthetic qualities make the functions of aesthetics compatible with preservation.

2. **Let natural succession happen.**
Areas of the park without intensive use can be dedicated to natural regeneration and emergent species. The vegetation patches that will appear in time will reveal how natural processes take place. By including those patches in the park, this strategy can educate people on how to appreciate natural landscapes.

3. **Provide novel trees to give places identity.**
Tree species with peculiar shapes and forms can be used to give places strong identity. Singular trees are easy to identify and provide character to the surroundings.

4. **Scattered trees near sport facilities.**
Scattered trees that provide shade over grass were used near sport facilities to provide comfortable spaces for resting and passive recreation. These places were usually located where open views could be seen from them.

9.3.3. PATTERNS ASSOCIATED TO SPECIES DIVERSITY

- ***Singularly shaped trees***
- ***Tree place, novel tree***
- ***Conifers barrier***
- ***Plant heterogeneity***
- ***Mystery of the forest***
- ***Leave texture variety***
- ***Spontaneous vegetation***

9.4. **CARBON STORAGE AND SEQUESTRATION**

The concept of carbon storage and sequestration was explained in Methods chapter. These are the summary results for the two cities of the study.

9.4.1. FUENLABRADA

9.4.1.a. RESULTS

Parks	Trees (no.)	Carbon storage (kg)	Carbon seq (kg/yr)	Net carbon seq (kg/yr)
La Solidaridad	1,990	11,820	1,800	1,750
El Olivar	2,665	682,650	19,250	17,240
La Paz	963	42,200	2,570	2,450
Fuenlabrada	5,618	736,670	23,620	21,430

Table 9.4.a. C storage and sequestration for Fuenlabrada parks.

Parks	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
La Solidaridad	166	988.8	150.2	146.2
El Olivar	260	66,671.8	1,880.5	1,683.7
La Paz	207	9,091.3	554.4	527.3
Fuenlabrada	209	27,447.1	880.2	798.6

Table 9.4.b. C storage and sequestration per area for Fuenlabrada parks.

Species	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
Olive tree	45.2	23,178.8	579.2	516.3
Chinese poplar	7.2	837.4	39.77	37.83
Siberian elm	10.1	759.3	39.5	22.3
Italian stone pine	9.3	612.7	25.5	22.6
Carolina poplar	8.7	475.6	31.9	16.7

Table 9.4.c. C storage and sequestration per area by species for Fuenlabrada parks.

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The trees of the parks in Fuenlabrada store a total of 736,670 kg of carbon. The park that stores more atmospheric carbon is El Olivar with 682,650 kg (92.6% of the total), followed by La Paz (5.7%) and La Solidaridad (1.7%).

The carbon storage per area for the parks of Fuenlabrada was 27,447 kg. per hectare. This amount was a bit higher than the 25,344 kg. per hectare obtained for Porto Alegre parks. On the other hand, the gross carbon sequestration for Fuenlabrada (880 kg/ha) was slighter than in Porto Alegre (1,049 kg/ha).

The species that currently store more carbon in Fuenlabrada parks are Olive tree, *Olea europaea* (84.4% of total C stored); Chinese poplar, *Populus simonii* (3.1%); Siberiam elm, *Ulmus pumila* (2.8%) and Italian pine stone, *Pinus pinea* (2.2%). Gross and net carbon sequestration was greatest for Olive tree (65.8%), Chinese poplar (4.5%), Siberian elm (4.5%) and Carolina poplar, *Populus x canadensis,* (3.6%).

9.4.1.b. DISCUSSION

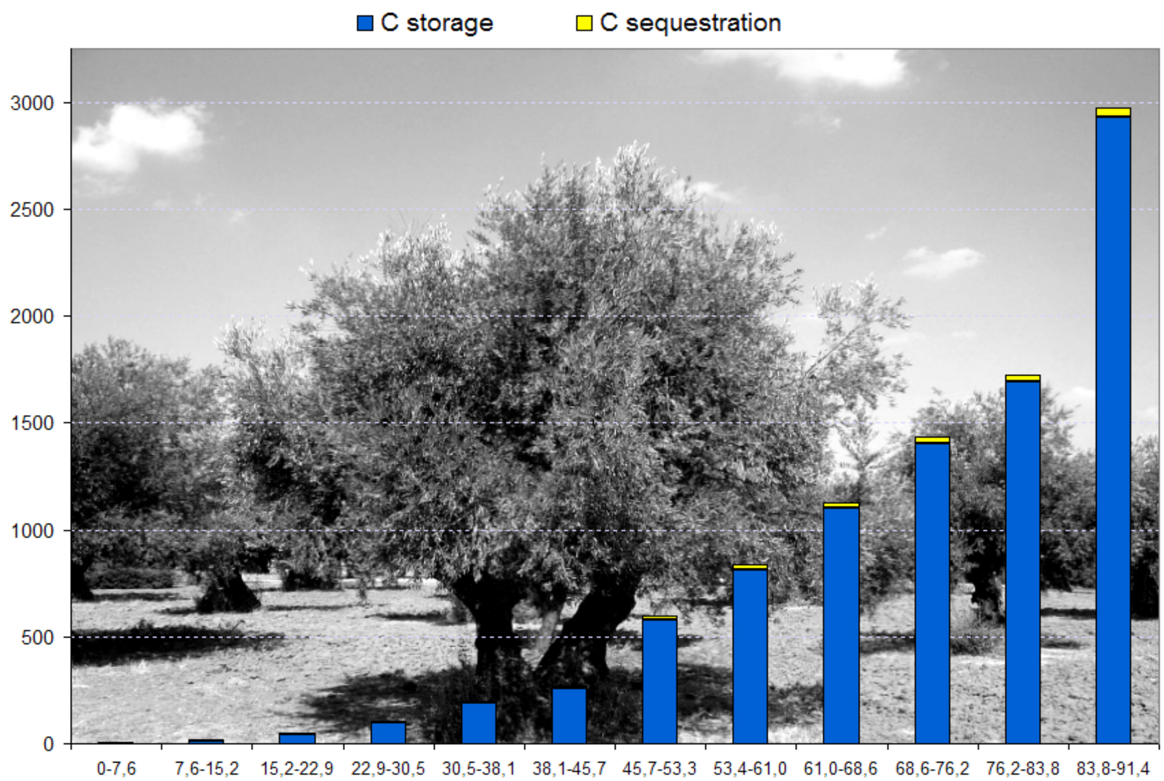

Fig. 9.4.a. C storage (kg/ha) and sequestration (kg/yr/ha) per area by dbh class (cm) in Fuenlabrada.

The great differences found between parks in relation to carbon storage and sequestration is very much related to the age of their trees. As the graphic in **Fig. 9.4.a.** shows, the carbon storage and sequestration is much higher in older trees (trees with greater dbh: diameter at breast height) than in younger trees (smaller dbh class).

La Solidaridad is the most recent park in the city (from 1990's). Although it has almost 2,000 trees, those are the youngest, and they only store 1.7% of the total carbon stored by the three parks together. La Paz Park was built during the 1980's. With approximately a thousand trees in it, the park stores 5.7% of the total.

El Olivar is the park that contributes the most by far to carbon storage. With around 2,700 trees, it stores 92.6% of the total. The park is a remnant olive grove (picture behind the graphic) transformed into a public green space. The olive trees are very old, have enormous diameter trunks and well formed canopies. The olive grove sequesters 19,250 kg of atmospheric carbon as its trees keep growing every year.

These results explain the importance of preserving former woodlands in urban parks and the significant protection value of old trees. The carbon they store has essential benefits on local and global climate. A central discussion is what to do with decaying trees. If trees die and decompose, the stored carbon will be released to the atmosphere. Wood should be used for building purposes or landfill to avoid carbon release.

9.4.1.c. CONCLUSIONS - DESIGN STRATEGIES

1. **Increasing tree cover**
   For any park, areas planted with new trees will contribute to store carbon. As trees grow they will sequester carbon from the atmosphere and incorporate it into the tree biomass.

2. **Preserving old trees and remnant vegetation**
   Old trees in parks or former woodlands keep the stored carbon from being released to the atmosphere. This is another function besides the biodiversity preservation value.

3. **Reusing wood from dead trees**
   To avoid carbon release, wood from dead trees in the park could be given a new use. Furniture like benches, picnic tables, trashcans, flowerbeds or fences can be made out of that wood. In the case of El Olivar, olive wood is also appreciated for its aesthetic quality and could be sold in the wood market.

4. **Creating wooden platforms and buildings**
   El Olivar was one of the parks with less ADA accessibility because of sandy soil surface. Wood from dead trees could be used to build plain surface paths that give access to the interior of El Olivar (see picture below). Reusing olive wood will also be a reference to the past of the place and retain some of the *dehesa* identity. If any building would be necessary in the park, such as toilets or an interpretative center, wood from the park should be one part of the materials.

5. **Selecting long-lived, low maintenance species**
   Large trees and long-lived species maximize the carbon storage. Low maintenance species will contribute to reduce the use of fossil fuel in the park management. Olive tree, *Olea europaea,* Chinese poplar, *Populus simonii,* Siberiam elm, *Ulmus pumila* (2.8%) and Carolina poplar, *Populus x canadensis,* were the best species in Fuenlabrada for carbon sequestration all being exotics but the olive tree.

9.4.2. PORTO ALEGRE

9.4.2.a. RESULTS

Parks	Trees (no)	Carbon storage (kg)	Carbon seq (kg/yr)	Net carbon seq (kg/yr)
Farroupilha	9,774	2,793,390	103,960	92,370
Harmonia	4,469	567,190	31,690	30,010
Marinha	3,553	865,610	39,280	36,400
Porto Alegre	17,796	4,226,190	174,930	158,820

Table 9.4.d. C storage and sequestration for Porto Alegre parks.

Parks	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
Farroupilha	242	69,210.6	2,575.8	2,288.7
Harmonia	76	9,616.5	537.2	508.8
Marinha	53	12,840.7	582.7	540.6
Porto Alegre	107	25,344.1	1,049.0	952.4

Table 9.4.e. C storage and sequestration per area for Porto Alegre parks.

Species	Trees/Area (no./ha)	Carbon storage/Area (kg/ha)	Carbon seq/Area (kg/yr/ha)	Net carbon seq/Area (kg/yr/ha)
Paineira	3.1	3,490.1	99.4	89.0
Tipa	7.7	3,461.9	136.1	128.2
Eucalipto perfumado	2.8	3,355.1	91.9	78.7
Beakpod ecualyptus	2.4	3,259.6	79.4	55.0
Inga banana	10.2	2,296.1	102.3	95.3
Salgueiro	6.5	2,254.2	90.3	83.0

Table 9.4.f. C storage and sequestration per area by species for Porto Alegre parks.

The trees of the parks in Porto Alegre store a total of 4226,190 kg of carbon. Farroupilha Park is the oldest park and stores greatest amount of carbon: 2793,390 (66.1% of the total C stored). Marinha Park stores 865,610 kg. (20.5%) of atmospheric carbon and the less carbon storage is hold in Harmonia Park with 567,190 kg (13.4%).

The carbon storage per area for the parks of Porto Alegre was 25,344 kg. per hectare. The gross carbon sequestration for Fuenlabrada was 1,049 kg/ha. By subtracting the carbon released by dying trees the net sequestration for Porto Alegre parks resulted in 952 kg/ha

The species that currently store the most carbon in Porto Alegre parks were Paineira, *Chorisia speciosa* (13.8% of total C stored); Tipa , *Tipuana tipu* (13.7%); Eucalipto perfumado, *Eucalyptus citriodora* (2.8%*)* and Beakpod eucalyptus, *Eucalyptus robusta* (2.2%). Gross carbon sequestration was greatest for Tipa (13.0%), Inga banana, *Inga vera* (9.8%), Paineira (9.5%) and Eucalipto perfumado (8.8%). Net carbon sequestration was greatest for Tipa (13.5%), Inga banana (10.0%), Paineira (9.3%) and Salgueiro, *Salix humboldtiana* (8.7%).

9.4.2.b. DISCUSSION

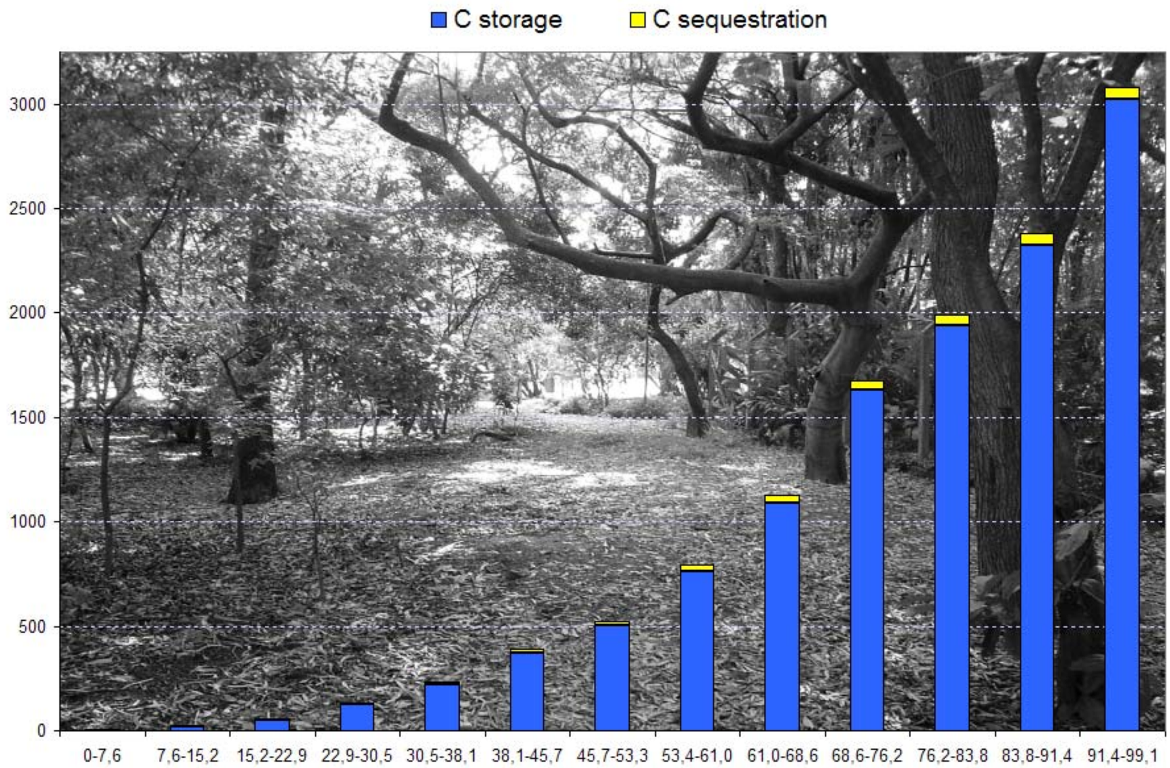

Fig. 9.4.b. C storage (kg/ha) and sequestration (kg/yr/ha) per area by dbh class (cm) in Porto Alegre.

The graphic in **Fig. 9.4.b.** shows how older trees (greater dbh class) accumulate more carbon and sequester more carbon as they grow than younger trees (smaller dbh class). In Porto Alegre, the difference the distribution of the age classes is not as polarized into young and old as in Fuenlabrada, and all dbh classes are present. There is a high storing of carbon (about 2,500 kg/ha) for the trees with dbh between 83.8 and 91.4 that did not exist in Fuenlabrada.

Farroupilha Park has almost 10,000 trees. It is the oldest park, with the highest number of exotics and stores 66.1% of the total carbon for Porto Alegre. Harmonia Park has around 4,500 trees but stores only 13.4% of the total. It is a park with many unmanaged areas were young trees are emerging. Marinha Park has approximately 3,500 trees that store 20.5% of the total carbon stored.

While the total carbon stored per area in Fuenlabrada parks (27,447 kg/ha) was a little higher than in Porto Alegre parks (25,344 kg/ha), the carbon sequestered ever year was higher in Porto Alegre: 1,049 kg/yr/ha versus 880 kg/yr/ha, and the same was true for the net carbon sequestration: 952 kg/yr/ha versus 749 kg/yr/ha. As the condition for trees was better in Fuenlabrada, the reason for this difference may be that growth rates for the trees of Porto Alegre are greater than those in Fuenlabrada. A subtropical climate without hard winters and the presence of more semi-deciduous and permanent leaf species could also explain it.

Both in Fuenlabrada (picture on the right) and Porto Alegre, machinery based on petrol fuel was used for maintenance purposes. The emissions produced by their combustion reduce the overall park's benefit on carbon and pollution removal. In Porto Alegre, maintenance practices such as mowing the lawn were reducing by letting natural succession occur. Manual labor should be encouraged to substituted fuel-based machinery.

It should be noted that the species with greatest net carbon sequestration results in Porto Alegre are all native except for *Tipuana tipa.* This last one is from Bolivia but has adapted very well to the local conditions. It is extensively used as a street tree and it forms beautiful street corridors. Inga vera and Paineira are natives with splendid forms and were noted as novel trees in many plots.

In relation to the management of decaying trees, Marinha Park collects and trims removed trees from the city parks in an area called 'Urban forest residues collection and treatment center'. They transform the wood into mulch and compost. Some of the carbon will be then stored in the soil and some will be liberated through decomposition, but they are definitely contributing to sustainability by recycling the waste, reducing expenses in buying fertilizers and avoiding chemicals from artificial fertilizers.

9.4.2.c. CONCLUSIONS – DESIGN STRATEGIES

1. **Selecting species**
   The best species for net carbon sequestration were Tipa, *Tipuana tipu,* Inga banana, *Inga vera,* Paineira, *Chorisia speciosa* and Salgueiro, *Salix humboldtiana.* Tipa is highly recommended to create street or park corridors. Inga banana and Paineira are native species with stunning forms and can be planted individually. Both Inga banana and the native salix Salgueiro are suitable for riverfronts.

2. **Management of decaying trees**
   Establishing a center for collecting and treating urban forest residues is a great strategy to be followed in any city. Recycling the wood products into compost, wood for fires or landfills increases the self-sufficiency of the urban forest, including parks and street trees.

3. **Maintain old specimens in parks**
   Similar to what happened in Fuenlabrada, Porto Alegre's main contribution to carbon storage was found in the oldest park: Farroupilha Park. This park has the oldest specimens of the city and they should be maintained until decay.

4. **Avoid use of fuel based management machinery**
   Maintenance labor could be done manually to avoid the use of fuel-based machinery. The use of alternative fuels could be studied. Letting natural regeneration occur saves maintenance costs and increases biodiversity.

9.4.3. PATTERNS ASSOCIATED TO CARBON STORAGE

- ***Aged trees***
- ***Thick trunks and branches***
- ***Wide canopies***
- ***Remnant forests***
- ***Healthy trees***
- ***Light and shade on the ground***

9.5. **POLLUTION REMOVAL**

One of the ways park trees improve air quality is by directly removing atmospheric pollutants. Trees remove the majority of the air pollution through their leaves gas interchange during photosynthesis processes. Trees also remove pollution in the form of particles, most of them retained in the plant surface. Pollution removal is very dependant to the local concentration of pollutants, the condition of the trees and the local weather.

Local pollution data, weather data and tree data was input into the UFORE Model from the USDA Forest Service to estimate tree pollution removal for the year 2002 in the parks of Fuenlabrada and Porto Alegre. For details refer to the methods chapter. The pollutants analyzed were carbon monoxide (CO), nitrogen dioxide (NO_2), tropospheric (ground-level) ozone (O_3), particulate matter less than 10 microns (PM10), and sulfur dioxide (SO_2). The following are the summary results.

9.5.1. FUENLABRADA

9.4.3.a. RESULTS

The trees in the three parks studied in Fuenlabrada removed 577 kg. of pollutants during the 2002. As seen in **Fig. 9.5.a.** the park that contributed more to air quality improvement was El Olivar with 317 kg. of pollutants removed (54.9% of the total), followed by La Paz (23.4%) and La Solidaridad (21.7%).

Pollution removal was greatest for PM10 followed by O_3, NO_2, SO_2 and CO.

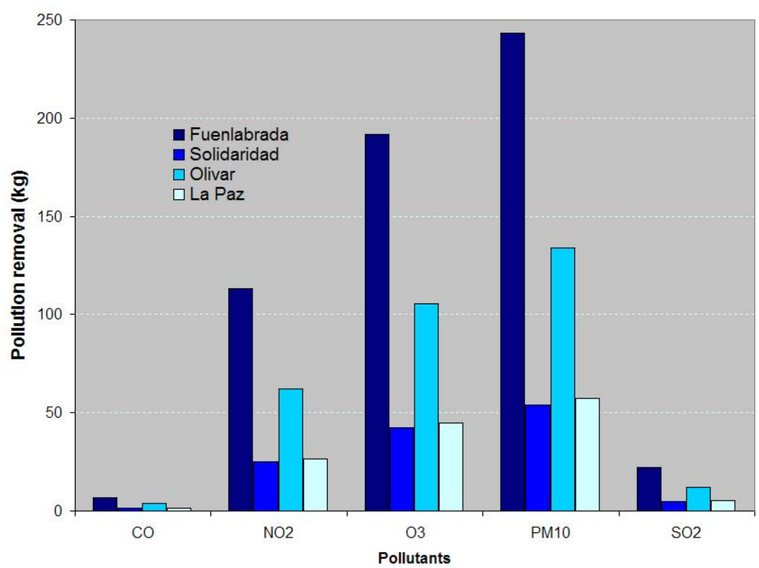

Fig. 9.5.a. Total pollution removal in Fuenlabrada parks.

9.4.3.b. DISCUSSION

Pollution removal levels depend on many factors such as tree canopy cover, tree health, local meteorology, and pollutant concentration in the air. El Olivar is the park with more trees and canopy cover so its contribution to air quality improvement was the greatest.

Ozone levels were very high for Fuenlabrada during the year 2002, mostly in the summer months. The Spanish and European Community health departments have established several thresholds for ozone concentration. A limit of 180 ug/m3 was set up for public warning. Levels beyond 360 ug/m3 are thought to be directly related to health problems, such as asthma and other pulmonary complications. In Fuenlabrada, the ozone levels went over the warning threshold 29 times in 2002, and 81 times in 2003. High temperatures, intense sunrays and high levels of NO_2 can lead to ozone formation during summer days. These levels were higher around noontime and citizens were recommended to avoid active sports during those hours. There is a real preoccupation among citizens and politics on this particular problem and any strategy leading to reduce it would be welcome.

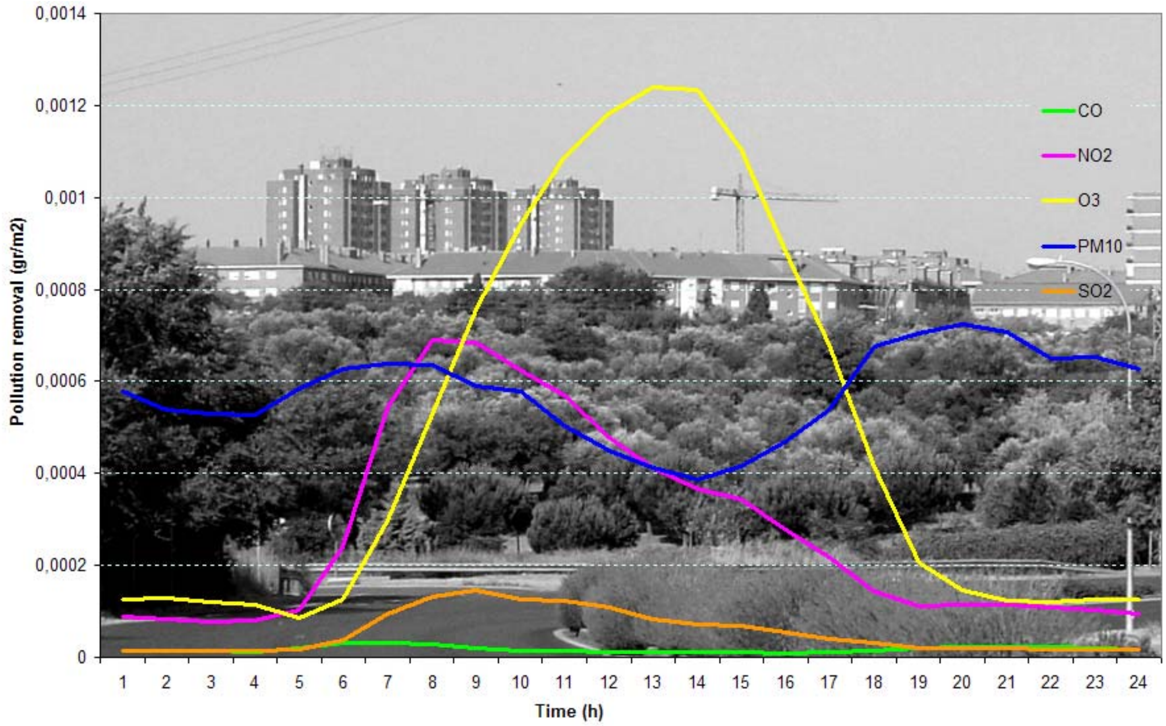

Fig. 9.5.b. Average pollution removal rate during the day in Fuenlabrada parks.

Pollutant removal was higher during day hours as the graphic in **Fig. 9.5.b.** shows. Reasons for this are higher concentration of pollutants from vehicular traffic and more photosynthetic activity during those hours. Particulate matter (PM10) and carbon monoxide (CO) are mainly retained by deposition on plant surface and did not show such daily variation.

9.4.3.c. CONCLUSIONS – DESIGN STRATEGIES

1. **Increase canopy cover**
   If the city of Fuenlabrada is interested in reducing urban pollution levels more trees should be planted, preferably along main traffic corridors. La Solidaridad park is a great example of a park as a buffer of permanent leaf vegetation against the highway. Trees planting can occur within the parks or in public streets.

2. **Preserve old trees and remnant forests**
   As old trees have greater canopies and leaf area indexes their contribution to pollution removal is greater. In the case of El Olivar, this old park accounted for more than 50% of the total pollution removed. Old specimens and former vegetated areas

should be valued as great pollutant removers from an air quality improvement perspective.

3. **Sustain existing tree cover**
The existing green structure in the parks should be preserved to maintain the current pollution removal levels.

4. **Used long-lived trees**
It reduces long-term pollution pollutant emissions from planting and removal.

5. **Reduce fossil fuel in maintaining vegetation**
Some machinery work can be substituted by manual labor or more efficient equipment to reduce pollutant emissions.

9.5.2. PORTO ALEGRE

9.5.2.a. RESULTS

The trees in Porto Alegre parks removed 4,085 kg. of pollutants during the 2002. As seen in **Fig. 9.5.c.** the park that contributed more to air quality improvement was Farroupilha with 1,659 kg. of pollutants removed (40,6% of the total), followed by Marinha (36,2%) and Harmonia (23,2%).

Pollution removal was greatest for PM10 followed by NO_2, O_3, SO_2 and CO.

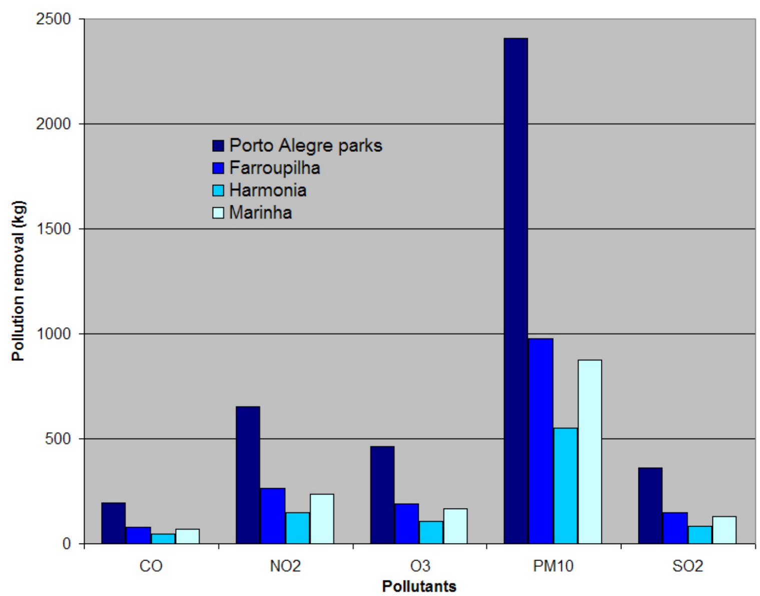

Fig. 9.5.c. Total pollution removal in Porto Alegre parks.

9.5.2.b. DISCUSSION

Pollution removal was higher in those parks that had greater canopy cover. Even though Farroupilha Park is the smallest green space in area, their trees are older and have larger leaf surfaces. 6.1% of the trees had diameters at breast hight (dbh) greater than 76 cm. Marinha is the greatest park in area but has no large trees (0% dbh greater than 76 cm.). Harmonia is the smallest park in area with the lowest canopy cover as well.

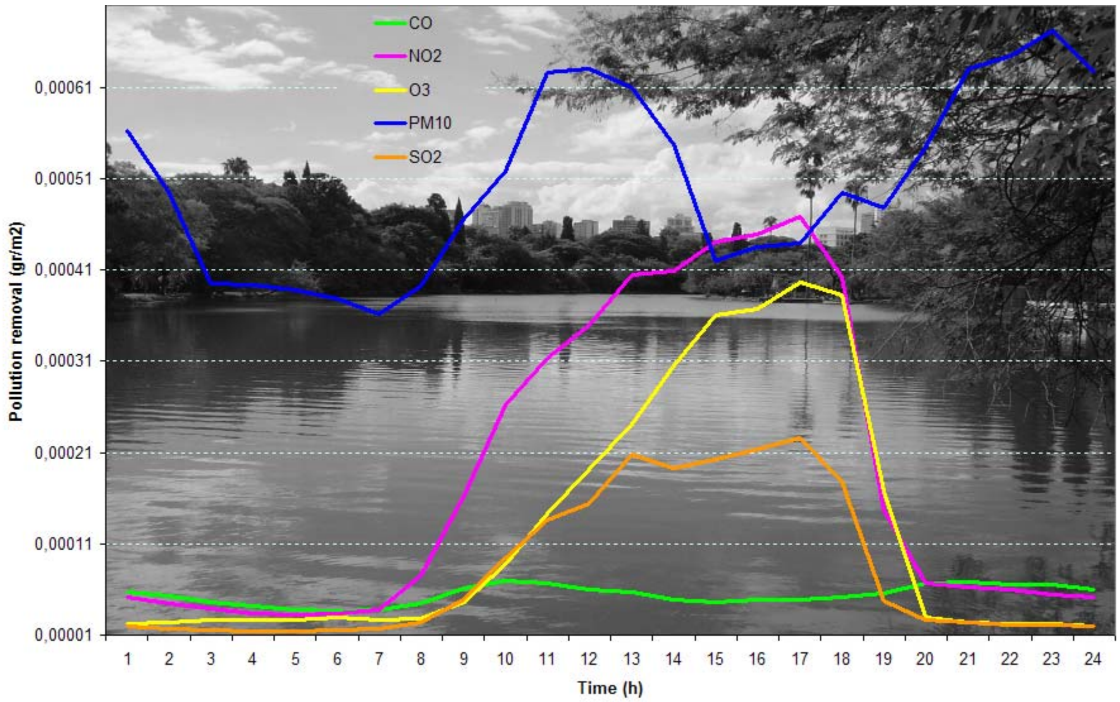

Fig. 9.5.d. Average pollution removal rate during the day in Fuenlabrada parks.

The previous graphic on **Fig. 9.5.d.** shows the daily variation in pollution removal. Like in Fuenlabrada, removal rates were higher during the day hours with the highest levels around 5 p.m. (17 h). Particulate matter, as explained before, has less daily variation.

9.5.2.c. CONCLUSIONS – DESIGN STRATEGIES

1. **Increase canopy cover**
   Increasing the tree density in parks will contribute to reduce air pollution. Harmonia Park and Marinha Park are more eligible for new planting as they have more vacant spaces. They both have main traffic road going through them than could be buffered with tree planting on the edges. At some specific locations landscape views may conflict with these vegetated barriers.

2. **Preserve old trees**
   Like in Fuenlabrada, the oldest park of Porto Alegre contributed the most to pollution removal. Farroupilha Park has huge size specimens that should be preserved for their canopy cover while they are in good condition. The park is located in the center of the city and surrounded on three of its four sides by traffic corridors. To the north side of the park planting could be more intense as that edge meets the main East-West transportation access of the city with dense traffic during day hours.

3. **Plant trees in polluted areas or heavily populated areas**
   To maximize the tree air quality benefits.

9.5.3. POLLUTION REMOVAL RATES

As the concentration of the pollutants in each city was different, the pollution removal rate also differed from Fuenlabrada to Porto Alegre. The graphic on **Fig. 9.5.e.** shows the comparison between the two cities city removal rates for each pollutant.

As mentioned before, Ozone (O3) concentration levels in Fuenlabrada were very high during the summer. For that reason, trees were removing more atmospheric ozone in Fuenlabrada than in Porto Alegre. Nitrogen dioxide removal rates were also higher in the Spanish city while CO got higher removal rates in Porto Alegre.

The total removal rate was higher for Fuenlabrada (10.13 g/m2 of canopy cover) than for Porto Alegre (7.45 g/m2 of canopy cover).

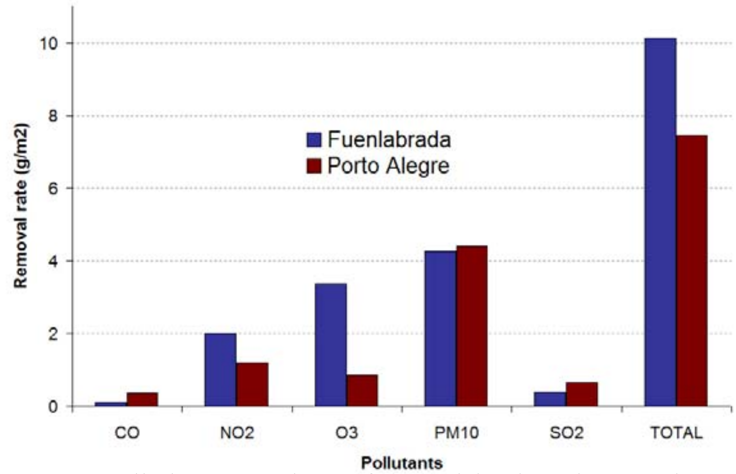

Fig. 9.5.e. Pollution removal rates for Fuenlabrada and Porto Alegre.

The average pollution removal rate during the day also differed for each city as **Fig. 9.5.f.** shows. Ozone (O_3) and nitrogen dioxide (NO_2) levels were higher in Fuenlabrada. In Fuenlabrada NO_2 and SO_2 levels were higher during the morning hours while in Porto Alegre that happened during late afternoon hours. Traffic patterns may be the reason behind. As particulate matter (PM10) is mainly retained by deposition on plant surface it did not show a drastic variation.

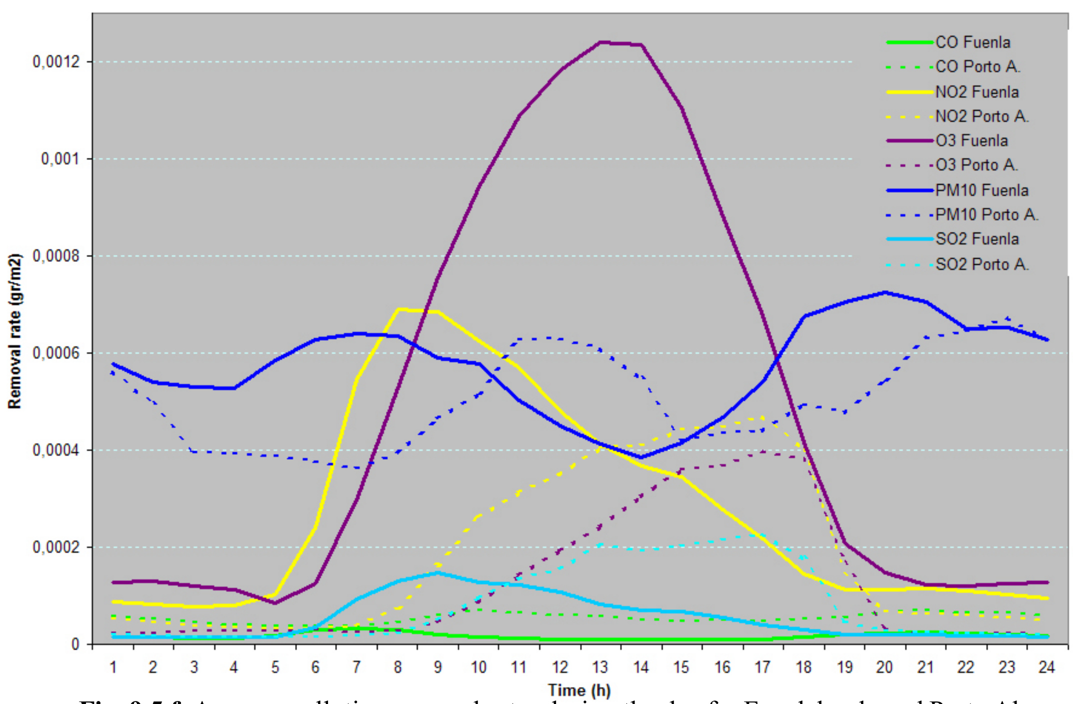

Fig. 9.5.f. Average pollution removal rates during the day for Fuenlabrada and Porto Alegre.

9.5.4. PATTERNS ASSOCIATED TO POLLUTION REMOVAL

- ***Noise reduction***
- ***Conifer barrier***
- ***Wide canopies***
- ***High percentage of evergreen trees***
- ***High percentage of tree cover***

9.6. WATER AND SOIL PROTECTION

Urban parks contribute to protect water and soil resources in many ways. Vegetation reduces soil erosion and compaction. The tree roots fixed the particles of soil and facilitate air movement. Trees within soils also help water infiltration on site. By reducing surface run-off and lowering water movement they help refill water tables. Canopy cover also reduces temperatures through evaporation.

In this study the protection of water bodies and soil was measured in plots with vegetation as the percent of land protected. Water bodies were considered protected by vegetation when the green structure is located within 150 m. from the water. Irrigation frequencies were also measured to estimate water waste.

9.6.1. **FUENLABRADA**

9.6.1.a. RESULTS

The park trees in Fuenlabrada are protecting soil more than water, as shown in **Fig. 9.6.a.** El Olivar is the park where vegetation prevents more from compaction (54% of the total area is being protected). In La Paz the area protected from compaction was 24%. Soil protection from erosion was similar in the three parks (around 10% of the area).

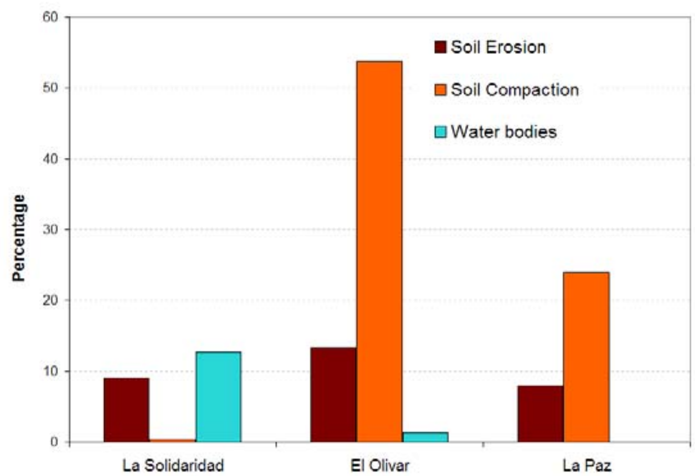

Fig. 9.6.a. Soil and water protection in Fuenlabrada Parks.

La Solidaridad is the only park contributing to protect water bodies (10% of the area).

Water needs were higher in La Paz Park where 71% of the areas are watered daily. El Olivar Park was the most efficient in water saving, as 70% of the areas need no watering and only 10% is watered daily. La Solidaridad has 40% of the area watered 3 times a week, 21% watered daily.

Both La Solidaridad and La Paz had only 12% of the area without watering needs.

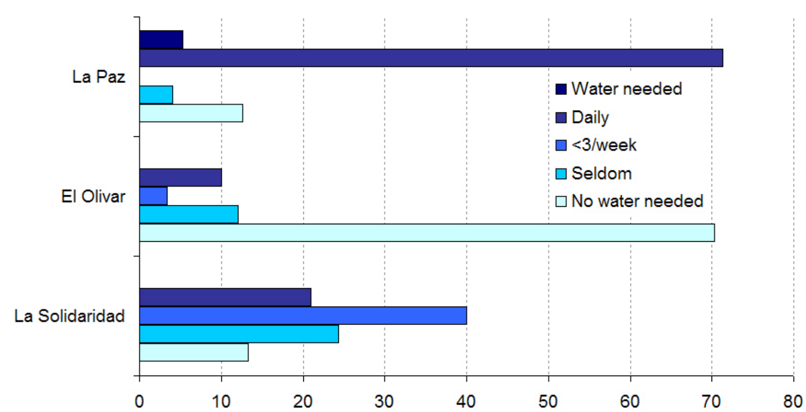

Fig. 9.6.b. Watering waste in Fuenlabrada Parks by area percent.

9.6.1.b. DISCUSSION

El Olivar is an old olive grove transformed into a park. Located in an arid area the soil would be compacted and water would not infiltrate without the olive tree cover. There are also some management strategies to avoid compaction such as laboring within the tree lines to break the soil surface once a year. This is a strategy followed traditionally by farmers working the olive grove land that was adopted by the park managers. As the vegetation is adapted to the local climate the watering needs and waste are minimal.

Protection of water bodies was highest in La Solidaridad as it is the only park with considerable water bodies. There is reservoir located in the north of the park where water is stored. From there a series of water canals run through the park providing a series of water features: ponds, channels, waterfalls and jets. In some areas water is used for irrigation. The whole park has permanent water irrigation systems installed on site. The water system is closed and recycles the water. This is a great example of water management.




La Paz Park was planted with many exotics and ornamentals that demand much more water than the weather provides. The irrigation system is manual and movable so park staff needs to work daily in the park during the summer placing the systems in different areas. It is the least efficient in water savings.

9.6.1.c. CONCLUSIONS - DESIGN STRATEGIES

1. **Recycle water**

If a water system is to be installed in the park it should be carefully design to avoid water waste. Water running through the park can be used for irrigation purposes. Water not taken by the plants should go back to the water system and circulate again. Water reservoir will be located at the highest elevation point so water circulation will happen by gravity.

2. **Permanent irrigation systems**

When using vegetation that requires irrigation it is recommended to use permanent watering systems. These systems are automatic and can be programmed to water in the more efficient hours (nights and mornings). They save water waste and labor.

3. **Protecting slopes**

Soil erosion is more likely to happen in steep terrain. Vegetation should be planted where slopes are steep to facilitate water infiltration, prevent surface run-off and soil losses from erosion.

9.6.2. PORTO ALEGRE

9.6.2.a. RESULTS

As can be seen in the graphic on **Fig. 9.6.c.** Porto Alegre parks contribute more evenly to water and soil protection.

Marinha Park has the great contribution with almost 29% of the area with trees protecting water and 19% protecting from soil compaction. Farroupilha Park contributes to protect water bodies in 23% of the area and Harmonia in 19% of its park area.

Watering waste in Porto Alegre was very low compared to Fuenlabrada. Marinha was the least demanding park in water with 50% of the area without needs and 8% watered seldom. Harmonia did not need water in 47% of the area and 19% was watered seldom.

Farroupilha was watered seldom in 56% of the areas and only 9% needed no water.

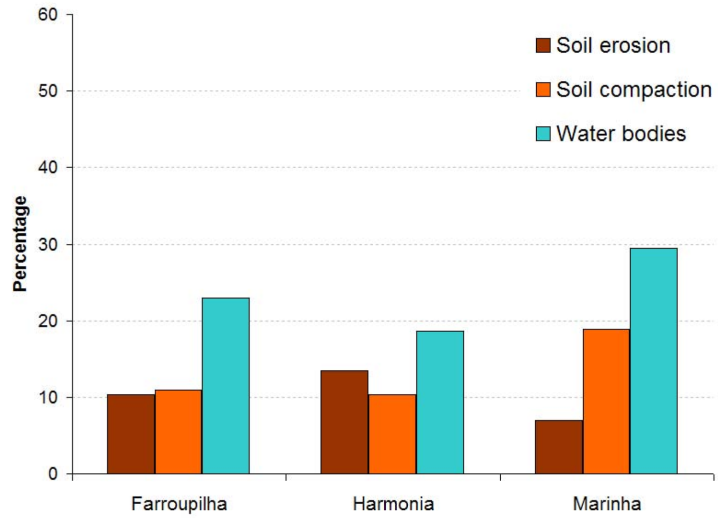

Fig. 9.6.c. Soil and water protection in Fuenlabrada Parks.

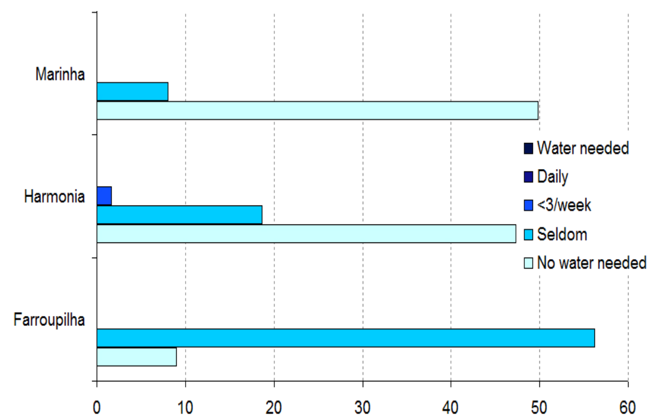

Fig. 9.6.d. Watering waste in Porto Alegre Parks by area percent.

9.6.2.b. DISCUSSION

Marinha Park and Harmonia Park are located in the edge of the city, where the land meets the Guaiba River. The terrain was a landfill to expand the city area. This riverfront is not very well managed by the city and few areas are planted. Most of the shoreline being colonized by remnant vegetation, is either vacant land or open space (see picture).

The contribution of these parks to protect water bodies could be much higher if more trees were planted. Some areas of Marinha Park have been redesigned and the area protecting water reached 29%. Marinha Park has also a water system running in some areas with two main ponds connected by an artificial creek. A small wetland is being set aside inside Harmonia Park. Harmonia and Marinha park have the highest percentage of native species. The adaptation to the local weather reduces the need for watering. The low levels of water waste are a consequence of many areas in these parks without any vegetation.

Farroupilha Park contributes to protect water in 19% of its area. There is an artificial lake located over a terrain that naturally collects water from the watershed. The lake fills in naturally and the exceeding water was used for fountains in the past. Today it goes to the city sewer.

Watering needs are not very high in Porto Alegre (in comparison to Spain) due to the humidity of the subtropical climate. Farroupilha has a good percent of exotic species and in times of drought, cars with pipes (*carro pipa*) collect water from the lake to irrigate the areas of the park with water needs.

9.6.2.c. CONCLUSIONS

1. **Locate ponds and lakes where water stores naturally**
The lake in Farroupilha Park is managed successfully because it lies in the lowest elevation of the park. Water was naturally stored there before the park existed and the water table is very close to the surface.

2. **Increase vegetation on the riverfront**
As a recommendation, park managers in Porto Alegre should increase tree planting along the riverfront. There are many vacant lands being vandalized and unused. Some areas with emergent vegetation could be set aside for natural succession as the total are seems to big to be successfully managed by the park department.

3. **Experiment with new soil types**
Farroupilha Park had a serious problem of soil compaction and water pool formation. The type of soil used for walking does not let water percolate neither let persons with disabilities walk over it. New types of porous soil in combination with paved surfaces may be a solution.

4. **Use stored water to irrigate**
Using the water that exceeds from storage for irrigation purposes will make the park more self-sufficient.

9.6.3. PATTERNS ASSOCIATED TO WATER AND SOIL RESOURCES PROTECTION

- ***Presence of birds***
- ***Views of the river***
- ***Roots on earth***
- ***Relation to regional ecology***
- ***Trees on the water***
- ***Breeze sound***
- ***Grass on sand***
- ***Path in the sand***
- ***Colonizing vegetation***
- ***Foliage on the ground***
- ***Water related plants***
- ***Soil texture variety***
- ***Water edge***

9.7. VITALITY

Under this theme, vitality of the parks was studied through the vitality of the trees. The healthier the trees are, the higher the park's contribution to sustainability. Improvement of air quality, carbon storage, soil and water protection and other benefits are maximized when trees are in good condition. The health of the trees is also an indicator of how well maintained the parks are and how long the park can last in good shape. Healthy trees also reduce maintenance costs drastically.

In this study condition of the trees was estimated through missing canopy. Refer to the methods chapter for condition definitions. The results are used to estimate the park condition but also to identify the species that have adapted better to the environment.

9.7.1. **FUENLABRADA**

9.7.1.a. RESULTS

The following table summarizes the conditions of the trees in the three parks of Fuenlabrada by percentage.

	Excellent	Good	Fair	Poor	Critical	Dying	Dead
Parks	%	%	%	%	%	%	%
La Solidaridad	48.5	38.6	6.9	2.0	1.0	3.0	0.0
El Olivar	25.8	47.8	19.5	1.9	4.4	0.0	0.6
La Paz	29.4	53.2	12.7	2.4	2.4	0.0	0.0
Fuenlabrada	**34.4**	**45.5**	**13.9**	**2.0**	**2.9**	**1.0**	**0.3**

Table 9.7.a. Tree condition for Fuenlabrada Parks

The park with highest percent of trees in good condition was La Solidaridad, with almost 50% of the trees in excellent condition and near 40% in good condition. La Paz was the second park in health ranking, with around 29% of its trees rating excellent and 53% rating good. El Olivar was had 26% of its trees in excellent condition and 48% as good. As an average result, Fuenlabrada parks have about 80% of the trees in excellent or good condition.

The following table summarizes those species that were 100% (unless noted) in best (excellent and good) and worst (critical to dead) condition.

Excellent	Good	Critical	Dying or Dead
Tree of heaven (*Ailanthus altissima*)	Japanese flowering crabapple (*Malus floribunda*)	Sycamore maple (*Acer pseudoplatanus)* (36%)	Saucer magnolia *(Magnolia xsoulangeana*
Port orford cedar (*Chamaecyparis lawsoniana*)	Norway maple (*Acer platanoides)*	Mediterranean fan palm *Chamaerops humilis (33%)*	Mimosa *Albizia julibrissim)* (50%)
Drácena (*Dracaena sp.)*	European alder (*Alnus glutinosa)*	Siberian elm *Ulmus pumila* (29%)	Hackberry *(Celtis australis)* (16%)
Southern magnolia (*Magnolia grandiflora)*	Juniper (*Juniper spp.)*		Siberian elm (*Ulmus pumila)* (6%)
Giant sequoia (*Sequoiadendrom giganteum*)	Laurel (*Laurus nobilis)*		
European mountain ash (*Sorbus aucuparia*)	Ligustro (*Ligustrum vulgare)*		
Montezuma cypress (*Taxodium mucronatum)*	Tulip tree (*Liriodendron tulipifera)*		
	London planetree (*Platanus hybrida)*		

Table 9.7.b. Tree condition summary for Fuenlabrada Parks by species

In Fuenlabrada parks seven species were in excellent condition and eight species were in good condition. The natives *Sorbus aucuparia, Alnus glutinosa, Dracaena sp. and Laurus nobilis* were among them. Only three species had specimens in critical condition, three dying and one dead. Nevertheless, still 73% of the trees are in good or excellent condition. For being such an old park this is a very decent vitality rank that shows how adapted vegetation, such as the olive trees, can live long even without being managed for years.

9.7.1.b. DISCUSSION

La Solidaridad was the park with greatest vitality and El Olivar was the park with the lowest vitality. The condition is very much related to the age of the vegetation.

La Solidaridad is the most recent park in the city; most of the individuals present are those who after surviving the first years of planting are well in the present. Most of them haven't gone trough drought periods, heavy storms or pest attacks. La Solidaridad has also a higher percentage of native species and an efficient irrigation system. (See picture, with Saucer magnolia in bad condition as the dead branches show)

La Paz is a park from the 1980's with more presence of exotics that demand a lot of water. That could be reason for more trees in good condition and less in excellent, although the overall condition is good as well.

El Olivar is the oldest park and the only one with trees in critical condition and some dead.

9.7.1.c. CONCLUSIONS – DESIGN STRATEGIES

4. **Supervise tree development in the first years**
   Most of the problems with vegetation happen in the first years after planting. If the plant gets well established in the first years it will probably be a healthy tree in the future. Spending more money in supervising the establishment of the park can reduce greater future investments for maintenance. A strategy followed in some parks is to keep them closed in these first years of tree establishment.

5. **Use of adapted vegetation**
   The species to be planted must be adapted to the local climate to avoid health problems. In general, exotic species require more care and have fewer defenses against harsh conditions. Natives should be preferred to preserve diversity.

6. **Choice of species**
   Low maintenance species are preferable. Maintaining healthy parks through the expense of watering, pruning and use of pesticides is not a sustainable strategy. The best species will should not require much attention to grow healthy and will not be easily threatened by pests or diseases. S*orbus aucuparia, Alnus glutinosa, Dracaena sp.* and *Laurus nobilis* were doing well in Fuenlabrada, although the two first should be associated with humid environments.

9.7.2. **PORTO ALEGRE**

9.7.2.a. RESULTS

Table 9.7.b. summarizes the tree condition for Porto Alegre parks.

Parks	Excellent %	Good %	Fair %	Poor %	Critical %	Dying %	Dead %
Farroupilha	29.1	50.7	13.5	2.7	2.7	0.7	0.7
Harmonia	28.3	41.3	26.1	4.3	0.0	0.0	0.0
Marinha	28.1	43.8	21.9	6.3	0.0	0.0	0.0
Porto Alegre	**28.7**	**47.0**	**18.3**	**3.8**	**1.5**	**0.4**	**0.4**

Table 9.7.c. Tree condition for Porto Alegre Parks

The vegetation in the parks of Porto Alegre is mostly in good condition, 47%, and excellent condition, nearly 29%. The healthiest park was Farroupilha with about 51% of the trees in good condition and 29% in excellent condition, but it is also the park with more trees below critical condition (4.1%). Marinha Park was second in vitality ratings with almost 44% of the trees under good condition and 28% as excellent. Harmonia Park was similar to Marinha but with less trees in good condition (41%).

The number of species in good health was higher for Porto Alegre parks than for Fuenlabrada. A total of 13 species were in excellent condition, seven of them being native. A total of 10 species were in good condition, eight of them being native. Only one species was in critical condition, an exotic. The 0.7% of dying or dead species present in Farroupilha Park were not identified.

Excellent	Good	Critical	Dying or Dead
Palmeira (*Phoenix sylvestris)*	*Aegiphila sp.*	Slash pine (*Pinus eliotii*)	Unknown
Ombú (*Phytolacca dioica*)	Angico vermelho *(Parapiptadenia rigida)*		
Jerivá *(Syagrus romanzoffiana)*	Capororocao *(Myrsine umbellata)*		
Figueira (Ficus microcarpa)	Chinaberry *(Melia azedarach)*		
Mexican fan palm (*Washingtonia robusta*)	Figueira de folha miuda *(Ficus organensis)*		
Guapuruvú *(Schizolobium parahybum)*	Goabiroba miuda *(Campomanesia rhombea)*		
Common crapemyrtle *(Lagerstroemia indica)*	Jerusalem thorn *(Parkinsonia aculeata)*		
London planetree (*Platanus x acerifolia)*	Senegal date palm *(Phoenix reclinata)*		
Cerejeira *(Eugenia involucrata)*	Taruma de espinho (*Citharexylum montevidense*)		
Camboatá vermelho (*Cupania vernalis)*	Timbaúva (*Enterolobium contortilisquum)*		
Cabriuva *(Myrocarpus frondosus*)			
Arbol del coral *(Eritrina crista-galli*)			
Araçá *(Psidium cattleyanum)*			

Table 9.7.d. Tree condition summary for Porto Alegre Parks by species

9.7.2.b. DISCUSSION

While there is much less maintenance in the parks of Porto Alegre, the vitality of the trees did not show a big difference from those in Fuenlabrada. Species seem to have been selected more carefully than in Fuenlabrada as the percent of critical, dying and dead trees was lower. Fuenlabrada had more trees in excellent condition, but the total number for excellent, good and fair condition trees was very similar in both cities (around 94%).

The only park with decaying trees in Porto Alegre was Farroupilha Park. As an old park, it contains aged trees that are dying that will not be removed until they are completely dead or proved to be a danger for the people. As they let natural succession occur in this park, there is also a young population of trees growing. This is the only park of the three with watering management, and the one with highest percent of excellent trees. There seems to be a direct relation between watering practices and excellent condition in trees.

The strategy used in Porto Alegre parks is that by using native species they reduce costs on watering and maintenance. This is a more sustainable approach because it preserves biodiversity and protects water resources while keeping the same percent of trees above fair condition. The cost is having fewer trees in excellent condition and more under good or fair.

The total percent of excellent condition trees was smaller than in Fuenlabrada, but the variety of the species was higher (13 versus 8, 7 natives versus 4).

9.7.2.c. CONCLUSIONS – DESIGN STRATEGIES

1. **Use of native species**
   Native species are recommended to keep parks healthy. In Porto Alegre 100% of the trees in the following species were in excellent condition: *Eritrina crista-galli, Myrocarpus frondosus, Cupania vernalis, Eugenia involucrata, Schizolobium parahybum, Syagrus romanzoffiana,* and *Phytolacca dioica.* The following natives were in good condition: *Aegiphila sp., Parapiptadenia rigida, Myrsine umbellata, Ficus organensis, Campomanesia rhombea, Parkinsonia aculeata, Citharexylum montevidense,* and *Enterolobium contortilisquum.*

2. **Select suitable locations for species**
   As lack of watering and low maintenance was common in Porto Alegre, species were carefully selected to meet the site conditions. It is a more sustainable strategy to put the effort in the establishment of the vegetation (species selection, substituting wrong plantings, etc) than in later maintenance practices that can last longer periods.

9.7.3. PATTERNS ASSOCIATED TO VITALITY

- ***Young forest***
- ***Healthy trees***
- ***Vegetation thickness***
- ***Presence of shrubs, vines and herbs***
- ***Tree place***
- ***Shaded areas***

9.8. CONNECTIVITY

9.8.1. RESULTS

Connectivity of the ecosystems was measured through a subjective connectivity index value (C.I.) and the degree of area fragmented. Refer to the methods section for more details. Connected green areas are more resistant to pest, diseases and invasive species. They also provide migration corridors for fauna from the surroundings and habitat opportunities for urban wildlife. The overall results for the two cities are shown in **Table 9.8.a.**

	Fuenlabrada				**Porto Alegre**			
	La Solidaridad	El Olivar	La Paz	**Avg.**	Farroupilha	Harmonia	Marinha	**Avg.**
C.I.	2	4	2	**3**	3	2	2	**2**
Fragmentation	43%	22%	59%	**42%**	40%	47%	68%	**52%**

Table 9.8.a. Connectivity results for Fuenlabrada and Porto Alegre parks.

Connectivity was higher for Fuenlabrada than for Porto Alegre parks. In both cases, the parks with best results (El Olivar and Farroupilha) are the oldest ones in each city.

9.8.2. DISSCUSION

Although results for Fuenlabrada were better than for Porto Alegre, La Solidaridad and La Paz have a poorly connected green structure. These two parks have a great percentage of hardscape that fragments the ecosystems and breaks continuity inside the park. In Porto Alegre, Harmonia and Marinha got the worst results as they contain many vacant lands in their limits that remain unmanaged.

La Solidaridad has a good example of a greenway inside the park. Following an artificially created water system, green cover was planted surrounding the different elements: ponds, cascades, creeks and canals. The green corridor connects the two halves of the park and brings a sense of unity.

El Olivar is the park with the highest connectivity among all. It is a former olive grove that was incorporated in the city as a park. Unique aesthetic qualities such as horizontality and unity are associated with the continuous landscape of olive trees of El Olivar. The olive grove is also a reference of the traditional working landscapes of southern Spain.

La Solidaridad and El Olivar are fenced parks, a fact that isolates the green areas from the surroundings. When parks are located in the periphery of the city, as in this case, links with the surroundings become essential to allow interaction between the urban green area and the plant and animal species from the region.

Farroupilha Park was the least fragmented park in Porto Alegre. Being the oldest of the three parks, the tree cover was greater and the green structure was more continuous. Another important factor that contributed to connectivity was that natural succession was allowed to occur inside the park. A number of new growing trees will maintain the green connectivity in the following years.

In Marinha and Harmonia parks, some of the areas with great connectivity were located in the Guaiba River shoreline. Emergent patches have colonized the terrain at some locations and they should be used to create a corridor along the water's edge. Both parks are divided by a smaller river that local fauna uses as a natural link between the city and the Guaiba River (right).

In Porto Alegre, a bike trail is also used to connect the parks through densely vegetated streets during the weekends.

9.8.3. CONCLUSIONS

9.8.3.a. DESIGN STRATEGIES - FUENLABRADA

1. **Use waterways to create green corridors**

As explained for La Solidaridad Park, green cover planted along water bodies can be used to connect different areas of the park.

2. **Connect parks with surrounding green areas**

Peripheral urban parks play an important role in connecting the city with the regional ecology. Surrounding fauna and flora interaction with the city should be included in the design concepts for those parks.

9.8.3.b. DESIGN STRATEGIES - PORTO ALEGRE

3. **Capitalize on existing natural connectors**

Rivers, streams, creeks and other waterways are used by animals to travel through urban areas. Increasing the vegetation cover on those areas will transform them in successful green connectors.

4. **Use riverfronts as green ways**

In Porto Alegre, Marinha and Harmonia parks are located on the riverfront. Unmanaged areas of the park have emergent vegetation patches. Connecting those patches will create a greenway that links the parks with the river ecology and provides recreational opportunities.

5. **Let natural succession increase vegetation cover**

Spatial green structure continuity is important, but continuity in time is vital as well. Letting natural succession occur, as in many parks in Porto Alegre, assures the sustainability of the tree cover through time.

9.8.4. PATTERNS ASSOCIATED WITH CONNECTIVITY

- ***Continuity***
- ***Wilderness feeling***
- ***Access to water***
- ***Connection with regional ecology***
- ***Presence of wildlife***
- ***Relation to the surrounding context***
- ***Horizontality***
- ***Sense of unity***
- ***Water connector***
- ***Line of trees***

10. FINAL CONCLUSIONS

10.1. REFLEXION

This capstone project was an attempt to study urban parks from an interdisciplinary perspective, using several theoretical frameworks and methods. Such an attempt was not easy and improvements were found for future studies.

Research studies on urban parks undertaken before were focusing either on the forest structure of the park (species composition, biodiversity, etc.), the analysis of the design (post occupancy evaluation, design issues, etc) or socioeconomic sustainability (social benefits, user satisfaction, etc.). During the literature review I did not find any research combining those themes.

My own experience as a forestry engineer, and recently as a landscape architect student, have given me some thoughts on why that was not being investigated. In my opinion, most of foresters have a strong scientific background, but lack design abilities and do not include aesthetic concerns in their research. Urban parks are interpreted as pocket forests in the city. On the other hand, landscape architects have a firm design education, and they understand ecological processes as well, but their knowledge is so broad that they do not usually apply scientific methodology to analyze those processes in enough depth.

This capstone project was a test of combining the perspectives of the forester and the designer together under a sustainability framework. As an experiment, it was a learning experience.

The intention of the study was to broaden the approach to urban park design and demonstrate that environmental benefits, aesthetic qualities and sustainable green structure can, and should be, planned together. In my understanding, that intention was accomplished.

Recommendations for the city parks were also made and they will be sent to the city's parks departments.

The core of the study was based on quantitative scientific methods, with the advantage that it could be replicated in any city or any park. A simplified version could also be used as a tool to measure how urban parks in a city are achieving sustainability goals, and what strategies could by apply to maximize them.

10.2. CONSTRAINTS

Data collection took 9 months of work. The most difficult part was measuring the forest structure, which took 3 months for each city (a month per park) for two people working about 25 hours a week. If inventories of the vegetation were available data gathering time would be reduced.

Using randomly located plots was necessary to have sound forest structure data and a broad variety of design strategies. Good and bad strategies were both interesting for this study. If the main interest is to focus on best strategies, a first analysis of the parks could be made to locate plots in the most interesting areas, thus reducing data collection and analysis time.

City aerial photographs and weather data are usually accessible for researchers through municipal departments. Hourly pollution data is becoming available in most big cities but some have not established pollution stations making air quality results unavailable when applying the study to those cities.

A final difficulty was finding ways to relate design and sustainability. That was approached quantitatively by comparing the results of the best and worst examples. Some sustainability themes had a relationship with design qualities but others did not. It was more complex to analyze those relationships qualitatively. Christopher Alexander's theory of pattern language was of great help for this part, but other methods could have been used.

10.3. FUTURE STUDIES

A variety of studies could follow up and improve the research done in this capstone project.

A considerable amount of data was gathered that could be analyzed in other ways. For instance, park functions (recreation, protection, preservation, aesthetics…) and design qualities (forms, textures, topography, identity, relation to context…) were both studied as a whole and compared against sustainability themes (biodiversity, connectivity…). Each function or aesthetic quality could have been studied independently against each other or against the sustainability themes to find specific design strategies. An variety of research could be made combining all the features measured such as, the relationship between aesthetic quality and topographic variety or, the relationship between protective functions and biodiversity, and so on.

In my opinion, it would also be worthy to experiment with other design theories to relate the sustainability results with the design quality ratings. Christopher Alexander's theory gave some understanding on that theme, but other authors with analysis more related with space morphology, such as Kevin Lynch, could be tested as well.

A reliable use of this study would also be to select two or three sustainability indicators for each theme and create a "sustainable parks indicators framework". This framework could be applied in many cities to keep track of the condition and environmental contributions of urban parks.

Mostly only environmental sustainability was addressed in this study. Through literature review and some testing, the framework could be updated to include indicators that measure the economic and social aspects of sustainability.

Another way to broaden the study would be to extend the methodology beyond the urban park limits. Street trees, plazas, greenways, roof gardens, or any urban place containing vegetation could be analyze in terms of environmental sustainability and design qualities, and new design strategies and recommendations could be found.

I would like to add as a final note that the most stimulating part of the study was doing it. The experience of many visits to the parks, talks with the park managers and users, and other observations of how design can influence park quality and people's behavior did not have a place in this document, but that hopefully will be incorporated in my future landscape architecture profession.

I hope the writing text will help others to appreciate how valuable urban parks are and how much they contribute to our quality of life.

11. BIBLIOGRAPHY

Abolina, K. and Zilans, A.: 2002, 'Evaluation of urban sustainability in specific sectors in Latvia'. *Environment, Development and Sustainability* 4: 299-314. Kluwer Academic Publishers, Printed in the Netherlands. 2002.

Alexander, C. et al.: 1977, '*A Pattern Language'.* Published by Oxford University Press, New York.

Alexander, C.: 1979, '*The Timeless Way of Building*'. Published by Oxford University Press, New York.

Atlas Ambiental de Porto Alegre. 1999. Coordinated by Rualdo Menegat, Maria Luiza Porto, Clovis Carlos Carraro and Luis Alberto Davila Fernandes. Ed. Universidade/UFGRS. Porto Alegre.

Beatly, T.: 2000, '*Green Urbanism: Learning from European Cities'.* Published by Island Press, D.C.

Carter, E.J.: 2003. Personal conversation May 6, 2003.

Cranz, G. et al.: 2003, 'The ecological park as an emerging type'. *Places* 15(3): 44-47. Published online by The H. W. Wilson Company. (http://vnweb.hwwilsonweb.com/hww/Journals)

Dwyer, J.F. et al.: 2003, 'Sustaining urban forests'. *Journal of Arboriculture* 29(1): 49-55. International Society of Arboriculture. Champaign. IL.

Hough, M.: 2001, 'Cities and Natural Process'. Published by Routledge. 29 West 35th Street, New York, 10001.

Jensen, M.B. et al.: 2000, 'Green structure and sustainability – developing a tool for local planning'. *Landscape and urban planning* 52: 117-133. Elsevier Science Inc, 655 Avenue of the Americas, New York, NY. Published online by Elsewier Science Inc. (www.elsevier.com/locate/landurbplan)

Ministerio del Medio Ambiente, 2000. 'Indicadores Ambientales: Una Propuesta Para España'. Centro de Publicaciones, Secretaria General Tecnica, Ministerio de Medio Ambiente.

McPherson, E.G.: 1992, 'Accounting for benefits and costs of urban greenspace'. *Landscape and Urban Planning,* 22: 41-51. Elsevier Science Publisher B.V., Amsterdam.

McPherson, E.G. et al.: 1997, 'Quantifying urban forest structure, function and value: the Chicago Urban Forest Climate Project'. *Urban Ecosystems*, 1: 49-61. Chapman & Hall.

McPherson, E.G. et al.: 1987, 'A Community Forest Planning Process: Case Study of Citizen Participation'. *Landscape and Urban Planning,* 15: 185-194. Elsvier Science Publishers B.V.

Nowak, D.J.; Dwyer, P.J.: 2000, 'Understanding the benefits and costs of urban forest ecosystems'. In: Kusher, J., ed. *Handbook or urban and community forestry in the Northeast*. New York. Plenum Publishers: 11-25.

Nowak, D.J. et al.: 2000, 'Brooklyn's Urban Forest'. US Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Nowak, D.J. et al.: 1996. 'Measuring and analyzing urban tree cover'. *Landscape and Urban Planning,* 36: 49-57. Published by Elsevier Science B.V.

Renn, O. et al.: 1998, 'How to apply the concept of sustainability to a region'. *Technological Forecasting and Social Change* 58: 63-81. Elsevier Science Inc, 655 Avenue of the Americas, New York, NY. Published online by Elsewier Science Inc. (www.elsevier.com/locate/eiar)

Schleicher-Tappeser, R. and Strati, F.: 1999, 'Sustainability- a new paradigm for research?', in M. Catizzone (ed.), *from Ecosystem Research to Sustainable Development: Towards a New Paradigm for Ecosystem Research,* Ecosystem Research Report No 26; European Commission, Directorate-General Science, Research and Development, Brussels, pp. 45-58.

Spangenberg, J.H.: 2002, 'Institutional sustainability indicators: an analysis of the institutions in Agenda 21 and a draft set of indicators for monitoring their effectivity'. *Sustainable Development* 10: 103-115. Published online by Wiley InterScience (www.intersience.wiley.com)

Thorén, K.H.: 2000, '"The green poster" A method to evaluate sustainability of the urban green structure'. *Environmental Impact Assessment Review* 20: 359-371. Published online by Elsewier Science Inc. (www.elsevier/locate/eiar)

Upham, P.: 2000, 'Scientific consensus on sustainability'. *Sustainable Development* 8: 180-190. Published online by John Wiley and Sons, Ltd and ERP Environment.

US Department of Agriculture, 2002. 'Sourcebook on Criteria and Indicators of Forest Sustainability in the Northeastern Area'.

World Conservation Union, UN Environment Programme, World Wide Fund for Nature: 1991, *Caring for the Earth.* IUCP/UNEP/WWF, Gland.

APPENDIX 1. FIELD DATA COLLECTION FORM

PLOT ID /parcela=	DATE/data =	CREW/equipe=	GPS COORD =	PHOTO #/foto =

PLOT SKETCH AND NOTES FOR PLOT RELOCATION

DESENHO DA PARCELA E NOTAS PARA LOCALIZACAO

(Note distance and direction from plot center to fixed objects; sketch fixed objects in relation to plot center)

Plot address =

Notes:

Plot contact Info: (for non-residential plots)

Name and Title ____________________________

Phone # __________________________________

LOCATING LANDMARKS (Identify at least 2 objects)

Measured Object (1) ________________________ Measured Object (2)_________________________

Distance to Object (1)_____________ Distance to Object (2)______________

Direction to Object (1)______________ Direction to Object (2)_____________

N

1. ACTUAL LAND USE/ uso do solo actual =	2. MAP LAND USE/ uso do solo aereo =	4. SHRUB COVER (%) cobertura arbustiva (%) =	3. PLOT TREE COVER = /cobertura arvorea	5. PLANTABLE SPACE (%) espaco disponivel plantacao (%) =	4.MEASUREMENT UNIT M / E

GROUND COVER Coberturas do solo	%BLDG predios	%CMNT concreto	%TAR asfalto	OTHER IMP? Out. Imp.	%SOIL terra	%PERM ROCK pedra perm.	%DUFF/ MULCH folhagem	%HERB/ IVY talhos/vegetais/herbas	%MAIN GRASS. Grama mant.	%UNMAIN. GRASS Grama nao	H2O agua	OTHER PERV. Outros pem.

Plot ID (parcela)=

			TREE SPECIES Especies arbóreas	DBH Diametro altura do peito								HEIGHT Altura				CROWN WIDTH Ancho copa					
#	DR	DS		1	2	3	4	5	6	7	HT t Dian	DIS	%	TOT	CRWN BASE Base copa	N-S	E-W	FOLIAGE DENSITY% Dens. folhagem	DIEBACK Ramas mortas%	CLE luz	NOTES/notas
1																					
2																					
3																					
4																					
5																					
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29																					

PARK:			PLOT#
Date		Researcher:	SHEET#
BIODIVERSIDAD: diversidad de ecosistemas			unidades
B1	Ecosistemas protegido		%
B2	Estado en la sucesión	(Remanente, Emergente, Plantado)	
B3	Tipo de ecosistema	Tipo:	%
	Hábitat Fauna? S/N	Tipo:	%
	Com.	Tipo:	%
B4	Estrato arbóreo	Estrato arbustivo Estrato herbáceo	
BIODIVERSIDAD: diversidad de especies arbóreas			
B4	Número de especies diferentes		
B5	Porcentaje de especies protegidas		%
B6	Porcentaje de especies nativas		%
CONECTIVIDAD de lo verde			
C1	Grado de conectividad		
C3	Porcentaje de ecosistema fragmentado		%
VITALIDAD			
D2	% con árboles con peor condición que buena (>10% dieback)		%
RECURSOS DEL AGUA Y SUELO			
E1	% de terreno con vegetación protegiendo suelo con problemas de erosión		%
E2	% de terreno con vegetación protegiendo recursos de agua (o zona acuática <150 m.)		%
E5	% de terreno con problemas de encharcamiento/ compactación		%
E6	% de terreno gestionado el recurso del agua con riego de calidad		
	Muy alta (vegetación xerófila)		%
	Alta (riego ocasional)		%
	Media (riego permanente diario)		%
	Baja (riego móvil diaria)		%
	Muy baja (necesita riego y sin riego)		%
OTROS			
O3	Transporte público < 500 m		S N
O4	Distancia a transporte publico		m
O5	Accesible ADA?		S N

CALIDAD DEL DISEÑO		Muy baja	Baja	Media	Alta	Muy alta
P1	Variedad de texturas / colores	1	2	3	4	5
comentarios						
P2	Variedad de silueta / forma	1	2	3	4	5
Com.						
P2	Lugar con identidad	1	2	3	4	5
Com.						
P4	Variedad de topografía	1	2	3	4	5
comentarios						
P5	Conexiones físico con lo circundante	1	2	3	4	5
Com.						
P6	Relación con el pasado / Conexiones con contexto	1	2	3	4	5
Com.						
P7	ESTADO (limpieza, vandalismo, ...)	1	2	3	4	5

FUNCIONES Estética Activo Pasivo Conservación Protección (barr.traf) Producción

OTHERS - elemento estético remarcable

Critica	disenho con suceso? Y N
Ideas	usado por la gente? Y N

APPENDIX 2. INTERVIEW FORM

ENTREVISTA CUESTIONARIO

FACTORES QUE INFLUYEN EN EL DISEÑO

1. ¿Creéis que el diseño de los parques en Fuenlabrada ha evolucionado en los últimos años?

2. En caso positivo, ¿a qué se debe esta evolución?

3. En vuestra opinión, ¿cuales son los factores más importantes a la hora de proyectar un parque?

4. ¿Tiene importancia el mantenimiento futuro a la hora de planificar un parque? (mucha, normal, poca)

5. ¿Es el riego un factor decisivo? (mucha, normal, poca)

LOCALIZACIÓN DEL PARQUE

6. ¿Existe algún criterio a escala municipal para la localización de nuevos parques en Fuenlabrada?

7. En vuestra opinión, ¿qué determina la localización de un parque?

8. ¿Consideráis importante que los parques estén conectados entre sí?

9. ¿Creéis que se puede proyectar un parque en una zona de interés biológico para protegerlo?

10. Que localización es preferible para un parque, ¿el centro de la ciudad o la periferia?

11. ¿Creéis que se pueden utilizar los parques para proteger zonas con problemas de erosión, inundaciones u otros problemas que la vegetación podría suavizar?

12. ¿Consideráis que se pueden utilizar parcelas abandonadas donde la vegetación va colonizando el terreno para proyectar futuros parques?

13. ¿Consideráis importante que un parque tenga accesos a transporte público en su cercanía? (mucho, normal, poco)

DISEÑO y MANTENIMIENTO DEL PARQUE

14. En vuestra opinión que es preferible:
    a. Una zona ajardinada con muchas especies diferentes
    b. o con un numero menor de especies (con el mismo numero de plantas)

15. ¿Que consideráis preferible?
    a. Una zona ajardinada con césped
    b. césped y árboles
    c. o césped, arbustos y árboles

16. ¿Consideráis importante de agua en los parques (estanques, canales de agua, riachuelos)? (mucho, normal, poco)

17. Cuando un árbol en un parque esta moribundo o muerto, ¿qué medidas se toman?

18. ¿Que importancia se da a las barreras arquitectónicas (inaccesible a personas minusválidas) en el diseño? (mucha, normal, poco)

19. ¿Consideráis importante la conexión con los alrededores o la historia del lugar en el diseño del parque? (mucha, normal, poco)

20. ¿Consideráis importante que exista una topografía variada en un parque? (mucha, normal, poco)

21. Para un parque, que funciones consideráis más importantes (de mayor a menor)
    a. Estética
    b. Recreo pasivo (paseo, sentarse a leer, ...)
    c. Recreo activo (correr, practicar deportes...)
    d. Protección del medioambiente (contaminación, recogida lluvia, regulación temperaturas..)

ELECCIÓN DE PLANTA

22. ¿Qué consideras prioritario en la elección de planta?
    a. Adaptación al medio
    b. Disponibilidad en vivero
    c. Precio
23. ¿Es preferible el empleo de especies autóctonas frente a exóticas?

24. ¿Es posible el empleo de especies protegidas (raras, en peligro de extinción) a la hora de elegir las especies?

25. ¿Consideráis importante la variedad de colores, formas o texturas en la elección de planta?

26. ¿Qué especies consideráis que han resultado mejor en los parques de Fuenlabrada?

PARQUES DE FUENLABRADA

27. ¿Cómo clasificarías (de mejor a peor) los siguientes parques en función de su calidad estética?
    a. La Paz
    b. La Solidaridad
    c. El Olivar

28. ¿Cómo clasificarías (de mejor a peor) los siguientes parques en función de su valor ecológico?
    a. La Paz
    b. La Solidaridad
    c. El Olivar

29. Podrías citar una característica que consideréis interesante para cada uno de estos parques
    a. La Paz
    b. La Solidaridad
    c. El Olivar

PARTICIPACIÓN CIUDADANA

30. ¿Qué influencia tiene la opinión del ciudadano en el diseño de los parques?

31. ¿Recibís comentarios de los ciudadanos con respecto a los parques?

32. En caso positivo, ¿sobre que temas suelen preocuparse?

33. ¿Qué opinión os merecería una iniciativa que involucrase a los ciudadanos en el diseño de un parque? ¿Y en su mantenimiento?

APPENDIX 3. SPECIES LIST

TREE SPECIES AND THEIR CONSTANTS FOR THE PARKS OF FUENLABRADA

CODE	GENUS	SPECIES	COMMON NAME	SHADING FACTOR	LEAF AREA TO BIOMASS FACTOR (m2/g)	LEAF BIOMASS TO VOLUME FACTOR (g/m3)
ABPI	Abies	pinsapo	Abeto de espaÑa	0.91000	0.007100	443.33
ACNE	Acer	negundo	Boxelder	0.85800	0.010931	116.67
ACPL	Acer	platanoides	Norway maple	0.88000	0.018528	116.00
ACPS	Acer	pseudoplatanus	Sycamore maple	0.85800	0.014300	116.67
AEHI	Aesculus	hippocastanum	Horsechestnut	0.88000	0.014300	379.31
AIAL	Ailanthus	altissima	Tree of heaven	0.83362	0.013461	379.31
ALJU	Albizia	julibrissin	Mimosa	0.83000	0.023000	379.31
ALGL	Alnus	glutinosa	European alder	0.83362	0.013717	379.31
ALIN	Alnus	incana	Grey alder	0.83362	0.013717	379.31
CADE2	Calocedrus	decurrens	Incense cedar	0.91000	0.004267	1290.00
CABI	Catalpa	bignonioides	Southern catalpa	0.76000	0.018750	379.31
CEAT	Cedrus	atlantica	Atlas cedar	0.91000	0.004267	920.00
CEAU	Celtis	australis	European hackberry	0.92000	0.016964	312.50
CEOC	Celtis	occidentalis	Northern hackberry	0.88000	0.019220	75.00
CESI2	Cersis	siliquastrum	Arbol de judea	0.83362	0.015616	379.31
CHLA2	Chamaecyparis	lawsoniana	Port orford cedar	0.91000	0.004000	2031.67
CHHU	Chamaerops	humilis	Mediterranean fan palm	0.91000	0.005963	620.00
COAV	Corylus	avellana	European filbert	0.83362	0.014400	379.31
CUAR	Cupressus	arizonica	Arizona cypress	0.91000	0.004267	3020.00
CUSE	Cupressus	sempervirens	Italian cypress	0.91000	0.004267	5100.00
DR	Dracaena	spp.	DrÁcena	0.91000	0.005963	620.00
ELAN	Elaeagnus	angustifolia	Russian olive	0.87000	0.013461	379.31
FICA	Ficus	carica	Common fig	0.83362	0.013461	379.31
JURE	Juglans	regia	English walnut	0.91000	0.023725	379.31
JU	Juniperus	species	Juniper	0.91000	0.003600	3700.00
LANO	Laurus	nobilis	Laurel de olor	0.83362	0.013461	379.31
LIJA	Ligustrum	japonicum	Ligustro	0.83362	0.011000	230.00
LIFO	Liquidambar	formosana	Chinese sweet gum	0.82000	0.021782	368.00
LIST	Liquidambar	styraciflua	Sweetgum	0.82000	0.021782	368.00
LITU	Liriodendron	tulipifera	Tulip tree	0.90000	0.016964	379.31
MAGR	Magnolia	grandiflora	Southern magnolia	0.83362	0.007405	350.00
MASO	Magnolia	x soulangeana	Saucer magnolia	0.83362	0.014967	350.00
MAFL80	Malus	floribunda	Japanese flowering crabapple	0.85000	0.011600	379.31
MEAZ	Melia	azedarach	Chinaberry	0.83362	0.013461	379.31
MOAL	Morus	alba	White mulberry	0.83362	0.013671	379.31

OLEU	Olea	europaea	Olive	0.83362	0.013461	500.00
PIHA	Pinus	halepensis	Aleppo pine	0.83000	0.010376	430.00
PIPI2	Pinus	pinea	Itailian stone pine	0.83000	0.010376	430.00
PLAC	Platanus	x acerifolia	London planetree	0.86000	0.022900	200.00
POAL	Populus	alba	White poplar	0.79500	0.011500	240.00
POSI	Populus	simonii	Chinese popular	0.79500	0.013860	240.00
POCA2	Populus	x canadensis	Carolina poplar	0.79500	0.010820	240.00
PYCO	Pyrus	communis	Common pear	0.80000	0.013461	180.00
ROPS	Robinia	pseudoacacia	Black locust	0.83362	0.018575	19.00
SEGI	Sequoiadendron	giganteum	Giant sequoia	0.91000	0.009055	443.33
SOAU	Sorbus	aucuparia	European mountain ash	0.83362	0.012600	379.31
SOJA	Styphnolobium	japonicum	Japanese pagoda tree	0.78000	0.008800	379.31
TAMU	Taxodium	mucronatum	Montezuma cypress	0.91000	0.009055	443.33
THOR	Thuja	orientalis	Oriental arbor vitae	0.91000	0.005200	2031.67
ULPU	Ulmus	pumila	Siberian elm	0.85000	0.014682	36.50

TREE SPECIES AND THEIR CONSTANTS FOR THE CITY OF PORTO ALEGRE

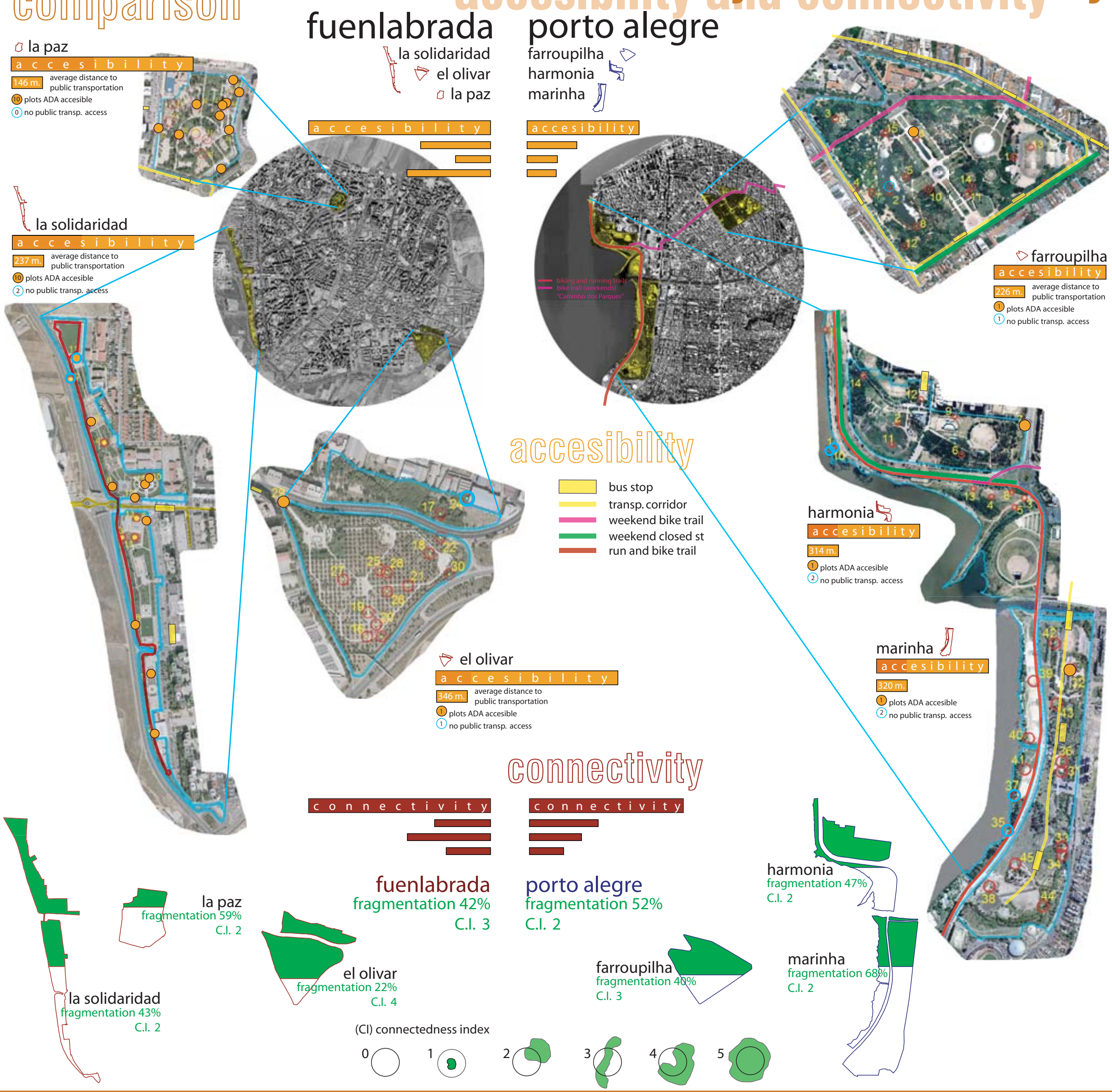
CODE	GENUS	SPECIES	COMMON NAME	SHADING FACTOR	LEAF AREA TO BIOMASS FACTOR (m2/g)	LEAF BIOMASS TO VOLUME FACTOR (g/m3)
AE2	Aegiphila	species	Aegiphila	0.83362	0.013461	379.31
ALED	Allophylus	edulis	Chal-chal	0.83362	0.013461	379.31
BAFO	Bauhinia	forficata	Bauhinia	0.83362	0.013461	379.31
BRPO	Brachychiton	populneum	Kurrajong	0.83362	0.011425	379.31
CAEQ	Casuarina	equisetifolia	Australian pine	0.91000	0.009055	443.33
CHSP	Chorisia	speciosa	Palo borracho	0.83362	0.013461	379.31
CIMO	Citharexylum	montevidense	Taruma de espinho	0.83362	0.013461	379.31
CARH	Cmpomanesia	rhombea	Goabiroba miuda	0.83362	0.013461	379.31
CUVE	Cupania	vernalis	Camboata vermelho	0.83362	0.013461	379.31
CUSE	Cupressus	sempervirens	Italian cypress	0.91000	0.004267	5100.00
DOWA	Dombeya	wallichii	Dombeya	0.83362	0.013461	379.31
ENCO2	Enterolobium	contortisilquum	Timbauva	0.83362	0.013461	379.31
ERCR	Erythrina	crista-galli	Arbol del coral	0.83362	0.013461	379.31
ERAR	Erythroxylum	argentinum	Cocao	0.83362	0.013461	379.31
EUCI2	Eucalyptus	citriodora	Eucalipto perfumado	0.83362	0.007725	450.00
EURO	Eucalyptus	robusta	Beakpod euclayptus	0.83362	0.007725	450.00
EUIN	Eugenia	involucrata	Cerejeira	0.83362	0.013461	379.31
EUUN2	Eugenia	uniflora	Pitangueira	0.83362	0.013461	379.31
EUBR	Euphorbia	brasiliensis	Euphorbia	0.83362	0.013461	379.31
FIEN	Ficus	enormis	Figueira	0.83362	0.013461	379.31
FIMA	Ficus	macrocarpa	Ncn - ficus macrocarpa	0.83362	0.013461	379.31
FIOR	Ficus	organensis	Figueira de folha miuda	0.83362	0.013461	379.31
GRRO	Grevillea	robusta	Silk oak	0.83362	0.008225	379.31
HODU	Hovenia	dulcis	Japanese raisin tree	0.83362	0.013461	379.31
INVE	Inga	vera	River koko	0.83362	0.013461	379.31
JAMI	Jacaranda	mimosifolia	Jacaranda	0.83362	0.013461	90.00
JUNI	Juglans	nigra	Black walnut	0.91000	0.012478	379.31
LAIN	Lagerstroemia	indica	Common crapemyrtle	0.83362	0.013461	950.00
MEAZ	Melia	azedarach	Chinaberry	0.83362	0.013461	379.31
MIBI	Mimosa	bimucronata	Marica	0.83362	0.013461	379.31
MOAL	Morus	alba	White mulberry	0.83362	0.013671	379.31
MYFR	Myrocarpus	frondosus	Cabriuva	0.83362	0.013461	379.31
OTHER	Other	species	Other species	0.83362	0.013461	379.31
PARI	Parapiptadenia	rigida	Angico vermelho	0.83362	0.013461	379.31
PAAC	Parkinsonia	aculeata	Jerusalem thorn	0.85000	0.013461	379.31

PEDU3	Peltophorum	dubium	Canafistula	0.83362	0.013461	379.31
PHRE	Phoenix	reclinata	Senegal date palm	0.91000	0.005963	540.00
PHSY	Phoenix	sylvestris	Palmeira	0.91000	0.005963	540.00
PHDI	Phytolacca	dioica	OmbÚ	0.83362	0.013461	379.31
PIEL	Pinus	elliottii	Slash pine	0.83000	0.010376	430.00
PITO	Pittosporum	tobira	Japanese pittosporum	0.83362	0.013461	2700.00
PLAC	Platanus	acerifolia	London planetree	0.86000	0.022900	200.00
PSCA	Psidium	cattleyanum	Araca	0.83362	0.013461	379.31
RAUM	Rapanea	umbellata	Capororocao	0.83362	0.013461	379.31
SAGL	Sabal	glaucescens	Palmeira de leque	0.91000	0.005963	620.00
SAHU	Salix	humboldtiana	Salgueiro	0.83362	0.016200	151.50
SCTE	Schinus	terebinthifolius	Brazilian pepper	0.83362	0.013461	70.00
SCPA9	Schizolobium	parahybum	Guapuruvu	0.83362	0.013461	379.31
SESC	Sebastiana	schottiana	Sarandi	0.83362	0.013461	379.31
SEMA	Senna	macranthera	Manduirana	0.83362	0.013461	379.31
SYRO	Syagrus	romanzoffiana	Ncn - syagrus romanzoffiana	0.91000	0.005450	620.00
TAAV	Tabebuia	avellanedae	Ipe roxo	0.83362	0.013461	379.31
TEST	Tecoma	stans	Ginger-thomas	0.83362	0.013461	379.31
MATI	Tipuana	tipu	Tipa	0.83362	0.013461	379.31
WARO	Washingtonia	robusta	Mexican fan palm	0.91000	0.006475	700.00

accesibility and connectivity

accesibility and connectivity

comparison



design strategies

accesibility

1. Park areas should be located within walking distance
2. Bike and running trails to connect segregated areas
3. Increase universal accessibility
4. Transportation points along park edges. Free day bus.
5. Close adjacent streets on weekends
6. Avoid roads crossing the parks without pedestrian bridges
7. Provide uses for areas to be connected

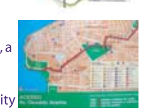
connectivity

1. Protect continuous ecosystems from fragmentation
2. Provide wildlife corridors from the parks to the surroundings
3. Use paths, trails, streams and other vegetation corridors to connect
4. Plant street tree lines as 'green fingers' into the city

2. In La Solidaridad, a successful trail design connects the north and south parts of the park. Located on top of a berm it separates the park from the highway surrounding. On one side, dense conifers were planted as a traffic barrier, on the other, single trees allow to bikers and strollers enjoy the park views.

5. In Farroupilha Park, an adjacent street is closed to traffic to extend the park in the weekends. Park users visit fresh produce and craftmarkets.

2.,5. In Porto Alegre, a weekend bike trail connects the park system through the city



2. A trail along the riverside connects Harmonia and Marinha park continues through residential neighborhoods

landscape patterns

comparison species diversity

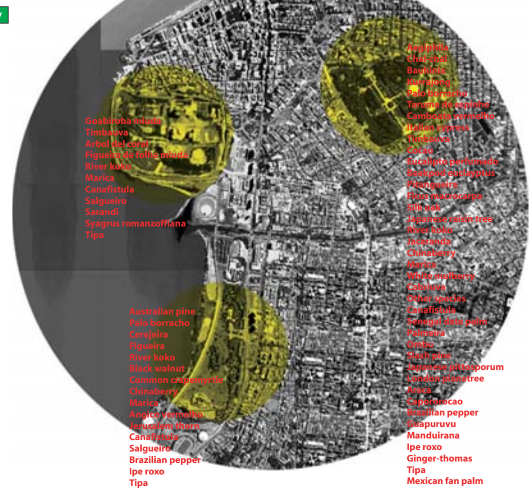
biodiversity

fuenlabrada

la solidaridad
el olivar
la paz

porto alegre

farroupilha
harmonia
marinha

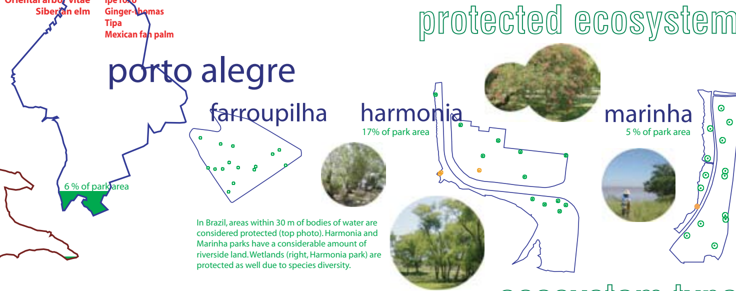


fuenlabrada	porto alegre
biodiversity	biodiversity
Abeto de España	Aegiphila
…elder	Chal-…
Norway maple	Bauhinia
Sycam… maple	Kurra…
…stnut	Austr… pine
Tree of heaven	Palo borracho
…mosa	Taru… espinho
European alder	Goabiroba miuda
Grey alder	Camboata vermelho
Incense cedar	Italian cypress
Southern catalpa	Timbauva
Atlas cedar	Arbol del coral
European hackberry	Cocao
Northern hackberry	Eucalipto perfumado
Arbol de judea	Beakpod euclayptus
Port orford cedar	Cerejeira
Mediterranean fan palm	Pitangueira
European filbert	Figueira
Arizona cypress	Ficus macrocarpa
Italian cypress	Figueira de folha miuda
DrÁcena	Silk oak
Russian olive	Japanese raisin tree
Common fig	River koko
English walnut	Jacaranda
Juniper	Black walnut
Laurel de olor	Common crapemyrtle
Ligustro	Chinaberry
Chinese sweet gum	Marica
Sweetgum	White mulberry
Tulip tree	Cabriuva
Southern magnolia	Other species
Saucer magnolia	Angico vermelho
Japanese flowering crabap	Jerusalem thorn
Chinaberry	Canafistula
White mulberry	Senegal date palm
Olive	Palmeira
Aleppo pine	Ombù
Itailian stone pine	Slash pine
London planetree	Japanese pittosporum
White poplar	London planetree
Chinese popular	Araca
Carolina poplar	Capororocao
Common pear	Salgueiro
Black locust	Brazilian pepper
Giant sequoia	Guapuruvu
European mountain ash	Sarandi
Japanese pagoda tree	Manduirana
Montezuma cypress	Syagrus romanzoffiana
Oriental arbor vitae	Ipe roxo
Siberian elm	Ginger-thomas
	Tipa
	Mexican fan palm

ecosystem diversity

protected ecosystems

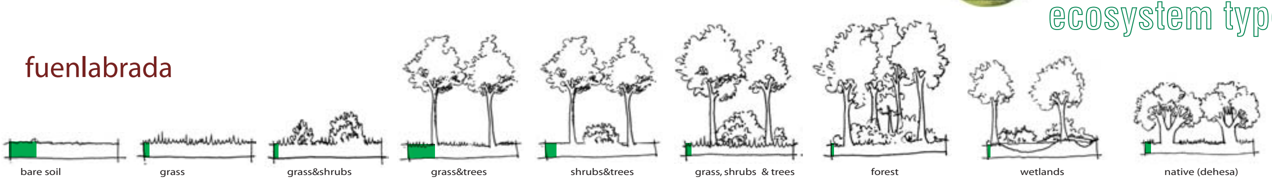
The "dehesa", in el olivar park, is a traditional olive tree cultivation. Nowadays is under protection in Spain. In this case, it was transformed into a park as the city grew over old agricultural lands.



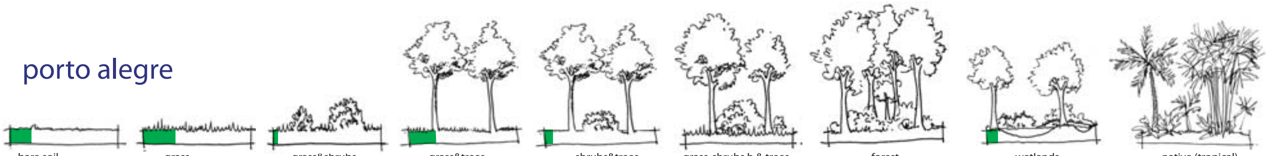
In Brazil, areas within 30 m of bodies of water are considered protected (top photo). Harmonia and Marinha parks have a considerable amount of riverside land. Wetlands (right, Harmonia park) are protected as well due to species diversity.

ecosystem types

fuenlabrada



porto alegre



design strategies

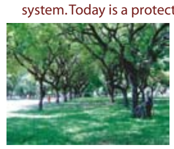
for ecosytem and species diversity

1. Surrounding landscapes (agricultural lands, woodlands) can be incorporated successfully into parks
2. Provide diversity of water features with suitable vegetation
3. Use water to unify and connect park areas
4. Locate green areas closed or adjacent to water bodies
5. Increase the green structure cover
6. Plan trees in scattered groups near sport facilities
7. Main function can be preservation and soil and water protection
8. Use criteria to group species
9. Plant first pioneers to create shade and secondly shady species
10. Select species based upon future use of the place
11. Use protected and native species
12. Let natural sucession occur
13. Provide novel trees to give places identity

1. In El Olivar Park, an old olive grove (*dehesa*) was incorporated into the park system. Today is a protected ecosystem with valuable specimens.

2. In La Solidaridad Park, an artificial pond is surrounded by riparian vegetation mimicking a natural ecosystem.

3. Water provides ecosystem diversity and is the element that unifies the different areas of the park.



10. In Marinha Park, the species *Tipuana tipu* was selected for a transitional space. It shape with wide-open canopies far above the ground fits with the corridor function. It provides shade from the sun and lets air circulate during hot days. It can be used as a street tree as well.

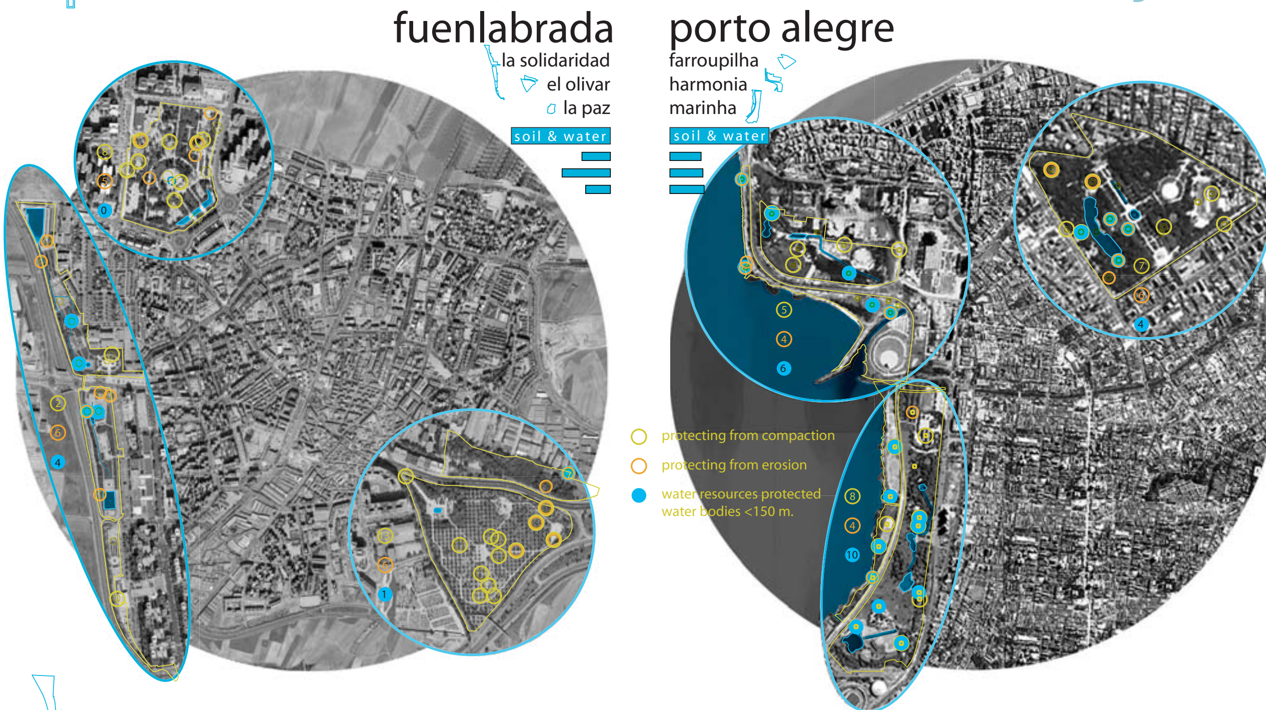
12. In Harmonia Park, native plants coming from the river are colonizing the shoreline. This emergent vegetation is allowed to grow in some areas by park managers. They provide an excellent source to learn about natural succession.

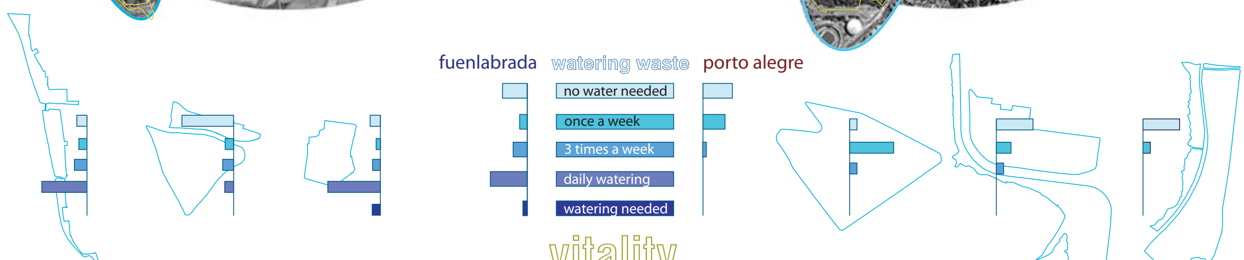
6. In Marinha Park, similar trees were planted in scattered groups to create shade. The area, located near sport facilities and looking at the river, is intensively used for passive recreation.

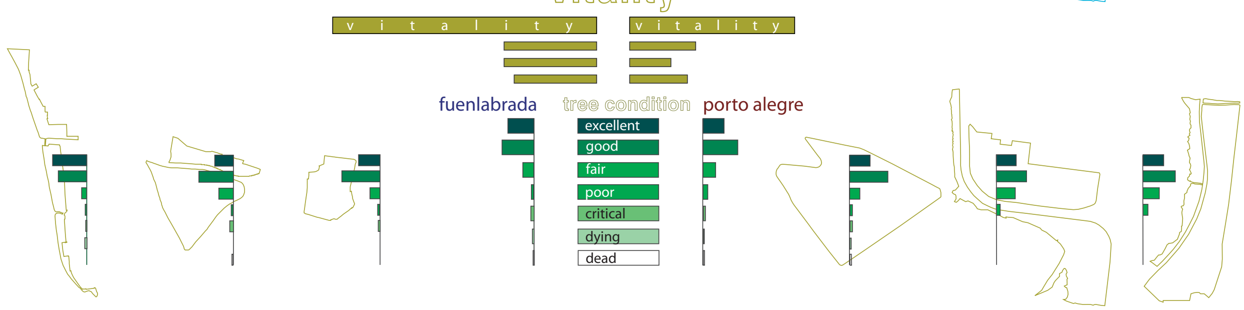
landscape patterns

comparison

water, soil resources and vitality







design strategies

for water and soil protection

1. Locate lakes and ponds where water stores naturally
2. Water systems should be closed loops that recycle water
3. If watering is needed, use permanent irrigation systems
4. Use stored water to irrigate
5. Plant vegetation on steep slopes to avoid erosion
6. Increase vegetation in the riverfronts to retain soil
7. Experiment more pervious soil types to avoid compaction

for vitality

1. Supervise tree development in the first years
2. Use of native vegetation
3. Choice of low maintenance species
4. Concentrate management efforts during establishment
5. Select species suitable with site conditions and management

2.,4. In La Solidaridad Park, a closed water system runs through the park connecting different areas. Water is first stored in a reservoir, then travels by gravity trhough canals feeding different ponds, cascades and jets, and finally is pumped to the reservoir to be reused. This water is used in some locations for irrigation purposes.

5. In La Solidaridad species were selected to meet site conditions. Riparian vegetation was located along water canals and wetland vegetation adjacent to ponds.

1.,4. In Farroupilha Park, an artificial pond was created where water naturally stored. Exceding water was used to feed fountains before. During extremely hot conditions, a small car with a hose collects the water for irrigation.

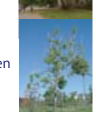
1.,2. In Marinha Park there is also a water system connecting ponds, pools and wetlands. It includes a retention pond for storm water management of the surrounding watershed.

5. Dense rows of conifers were planted on this slope to control soil erosion and protect from traffic noise and pollution

3. In La Solidaridad Park, a permanent irrigation system water vegetation automatically during the summer days.

2. In Porto Alegre, the use of native species (Guapuruvu, right) has led to healthy specimens with few maintenance.

5. In Fuenlabrada, some exotics placed in inappropiate locations become tress in poor condition even with good management



7. The soil in El Olivar is tilled to allow water infiltration fot the olive trees.

landscape patterns

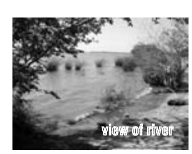

presence of birds


trees in the water


soil texture


lake as a mirror


roots on earth

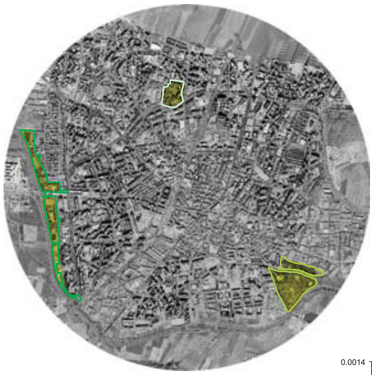

view of river

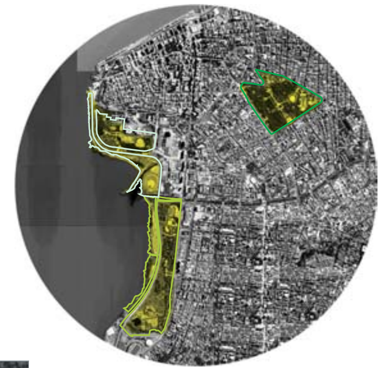
Urban Parks Contribution to Sustainability. MLA Capstone Project. Juan Vilela. May 04

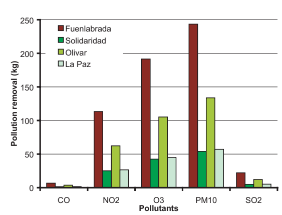
air quality and C storage

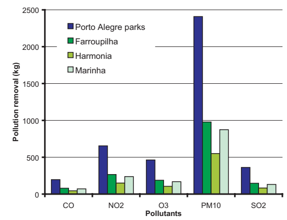
comparison
air quality

fuenlabrada	porto alegre
la solidaridad	farroupilha
el olivar	harmonia
la paz	marinha

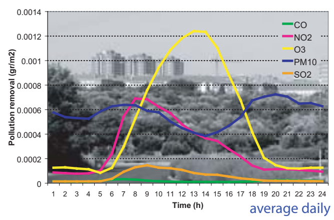


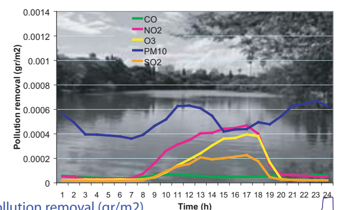






total kg of pollutants removed by the city parks in 2002





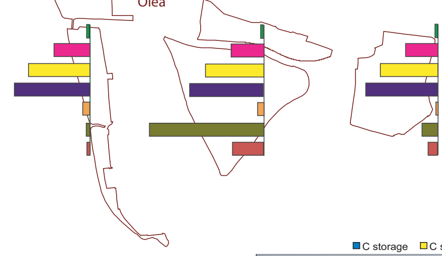
average daily pollution removal (gr/m2)

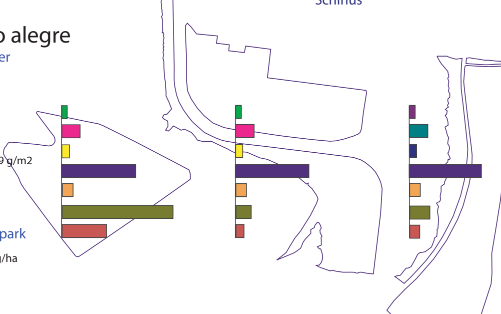
Best genera for pollution removal in Fuenlabrada

Sorbus
Malus
Catalpa
Pyrus
Laurus
Ulmus
Melia
Morus
Celtis
Styphnolobium
Eleagnus
Albizia
Chamaecyparis
Liriodendron
Olea

Best genera for pollution removal in Porto Alegre

Jacaranda
Pittosporum
Tabebuia
Lagerstroemia
Melia
Grevillea
Morus
Cupressus
Eugenia
Schinus





fuenlabrada **pollutants** porto alegre

grams of pollutants removed by m2 of canopy cover

fuenlabrada		porto alegre
0,12 g/m2	CO	0,36 g/m2
1,99 g/m2	NO2	1,19 g/m2
3,36 g/m2	O3	0,84 g/m2
4,27 g/m2	PM10	4,39 g/m2
0,39 g/m2	S02	0,66 g/m2

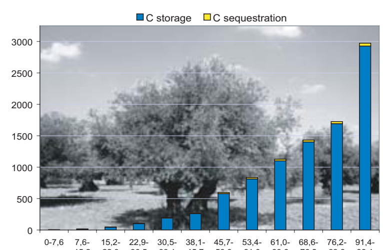
carbon

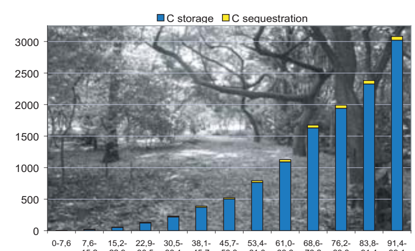
kg of carbon storaged and sequestered a year by ha of park

fuenlabrada		porto alegre
27,447 kg/ha	C storage	25,344 kg/ha
880 kg/yr/ha	C sequestration	1049 kg/yr/ha

Best species for carbon storage in Fuenlabrada

Olive tree (*Olea europaea*)
Chinese poplar (*Populus simonii*)
Siberian elm (*Ulmus pumila*)
Italian stone pine (*Pinus pinea*)
Carolina poplar (*Populus x canadensis*)





kg of carbon storaged and sequestered a year by dbh class

Best species for carbon storage in Porto Alegre

Paineira (*Chorisia speciosa*)
Tipa (*Tipuana tipu*)
Eucalipto perfumado (*Eucalyptus citriodora*)
Beakpod eucalyptus (*Eucalyptus robusta*)
Inga banana (*Inga vera*)
Salgueiro (*Salix humboldtiana*)

design strategies
air quality

1. Preserve existing tree cover to mantain pollution removal levels
2. Increase the number of healthy trees to increase pollution removal
3. Use long-lived trees
4. Use low mainteinance trees
5. Avoid fossil-fuel machinery for maintenance
6. Plant trees in polluted areas or heavily used park areas
7. Utilize evergreen trees for particulate matter reduction

carbon storage

1. Increase canopy cover
2. Preserve old trees and remnant vegetation
3. Reutilize wood from dead trees for constructions in the park
4. Select long-lived and low mainteinance species

2. A sustainable strategy is followed in Marinha Park, where urban forest residues area collected for reuse. Wood will be transformed into compost or used for landfills. Part of the carbon will be released during decomposition and some will remain in the soil.

3. In El Olivar, the carbon stored in the olive trees could remain in the park if their wood is given a use. Construction of buildings or street furniture will keep the carbon stored. A boardwalk through the *dehesa* would also do it and solve its accessibility needs as well.

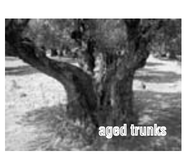
2. In both Porto Alegre and Fuenlabrada fossil-fuel machinery is employed for maintenance purposes. Pollution from these machines emissions reduces the overall benefits of the parks pollution removal. Alternative fuel or manual mainteinance should be encouraged.

6.,7. Vegetation can be used as a barrier against traffic pollution. In La Solidaridad Park, dense rows of conifers remove pollutants and particulate matter the year round.

1. The trees in El Olivar, an olive grove more than two centuries old, account for 92% of the total carbon stored in Fuenlabrada. They also have a high rate of pollution removal. Keeping the ecosystem healthy will maximize the benefits


wide canopy


light and shade


aged trunks

landscape patterns


noise reduction


remnant forest


healthy tree

Urban Parks Contribution to Sustainability. MLA Capstone Project. Juan Vilela. May 04