Designing for Complete Urban Systems:
A Participatory Approach for Measured Ecological Change in Santiago, Chile

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Abstract

This project will contribute to and expand upon the wealth of research within the disciplines of urban forestry and environmental behavior. While there has been compelling work within each domain they continue to operate separately of each other as if they were not inherently linked. This project will look at how environmental health data can be applied to the social perceptions of urban tree coverage to ecologically and socially improve the existing urban neighborhood framework in Santiago, Chile. The meshing of ecological health data and the social acceptability of woody vegetative cover in the urban environment will lead to the development of increased environmentally and socially sustainable urban communities.

By determining the level of increased canopy coverage that is socially acceptable it will not only improve environmental air quality but will increase the connectivity between urban dwellers and the ecological processes that shape the world they live in.

For this capstone I will be using quantitative urban forestry data collected using the UFORE (Urban Forestry Effects Model) model developed by the USDA Forest Service along with results from a qualitative social perception study to arrive at a level of increased tree canopy coverage that is socially acceptable. The use of the UFORE model will allow for the illustration of the increased ecological benefits directly related to trees within the urban environment.

By directly engaging the community members within the research process the final proposed urban design will be a reflection of increased environmental and social sustainability. The proposed ecological design insertion within the existing community will educate and inspire local residents thorough a participatory process. The final design scheme will graphically demonstrate the acceptable level of canopy coverage along with the measured increase in air quality. The design will focus on a two block area to present a detailed study that will serve as a module for the surrounding *comuna* to adapt and apply.

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Introduction

With buildings and population density rapidly increasing in our cities, residents have become ever more disconnected from their local ecologies and vital ecological processes. This growing gap between environmental health and society is only beginning to be seriously considered by leaders in the fields of landscape architecture, urban forestry, and architecture. Researchers have progressively addressed the diverse elements of the urban environmental conditions including air, water, and vegetation. There is, at the same time, a wealth of research within the field of environmental behavior on how we as a public perceive our landscapes and environment. These two arenas have produced compelling work; however they continue to operate separately of each other, as if they were not inherently linked. Clearly how we plan and design urban landscapes should respond to resident's perception and the urban ecology. This separation has led to a social perception that urban environments are distinct from overall ecosystem health. The hope for more ecologically sustainable cites lies in the merging of both domains and designing as a collaboration between ecological and social data.

This USDA Forest Service funded project will look at how environmental health data (air, water, vegetation) can be applied to the design efforts to improve existing urban neighborhood frameworks in Santiago, Chile. The City of Santiago's dense, semi-arid urban landscape of almost six million people has been chosen by the local government and the University of Chile, Faculty of Forest Sciences in efforts to develop a framework to incorporate the city's expansive urban forests into the existing context of their urban neighborhoods. This proposed capstone project will address Unidad Vecino Trece in the

La Florida *comuna* of the Gran Sanitago Area (GSA). In the GSA there are 36 *comunas* that operate as separate municipalities and are responsible for providing basic public services and amenities for Santiago's urban inhabitants.

As a designer I will draw on the quantitative ecological and environmental health data while simultaneously working from the qualitative research on social perceptions of the environment. The current urban forestry data for each *comuna* has been produced by Francisco Escobedo (2004) as a portion of a larger diagnostic study performed by the University of Chile. Escobedo analyzed the GSA's urban forest structure, function, management and effectiveness as an air quality improvement policy (Escobedo et al., 2006). This qualitative data will be incorporated into an essential participatory design approach in order to test the viability of modifying residents' perceptions in order to improve ecological health.

This proposed community ecological design insertion within the designated medium socioeconomic (Escobedo 2004) La Florida *comuna* will seek to educate and inspire local residents through a community participatory process. This process will consist of a series of meetings designed to present a series of graphic simulations at various vegetation cover percentages within the study area. The proposed product for this project will be an urban design that will incorporate local ecology, community participation, and the built urban landscape. This constructed nature within the existing urban fabric will demonstrate a meshing of the research of current ecological conditions, predictive urban forestry models, and social perceptions and acceptability.

Literature Review

Environmental Behavior and Social Perceptions

Environmental behavior research is critical for beginning to understand how our surroundings are perceived by the public. This project focuses in large part on public and individual responses and perceptions of their urban environment. This research is vital to developing the project framework and methodology. This research will frame my work to define perceptions, acceptability, and cultural differences in the process of collecting quantitative data in Santiago, Chile. The data collected will provide a framework for information and evidence that will be used in determining socially appropriate and ecologically sensitive schematic designs.

The most important research in this area is not the most recent but is the work done over twenty years ago. This foundational research addresses perceptions and interpretation of the environment documented and studied by Rachel and Stephen Kaplan in two of their books *The Experience of Nature* (1989) and *Humanscape* (1984) which is an edited collection of essays by researchers and scientists. These two books set a standard of how we understand the experience of the environment by most people and remain the work from which most researchers build upon.

For this project the work of Kaplan and Kaplan will remain an important source as their framework has not been replaced. However, important extensions of their research have been done by Frances Kuo, Joan Nassauer, and Kevin Lynch. Kuo and Nassauer have looked at how to frame the environment to increase social acceptability to increased vegetation and ecological productivity. The article *"The Goals of Perception"* in *Humanscape* (1982) by Ernest R. Hilgard uses the word interpretation as a way to identify cultural influences and how that has an effect on patterns, structure, and means for identification of what is socially acceptable. This definition of interpretation frames the process that this study will take from research to understanding. In addition, recent literature has focused on presenting the Kaplan work in a way that is more accessible to design research. From the foundation of Kaplans' work, John Zeisel has refined the framework for constructing questionnaires, interviews, and presentations in his book *Inquiry by Design (2006)*. The information gathered in these studies relates to community decision making, preferences, and collaboration. William Whyte also presents a refreshing look at how our landscapes are perceived in *The Last Landscape (2002).* Whyte presentes the idea of social perceptions in concert with ecological performance and that both need to be integrated for a landscape to be functional.

The field of environmental behavior is broad and covers an incredible range of issues. This is both an opportunity and a constraint. While it is easy to apply this range of research to a topic it is lacking the specific information about social perceptions as an indicator for ecologically responsible design. This project will begin to define how such research can be used to measure people's perception of ecologically responsible design and how in turn, people's perceptions can be utilized to further design goals and objectives.

Urban Forestry, Ecology, and Environmental Data Research

Understanding urban forestry and ecological processes is critical for this capstone project. The ecological data that will be collected, used, and analyzed during this project will guide the design process by setting ecological performance standards. These performance standards will be in the form of vegetative cover percentages that will lead to the production of data about air, water, and soil quality on the study site. This quantitative data will create one framework and baseline on which the project will be able to be measured. This measurable change in environmental quality will help the public better understand the benefits of urban forestry and ecology.

Urban forestry and research on ecologically responsible cities has surged over the past five years and has been driven by the emergence of new research by the U.S Forest Service, books such as*, Sustainable Urban Design: An Environmental Approach (2003), Shaping Neighbourhoods (2003)*, and a wide variety of readers that are focused on using quantitative environmental data to think about how urban neighborhoods and communities are designed. The majority of the research on developing ecologically sensitive neighborhoods has been produced and studied in Europe in the past twenty. This is still true today but the emergence of Portland, Oregon, Seattle, Washington, and Chicago, Illinois' progressive urban planning strategies reflects the new interest throughout the United States.

Research in this area has been steadily growing ever since Ian McHarg published his foundational *Design with Nature* in 1968. This was an important moment in increasing interest in the integration of ecological processes into our built landscapes. McHarg urged urban designers to incorporate natural factors such as, topography, drainage, and vegetation into their plans instead of relying on technology to overcome constraints. While McHarg focused mainly on upscale suburban developments, his work can be easily be transferred to more urban environments. Taking McHarg's view and applying it directly to the urban context Anne Whinston Spirn in her 1985 book the *Granite Garden* argues that the rural, suburbs, and city need to be viewed as one developing system not as individual elements. Spirn continues to respond by saying "nature in the city must be cultivated like a garden rather than ignored or subdued." From this foundational literature urban forestry models such as the *Urban Forest Effects Model* (UFORE) have been developed by the USDA Forest Service to help quantify the benefits of ecological processes in cities. This model has become a framework that has been used as a basis for other studies produced by David Nowak and Rowan A. Rowntree on the ecological and economic benefits of urban forestry within our cities.

Figure 1. *Maximum ambient pollutant concentrations in Major Latin American cities in 1995 (World Bank 1997)*

Pollutant	Santiago	Buenos Aires	Sao Paolo	Bogota	Mexico City	WHO Guideline
PM_{10} Annual	109	n/a	105	70	1	50[a]
O_3 1-hour	448	n/a	763	241	698	150-200
NO_2 Annual	98	157[bd]	99	190[c]	87	100[a]
SO_2 Annual	37	9d	46	72[d]	62	40-60
CO 8-hour	26	15	22	n/a	19	10

[a] US standard; WHO guideline not established. [b] NOx concentrations.
[c] 1991 measurements. [d] 1994 measurements

In 1995, Santiago was determined to be the most polluted major metropolitan area in Latin America in both PM_{10} and CO ambient concentrations (Escobedo 2004) (Figure 1). Urban vegetation specifically affects air quality through: removal of atmospheric pollutants, emission of atmospheric chemicals either directly from the vegetation or indirectly through vegetation maintenance practices, altering urban microclimates by lowering temperatures, changing wind patterns and boundary layer heights, and affecting building energy use (Nowak et al. 1998). Understanding scale in the context of this research is critical to being able to apply this knowledge to a project such as this capstone. Much of the research is on an entire city scale or more commonly on a regional scale. While this is beneficial to understanding the major principles it often does not get at the site specific data that will enable me to understand and measure change within a neighborhood scale project. A major gap in the research on ecological cities and urban forestry is the integration of these movements into the existing and actual urban framework. There is a wealth of planning literature dealing with developing new cities and communities in an environmentally sensitive manner but little on how to integrate ecological processes into the already built and socially established urban structure.

Urban Ecological Initiatives and Programs

There have been a number of organizations, initiatives and programs dedicated to urban ecology and sustainability in our cities developed over the past 10 years. These initiatives range from non profit organizations to city programs that are aimed at increasing the ecological performance within their urban context. Chicago, Montreal, Seattle, and

Portland are all examples of progressive city planning and commitment to the health of the urban environment.

Urban ecology initiatives within the public sector have been highlighted by the Mayor of Chicago, Richard Daley. Mayor Daley has promoted a progressive environmental movement in the City of Chicago resulting in environmental education, ecological health, and social well being within the city. Chicago developed *The Chicago Standard: Building Healthy, Smart, and Green* which outlines the goals of construction, renovation, and design of municipal and public facilities. This standard sets the framework for how the city views its natural resources and its commitment to the greening of Chicago. The programs developed by the Mayor are highlighted in an article in Metropolis Magazine titled *Mayor Daley's Green Crusade (2004).* This article outlines how Chicago has been able to keep the environmental movement alive and keep the public involved. Another city specific program is the *Montreal Urban Indicators Systems Project* at McGill University. While Chicago developed a top down approach to its environmental programs, McGill University has developed a system that providing information about gathering, applying and understanding environmental indicators for urban sustainability. The study in Montreal, Quebec utilizes quantitative data to guide its design decisions.

Understanding the scope and scale of ecological processes in cities has been a concern of many planners, designers, and scientists over the past two decades. The Ecological Cities Project was founded in 1999 by Dr. Rutherford H. Platt to "promote sharing of knowledge and experience among disciplines, sectors, and urban regions regarding new approaches to urban greenspace creation and management." This project has become a force in how we view ecology in our cities. A major contributor to this project is now Director, Rowan A. Rowntree who has provided valuable scientific data and books such as, *The Ecological City: Preserving and Restoring Urban Biodiversity (1994).* The Ecological Cities Project works to not only develop urban ecological systems but to develop socially initiated ecological systems that have a positive impact on overall urban health.

Methods

This project in Santiago, Chile will be utilizing a sequential, mixed methods study to understand the convergence of qualitative and quantitative data collected. The research design framework that will organize the data collection and analysis will be the sequential explanatory strategy. This study is strengthened by continual decision making and understanding in both the quantitative and qualitative realms. Decisions relating to ideal ecological performance vs. social perceptions will be derived from community meetings to drive both methods individually and then in combination for a single outcome. These decisions will ensure that appropriate data is analyzed which will inform the synthesis and overall design.

Quantitative Methods

The sequential explanatory design strategy within this mixed method study places the highest priority on the quantitative data. This is partly because it is collected and analyzed first in the sequence of the method design but also because it provides a starting point or goal that the quantitative research can be based on. For the purpose of this study priority will not mean “higher importance” but will set the boundaries for the study. Data has been collected and analyzed for the highly urbanized Gran Santiago Area during a 2004 study by Francisco Escobedo and The University of Chile. Escobedo (2004) assigned one of three socioeconomic classes for each *comuna*. The three classes of high, medium, and low were determined using household income, education, and vehicle ownership data.

From this data it will be necessary to interpret how Unidad Vecino Trece within the La Florida *comuna* relates to the semi-arid, urban GSA. The La Florida comuna is the most populous *comuna* in Chile with 365,674 residents and occupies 70,2 km^2, the largest surface area of any other *comuna* in the Santiago metropolitan area. La Florida is consistent with the research that the low socioeconomic stratum had the highest percentage of public trees and building plus impervious surface cover. High socioeconomic stratum’s urban forests are characterized by greater tree cover, LAI, trees with a greater leaf area density, and greater densities of well-maintained trees. (Escobedo et al., 2006). Within the limits of the project site there are 88 public trees in varying conditions and 135 residents. La Florida is divided by Avenida La Florida which runs in a

Northwest/Southeast direction and defines the “barrio alto” and “barrio bajo” or high and low socioeconomic areas.

While having a large population and surface area it receives the third largest urban forest budget. These municipal budgets remain constant through time yet may vary from year to year due to government budget constraints. This can include increased spending due to infrastructure improvement projects and other political/social variables (Escobedo 2004). The municipal budgets for green areas and street trees within La Florida were Ch$713,000,000 and Ch$57,000,000 respectively in 2002 (Escobedo 2004). Expenditures for watering and irrigation accounts for a substantial portion of the annual budget due to the climate and species present. In 2003 it was reported that La Florida spent Ch$868,000 on watering green areas alone (Escobedo, 2004).

Urban forest structure data has been collected for each *comuna* using digital aerial orthographic photos and 4355 random points to classify tree crown, building, pervious (e.g. bare soil, other vegetation), and impervious cover (e.g., asphalt, rock, or concrete) percentages (Escobedo et al., 2006, Nowak et al., 1996) The La Florida comuna data collection has been prepared and analyzed by using the Urban Forestry Effects Model (UFORE) (Figure 2). This model uses standard field, air pollution, and meteorological data to quantify urban forest structure and numerous forest related effects on cities (Nowak and Crane 2000). Canopy coverage within the urban forest is used to evaluate the effects of vegetation on the current air, water, and the overall compensatory value of trees within the urban environment. This data shows how urban forests can mitigate the detrimental effects of cities on our environment. The current data will be used throughout the study to serve as a baseline for the schematic design proposals to be measured against.

Figure 2. *Photo-interpreted La Florida comuna percent tree and surface cover*

Tree Cover	Impervious	Pervious	Building
18%	25.80%	27.60%	27.60%

(Escobedo 2004)

The results of the UFORE model will serve to provide the necessary data to develop a predictive model that represents the ecological benefits of planting all pervious space within the study site. Using a correlation method of analysis this coverage level will be developed using variables of available plantable space and current landuse classification. These two variables are derived from the amount of current gray infrastructure and impervious surfaces that will affect plantable space. This level of highest possible ecological performance will be predicted as another baseline to be measured against.

There has been new research in the area of quantifying the canopy coverage level that is ecologically optimal but for the purpose of this study "optimal" will be defined as all plantable space filled with tree canopy. This classification has allowed for consistent inputs to the predictive model. This measurable quantitative data provides air pollution removal data including carbon storage, carbon sequestration and particulate matter reductions**.** This data has been calculated using the Air Pollution Calculator which was developed by the U.S.D.A Forest Service. The data produced using this program has been used consistently throughout the public meetings yet was the focus during the second meeting. The second public meeting concentrated on determining an acceptable level of urban vegetation with regard to density and location. A scale was developed to demonstrate two ends of an environmental and urban ecology spectrum that spans from the current urban reality of 18% canopy coverage to the highest level of 46%. 46% has been determined by calculating the total plantable space in the *comuna.* Accompanying the spectrum of computer simulations showing 18%, 27%, and 46% on three different streets was the ecological data associated with each percentage. Highlighted on each simulation was the total metric tons removed from the air per year and the percent increase in air quality.

In the spring semester of 2006 the average acceptable canopy coverage will be imputed into Growout, a predictive urban forestry model. This model, developed by the U.S.D.A Forest Service, will aid in defining annual planting schemes to reach the desired percentage goals over time. Growout will also provide greater air pollution sequestration data predicted for future years at new, increasing, canopy coverage percentages. Costs with regard to energy savings due to increased urban vegetation will also be a factor explored. This quantitative component of the study will help structure the planning guidelines for the community and provide annual goals. There is great importance for having annual goals and clearly defined guidelines for this community and municipality. With limited access to funding and resources, being able to comprehend the overall scope of work will be critical to being able to prepare, educate, and gain the appropriate support.

Qualitative Methods

The data is clear that if we increase the canopy coverage in our cities our overall environmental quality will improve. It would be straightforward to greatly increase our vegetation levels to a point of filling our available pervious spaces. While straightforward, it is not realistic due to our social perceptions and levels of acceptability regarding urban vegetation.

The subsequent integration of quantitative ecological data has provided the framework for this qualitative ecological perception study. The spectrum developed during the quantitative data collection will be used to structure this qualitative phase. Upon this framework three computer generated simulations were developed for 27% and 46% canopy coverage. 46% represents the total possible plantable space and 27% shows the median percentage increase between the current condition of 18% and 46% canopy coverage. Presenting the highest coverage level possible for ecological performance showed neighborhood residents what ecological performance is obtainable and how much work their urban forests will do in terms of improving air quality. These three schemes have framed the attempt to explore the acceptance levels of the local neighborhood residents with regard to environmental landscape change in the urban environment. This data collection and analysis occured in Santiago during the fall semester of 2006.

Understanding how people perceive landscape change and what they are willing to accept is critical to implementing environmentally sensitive designs. Categorization and design decisions have depended on the landform and land use categories of professionals and do not correspond with the knowledge or perceptions of the untrained citizen (Kaplan and Kaplan 1989). This has furthered the disconnect between urban residents and their environment. Thus social perception of increased vegetation cover in a neighborhood has provided the framework for this project.

The study site of Unidad Vecino Trece in the La Florida *comuna* is a strong representation of the city of Santiago as a whole due to its variations of socioeconomic strata and canopy coverage. The simulations of vegetative cover will be developed using the current infrastructure and vegetation of the study site as a base to help residents orient themselves to the presented designs. Computer generated photographic simulations have been chosen as the method to represent the various vegetative coverage percentages to clearly orient and engage the participants. This method of representation removes the "noise" (sound, smell, touch) that can be present in realistic settings (Kaplan and Kaplan 1989). The spatial configurations of the graphics provided a 2-dimensional picture plane but an inferred 3-dimensional space of the scene accounted for a basis for the participant's perceptions. A photograph of the current condition of 18% was used as the base for the simulations of increased vegetative cover.

The first step in obtaining a group of participants was contacting and presenting the proposed project to the Municipality of La Florida. Accompanied by Professor Manuel Rodriguez of the Faculty of Forest Sciences, I presented a proposal of the project and sample graphics to communicate the intent. This presentation was to the Director of Community Organizations and the Director of Unidad Vecino Trece. The presentation of site context, current conditions, and examples of possible graphic simulations provided a baseline for understanding and determined the next appropriate step in obtaining a group of interested citizens. This included an invitation to make a presentation following a community meeting with the study neighborhood.

The first presentation to the community focused on gaining support, acceptance, and providing an understanding to the benefits of this project to the community. The first meeting consisted of fifteen citizens and two officials from the municipality. During this initial meeting, the study site was graphically represented in context with the Gran Santiago Area to allow for the participants to appreciate the scale relationship that Unidad Vecino Trece has with the GSA. It was clear that the citizens understood the relationship of their neighborhood to La Florida at the *comuna* scale but not to the City of Santiago at a larger scale. The major concepts illustrated to the participants included the costs of the project, benefits of urban vegetation, and the value of public participation. The costs of the project as agreed by the Municipality and citizens:

- Trees and Shrubs will be provided by the Municipality
- Groundcover and low growing plants will be the responsibility of the community
- Maintenance will be the responsibility of the community
- Equipment and training associated with increasing urban vegetation will be provided by the municipality

Structuring the costs in this manner creates a new dimension in the decision making process of increasing vegetation. A secondary question becomes “how much are you willing to maintain?" This question became a topic of discussion after the presentation and was of concern to the municipality and to the citizens. This will construct another layer of data that will help in the final design phase due to the inclusion of personal space and level of caring. The Municipality agreed to provide equipment and education to offset costs of increased mortality rates associated with poor installation and maintenance practices. As was discussed earlier, maintenance represents a large percentage of the municipal urban forestry budget and ways to decrease this cost will allow for funds directed towards new plantings.

The second meeting occurred on October 12, 2006 at the Casa de Juntos or The House of Us in Unidad Vecino Trece. This meeting consisted of thirteen people, two of which were new and did not attend the first introductory meeting. The purpose of this meeting was to discuss the preferences of the citizens regarding increases of urban vegetation in their neighborhood. As with the first meeting, this presentation was given with the aid of a projector to ensure the entire group was able to view the slides. Spatial context graphics were repeated from the first meeting to allow for the new members to understand the study site. The perception study was based on a scale of 18% canopy coverage (current condition), 46% canopy coverage (full plantable space) and 27% (the median percentage). Three streets were chosen from within the study area to be represented in a set of computer simulations depicting increased vegetative cover. The three streets were El Abedul, El Tamarindo, and El Mostellar. These three were chosen for distinct spatial characteristics such as, height of boarder walls, plantable space between sidewalk and street, and current vegetative cover.

As previously discussed, a photograph of the current condition on each of the streets was used to anchor one end of the percentage spectrum. Using the qualitative data discussed in the previous section the total available space was calculated to be 46% and thus used to anchor the other end of the spectrum. Before public opinion was discussed, the three images associated with each coverage percentage were shown together in correspondence with the air quality data associated with each. In this scheme the three streets were shown together, highlighting the differing spatial configurations at the same percentage. This introduction of environmental data will add a new dimension to the idea of acceptability and place an emphasis on ecosystem health. One species of deciduous tree and one species shrub was used in the computer simulations to allow for a level of coherence that gives a sense of order and helps delineate the patterns present (Kaplan and Kaplan 1989).

For each of the three streets there were simulations highlighting the discussed three coverage percentages. Each of the three situations were first presented alone in a larger format. This allowed for accompanying air quality data and the attention of only that situation. The data presented was an associated percentage increase in total air quality from the current situation for the *comuna* of La Florida. After the three percentages were presented for each street, a public opinion page was displayed illustrating the spectrum of three simulations on one slide. This slide acted as a summary for the participants to refer to and see the spatial and density characteristics associated with each. A questionnaire was distributed to the participants to record their preference of vegetative cover on each street. After deciding on an acceptable percentage the group was asked to explain the reason for their preference. The descriptions of why will provide insight to design during the second phase of this project. The graphic simulations and questionnaire were pretested with graduate students from the Landscape Ecology program at the Universidad de Chile to ensure clarity.

Different characteristics were highlighted in each of the three streets used for simulations. This included height of the trees presented, groundcover, shrubs, width of canopy and double rows of trees and shrubs. These various spatial characteristics were presented for each street while keeping the percentages consistent. The characteristics illustrated on each street were:

- Avenida El Abedul- Small trees with narrow canopy and groundcover
- Avenida El Tamarindo- Large trees, wide canopy and groundcover
- Avenida El Mostellar- A variety of trees and shrubs

These characteristics were used in order to be certain about obtaining information relating to large scale spatial relationships that will be critical during the design phase. The goal of comprehending the acceptable vegetative cover percentage within the neighborhood relies on the "affordance", or what the situation provides the perceiver, and what they are able to do within that environment (Gibson 1979).

The meetings have been a balance of education, understanding, and working to empower a group of citizens to enact change. Finding this balance has been about sequential decision making. Prior to the start of the participatory process a plan for each of the proposed meetings was described. This plan was followed closely for the first introductory meeting in terms of site context and presenting large scale concepts relating to urban forestry. It was beneficial to have a prescribed method for the meetings yet this did not account for the variables present. These variables included the participants understanding of urban vegetation, ability to comprehend graphic representations (plans, perspectives, sections), and their overall level of interest. A discussion was held after the first meeting relating to these variables and it became clear that there was a low level of understanding about the benefits of urban vegetation. Photo perspectives were determined to be the most easily understood. This was determined by presenting different graphic techniques to represent various vegetative cover percentages and monitor the reactions of the participants. Plans were found to be the most difficult to understand and there was apparent difficulty in orientating to the displayed information.

A third public meeting included eight repeat participants and one official from the municipality. This meeting utilized and presented the average acceptability percentages and preferences of the participants learned during the second meeting. As was true with the progression from the first meeting to the second, the third employed a sequential process based on the previous meetings findings. The key components of this meeting explored were recommended species for avenues and streets and presenting new ways of increasing plantable space in this built environment. A questionnaire was also designed and distributed to gain further information about the benefits and concerns regarding urban vegetation and the associated costs. This meeting also served as a forum to discuss the design process that is to take place during the spring semester.

The concept surrounding the design of the third presentation was to reiterate what the participants expressed during the second meeting. By presenting the data collected it allowed for further examination by the participants as a group of their collective acceptability. This constructed a discussion regarding why certain levels of acceptability were expressed. As Zeisel says “respondents like to see themselves as advice givers rather than guinea pigs”. This formulated the decision to focus on a structured discussion and utilize the voices of the people.

Based on the second meetings findings regarding spatial concerns a list of recommended species was compiled for avenues and streets. These species were drawn from a collection of recommended species for a project to develop a master plan for street trees in the comuna of La Reina, Santiago, Chile. This project titled, *Propuesta de un Plan Director del Arbolado Publico de Calles Para la Comuna de La Reina* by Andres Diaz in 2006 provided recommendations based on tree height, canopy spread, water needs, and resistance to urban conditions and pests. Trees were chosen for this project due to the spatial constraints, watering needs, and leaf type. The Mediterranean climate in Santiago leads to drought like conditions in the summer months. Selecting native and xerofitic species is critical to decreasing the cost of maintenance from watering and decreasing the mortality rates of urban vegetation. Broad leaf trees were also chosen due to their increased benefits for improving air quality. The height and the spread of the tree canopy played a large role in which species were selected for certain urban conditions.

The issue of available plantable space became an important factor in this meeting due to the perceptions of participants and spatial constraints. The public opinion was clear that it is not possible to increase urban vegetation (parking, play space, infrastructure) in many plantable areas of the site. These raised a question of where on the site plantable space could be reclaimed or have the ability to serve multiple purposes. Examples of pervious paving options and simulations of median strip plantings were offered in the presentation.

The pervious paving will allow for increased stormwater retention during rain events and decrease the need for watering. This paving option is proposed for the parking areas and will also serve as a filter for contaminants originating from parked cars. From these two ideas the participants were offered an opportunity supply other suggestions on the questionnaire. The questionnaire also included a question asking whether participants would be willing to contribute personal money for these improvements and to increase urban vegetation. This question was to serve two purposes, one to see if they would actually contribute personal money and two, as a gauge of commitment.

Outcomes

Using design as a mode of communication, understanding, and integration of disciplines is a way of defining this project. It is also a vehicle to increase ecological sustainability in our cities. From the second presentation it has been determined what percentage of canopy and vegetative cover will be implied within the final design scenarios that are produced for the Gran Santiago Area, University of Chile, and the La Florida *comuna* that has been used for this study. This number was arrived at by comparing the qualitative data that was collected using the three simulation format that was discussed earlier.

The results of the public opinion were compiled and averaged for each of the three streets and for the overall average. The average responses for the simulations were:

- Avenida El Abedul- 31.8%
- Avenida El Tamarino- 34.6%
- Avenida El Mostellar- 33.7%
- Average Acceptable Coverage Percentage- 33.4%

For each set of simulations the 27% option was the majority choice yet all responses have been factored into calculating a group average. This average acceptable percentage of canopy coverage within the *comuna* will now be evaluated and analyzed using the U.S. Forest Service developed Growout program to create a predictive model to determine planting schemes and determine air pollution removal on an annual basis. Design will also be an important facet in this representation of data to allow it to be understandable to all interested parties and provide the impact that it deserves. This new percentage of increased canopy coverage will be placed along the scale which is anchored by current and highest possible levels that will clearly show what has been achieved and what further ecological benefits could be achieved with increased acceptability of vegetative cover. This scale will not only be an important graphic display for the residents and leaders of this *comuna* but for the final design scenario. It will show a clear progression of studies and methods that has produced boundaries and limits that will frame the final design scenarios surrounding the accepted vegetative cover increase percentage.

The integration of quantitative data analysis relies heavily on the explanatory method that was outlined in the beginning of this section. Both sets of data have been analyzed and comprehended to arrive at a common conclusion. This common conclusion is the socially acceptable canopy coverage increase in the Unidad Vecino Trece within the La Florida *comuna*. The linear nature of this project speaks directly to the methodology in that one analysis leads to another conclusion and this process continues ever reliant on the accuracy of the previous step to further the study. This is to be true in this phase of the capstone project.

From the development of a socially acceptable vegetative cover percentage attention was turned to species recommendations. Using the assistance of the Faculty of Forest Sciences at the Universidad de Chile and the thesis produced by Andres Diaz in 2006 appropriate species were selected for the study area. The species recommended were selected using the input from the participants of the study with regard to spatial concerns and desires for sun and shade. The Semi-arid Mediterranean climate of Santiago and its associated maintenance requirements of drought like conditions in the summer months led to the selection of trees that have xeric, or a high drought tolerance. This will allow for a decrease in the need for watering and place less dependence on the municipality's urban forestry budget.

Figure 3. *Specie Recommendations for Unidad Vecino Trece:*

Streets				
Scientific Name	*Common Name*	*Hydritic Req.*	*Height*	*Tolerant*
Ceratonia siliqua	Garrofera	Xeric	<8 m	Yes
Acer campestre	Arce Menor	Mesofitic	<8 m	Yes
Robinia hispida	Falsa Acadia Roja	Xeric	<8 m	Yes
Avenues				
Scientific Name	*Common Name*	*Hydritic Req.*	*Height*	*Tolerant*
Celtis australis	Almez	Xeric	>8 m	Yes
Propensis chilensis	Algarrobo	Xeric	>8 m	Yes

These species recommendations are to be used as a framework for the selection of other appropriate vegetation during the design phase. From the public opinion received it was clear that there was a safety concern with shrubs and other vegetative types that reduced sightlines. This conclusion was a direct result from the comments regarding the Avenida El Mostellar simulation. While it was found to be a benefit to aesthetics and wildlife, the spatial concerns and perceived decrease in safety outweighed these benefits. The most prominent concerns due to increased urban vegetation were decreased parking and child play space, increased maintenance, and the presence of low overhead cables.

This next phase in the spring of 2007 will be creating design scenarios that use the previously obtained quantitative and qualitative data as parameters. This data will guide the design process of developing ecologically responsible design alternatives that will be integrated into the existing framework of infrastructure within this high density urban neighborhood. The scale of this phase of the study is to be consistent with the area that was used for the qualitative study. The study site is 1.7 hectares or approximately 5 square blocks in area. This scale will allow for detail design and large enough to provide a module that will be easily transferable to the *comuna* as a whole. The size of the area used for the design process has the possibility of being expanded to include a variation of land use patterns. Variation that is present includes small park spaces and play spaces. This is not for the purpose of detail design but for the inclusion new opportunities to increase vegetative cover and permeable surface at the site scale. This design process will not only draw on the research conducted in this study but will rely on precedents and knowledge gained from experience on the site.

Conclusions

Findings

This capstone project is an exploration of developing a new process for increasing ecological health within our urban environments. While it is possible to increase ecological health by solely increasing tree canopy coverage it does not address the most critical component to successful environmentally responsible design, us. As was stated in this proposal, urban dwellers are becoming increasingly disconnected from the ecological processes that provide the environmental essentials for our existence. This proposed process of using the USDA Forest Service predictive models as a tool to explain, empower, and illustrate the benefits of urban forests to a community will drive the proposed participatory design process. The final designs for this project will be specific to Unidad Vecino Trece in the La Florida *comuna* but the larger picture of this project is the knowledge transfer of the process to other cities and urban areas that are interested in maximizing the ecological and social benefits of urban forests.

This study has gained the financial and research support of the USDA Forest Service due to the application of their quantitative models as a vehicle for design and community action. The State University of New York College of Environmental Science and Forestry along with the University of Chile, Faculty of Forest Sciences will be active participants in this study through their combined efforts to develop a relationship that continues to provide research and knowledge that is ever advancing the concept of increased ecological health within our urban environments.

Dissemination

A defining characteristic of landscape architects is that through our training we develop a unique skill that enables us to translate complex information between professional disciplines in a way that is understandable to the full spectrum of users. The dissemination for this study will likely take a variety of forms to reach a broad audience that includes community members, city planners, urban foresters, ecologists, and designers. A scientific paper will be produced in concordance with the USDA Forest Service to directly represent how the predictive quantitative urban forestry data is applied within a community participatory design process. This will reach an audience of academics and scientists due to its likely distribution in journals such as, Urban Forestry and Urban Greening.

A second point of dissemination could be a workbook or a guide that is appropriate to city planners and local municipalities interested in applying this process. While providing quantitative methods of data collection and analysis will be necessary, this form of dissemination would focus on a series of steps that will easily guide a community in a way that empowers and enables the participants to engage this participatory process. Graphics and representation of data will be critical in this process due to the range of understanding regarding ecological processes.

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