IMPACT OF SUBURBS: ASSESSING TREE COVERAGE USING GEO-SPATIAL TOOLS IN THE CITY OF FORT WORTH

by

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ABSTRACT

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Throughout the last century, developers kept pace with the growing housing demand, and in doing so, former rural landscape continued to become part of the urban fabric (Corrigan et al, 2004; Secker 2007). This newly acquired land is primarily being shaped by development typically in the form of single-family residential subdivisions (Berger, 2006). With the increasing consumption of land for development there are increasing concerns from the public surrounding issues of land use changes, natural resources, and the protection of land through conservation efforts (Johnston et al, 2006). One of these issues is the acceptance of the urban forest as a major asset "that can contribute to reduced energy use, a smaller carbon footprint, and a more livable region" (VNT, 2008, 8).

The purpose of this research is to assess the impact of suburban development on tree coverage in order to understand and address the issues surrounding natural resources in urbanized areas. This is addressed by analyzing changes that have taken place with the tree

canopy, primarily in the city of Fort Worth's suburbs within the past two decades. Three primary research questions were proposed in order to address development related impact issues while exploring geo-spatial tools and methods that could be suitable for such an investigation on a broader scale. 1) How do subdivisions impact tree coverage within the city of Fort Worth's suburbs? 2) What are the changes in tree coverage in the city of Fort Worth within the past two decades? 3) What geo-spatial methods are available and/or suitable for North Texas to assess changes in tree coverage?

The city of Fort Worth and its suburbs was chosen as the study area due to the variety of environmental settings contained within the city limits ranging from urban to rural. Additionally, analyzing an area governed by a common set of ordinances dismisses possible unknown variables related design requirements set forth by the city when making comparisons. The study uses Geographic Information Systems (GIS) and the associated data as the means of analysis. Datasets attained from secondary sources were used for the research. This data includes but is not limited to: city limit boundaries, water bodies, highways, and orthoimagery. A few common methods of analyzing tree coverage were addressed and tested on a small scale for accuracy, efficiency, and applicability such as orthoimagery conversion techniques outlined in Morrow (Morrow, 2001). Then a methodology was adopted based on the strengths of the known methods and further developed isolating tree canopy using spectral band 5 from the 1990 and 2005 Global Land Survey (GLS) derived from Landsat 5 and 7 TM. City annexation, subdivision parcels, and land use data were used as boundaries in order to extract tree canopy area for analysis and comparison.

Findings from the analysis indicate that subdivisions in the city of Fort Worth have substantially impacted tree coverage when compared to the same land in a pre-development era. In addition, the comparison of Fort Worth's urban and suburban environments shows that in 2005, the tree canopy coverage was of a higher percentage in the urban setting. Moreover, the methods adopted and further developed for this research seemed to provide easily adoptable, relatively accurate, time and cost efficient results, yet to remain proven by statistical means with further research.

In conclusion the method developed and findings assessed through this research can be used for landscape planning decisions in the city of Fort Worth and aid in environmental assessment in urbanized areas. Additionally, they elicit the need for further research in development related impact issues on the surrounding natural resources.

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CHAPTER I

INTRODUCTION

1.1 Background

Effective land use planning and environmental assessments have benefited greatly due to advancements in information gathering of land cover data (Goetz et al, 2003). A key feature of land cover data is the ability to evaluate tree canopy, which "is essential to environmental and economic health, providing additional cooling, reducing energy needs, increasing property values, improving air/water quality, reducing the cost of storm water control, and contributing to a more beautiful, friendlier, and livable community" (Morrow et al, 2001,1). In addition, Arthur Plotnik states, "The benefits [of trees] represent hefty dollar amounts, many millions to big cities even after the costs of tree management, which average less than 1 percent of municipal budgets. Psychological benefits, too, are worth plenty. People simply feel better and kinder around trees. Trees bring birdsong, and they provide privacy and a sense of protection" (Plotnik, 2000; Morrow et al 2001, 1).

A major influence in the nineteenth century was the railroad, by allowing people in urban areas to easily access the rural countryside. The ever-growing attachment to the country landscape coupled with the need for amenities in the city evolved into the development of the suburbs and the railroad provided easy access just as the automobile does today (Girling and Helphand, 1994). Suburban development has substantially shaped and molded the metropolitan regions into the twentieth century (Lee, 2005). "This type of development is viewed as detrimental to natural ecological processes and the resultant biodiversity that has become fractured and languished in the overall context of the regional landscape" (Bolund et al, 1999; Secker, 2007, 2).

As suburbs increasingly become part of the urban fabric, there continues to be an interest in land use changes and policies that drive them. The approaches these policies take are continually being examined to provide information to develop new policies which are more appropriate with modern land use trends (Irwin et al, 2002; Johnston et al, 2006). With the increase in research by evaluating and analyzing previous policies, it is assumed that, “appropriate decisions lead to favorable land-use changes and sustainable development” (Allen et al, 1999, 2).

In North Texas, Vision North Texas (VNT) has conducted comprehensive regional studies to develop alternate plans in preparation for future growth through 2050. One of the alternative futures polices concentrates on natural areas: “Places were the natural and environmental features should be the focus,” and “the purpose of this policy area is to preserve and protect open spaces, public parks, greenways, lake shores, significant views, stands of trees, and floodplains. The development that occurs near these natural features is planned with these important environmental features in mind. Retaining and managing the natural assets that are at the heart of these areas is the goal” (VNT, 2010, 19).

1.2 Purpose of the Study

The purpose of this research is to assess the impact suburban development has on natural resources; specifically, tree coverage. This is addressed by analyzing changes that have taken place with the tree canopy, primarily in the suburbs of Fort Worth within the past two decades. In order to assess tree canopy change, this research examined and evaluated previously applied methods to tree canopy evaluation before developing a more applicable approach using geo-spatial analysis tools for the North Texas region. The developed approach is applied to the city of Fort Worth to assess impacts on tree coverage from suburban development. Additional studies were conducted in the research to evaluate overall city tree canopy change based on varying land-use typologies.

An evaluation of how ecologically sound a community is can be determined by the surrounding tree canopy coverage (Morrow et al, 2001). These trees and other natural resources are being impeded upon by "new development that expands into the undeveloped rural or natural areas of our region [and] poses a threat to natural assets….It is important to understand the value and importance of the region's undeveloped rural and natural areas and to consider these when development and investment decisions are made" (VNT 2010, 26).

Appropriate decisions can be made based on good information, and with "95% of land use decisions made at the local level" (qtd. in Allen et al, 1999, 1), GIS, remote sensing, and satellite imagery provide an efficient and fiscally responsible method to evaluate tree canopy for municipalities (Morrow et al, 2001). Conducting analysis by isolating study areas, this research gives the capability to assess what impacts past development trends have placed on tree cover in the city of Fort Worth. In addition, the methodology can provide a current map of existing tree canopy that can be used for future studies. An existing tree canopy map can be beneficial as a reference in understanding how the area is transforming through development, what specific development trends are impacting these changes, and what areas need further study.

1.3 Research Questions

The research questions addressed in this study are:

1) How does subdivision development in Fort Worth suburbs impact tree coverage?
2) What are the changes in tree coverage in the city of Fort Worth within the past two decades?
    a) How does residential development compare to other land uses in their impact on tree coverage in the city of Fort Worth?
    b) How does tree coverage compare between Fort Worth's urban and suburban environments?
3) What geo-spatial methods are available to assess changes in tree coverage?

a) Are these methods easily replicated and applicable to research in North Texas?

1.4 Methodology

This research primarily uses quantitative techniques in the gathering of empirical data in response to the research questions set forth earlier. By using the geo-spatial analysis tools in Geographic Information Systems (GIS), data was collected and the tools were used to classify data attributes for each study and complete the data analysis. By conducting this research within the boundaries of one city, the collected data is unequivocally comparable due to the consistency of planning guidelines and zoning regulations. This means that each parcel of land to be developed will have the same design restrictions throughout the city. In order to conduct the research, methodologies had to first be identified and then tested for efficiency and applicability for its implementation in the collection of data in response to the outlined research questions. The tested methodologies, which will be examined in further detail in subsequent chapters, include the National Land Cover Dataset (NLCD), LiDAR, and infrared orthoimagery.

Of the known methods which were tested for applicability to this research set forth by established parameters, further review was conducted to evaluate a method which would combine the strengths of these known methods. The developed method, which was used for the research, is a variation of a methodology outlined in a paper from the United States Geological Survey (USGS) in which near-infrared orthoimages, in conjunction with spectral bands from Landsat 7 thematical mapper (see definition), were arranged to evaluate tree density over large areas (Huang et al, 2001). The developed method applied to this research relies on the availability to acquire secondary data.

The analysis method is a two-stage process with each stage containing specific steps:

Stage 1:

1. Acquire secondary data

2. Organize data for studies
3. Convert satellite imagery
4. Isolate tree canopy

Stage 2:

1. Designate boundaries of area to be studied
2. Collect analyzed data
3. Transcribe findings

Secondary data are obtained via online databases from various private institutions and governments on the municipal, state, and federal level. Data gathered include, but are not limited to, satellite and aerial images, land uses, street and highways, city boundaries and land parcels. After the completion of stage 1, tree coverage can be analyzed in various formats by changing the boundary parameters in stage 2.

1.5 Significance and Limitations

Remote sensing and the technologies behind this research have provided the means to easily access land cover data. Goetz writes that “Historically, land cover and land use information was obtained by a combination of field measurements and aerial photo interpretation. This approach typically required intensive interpretation by expert analysts, and cross validation methods to ensure that analyst interpretations were consistent” (Goetz, 2003, 1). The use of satellite imagery and geo-spatial analysis tools to evaluate, isolate, and analyze tree canopy have its own strengths and constraints. Strengths of the methodology applied in this study consist of:

- Ability to efficiently evaluate broad areas of land
- Effectively analyze shifts in tree coverage. (The applied methodology incorporates a dataset which derives from a time-series collection beginning in 1975).

- Applicability to any community or regional study involving the assessment of tree coverage.
- Financially feasible (ideal for municipalities due to using secondary data).
- Minimal restrictions on areas that can be studied. (The methodology incorporates a worldwide collection of satellite imagery which is publicly available).

In comparison, there are items which were forfeited or sacrificed due to having the ability to gain the listed strengths. Limitations that arose during the course of this study include:

- Precision and accuracy of the canopy isolation process (due to 30m resolution image).
- High learning curve
- Accuracy of secondary data sources (may not have effected accuracy of data analysis in this study).
- Did not consider influences on development outside of the study area.

1.6 Definition of Terms

Clear Cutting – The removal of all trees from a given tract (NRDC, 2010)

Developer – Individual or group who buy raw (usually agricultural) land on a speculative note to "improve" the land either residential living or commercial use

Geographic Information System (GIS) - A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (ESRI)

Metroplex – Area surrounding the two core cities of Dallas and Fort Worth

North Central Texas Council of Governments (NCTCOG) - A voluntary association of, by and for local governments, and was established to assist local governments in planning for common needs, cooperating for mutual benefit, and coordinating for sound regional development (NCTCOG, 2009) (see figure 1.1)

North Texas – When referenced in this paper the term refers to the North Central Texas Council of Governments 16 county planning area (see figure 1.1)

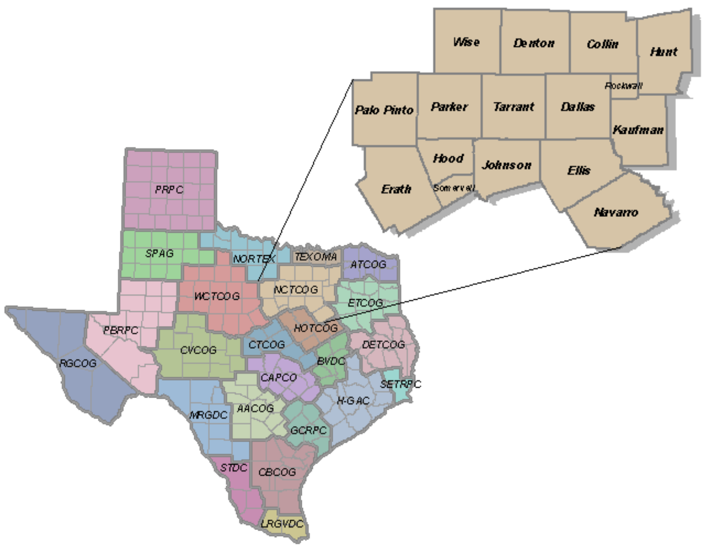

Figure 1.1: NCTCOG's 16 county planning area also referred to as North Texas (NCTCOG, 2009)

Remote Sensing – The acquisition of data from a distance, such as by satellite imagery or aerial photography (Lang, 1999, 116)

Rural – A place or census-designated place with fewer than 2,500 inhabitants located outside of a UA

Rural-Urban Fringe (also Urban Fringe)- 'That zone of transition which begins with the edge of the fully built up urban area and becomes progressively more rural whilst still remaining a clear mix of urban and rural land uses and influences before giving way to the wider countryside' (Countryside Agency, 2002; Gallent et al 2006, 5)

Spatial Analysis – The determination of the spatial relationships between geographic object, such as the distance between them or the extent to which they overlap (Lang, 1999, 116)

Subdivision – A sub-divided parcel of land catering to only residential living

Suburbs – A district/community located between the city and countryside

Thematic Map – A map that symbolizes features according to a particular attribute (Lang, 1999, 116)

Undeveloped Land – Land that has not been improved with any hardscape or other typical urban amenity and still in a naturalistic or agricultural state

Urban – Census defines urban as comprising all territory, population, and housing units located in urbanized areas (UAs), defined in terms of census tracts, and in places of 2,500 or more inhabitants outside of UAs

Urban Fringe – The built-up area just outside the corporate limits of the city (Pryor 1968, 202)

Vision North Texas (VNT) – A collaboration of private, public and academic organizations for the improvement of North Texas (VNT, 2010)

1.7 Study Overview

The objective of this research is to assess the impact of subdivision development on tree canopy coverage using Geographic Information System (GIS) within the city limits of Fort Worth. For the primary objective, various studies are organized and conducted to evaluate the impact in response to the research questions. A second objective in the study is to evaluate the strengths and limitations of existing methodologies which analyze the tree coverage data, in relevance to applicability to this research. Sections of this thesis are divided into five chapters: (1) introduction, (2) literature review, (3) research methods, (4) analysis and findings, and (5) conclusion.

Chapter 2 reviews the literature and evaluates current and historical patterns of growth that have influenced the initial quest of this research; provide an understanding of natural resources, specifically trees and their importance; describe the approach of assessing data; understanding of subdivision typologies; and review of geo-spatial analysis methods. Chapter 3 focuses on the research methodology; identifying and testing existing methods; describe the development of a new methodology and the systematic approach; and evaluate the strengths and limitations. Chapter 4 goes through the questions set forth and indicates each analysis methods and findings that were produced. Concluding is Chapter 5 which describe the studies that were conducted; collection of data obtaining information; the significance of the study and how it relates to Landscape Architecture; and possible topics for future research.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter begins with a brief discussion on growth in suburban areas and the factors that drive it. Following this is a section on the city of Fort Worth describing growth trends and where growth is taking place in relation to its impact to natural resources. The urban fringe is addressed in the next section with an emphasis on the role it plays in urban development on natural assets, specifically tree coverage. Also included, is information on subdivision typologies with brief pros and cons on how each typology is shaping the urban landscape. Following the subdivision typology section there is a discussion of the importance of urban forest and tree coverage. This review specifically focuses on trees in the urban makeup, and how they play a role in urban design, environmental health, and quality of life. Concluding the chapter is a review of geo-spatial research analysis literature. This section examines the relevance of Geographic Information Systems (GIS) in this type of study. In addition it looks into Land Cover and Land Use Change (LCLUC) and the role of potential uses by studying the available data for such study. Completing this section is a look into remotely sensed information and provides a description of methods of collection.

2.2 Growth

Population increase is one of the major "forces that drive urban growth," and as the metropolitan population increases the redistribution will expand into the outlying areas (Heimlich, 2001, 15). Heid (2003) states "Between 2003 and 2025, the United States will grow by almost 58 million people—a Census Bureau forecast that roughly continues the average 2.75

million to 3 million-plus-a-year increase since 1980. Even the most optimistic assumptions foresee accommodating at most 18 million or so of these new people through infill. That leaves at least 40 million to still be accommodated in some sort of new greenfield community" (2). In North Texas, the region has recently seen twelve consecutive years of growth exceeding 100,000 people (Fort Worth, 2010).

In addition to expanding development in outlying areas, redevelopment of urban areas is impacting natural resources and assets which occur in the higher density environments. This can include the dedication of parkland and floodways to culverting streams and removal of large mature trees. Each has an impact on the natural resources and proper assessment is needed to provide information for making appropriate planning decisions.

2.2.1 The City of Fort Worth

In a report produced by the city of Fort Worth, it states "Fort Worth has been the fastest growing large city of more than 500,000 populations in the nation since April 1, 2000. The population of Fort Worth as of January 1, 2009, is estimated to be 720,250 persons. From 2000 to 2009, Fort Worth's total population increased by 185,556 persons. This represents an average annual increase of approximately 20,600 persons since the 2000 Census, a growth rate of approximately 3.9 percent per year. By 2030, Fort Worth's population is projected to approach one million. The Far Northwest sector, which includes Lake Worth, is projected by the North Central Texas Council of Governments (NCTCOG) to be one of the fastest growing areas of the city through 2030" (City of Fort Worth, 2009, 5).

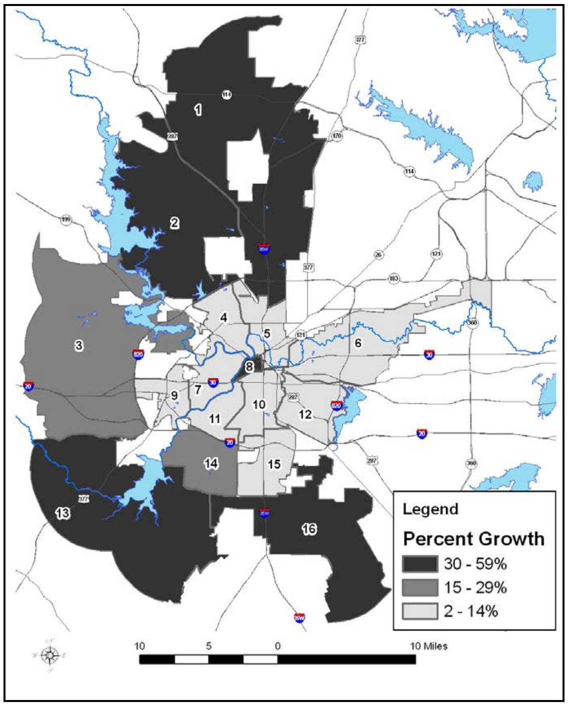

Figure 2.1: Population Growth in the city of Fort Worth from 2000-2005 (NCTCOG, 2005; City of Fort Worth, 2009)

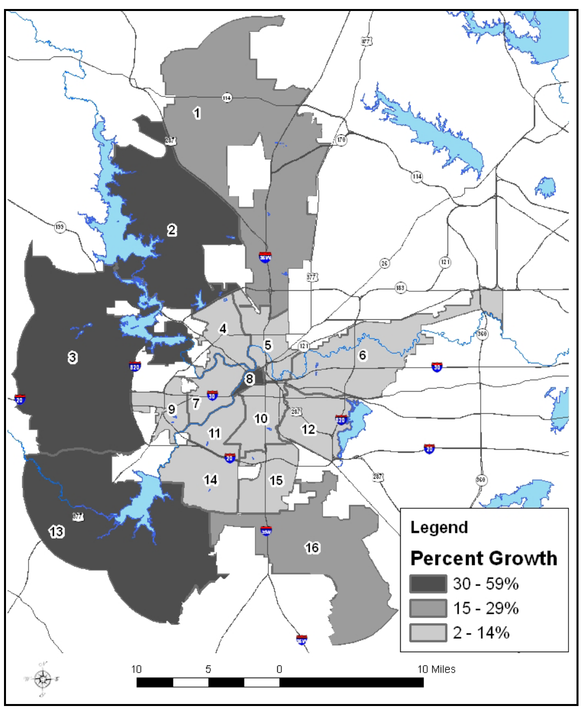

Figure 2.2: Projected Population Growth in the city of Fort Worth from 2005-2010 (NCTCOG, 2005; City of Fort Worth, 2010)

In figure 2.1, it illustrates that in-between 2000 and 2005 the suburban areas of Fort Worth have seen a growth between 30% and 59%, and the focus of this increase was in the northern and southern ends of the city. In figure 2.2, NCTCOG has projected that by 2010 the majority of growth for Fort Worth shifts and focus to the West. In both scenarios the majority of all population changes are occurring in the suburban fringe with Loop 820 acting as barrier to the minimally changing urban area.

Spanning through the city is multiple watersheds with a vast maze of streams and creeks that eventually feed into the Trinity River. Trees are usually associated with the collector streams and act as a filter to improve water quality. With changing land uses the management of these trees will be crucial to the improvement of the water quality in the city and the region. By assessing changes in tree coverage, it can be an indicator to potential problems within water bodies and riparian corridors.

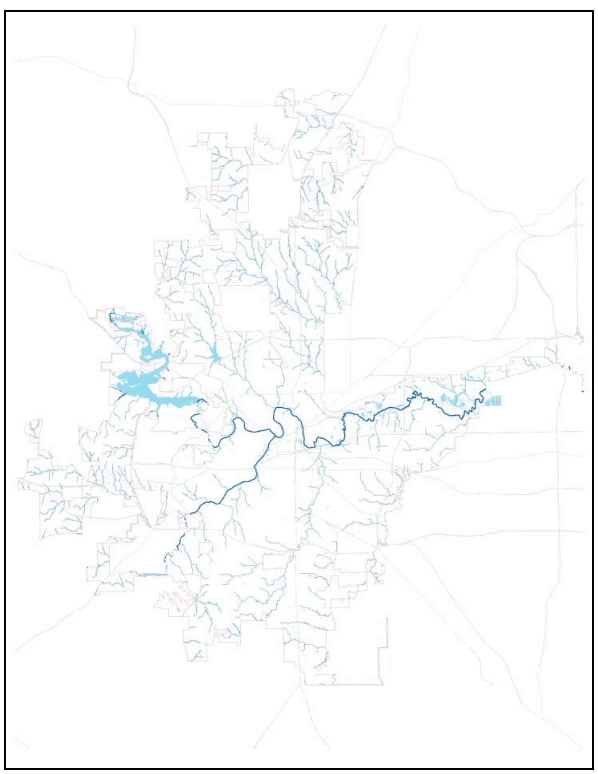

Figure 2.3: Hydrology map for the city of Fort Worth (NCTCOG, *date unknown*)

2.3 The Fringe

The urban fringe is a transitional area located on the outskirts of metropolitan areas that incorporate land uses associated with urban, suburban, and rural landscapes. It is an area that is influenced by the demands of the majority who inhabit the area. A growing majority of the American public prefers the lifestyle that only living in rural areas would fulfill, but with the urban population being divided, the fringe has and will continue to be "under development pressure from both sides" (Gallent et al, 2006, i).

In an October 2003 interview for *Metropolis,* former Milwaukee Mayer John Norquist stated:

"Most of the development in the United States, 90 percent or something like that, is new development on the edge. If we ignore that and just concentrate on infill, the edge city will never repair itself. New development needs to be informed by the principles of urbanism. It would be a mistake for people who care about cities and urban design to assume that any greenfield development is bad—because it's going to happen, and if it doesn't improve it will overwhelm whatever infill we are doing in the cities."(qtd. In Heid, 2004, 2)

The organic nature of the fringe is considered by some to "not be reined in" by land use planning unlike the urban areas, and there continues to be a "certain lawlessness" associated with how this area is occupied and used. The fringe has been referred to as "planning's last frontier' which is a vital and vibrant area that is vulnerable to poor planning (Gallent et al, 2006, 5). Figure 2.7 illustrates this fringe area and how the transition from urban to wilderness takes place. The natural assets located in this area are directly affected by the associated land use. Therefore, making informed decisions of what land uses should be in place is needed. The information to make these informed decisions relates back to studies as in this one which is evaluating the impact on tree coverage.

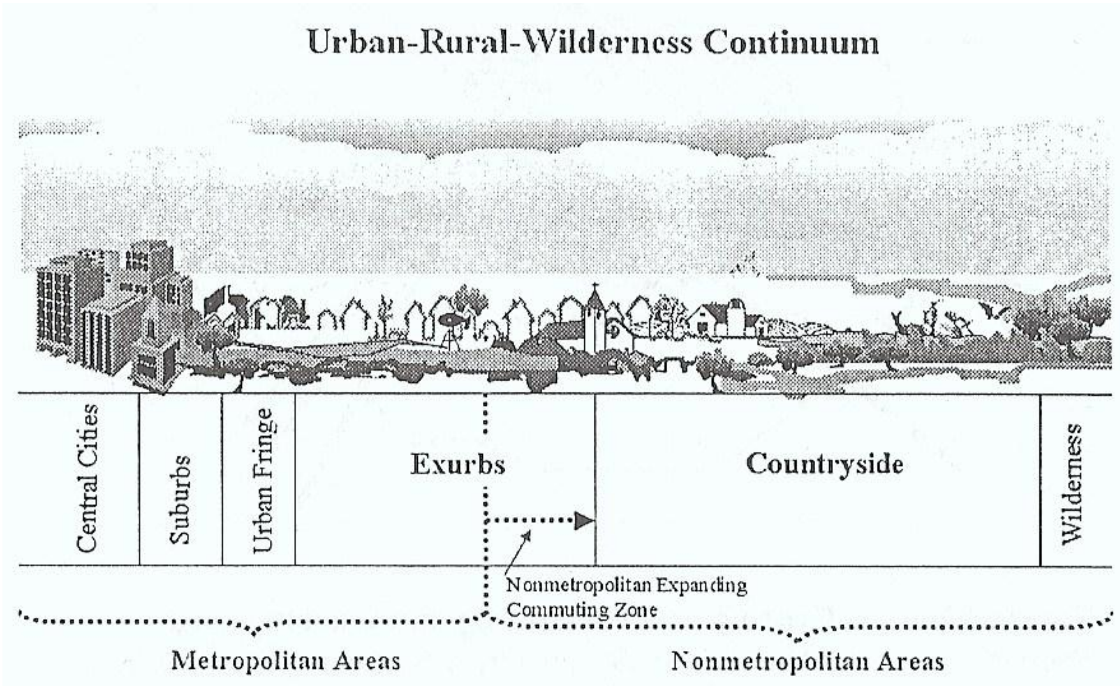

Figure 2.4: Diagram of various edges of development (Image Source: Healy and Short, The Market for Rural Lands, Trends, Issues, Policies, 1981)

2.4 Subdividing the Land

Post World War II was the era in which the subdivision evolved, and these early developments were commonly referred to as "cookie cutter" due to the "incrementally developed" land on which they stood. This style of development has continually been scrutinized by professionals and was even referred to in music from the era, as in Pete Seeger's "Little Boxes" in which he describes them as being "made of ticky-tacky" and "they all look the same." (Knox, 2008, 31). This style was a common practice, still in effect today in some places, was to purchase land, primarily in agricultural use, clear-cut the site, fill in low lying areas, and then "culverted streamways all in an effort to maximize buildable land" (Girling and Helphand, 1994, 83).

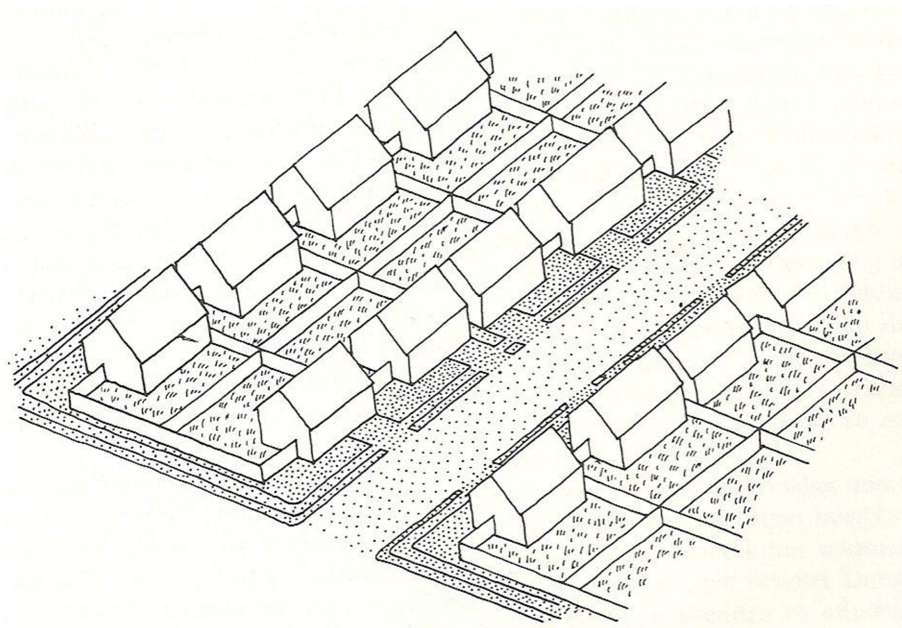

Figure 2.5: Illustration of a “cookie cutter” subdivision, “making reference to the aspect of everything being visually identical” (Girling and Helphand 1994).

Figure 2.6: Levittown in its early phase, 1949 (Girling and Helphand, 1994).

2.5 Planning Concepts and Typologies Influences Subdivision

The American public, as with most things they do, wanted variety and options in their living arrangements. This thought process, in addition to, the growing interest in conservation sparked a deviation from the original ‘cookie cutter’ subdivision. These new developments, in some instances, are similar to retail sales in the fact that they target certain markets. This could be anything from Active Living Communities (see Figure 2.7), in which most require a minimum age, to Master Planned Communities, which typically are geared toward young couples. These developments have shaped the landscape and influenced further development in the non-urban areas, and Figure 2.6 identifies a few of these communities and their defining characteristics. Subsequent sub-sections identify typologies in further examination that have been incorporated into the suburbs of North Texas and the city of Fort Worth. Each typology seems to have different impacts on natural assets; therefore it is important to understand some of the basics about them as outlined in subsequent sections and in Figure 2.7.

Planning Form	Defining Characteristic(s)	Image	Examples
New Communities/Towns	Large scale, long term, balanced/mixed land uses	A new town	• Reston, Virginia • The Woodlands, Texas • Summerlin, Nevada
Traditional Planned Communities	Moderate scale, moderate term, mixed uses, and high open space/recreation component	A new village, contemporary in form	• Ladera, California • Gainey Ranch, Arizona
Recreation Communities	Recreation and lifestyle organizing element(s), predominantly second home	A resort lifestyle community	• Desert Mountain, Arizona • Hualalai, Hawaii
Active Adult Communities	Age-restricted with central facilities for fostering resident interaction and lifestyle	A retirement lifestyle community	• Sun City, Arizona • Sun City, Nevada
New Urbanist Developments	Garages loaded from rear, street-separated sidewalks, fine-grain mixed use	A traditional village	• Seaside, Florida • Kentlands, Maryland
Conservation Developments	Conserved open space focus, typically under conservation trust	A rural hamlet	• Spring Island, South Carolina • Prairie Crossing, Illinois

Figure 2.7: Comparison of various planned communities (Heimlich 2001, 15).

2.5.1 Traditional Neighborhood Development

Traditional Neighborhood Development (TND) is primarily based on the concept of 'pedestrian movement and social interaction.' This style of development is traditionally designed on a grid system, but unlike previous subdivisions built on a grid concept, the TND gives second thought to the automobile. This is accomplished by providing garage access through alleys to the back of the house. Driveways and garages in the front of the house, facing the street, are avoided if possible, and is a development style reminiscent of pre-world war II neighborhoods. By focusing on 'pedestrian movement and social interaction' the cul-de-sac in addition, is typically avoided because it is 'thought to inhibit social contact' (Knox 2008, 99). Through the addition of proving alleys the separation of houses is typically further apart than other development styles. Although it is aesthetically pleasing to the eye, it is assumed that this style of development can negatively increase environmental impacts due to an increase in impervious surface and a by having a slightly lower density which results in expansion.

Figure 2.8: Illustration of a Traditional Neighborhood Development (Girling and Helphand, 1994)

2.5.2 Master-Planned Community

The master planned community (MPC) is based on the idea of creating a ‘more livable environment.’ The design of modern MPCs has scaled down the overall concept to focus on livability, security, cultural aspects, and importantly amenities. Historically when this concept was introduced, it was in an attempt to create a small town, which could cater to the needs of up to 50, 000 inhabitants, by providing an environment which hosted the ‘live, work, and play’ idea. Two examples of an MPC designed based on the original concept are: The Woodlands, which is locate near Houston, and was designed by Ian McHarg; the second is Las Colinas, which is MPC located in the city of Irving. A few common elements of a MPC are: open space, which can range from 37%-53%; village center; design guideline; committees and associations; security; and some form of commercial uses (Siembieda et al, 2005, 32).

Figure 2.9: Illustration of a Master-Planned Community (HMH 2010).

This style of development typically incorporates hundreds and even thousands of acres to facilitate residential housing, amenities, and in some cases, work. With more types of land uses incorporated in this development concept compared to others, it is assumed that this style of development has a large impact on pre development conditions with the extensive altering of land to accommodate the proposed amenities. This development does incorporate open areas but are usually natural features that have been enhanced or extensively designed.

2.5.3 Conservation Subdivision Development

Conservation Subdivision Development (CSD) as Randall Arendt defines, "in its purist form…refers to residential developments where, as in golf course communities, half or more of the buildable land area is designated as undivided, permanent open space. This result is typically achieved in a density-neutral manner by designing residential neighborhoods more compact, with smaller lots for narrower single-family homes, as are found in traditional villages and small towns throughout the United States," and "The most important step in designing a 'conservation subdivision' is to identify the land that is to preserved. This should always be the first major design step that is taken" (1996, 6).

CSDs are sometimes referred to as "natural neighborhoods," this is largely due to the fact that CSDs will 'preserve 50%-70% or more of the buildable land, in addition to land that is unsuitable for development such as flood plains, steep slopes, and wetlands. By incorporating these methods, stormwater runoff is minimized and sometimes seized completely by providing more impervious surface and giving the water time to infiltrate (Land Choices.org, 2010). This style of development not only preserves land in general, but of the land to be built upon, the impact on trees is minimized by working with and around them.

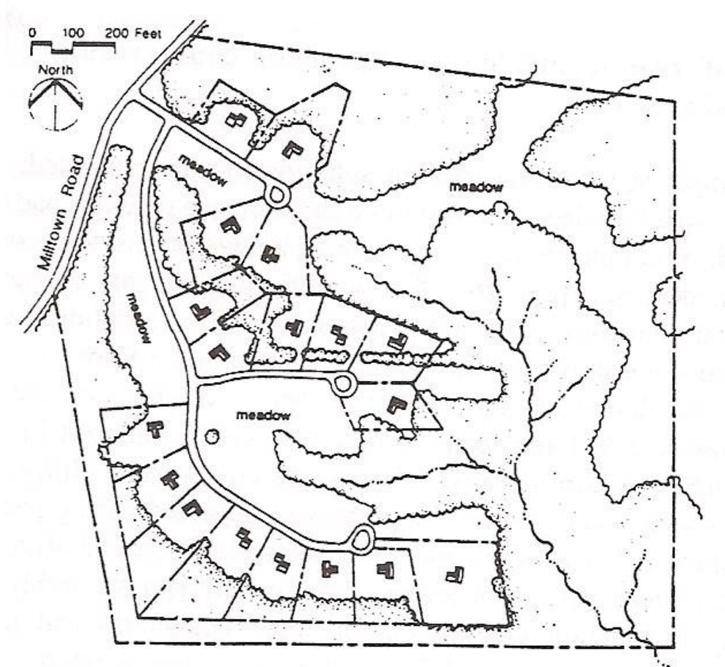

Figure 2.10: Illustration of a conservation subdivision (Girling and Helphand 1994)

2.5.4 Ranchettes

Ranchettes are a type of development that typically occurs on the fringe or even further out reaching to the exurbs and countryside. This style consists of characteristics that greatly differ from those in the suburban areas, where most subdivision developments may have a density of 4-6 houses per acre, ranchettes on the other hand, will consist of 1 house per 5-10 acres or more. This development style has been around, but due to its high impact on natural resources it may be getting more attention than it has in the past (Peterson and Branagan, 2000). A large majority of these developments may incorporate some agricultural uses, but it is typically on the recreational level. The rural lifestyle associated with this typology is often very enticing for most people, but due the fact that this typology “remove[s] more land from agriculture per person than any other kind of development…they are of great concern to agriculture” industry (American Farmland Trust, 2009).

Figure 2.11: Sign posted for the sale of subdivided parcel into 10 acre ranchettes (American Farmland Trust)

The city of Fort Worth seem to have various examples of these type of developments, and each of them has varying levels of impacts to natural assets. The higher density developments, such as the TND and MPC, seem to impact existing tree coverage more so than a development similar to ranchettes. As mentioned previously, the ranchettes seem to impact the agricultural industry, specifically with obtaining prime agricultural land and economically. Most of these develops usually require large areas of land and are developed in phases and in some cases all at once. With the acquisition of large tracts of undeveloped land the developers inherit the natural resources associated with the land. There are minimal regulations on how the development is designed, but typically the overall layout is decided upon by the developer. By assessing and understanding the specific impacts these typologies have on natural resources, positive or negative, it will provide landscape planners, developer and governing bodies the knowledge to make informed decisions as it relates to natural resources.

2.6 Urban Forest and Its Importance

Forests are key assets in issues evolving environmental changes such as climate variation, water cycles, and biodiversity. In addition they provide rich habitats for an extensive list of plants and animals (Stein, 2009, 4), and "the sustainable development of forests has emerged as one of the most difficult, serious, and pressing environmental issues of our time" (GOFC-GOLD, 2010). Natural resource availability is one asset that has been affected by the human-induced changes of the Earth's forests (GOFC-GOLD, 2010).

Forests in the United States that are privately owned and managed account for 56% of the total forest cover, and these privately owned forests provide clean water, recreational opportunities, and wildlife habitat. These benefits are being affected by increased housing market not only the rural areas, but in the urban areas as well (Stein, 2009, 3).

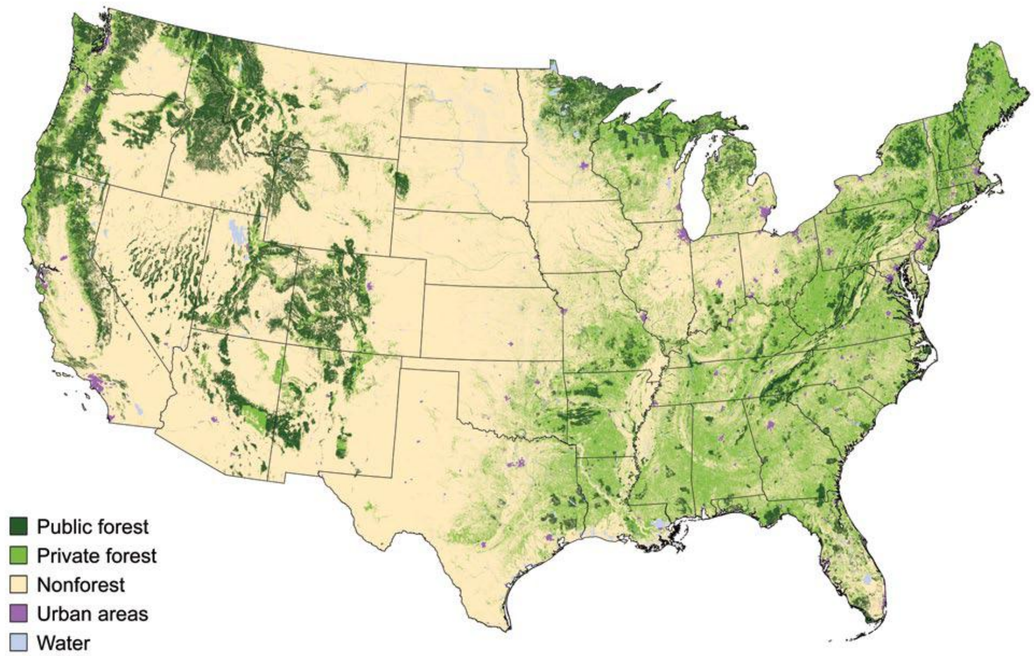

Figure 2.12: Illustration of Americas Privately owned forest. (Stein et al, 2009)

In a 20 city study conducted by the National Urban Forest Council (NUFC) in 1986, concluded that ‘the urban forest was on the decline, and losing an average four trees for every one planted. In a follow-up survey of the original 20 cities, American Forests, concluded the finding that the average life of a downtown street tree is merely 13 years, and revealed that there was an inability to assess a community’s entire urban forest population. (AF, Urban Forest, 2010).

Benefits of trees located in the urban context not only provide an aesthetic perception to visitors of the city, but can increase the economic value of the retail community. This has been determined by studies which have been conducted and results have indicated that consumers will typically extend shopping time and linger longer in districts with tree lined streets. Additionally, it has been shown that urban trees can alter the local climate with a cooling effect from the shade produced, which in return can reduce the urban heat island effect. Suburban and residential communities benefit from trees as a whole from the increase in property value directly associated to them (Lee et al, 2008). By incorporating the proper variety of trees in a design, the community and homeowners benefit from reduced noise and light pollution, in addition to reduced energy cost provided by the proper placement of trees (SCFC, 1990).

The protection, monitoring and management of trees are primarily conducted by government agencies on the federal, state, and municipal levels. As the public's interest in the protection of trees has grown, multiple professional and private organizations have evolved. These organizations range from community and regional forest projects, to American Forests and the Arbor Day Foundation, which sponsors the Tree City USA program. The Tree City USA program recognizes cities that have put forth the effort to establish and maintain a healthy tree population through sound forestry practices. "The City of Fort Worth is the oldest and longest running Tree City USA in Texas" (City of Fort Worth, Forestry, 2010).

Tarrant County and the city of Fort Worth fall into the "Blackland Prairies" and "Oak Woods and Prairies" eco-regions of Texas. The Blackland Prairies eco-region is an area known for "fertile black soil" and "once supported a tallgrass prairie dominated by tall-growing grasses such as big bluestem, little bluestem, indiangrass and switchgrass (TPWD, 2010, 4). A "transitional area" for many flora and fauna is the Oak Woods and Prairies eco-region. The characteristics of this region are described as belts or groupings of oak woodlands "interspersed with grassland" (TPWD, 2010, 4).

2.7 Geo-Spatial Research in Literature

The literature review in the section takes a brief look into how GIS and remotely sensed data can be used in order to document, analyze and assess tree canopy coverage data. While completing this primary objective the evaluation of land cover and land use change are also addressed through geo-spatial methods. In addition, information is collected on existing methods of analyzing tree canopy data which uses remote sensing techniques.

2.7.1 Geographic Information System (GIS)

Geographic information system (GIS) is organizational software for 'geographically referenced' data. Geo-spatial analysis tool associated with the GIS has the capability to manipulate, extract, and analyze various forms of data for research (ESRI, 2010). The strength behind using GIS is that 'discrete geographic locations' can be stored digitally. This data or a combination of data can be projected to display points that describe features on the Earth's surface. The information stored is composed of spatial data in the form of points, lines, and regions (Decker, 2001, 11) and by having the data referenced to exact points spatially the information will not change. Having the ability to project data that is geographically referenced, information can then be shared without compromising the integrity of the study due to human error. With the 'analytical power' of GIS, searches can be conducted based on a query to only extract the needed data (Lang, 1998, 4).

GIS is an ideal tool to aid in the information collection and analysis for studies that evaluate occurrences that can be spatially referenced, as in "The delicate balance between industrial development and environmental conservation [which] requires sophisticated modeling and spatial analytical tools" (ESRI, History, 2010). GIS can give researches insight on past trends, current issues and aid in future planning by providing information which can be used to make well-informed decisions. "Geographic information system (GIS) technology can extend this insight to address social, economic, business, and environmental concerns at local, regional, national, and global scales" (ESRI, History, 2010).

With this study being confined the city limits of Fort Worth, the ability to accurately analyze data at various scales, down to individual land parcels, is needed. Also, by having the ability to analyze large sets of data at a time, it provides an effective and efficient means of conducting research and analysis.

2.7.2 Land Cover and Land Use Change

Land cover is defined as “the discernible vegetation, geologic, hydrologic or anthropogenic features on the planet's land surface” (GLFC, 2010). Land cover features, such as forest and urban areas can be ’measured and categorized’ with the aid of satellite imagery. As changes continue to occur in our environment locally, regionally, and globally such as climate, demographics, water quality and development trends, “land-cover and land use change will continue to be an important topic for global environmental change research” (LULUC, 2010). The assessment of land cover data is conducted by comparing two or more images taken as different times and with the incorporation of GIS the slight variation in changes identified and analyzed to produce information for making decisions. Being able to know how much change has taken place, where it was taken and possibly why it changed is an essential part of the scientific approach using land cover (GLCF, 2010).

Since the 1960’s, the USGS has been ‘at the core’ of land use and land coverage image collection as well as its subsidy known as the Land Cover Institute (LCI). Through the years, changes in research and scope have provided means for continual enhancement of land cover data (USGS, 2010). Projects that have evolved from the USGS LCI studies and its affiliates are publically available and include:

- *The Global Land Survey (GLS)”* is a partnership between the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA), in support of the U.S. Climate Change Science Program (CCSP) and the NASA Land-cover and Land-use Change (LCLUC) Program. Characterizing trends in land cover and land use remains a key goal for Earth science. The GLS is assembling a global dataset of 30-meter resolution satellite imagery to support measurement of Earth's land cover and rates of land cover change during the first decade of the 21st century. The GLS builds on the existing Geocover data sets developed for the 1970's, 1990, and 2000" (USGS, *GLS,* 2010).

- *Land Cover Trends* "is a research project focused on understanding the rates, trends, causes, and consequences of contemporary U.S. land use and land cover change. The research is supported by the Geographic Analysis and Monitoring Program (GAM) of the U.S. Geological Survey (USGS) and is a collaborative effort with the U.S. Environmental Protection Agency (EPA) and the National Aeronautics and Space Administration (NASA)" (USGS, *LCT* ,2010).

- *The North American Land Change Monitoring System (NALCMS)* "The objective of NALCMS is to devise, through a collective effort, a harmonized multi-scale land cover monitoring framework, which can be applied across North America with high accuracy meeting each countries specific requirements. The new 2005 Land Cover Database of North America at 250 m spatial resolution is the first step toward achieving this objective. The product is based on observations acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS). Information provided by this land cover database is valuable for a range of users including, international organizations such as the United Nations Environment Programme, non-governmental conservation organizations, land managers, and scientific researchers. The continental scale land cover data generated under NALCMS can be used to address issues such as climate change, carbon sequestration, biodiversity loss, and changes in ecosystem structure and function, by helping users to better understand the dynamics and continental-scale patterns of North America's changing environment" (USGS, *NALC*, 2010).

2.7.3 Remote Sensing Land Cover

Imagery taken from aircraft, spacecraft, or satellite can produce substantial amount of information about natural resources, vegetation, and waterbodies. Once these images have been assigned a spatially referenced point, they are then known as remotely sensed images (USGS 1997). In studies being conducted, as in vegetation analysis, remotely sensed imagery is a must due to its capability to be brought into GIS and organized according to their reference point. By reviewing and layering multiple images from sub-sequential years, which are geo-referenced in the same location, is key in order to understand how coverage has changed in transient phenomena, such as seasonal vegetation vigor and contaminant discharges (USGS, 1997). There are a few common methods of collecting images in regards to analyzing land cover, and the resolution can vary depending on the size of the project and the accuracy needed. A few common methods of data collection include:

- *Aerial Photograph* "is a picture of the earth's surface taken with a camera mounted on aircraft (see figure 2.15) and also spacecraft such as the Space Shuttle" (USGS, 1997). "Millions of dollars are spent each year by local, regional, state, tribal, and federal government agencies to collect aerial imagery. The uses are many, thus the demand for up-to-date imagery is constantly increasing. Since the 1930's, aerial photos have been acquired using large format film cameras. Today, film cameras, along with newer digital cameras that can record black & white and color images simultaneously, are used for many projects" (WSCO ,2010).

- *Satellite Imagery* "is collected of the earth on a regular basis. Besides being outstanding pictures of the earth's surface, these images have many applications in agriculture, geology, forestry, regional planning, education and intelligence gathering" (WSCO, 2010). "In 1972, the United States launched its first Earth Resources Technology

Satellite, ERTS-1, later renamed Landsat 1, for experimental global coverage of the Earth's land masses. Landsats 2 through 5 were launched in 1975, 1978, 1982, and 1984. Data from these satellites are collected by sensors that measure a range of wavelengths of electromagnetic energy reflected or emitted from the Earth. The data are transmitted to Earth, where they are processed by computers and stored on magnetic tape. Landsats 1-5 carried versions of a sensor called the multispectral scanner (MSS), which collected data simultaneously from four broad bands of the electromagnetic spectrum, from visible green through near-infrared wavelengths. The MSS images in this booklet have a resolution of about 80 meters (260 feet). The thematic mapper (TM) sensor carried on Landsats 4 and 5, in addition to the MSS, has a resolution of about 30 meters (98 feet). The TM sensor also records a greater number of bands than the MSS, yielding more detailed spectral information. Landsat images can be processed to emphasize different features of the land" (USGS, 1997). Figures 2.13 and 2.14 schematically illustrate the approaches for coarse resolution mapping on a 5 year cycle and periodic monitoring of forested areas at fine resolution as proposed by Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD, 2009)

- *Orthophotos "*are aerial photographs or digital versions of these photographs that have been "orthorectified" using ground elevations data to correct displacements caused by differences in terrain relief and camera tilt. The process gives an orthophoto the accuracy of a map. Because aerial photographs show the texture of the ground in much greater detail than do maps, orthophotos are useful for updating maps and for studying surface features not necessarily visible in maps. The USGS produces digital orthophotos for map revision and for computer analysis using geographic information systems" (USGS, 1997).

- *LiDAR* stands for **Li**ght **D**etection **and R**anging **S**ystems. "It consists of a laser (light beam) being emitted from an aircraft to the surface of the Earth, and reflected back to a sensor on board the aircraft. Using Global Positioning System triangulation, the exact location of the aircraft is also recorded. Thus, elevations of the surface of the Earth's topography and cover, such as trees and buildings, can be mapped with minimal error. LiDAR has become widely accepted as a tool for generating highly accurate terrain models that are used in a variety of GIS applications" (WSOC, 2010). " LiDAR is an emerging technology that has many applications in resource management and it will likely have a great many more applications in the near future" (RSAC, LiDAR, 2010).

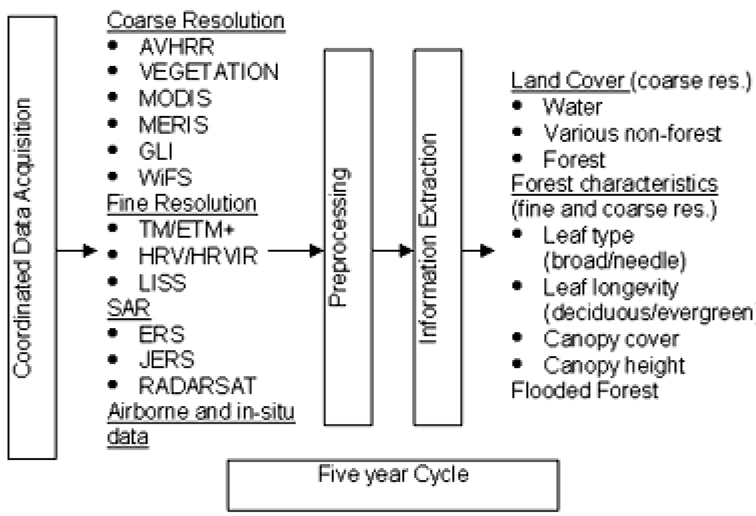

Figure 2.13: Illustration of five year cycle of forest cover characteristics (GOFC-GOLD, 2009)

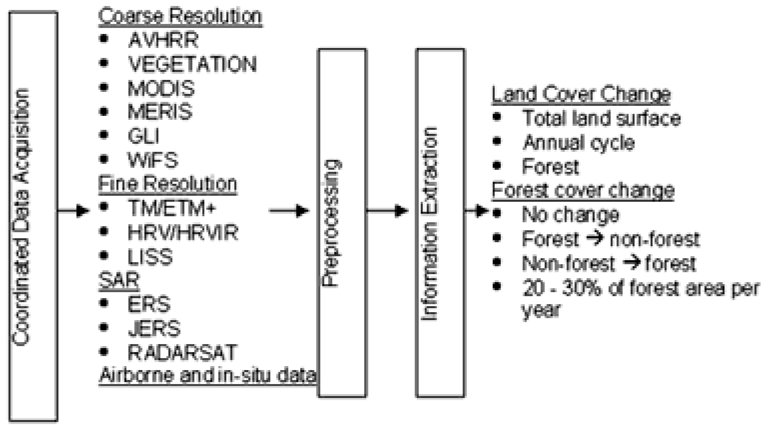

Figure 2.14: Illustration of forest cover changes in imagery collection process (GOFC-GOLD, 2009)

If acquiring secondary data, it will state weather the imagery is a leaf-on or leaf-off, and depending on the study being conducting will pertain to which style of imagery is need. Typically, if a study is being conducted on ground level the leaf off imagery is needed in order to see through the canopy, and vice versa for vegetation studies. Various films are used to take imagery and the style of the film is associated with what is needed from the study. "Typically black-and-white film costs less than color film. Depending on the area of coverage, this can be a costly factor to consider. Infrared film is typically used to view differences between types of vegetation and to clearly see the distinction between water and land" (WSCO, 2010). Listed are types of film used for photography:

- B&W = Back-and-White (panchromatic)
- B&W IR = Black-and-White Infrared*
- COLOR = Natural Color
- COLOR IR = Color Infrared (false color)

"Most aerial photography is taken with a large format camera using 9" x 9" film. Since the size of aerial film is the same, the scale and thus the detail visible on a photo depends on flying height above the ground. A photographic scale is basically an expression that indicates that one unit of distance (inches, centimeters, etc.) on an air photo is a representation of a specific number of the same units (inches, centimeters, etc.) of actual ground distance. As an example, a photo at 1:20,000 scale (1" = 1667') covers one quarter the area and shows objects at twice the size as a 1:40,000 scale (1" = 3,333') photo. This results because the 1:20,000 scale photo was flown at half the altitude of the 1:40,000 scale photo" (WSCO, 2010).

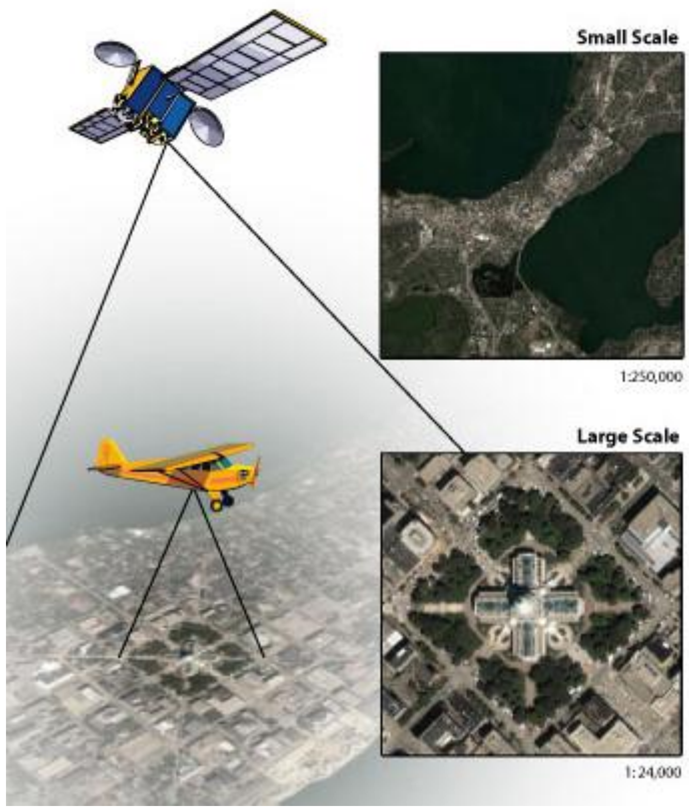

Figure 2.15: Illustration of imagery collection at various scales (WSCO, 2010)

CHAPTER III

RESEARCH METHODS

3.1 Introduction

This chapter focuses on the method used in the research. The chapter begins with a review of existing methodologies that use GIS and remote sensing techniques. This section highlights the limitations and constraints of these methods, and then proposes a newer methodology that stems from an earlier study which estimated tree canopy density using satellite and high resolution imagery (Huang et al, 2001). Following this section is a description of the study area including population, land uses, and growth. This chapter further discusses data availability from secondary sources and provides an inventory of acquired data. Concluding this chapter are sections which include a brief introduction of the study instruments, an outline of the analysis procedure including a description of the study area boundaries and finishing with the limitations of the applied analysis method.

3.2 Review of Existing Methodologies Informed Tree Coverage Methodology

Tree coverage studies are typically conducted using quantitative research methods with empirical data, and this research is not an exception. There are various methods available for this style of analysis ranging from site survey on smaller scales to aerial imagery interpretation for large areas. When the resources are available a complete tree inventory (which is simply a documentation of trees through site survey) would be "beneficial to planning a green environment, but logistically that's not feasible" (Morrow et al, 2001, 3). Varying with the size of the site's needs, it could take a municipality department years to complete a comprehensive tree inventory, but a more time efficient and financially responsible method is to use GIS and remote sensing to gather the data (Morrow et al, 2001).

As it applied to this research, a search for available means of finding appropriate data for tree coverage was first conducted through literature review. This initial phase of the research through literature review was to determine possible methods that would have the potential to work for this study. The review developed a combination of government and privately produced data, and an outline of developed methods from previous research. The methods that were identified include:

- National Land Cover Dataset (NLCD) is based primarily on 1992 vintage Landsat 5 Thematic Mapper (TM) data that were purchased and pre-processed to a common set of specifications for the Multi-resolution Land Characteristics (MRLC) consortium (Loveland and Shaw, 1996). The partner agencies, which included the USGS, the U.S. Environmental Protection Agency (EPA) (Vogelman et al, 2001)
- LiDAR - Light Detection and Ranging is a remote sensing system used to collect topographic data. This data are collected with aircraft-mounted lasers capable of recording elevation measurements at a rate of 2,000 to 5,000 pulses per second and have a vertical precision of 15 centimeters (6 inches) (NOAA, 2010)
- Infrared Orthoimages – (Two part description) infrared image are derived from aerial photos captured on color infrared film. The imagery is useful in detecting vegetation types and soil conditions (GISU Iowa State, 2010). “Ortho”-imagery is remotely sensed image data in which displacement of features in the image caused by terrain relief and sensor orientation have been mathematically removed. Orthoimagery combines the image characteristics of a photograph with the geometric qualities of a map (USGS metadata file, 2004)

Second phase was to gather the necessary data for each of these processes, and once the data was collected and imported in to GIS, a test was conducted on a small area to evaluate their efficiency. This was the determining factor for which process would potentially be used.

Initially, the LiDAR method, due to being primarily in the private sector, was excused due to the substantially high cost involved to obtain this data, and since it is a newer method of analyzing there is minimal amount of existing data available. Two articles (Morrow et al 2001; Huang et al, 2001) located during the literature review, had executed similar studies in an approach to assess tree canopy through remote sensing and geo-spatial technologies. Each analysis process of these two studies is replicated for applicability in this research. The study conducted by the USGS was looking into assessing large scale tree canopy and used 30m resolution imagery from the National Land Cover Dataset (NLCD). The other article was from Florida's Broward County GIS Department in which they were attempting to establish a county wide detailed canopy cover map (Morrow et al, 2001). The use of infrared orthoimagery on 1m and 3m resolution were used.

For applicability of an analysis method to this study, certain parameters were set prior to testing in order to be able to fulfill the needs for the study. The research questions set up the preliminary parameters based on the information that was needed to answer them, which include:

- *Chronological Time Series*- the primary question is to understand the impact subdivisions have on tree coverage. In order to accomplish this, at a minimum, consistent chronological imagery of pre and post development is needed. Imagery from the same source and resolution would provide the consistency for accurate comparison.
- *Scale* - to evaluate tree coverage from the scale of a large city down to subdivision parcels, the capability to extract canopy from large and small

groups of trees is needed. In addition to groups of trees the ability to depict single trees is needed for studies conducted in the urban setting.

In addition to the parameters set by the limitations of the data collected, there are additional parameters set forth by the limitations of the study:

- *Efficiency* – Due to the time constraints of the study, efficiency played a factor in the applicable methodology. Since the objective of the study was to examine the impact of development on tree coverage, the data collection process needed to be efficient in gathering this information over multiple and large areas throughout the study area.
- *Publicly Available Data* – the need for secondary data to be publicly available was a desirable component of this research. One of the thoughts behind the study was the ease of replication, and publicly available data would make this possible. By having this data already available, it did not require the expense of producing the information from scratch in the form of monies and man-hours.

Table 3.1 Assessment of Exisitng Known Methods

PROCESS	CHRONO-LOGICAL	SCALE	EFFICIENCY	PUBLICLY AVAILABLE	PROS	CONS
NLCD	yes	no	yes	yes	capable of analyzing state, regional and county level at one time	not detailed enough for site specific analysis
LiDAR	no	yes	yes	no	highly detailed and extremely accurate - capable of 3D analysis	newer technology - very limited existing studies completed in DFW area - cost prohibitive due to private resource collection
Infared Orthoimage	yes	yes	no	yes	highly detailed and extremely accurate - capable of extracting single tree canopy	learning curve - only analyze a 138 acres per image, process would have to be replicated 1600 times to analyze city of Fort Worth - large amount of memory storage

3.3 Defined Methodology for the Research

After testing and reviewing the existing methodologies, the strengths and limitations of the stemmed methods are evaluated in the attempt to develop a method by combining the strengths of each. In doing so, a few key elements evolved into parameters in defining this method. The two main goals that were defined included:

- Accuracy of the LiDAR and infrared orthoimages
- Efficiency of the NLCD by evaluating large areas at one time

By knowing the goals, a review of how the methods strengths are approached gives key elements in knowing what to look for to accomplish the task of developing an analysis method.

- NLCD is based off of the conversion of one large map
- Orthoimagery method's accuracy comes from the conversion of an aerial photo into classified pixels based on color wavelengths

Understanding the basis behind these two methods it is assumed that having the ability to convert one large image, which spanned the entire study area, would be the most efficient approach. Through research and review the Global Land Survey (GLS) became the ideal basis. The GLS is a time series 30 meter resolution image spanning the entire globe. It is derived from the Landsat project between USGS and NASA to evaluate changes on the Earth's surface from natural and human-based occurrences. The GLS is subdivided on sections of a grid, and each grid contains a bundle of 7 to 9 images with each image representing a different color wavelength band. The various combinations of these bands can produce various maps that can isolate certain features on the Earth. For this study the use of the mid-infrared band 5 was used. This band due to being mid-infrared has a high contrast to extract various vegetation layers. Band 5 was recommended for defining tree canopy from other vegetation. Note figures 3.1 as a limitation due to the reduced clarity from resolution difference, and figure 3.2 as a strength due to the capability to evaluate large areas of land at once.

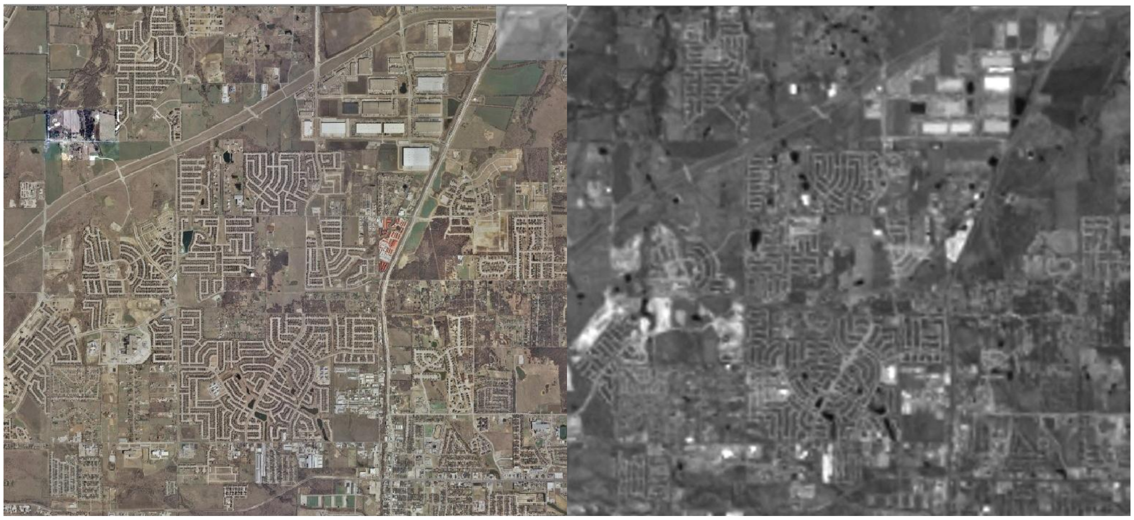

Figure 3.1: (left)2009 1m Resolution Orthoimage; (right) 2005 30m Global Land Survey spectral band 5 orthoimage (data source NCTCOG, 2010; GLS – USGS, 2010)

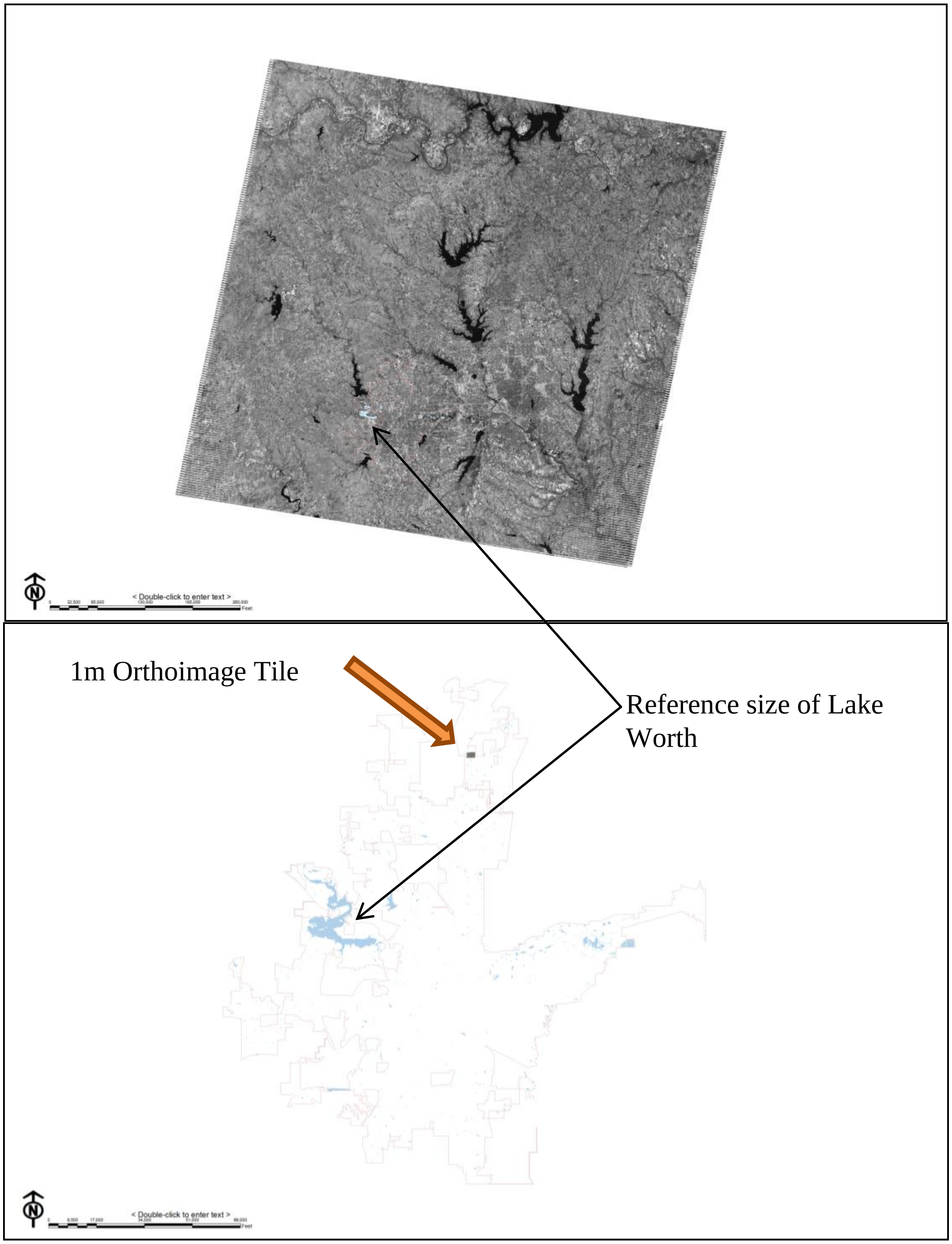

Figure 3.2: (bottom) Mosaic tile of 2009 1m Resolution Orthoimage; (top) section of 2005 30m Global Land Survey spectral band 5 (ortho – City of Fort Worth, 2010; GLS – USGS, 2010)

3.4 Study Location

Fort Worth was chosen as the study area due the exponential growth that was seen surrounding the city and vast array of land uses throughout the city limits in conjunction with rich natural assets. Fort Worth continues to increase in population at an extremely rapid rate. The estimated population for 2010 is almost 300,000 more people than there were in 1990 (NCTCOG, 2010). To match the growing population the city continues to acquire more land in rural areas. The Extra Territorial Jurisdiction (ETJ) of Fort Worth currently spans five separate counties (City of Fort Worth, 2010). As the city grows, the land use assigned to parcels change and land will be acquired for development. This research assesses the impact that past development trends in these land uses have had on tree canopy inside the city limits. To evaluate subdivision development impact the study will review pre and post development conditions in the suburban areas. Further examination will compare tree canopy coverage of the suburban and urban environments which is defined in the study as being located within Loop 820 (urban) or between Loop 820 and the city limit (suburban). In addition the land uses of the city, in 2005, will be separated into residential (single and multi-family) and all other uses for comparison of an average tree density per acre. Concluding the study will be an evaluation of the city tree coverage as a whole between the years of 1990 and 2005, which were years of large increase in population and housing.

	1990		2000		Change 1990-2000	
	Persons	% of Total	Persons	% of Total	Change	% Change
Total Population by Race (Hispanics included in all races)	**447,619**		**534,694**		**87,075**	**19.5%**
White	285,549	63.8%	319,159	59.7%	33,610	11.8%
Black	98,532	22.0%	108,310	20.3%	9,778	9.9%
American Indian	1,914	0.4%	3,144	0.6%	1,230	64.3%
Asian or Pacific Islander	8,910	2.0%	14,446	2.7%	5,536	62.1%
Other Race**	52,714	11.8%	75,100	14.0%	22,386	42.5%
Two or More Races*	N/A	N/A	14,535	2.7%	N/A	N/A
		100%		**100%**		
Hispanic Origin (Any Race)	87,345	19.5%	159,368	29.8%	72,023	82.5%

Click here for a breakdown of races by Hispanic and Non-Hispanic origin

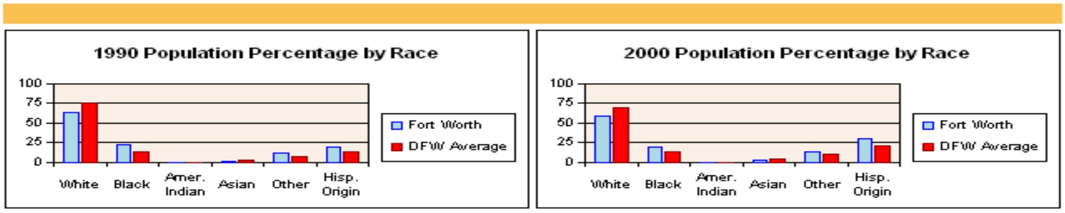

Figure 3.3: Population Demographics of Fort Worth from 1990 to 2000 (NCTCOG 2010)

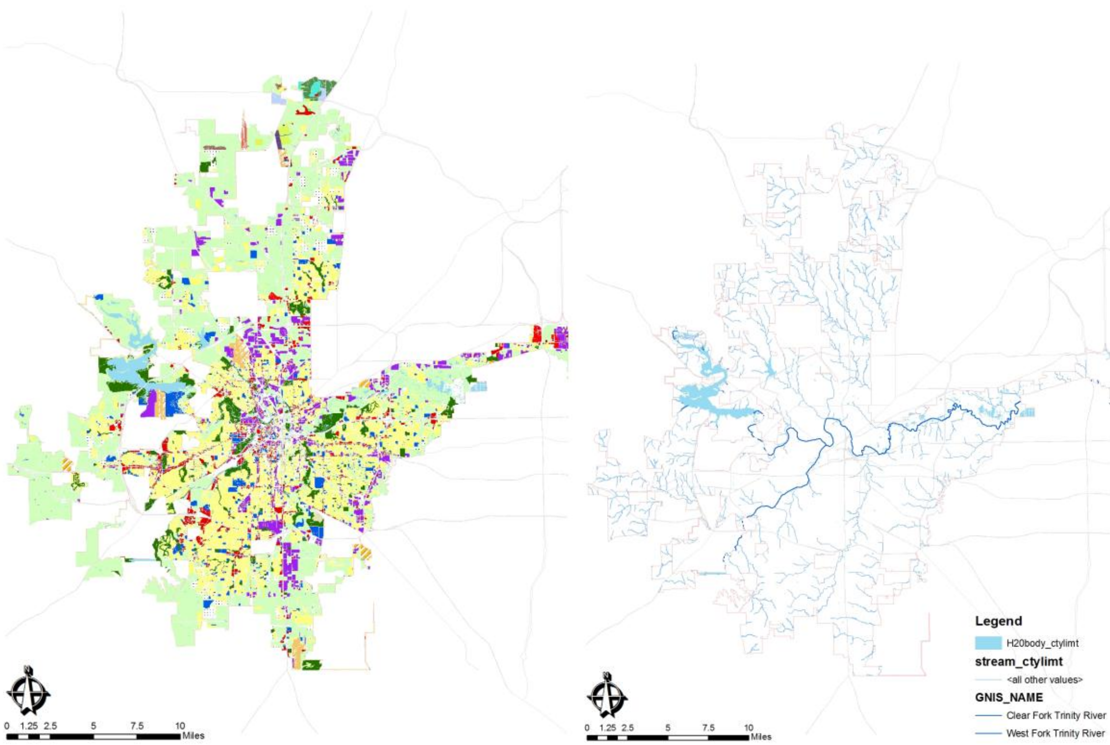

Figure 3.4: 2005 Land Use (left) and Hydrolocal Map (right) of Fort Worth. Note: light green on LU map is undeveloped area (NCTCOG 2005)

3.5 Data Acquisition

The proposed research heavily relied on the availability of land-use and natural resource data at the city scale. This inquiry not only required a deeper look at the availability but also quality, and accuracy of this information in order to conduct a sound analysis. Systematic review of data was one of the first steps completed in the course of the research. Until a methodology was to be implemented the collection of basic data such as: city limit boundaries, land uses, and hydrology were acquired for the possible implementation in the analyses. Secondary data was collected through four primary data warehouses. For data directly related to the city as in: subdivision parcels, city boundaries, and annexation boundaries was gathered from the city of Fort Worth's GIS department. Various regional and county data as in: streets, highways, watersheds, land use, and orthoimagery were obtained from North Central Texas Council of Governments (NCTCOG). All other data was provided by National Atlas, a partnership of over twenty government agencies.

Table 3.2: Total Aquired Data Through the Course of the Research

DATA TYPE	DATE OF DATA REPRESENTATION	SOURCE
Orthoimagery	2001	NCTCOG
Orthoimagery	2009	NCTCOG
Fort Worth City Limits:	2010	NCTCOG
Fort Worth City Limits:	1990	NCTCOG
Fort worth Annexation:	Historical	City of Fort Worth
Fort worth Annexation:	1997-Current	City of Fort Worth
Fort Worth Subdivisions	2010	City of Fort Worth
Tarrant County Parcels	2008	*
Tarrant County Landuse	1990	NCTCOG
Tarrant County Landuse	1995	NCTCOG
Tarrant County Landuse	2000	NCTCOG
Tarrant County Landuse	2005	NCTCOG
Highways	*	*
Streets	*	*
Hydrology: stream flowlines	*	*
Hydrology: waterbodies	*	*
Agriculture Census	2002	National Atlas
Agriculture Census	2007	National Atlas
Forest Cover Types	2002	National Atlas
Land Cover (1km)	2002	National Atlas
Land Cover (200m)	2005	National Atlas
Vegetation Growth	1995	National Atlas
Vegetation Growth	2005	National Atlas
City Boundries of Tarrant Co.	*	NCTCOG
Tarrant County Boundry	*	NCTCOG
Global Land Survey	1990	GLCF
Global Land Survey	2005	GLCF

3.6 Study Instruments

Geographic Information Systems (GIS) and the associated spatial analysis extensions were used to assemble and organize data for analysis through the course of the research. ArcGIS 9.3, which is produced by ESRI is an industry standard, therefore was used in this research for ease in the transition and distribution of data. During the course of literature review in identifying existing methodologies and certain spatially referenced data such as, satellite and orthoimagery, was collected in knowing it would be tested as a possible means of tree impact assessment. For the systematic approach taken using GIS for the developed methodology is outlined in the subsequent section.

3.7 Analysis Procedure

The procedure to extract tree canopy data follows systematic procedure in GIS environment with geo-spatial data and remote-sensing data. For this study it was completed twice in order to gather information from two time periods. This is needed to understand the impact of development by analyzing pre and post development. The overall process was completed in two phases. The first phase was collecting and organizing general data, and second phase was the implementation of the developed analysis method.

- PHASE 1
    - Accumulating geo-spatial data for the study area
        - Streets
        - Highways
        - Fort Worth City Boundaries (current)
        - Fort Worth Annexation Boundaries (historical and current)
        - Fort Worth Subdivision Parcels
        - Tarrant County Boundary
        - Tarrant County Land Use (1990, 1995, 2000, 2005)
        - Tarrant County Watersheds
        - Tarrant County Streams and Rivers

This data was imported into ArcGIS 9.3. (analysis software) and organized according to layers. By reviewing the properties of the imported data it was identified that between the years of 1991 and 2005, Fort Worth annexed the largest amount of land outside of Loop 820.

Comparing this information to population data it also confirmed that in between these years was the largest influx in population in the city limits. Knowing this information set up the parameters for the study in order to answer the research questions. The data was then manipulated in ArcGIS to establish boundaries also known as "clip layers" in which the tree coverage data would be extracted within the set boundaries.

- Subdivisions – clip layers were developed with the subdivision parcel layer
- Suburbs – clip layer was developed by land contained within the City's 1991-2005 annexation boundary and Loop 820
- Urban – clip layer was established by land contained within Loop 820
- Land Uses – clip layers were established from the Land Use map by isolating all other land uses from the residential (subdivision) land use

Upon the completion of establishing the clip layers, the tree canopy needed to be extracted in order to collect and analyze the data. The second phase was repeated twice, once for each year of the GLS acquired. Using the clip layers isolated in the years from 1991 – 2005, the acquisition of the 1990 and 2005 Global Land Survey (GLS) was implemented. This info would produce a pre and post development condition.

- PHASE 2
    - Conversion of GLS to isolate tree canopy
        1. Import 1990 GLS into ArcGIS software
        2. Change the image from stretched to classified in the layers properties
            - This takes the image and converts it into colored groupings
            - Each pixel is in the image is assigned a numerical value based off of the natural color reflected when the image was taken
            - The numerical values are then organized into ranges
            - Each color-coded grouping is identified by a given range value, i.e. each individual pixel reflecting medium to dark green in the

original image will be combined, based on which value grouping in falls into, to display as one group with the color orange

3. Compare the classified GLS with a natural color orthoimage
    - Continue to adjust the breakpoints in the grouping value scale until the pixels that are displaying tree canopy are isolated and matching the tree canopy on the 1m resolution orthoimage
4. Assign the grouping that contains the tree canopy a color and all other groups to white or “no color”
    - With this process only the tree canopies are displayed
5. Convert the raster data in to vector polygons
    - This process will give the ability to obtain a numerical value of tree canopy area
6. Clip and extract the tree canopy layer using the previous established clip layers based on subdivision, suburban, urban, and land use
7. Generalize tree canopy data that was extracted for comparison basis
8. Repeat steps 1 through 7 with 2005 Global Land Survey (GLS)

3.7.1 Methodological Limitations

An indicator of how development has progressed in an area can be evaluated by the assessment of changes in the tree canopy. In relation to this study, the tree canopy was only analyzed inside the city limits of Fort Worth. There are other possible influences impacting development from the surrounding area and communities that were not considered when conducting this research.

Accuracy is the primary limitation to the analysis method. The factor that influences the accuracy of this study primarily relates to the resolution of the GLS (see figure3.5). Due to the

GLS consisting of a 30m resolution image, there is room for the inability to gather exact tree canopy. This inability refers back to the combinations of tree canopy and non-tree canopy surfaces intermixing in organic forms. Because the conversion method only examines the pixel as a whole, it will either consider that pixel part of the tree canopy or not. This can cause the under and over exaggeration of a tree canopy per pixel. In comparison, by using this method, the 30m image is calibrated to match as closely as possible to the 1m orthoimage. Once the conversion process is completed on the 30m GLS it is substantially more accurate than if left untouched, but not as accurate as the 1m orthoimage. The study in which this methodology was derived from assessed an overall accuracy ranging from 75% to over 95% (Huang, 2001). It can be assumed that the method applied to this study provides, at a minimum, similar results due to the improved variation of the analysis process. Due to using 2009 1m resolution orthoimages to identify tree canopy and calibrate the GLS, ground-truthing was not applied in this study.

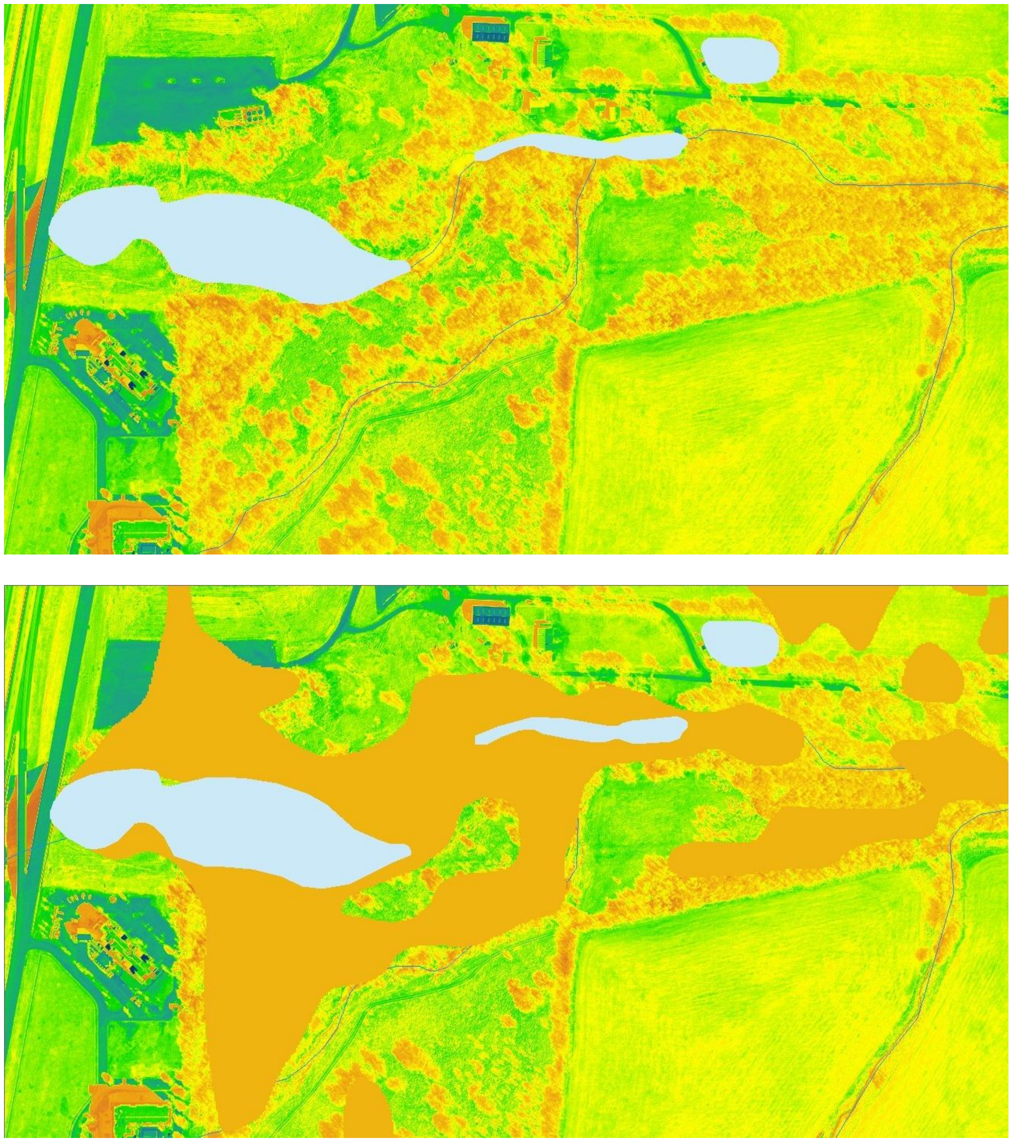

Figure 3.5: (top) “Classified” 2009 1m Orthoimage to isolate tree canopy; (bottom) “Classified” 2005 30m Global Land Survey overlaid the top image for comparison (ortho-NCTCOG, 2010; GLS USGS, 2010).

CHAPTER IV

ANALYSIS AND FINDINGS

4.1 Introduction

This chapter is the comprehensive review of the analysis and findings of the changes assessed in tree coverage in the city of Fort Worth. This research goes over four spatial analysis studies in order to assess changes in various environment settings. This chapter includes the tree cover change analysis, and a description of how the studies are organized and conducted in a manner to evaluate and assess the primary research questions: The analyses are organized to: (1) analyze what the impact subdivision developments have on tree coverage, (2) compare impact of tree cover between residential and non-residential land uses, (3) evaluate tree cover in an urban and suburban setting, and (4) assess the overall tree coverage change in the city of Fort Worth between 1990-2005.

Each scenario tested is identified in the sections below with a brief background, a description of how the study was organized and what parameters were set in place. Concluding each section consist of the findings that were found. Concluding the chapter is a study summary which discusses the overall findings.

4.2 Research Questions and Findings

4.2.1 City of Fort Worth

The city of Fort Worth has an extra territorial jurisdiction (ETJ) which expands into five counties, and it has been estimated that if the city continues growing at the current rate, it would reach a population of 1 million by 2030 (refer to Tables and Figures below). The city of Fort Worth was chosen for this study due to extreme variation from urban to rural while not exceeding the city limits. As stated in the second chapter NCTCOG has estimated that the population will expand primarily to the west of the city, which is a shift from previous development that was to the far north and south ends of the city. With the city continuing to grow in area and population, there is an evolving shift in land uses on the outlying areas. This has made a perfect testing ground to conduct research on how development has impacted the natural resources surrounding the city.

Table 4.1: Illustrating Population Growth of the City of Fort Worth (data NCTCOG 2010)

Fort Worth CBD

	2000	2005	2010	2015	2020	2025	2030
Population	2,601	5,035	6,840	8,604	9,877	10,088	10,088
Households	1,527	2,904	3,870	4,707	5,411	5,543	5,543
Employment	59,687	63,004	65,098	67,537	74,840	80,999	86,063

Fort Worth Outer CBD

	2000	2005	2010	2015	2020	2025	2030
Population	8,432	11,717	13,101	15,629	18,686	23,479	26,616
Households	3,100	4,515	5,122	6,369	7,826	9,954	11,415
Employment	59,468	65,096	66,022	68,710	74,137	78,827	79,998

City of Fort Worth

	2000	2005	2010	2015	2020	2025	2030
Population	524,535*	580,152	624,956	675,864	727,416	784,263	826,665
Households	197,779*	219,249	235,384	255,608	276,297	297,362	313,971
Employment	449,793	504,441	542,452	581,616	632,942	676,429	701,524

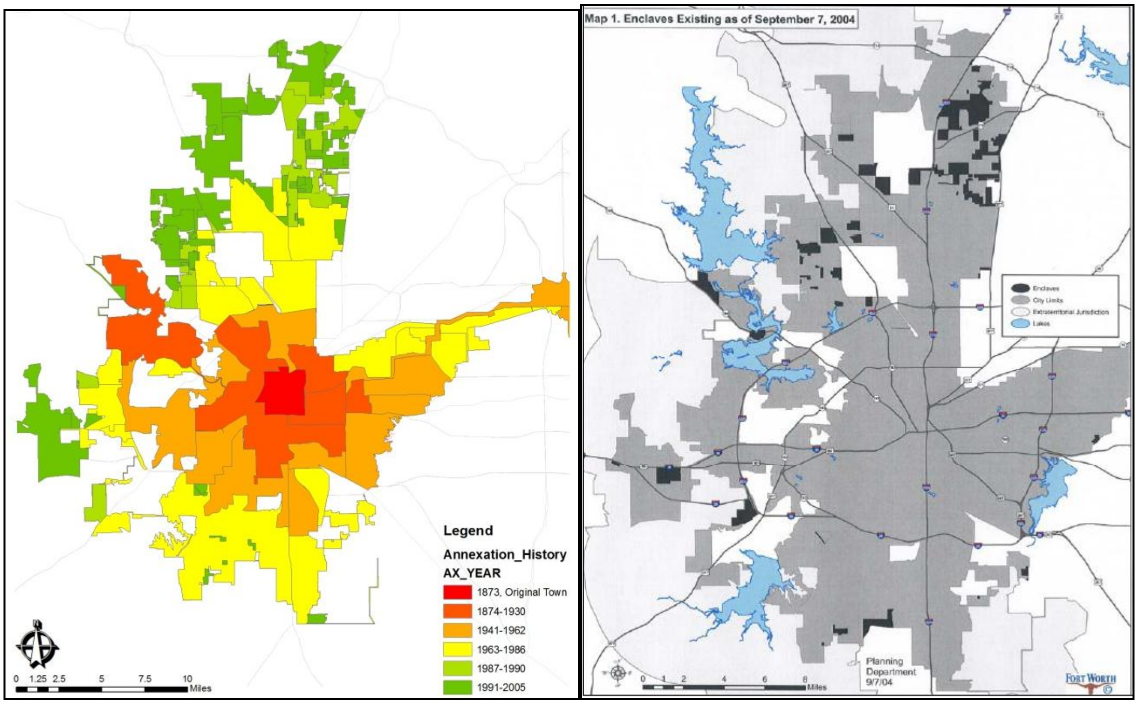

Figure 4.1: (Left) Fort Worth Annexation History, (Right) Enclaves bypasses from annexation process (City of Fort Worth, 2010)

4.2.2 Geo-spatial Analysis 1: Pre and Post Subdivision Development

4.2.2.1 Study 1: Introduction

This study was conducted to answer the primary question of, what impact has subdivision development had on tree coverage. As it was indicated in the earlier chapters, the primary datasets needed for this study included a subdivision parcel layer and the tree canopy layer. Due to the limitation of data availability this question is studied by using data from 1990 and 2005. The subdivision parcel layer was isolated to the annexed years of 1991 and 2005. This parameter allowed the gathering of tree canopy area located within subdivision developments in the given time frame. Upon isolating the subdivision layer, the 1990 and 2005 Global Land Survey were clipped to produce the pre and post development data.

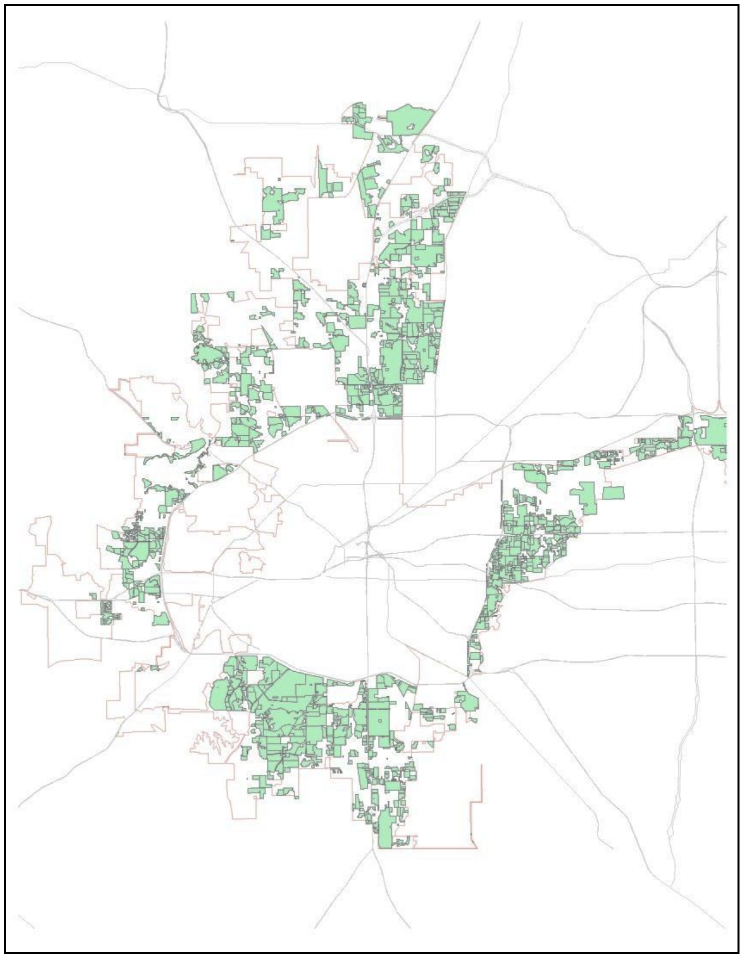

Figure 4.2: Subdivisions parcels located in the land annex by the city from 1992-2005. Was used as clip layer for study (subdivision data City of Fort Worth, 2010)

4.2.2.2 Study 1: Findings

The analysis conducted in this study is evaluating the impact of subdivision development on tree canopy in the suburban area outside of Loop 820. The area outside of Loop 820 has the most substantial increase in growth since 1990, and prior to this date it was primarily rural land. This provided an optimal scenario for assessing how subdivisions have impacted the tree coverage, and to do so, the study first isolated all subdivisions that fell into the area that was annexed by the city from 1991-2005. Once the subdivisions are isolated they are used as a boundary to clip the 1990 and 2005 Tree Canopy. All of the findings below are derived from this one time clip of tree canopy from each year. The findings of the first study revealed there is an overall decrease in canopy coverage percentage by a margin of 52.93%. In the study area, subdivision land area totaled 65,750.74 acres with tree coverage of 13.54% in 1990 and then reduced down to 7.17% in 2005.

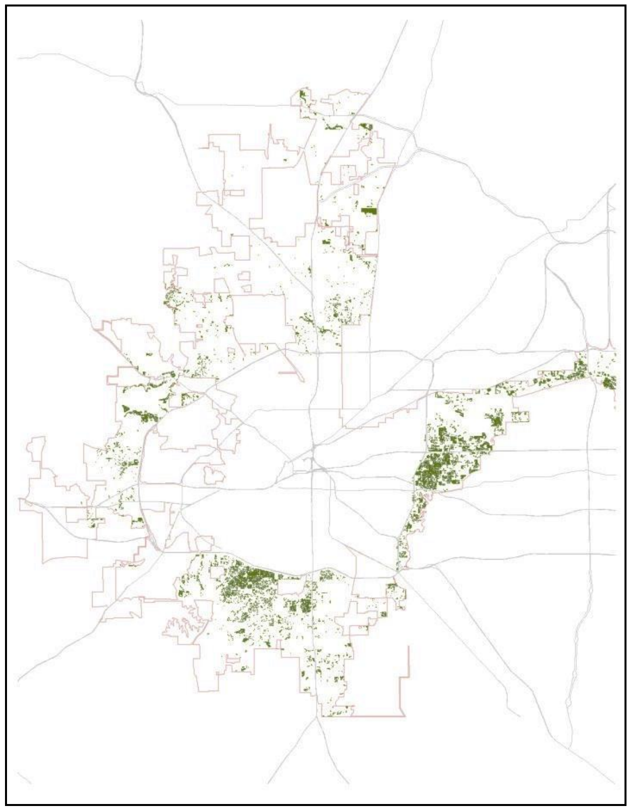

Figure 4.3: Geo-spatial analysis 1: 1990 Tree Cover Isolation

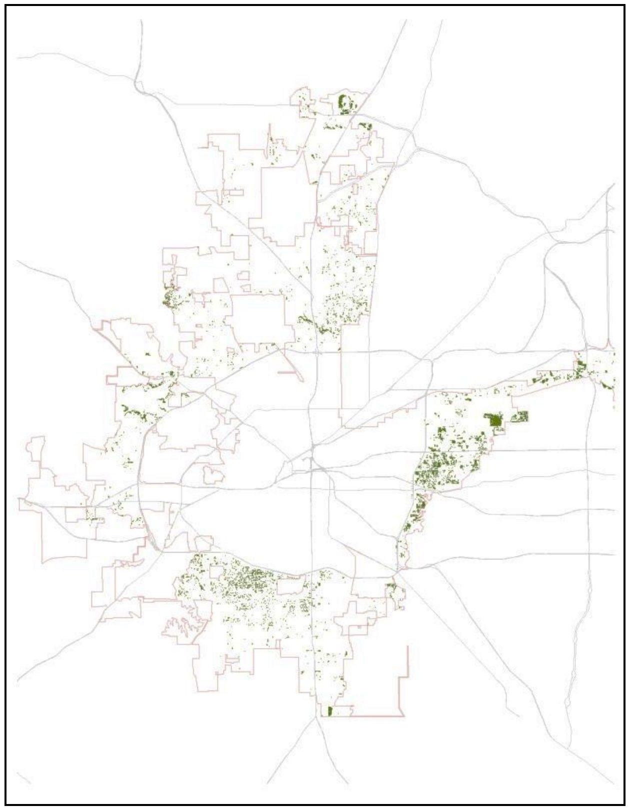

Figure 4.4: Geo-spatial analysis 1: 2005 Tree Cover Isolation

4.2.3 Geo-spatial Analysis 2: Subdivisions (Single and Multi-family Residential) versus All Other Land Uses in the Entire City

4.2.3.1 Study 2: Introduction

The purpose of this study is to compare the impact on tree cover of subdivisions against all other land uses in the city. This study primarily used 2005 land use data files to isolate subdivisions (residential: single and multi-family) from other land uses and the 2005 Global Land Survey (GLS). Upon isolation of all residential land use parcels, the GLS was clipped using the land use file. This separated tree canopy of residential land use from all other land uses.

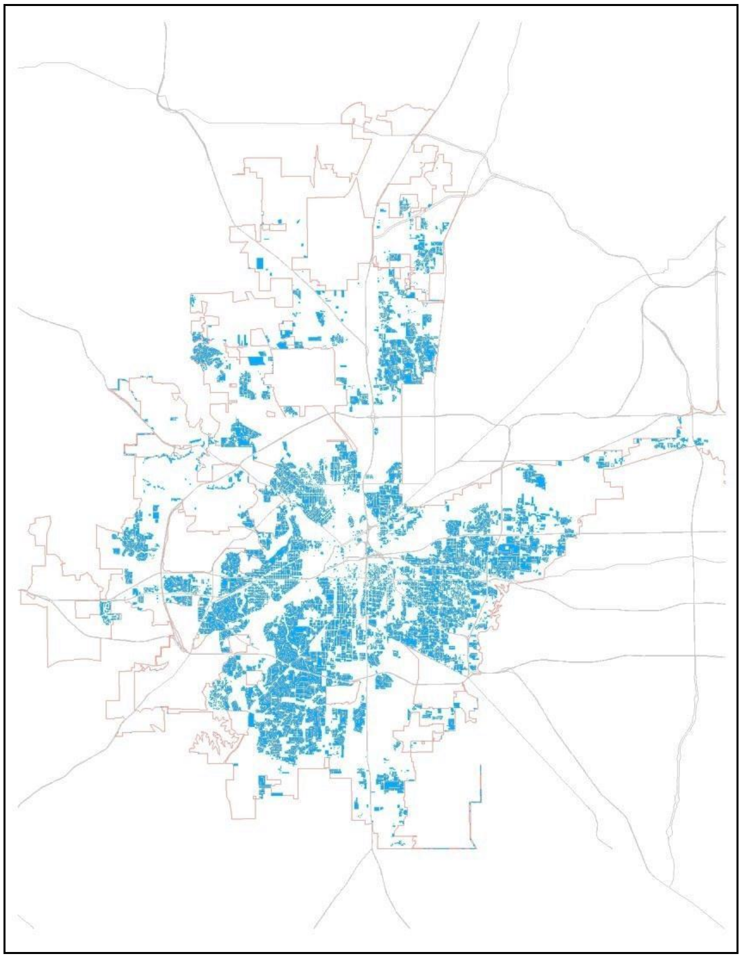

Figure 4.5: Land Use Data Displaying only Single and multi-family residential parcels (NCTCOG, 2005)

4.2.3.2 Study 2: Findings

Upon completion of data collection for this study, it was noticed that the percentage of tree coverage for the residential area, exceeded that of the non-residential area by more than 200%. The residential areas maintained canopy coverage of 20.55%, while the non-residential areas had coverage of 9.88%.

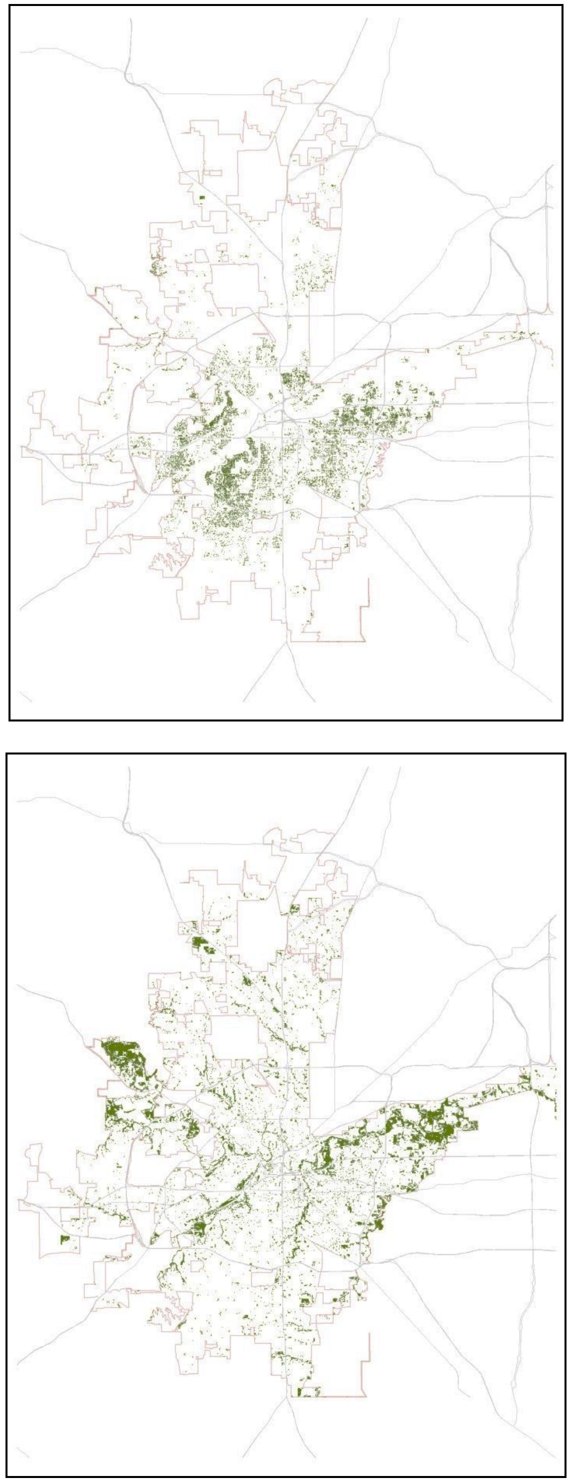

Figure 4.6: Geo-spatial Analysis 2: Comparison of 2005 Tree Cover Data; Residential (top) versus all other land uses (bottom) (NCTCOG, 2005)

4.2.4 Geo-spatial Analysis 3: Comparison analysis of tree coverage in a Suburban and Urban Environment

4.2.4.1 Study 3: Introduction

This study is conducted to analyze and compare the tree cover density of the urban and suburban environment. For this study, the entire boundary of Fort Worth's city limit is used to define the outer study perimeter, and Loop 820 is the defining barrier for which the two environments will be assessed. The use of Loop 820 as an edge nearly splits the total land area of the city of Fort Worth in half, with slight majority favoring to suburban area by 20,000 acres.

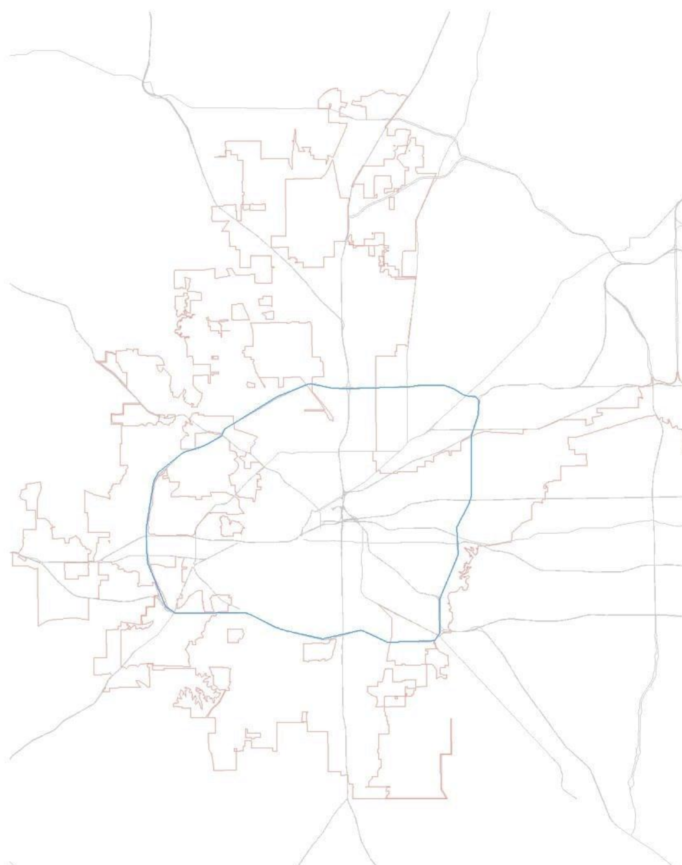

Figure 4.7: Loop 820, Used to Define Urban and Suburban Areas in Study 3

4.2.4.2 Study 3: Findings

In assessing the collected data from study 3, it was initially noted that comparatively each environment had the tree coverage area that was almost identical. Since the urban setting had a smaller total land area, once the data was calculated to address coverage percentage, the urban setting had a total higher coverage percentage than the suburban setting. The urban setting, as defined in this study, prevailed with a 13.67% canopy coverage to the 12.21% canopy coverage of the suburbs.

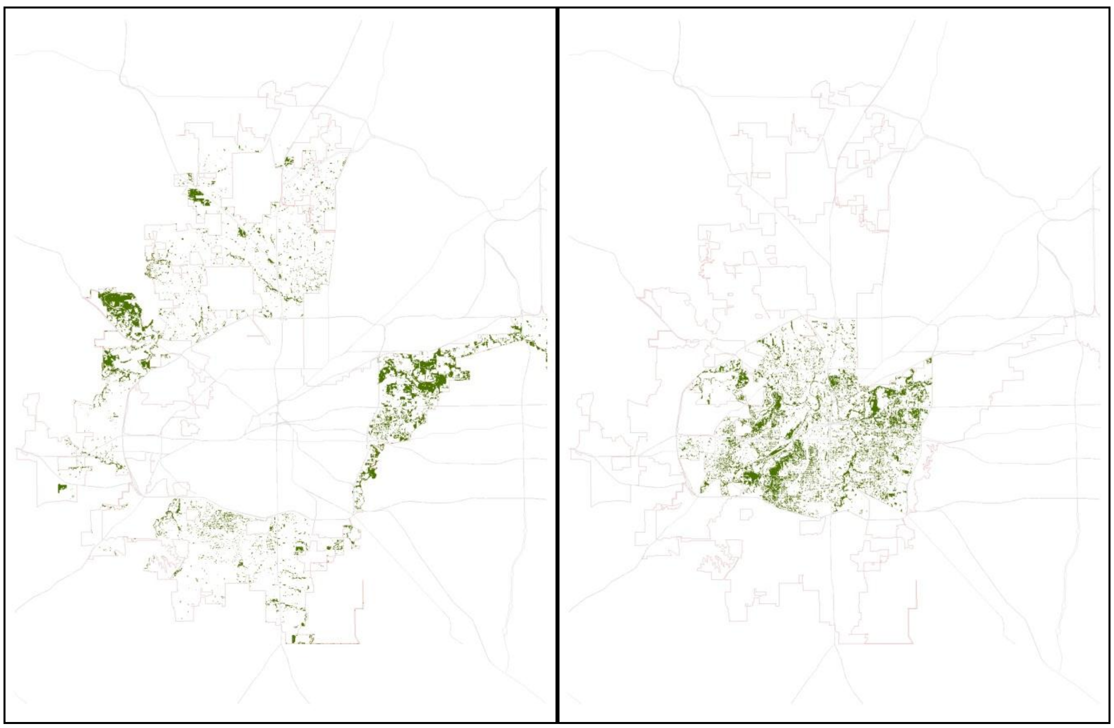

Figure 4.8: Geo-Spatial Analysis 3: Urban (right) and Suburban (left) Tree Canopy Coverage Percentages, 2005 data

4.2.5 Geo-spatial analysis 4: City Tree Coverage Change: 1990 - 2005

4.2.5.1 Study 4: Introduction

This analysis is conducted to compare the entire tree canopy of Fort Worth. Examining the entire city tree canopy as a one, will give a better understanding of the overall tree cover changes and where they are happening. This study will provide a basis in which the other studies can be compared to understand what features are having the largest impact on tree coverage. The study uses the 2010 city limit as a boundary and compares tree canopies derived from the Global Land Survey of 1990 and 2005.

4.2.5.2 Study 4: Findings

The fourth study conducted analyzed the canopy change of the entire city. In 1990 the city of Fort Worth had an established tree canopy consisting of 47,728.57 acres; this was canopy coverage of 22.14%. Over the next fifteen years, which was one the largest influx in population for the city, 2005 data records the city of Fort Worth had a reduction in tree canopy coverage down to 13.24%. This was a total loss of 19,198.15 acres of tree canopy. In 2005, the density per acre is determined to be at 43.35 trees per acre. This is a cumulative loss of 42% in density over a 15 year span.

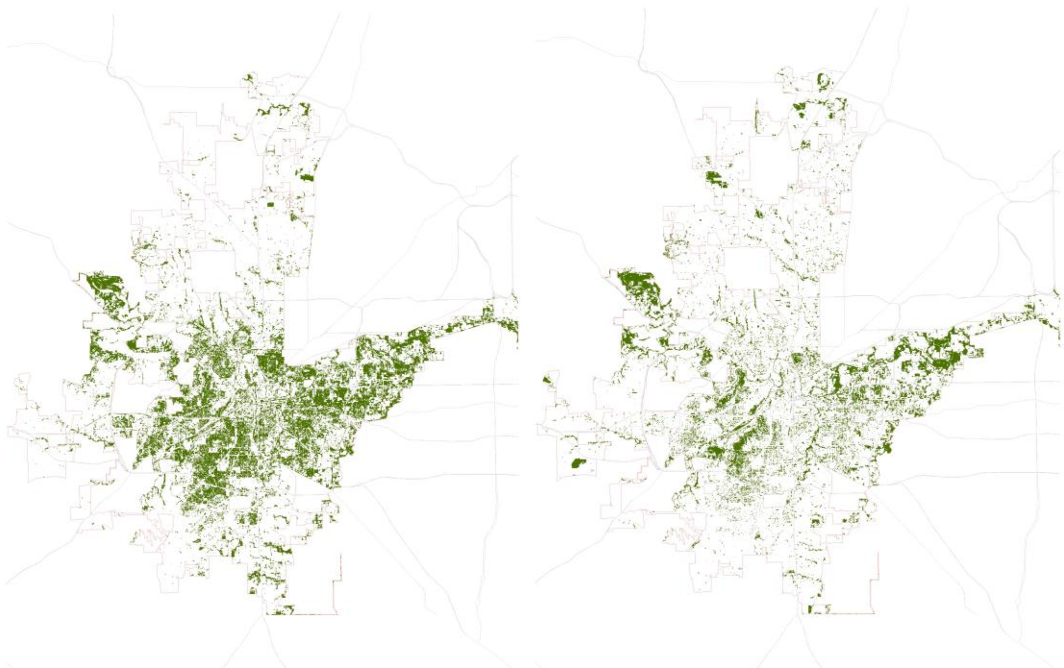

Figure 4.9: Geo-Spatial Analysis 4: Assessment of 1990 Tree Cover Data (left) and 2005 Tree Cover Data (right)

4.3 Review of All Findings

The geo-spatial analyses conducted in the research scenarios from city wide to specific development typologies for the city of Forth Worth from 1990 to 2005. An objective of this research is to examine and test a methodology for evaluating non-specific tree canopy coverage. The geo-spatial analysis that was conducted applied this new methodology which was developed prior to the start of data collection. Due to given methodological limitations of studying of one city had certain strength and limitations to the study overall. One of the strengths is the consistency in development policies and regulations. One of the limitations of studying one city is that outside influences are not assessed for possible impacts. The efficiency of gathering data with this method is ideal for city wide analysis, but the accuracy and precision may be lost as the study area becomes smaller, or in places where trees are establishing due to not being fully detectable via aerial and satellite imagery.

The overall analysis concludes that subdivision development had a negative impact on tree canopy coverage in the city of Fort Worth between 1990 and 2005. Unexpected findings were from study three, in which the urban area consisted of higher density and total coverage than the outer lying rural areas. Study two concluded that residential areas throughout the city have twice the tree density and canopy coverage. It was also found from study four, that over the course of 15 years dating from 1990 to 2005 the city of Fort Worth lost 42% of that of its tree density and nearly 50% of its total canopy coverage (See Table 4.2 for summary results).

Table 4.2: Table describing the totals of all the analysis conducted.

Study	Description	Year	Land Area (sq ft)	Acreage	Tree Canopy (sq ft)	Acreage	% Coverage
1	Subdivision - Pre	1990	2,864,102,227.84	65,750.74	387,760,580.30	8,901.76	13.54%
	Subdivision - Post	2005	2,864,102,227.84	65,750.74	205,247,264.56	4,711.83	7.17%
2	Residential LU	2005	1,768,464,307.84	40,598.35	363,443,087.17	8,343.51	20.55%
	Non-Residential LU	2005	7,355,739,820.25	168,864.55	727,050,336.85	16,690.78	9.88%
3	Suburban	2005	5,002,627,795.15	114,844.53	642,982,982.09	14,760.86	12.85%
	Urban	2005	4,386,760,285.60	100,706.16	599,801,904.98	13,769.56	13.67%
4	City of Fort Worth	1990	9,389,388,080.75	215,550.69	2,079,056,339.83	47,728.57	22.14%
	City of Fort Worth	2005	9,389,388,080.75	215,550.69	1,242,784,887.07	28,530.42	13.24%

CHAPTER V

CONCLUSIONS

5.1 Introduction

The primary objective of this research is to assess the impact subdivision development has had on tree coverage in Fort Worth over the past two decades; the study consisted of using GIS geo-spatial analysis tools and the acquisition of data from secondary sources. A methodology was developed for the research to assess tree canopy coverage and utilizes a quantitative approach to gather, analyze, and report empirical knowledge concerning the tree coverage changes in the city of Fort Worth from 1990-2005. To address the primary research questions outlined in the introduction chapter, four geo-spatial analyses were conducted:

1) Analyses of the pre and post subdivision development tree coverage impact, of land acquired by the city of Fort Worth beginning in 1990 and ending in 2005.
2) Comparison analysis of tree coverage impact of all residential land uses to all non-residential land uses over the entire city of Fort Worth.
3) Assessment of tree cover density in 2005 for both the urban and the suburban environments of Fort Worth.
4) Assessment of tree coverage change of the entire city of Fort Worth from 1990 to 2005.

This chapter reports on the summary research findings, evaluates its impact and discuss implications that evolved in comparing the data from each study. In addition, the significance of the research is also addressed along with the relevance of the study to the profession of landscape architecture, and suggestions for future research.

5.2 Summary of Findings

Between the years of 1990 and 2005, the city of Fort Worth has had a substantial growth in housing and acquired land. In addition, NCTCOG reports a population increase of over 270,000 people in these years (NCTCOG, 2010). According to the Real Estate Center at Texas A&M University, there was approximately 90,000 homes sold in the city of Fort Worth from 1990 to 2005 (Real Estate Center at TAMU, 2010). Additionally, review of secondary GIS data from the city of Fort Worth concluded that in the same years, Fort Worth annexed 41,268 acres of land, with the majority located on the urban fringe north of Loop 820 (City of Fort Worth, 2010).

There has been a major influx of subdivision development in the rural areas annexed by the city of Fort Worth. It is assumed that with a reduction of over 50% tree canopy coverage that a common practice of developers has been to clear-cut tracts of land or not makes tree preservation a high priority. This is taken with the understanding that a majority of the land developed in the study area was prairie and not woodlands. With the development of new subdivisions there are requirements set in place, such as a minimum number of trees per household, which Fort Worth is one tree per 5,000 square feet (City of Fort Worth, Urban Forest, 2009, 8). In an area such as the land these developments occur, as the communities mature the replacement of trees that were cut down or the installation of new smaller caliper trees where none had existed prior will eventually develop into a mature tree canopy. In some cases this newly assigned density is likely to be greater than what was existing prior to development, with the exception of some locations near water sources.

The second research question and analysis concentrated on land-use typologies. More specifically it compared all residential areas, including single and multi-family, inside the city limits to all other land uses including parks and open spaces. The residential area consisted of 8347.27 acres of tree coverage, which is nearly half of the tree canopy of the other land uses combined. Even though the total land area of the residential area is smaller, the tree canopy coverage was double that of all other land uses at 20.55%. Due to the outcome of the first study it is assumed that the findings for study 2 are influenced by the fact that there are older established neighborhoods closer to the urban core, which has large mature trees.

Tree canopy coverage in an urban and suburban environment were studied in response to the research question set earlier and compared for the third study. Loop 820 was adopted to define these areas for the study, and is based on the city of Fort Worth Planning and Development Department's 16 sector planning areas which use Loop 820 as a boundary for the majority of them. The analysis concluded that the urban area, as defined in this study, has a larger tree coverage percentage then the suburban area. This outcome can be influenced by a large portion of the area inside the loop but outside the city core has similar characteristics as the suburban environment.

The result of the geo-spatial analysis 4 illustrated that entire city tree canopy coverage has decreased by about 9%, which is just over 19,000 acres, from 1990 to 2005. The conclusion that the majority of this decrease is largely affected by subdivision development that has taken place in the suburbs is based on the capabilities and limitations of the methodology used.

As stated in the literature review the importance of tree canopy is multi-fold, especially in the complex and vulnerable area of the suburban fringe for growing metropolitan areas. Establishing and maintaining tree canopy has been a method to offset the urban heat island effect and as Goetz states, "There are clear linkages between the land cover within a watershed and the stream water quality" (Goetz, 2003, 206). In planning for the future, monitoring is a necessity to establish and maintain a healthy urban forest. A positive outlook is that if the developments in the suburban areas reach a maturity of the neighborhoods in the urban areas, eventually the newly planted trees will develop into a substantial stand of mature trees.

5.3 Significance of the Study

As the population continues to expand throughout the world, the acquisition of land by municipalities will increase to meet the demands of this population growth. The rural areas in the urban fringe have and will continue to be prime areas for development. Tree coverage and natural resources continually need to be monitored and managed to sustain a healthy ecosystem of which humans also inhabit. Trees and their canopy coverage help provide wildlife habitat, quality water, and help minimize the urban heat island effect, and essentially “supports the diversity of organisms that make human life possible in the nation’s complex ecology…which are a significant contributor to global socio-economic systems (ASLA, 2007, 1).”

This study develops a methodology for calculating tree canopy cover and evaluates a set of questions concerning tree coverage in relation to growth in the City of Fort Worth. This information can be used for numerous applications such as planning, evaluating, predicting, and as in this study, assessing impact. The systematic approach that was used can be replicated to produce information in other communities that have secondary data sources. With the availability to produce data, as this study has shown, it can have a greater impact on developers, clients, and policy makers by not leaving room for speculation.

The City of Fort Worth’s tree coverage was assessed in this study, but the methods applied are not limited to this area alone. Once overcoming the learning curve it is an efficient method that requires minimal man hours. This would be a financially responsible method for municipalities to establish a tree canopy map for the community or region. The only limitation would be the municipal base layer used for clipping data. If it is not already available it would have to be produced. Since the Global Land Survey encompasses imagery of the entire earth, there is no limitation of areas to be studied if using the applied conversion methodology.

However, there are a set of limitations which must be highlighted here for those who are planning to replicate the study for various geographies. There are certain levels of accuracies which can be attained with aerial and satellite photos by human interpretation and computational techniques are prone to deficiencies which may predict outcomes that may not be as accurate as on site tree surveys. It must be also realized that aging of trees may vary in various parts of the urbanized areas and tree canopy coverage cannot necessarily reflect the number of trees exist for the given environment.

It is likely however, if this study is completed on a regular basis, such as every 10 years, the ability to understand shifts in tree coverage changes may likely to be more apparent. Moreover, the impact of the findings to broader ecosystems issues can be better assessed in order to improve human systems. The possibility to expand this methodology by using other wavelength bands from the GLS can give the ability to examine other aspects of development impacts, as in impervious surface and prairieland.

5.4 Relevance to the Field of Landscape Architecture

A policy statement on rural landscapes from the American Society of Landscape Architects (ASLA) states, "ASLA urges that the unique qualities of rural landscapes and communities be protected, even as competing needs of a growing population and vibrant economies are met. The rural landscape, whether forest, field, farm, or village contains vital ecological, economic and cultural qualities that are a finite and dwindling resource. Their protection, conservation, and preservation are important to the well-being of the nation. Saving these assets for the benefit of future generations can only be achieved through the application of the sound principles, policies and practices including wise land use planning, design and management (Rural Landscapes, 2007, 1.)."

This study produces and evaluates existing methods which can be used to accomplish natural resource monitoring and conservation. The ability to assess impact from previous development trends plays a major role in knowledge based design and planning. All of these are the basis of the mission of the ASLA which is “to lead, to educate, and to participate in the careful stewardship, wise planning, and artful design of our cultural and natural environments (ASLA 2010).” The methodology is applied in the study by evaluating and testing scenarios for the impact on tree canopy from development and assessing tree coverage and density in various environment settings, which include urban, suburban, and non-residential land uses.

5.5 Recommendations for Future Research

During the course of the research, information was gathered in literature review and from the findings of the study. This information was derived from the possible uses of applying the research methodology of the study to numerous applications which would aid in landscape architecture environmental planning and managing of natural resources, community awareness, and design. Possible scenarios and questions for future research include:

1) Study the accuracy of the methods developed in this research with pilot tree surveys and/or statistical methods in order to substantiate empirical findings of the research.
2) Examine various subdivision typologies and their impact on tree coverage.
3) Determine which land use has the highest impact on tree cover.
4) What impacts have new linkages (roads) from the planning and development of subdivisions in undeveloped areas had on land cover?
5) Most subdivisions require a minimum tree installation, usually 2 trees per lot. In most subdivisions a standard lot is approximately 0.2 acres. This would give a minimum density of 10 trees/ac. Examine the area of land pre-development to determine tree cover and density. Compare this data with post-development conditions after many years to determine if the required tree density is greater than the pre-development state.

6) Compare water quality in various watersheds with its correlation to tree coverage and density.
7) Examine the impact of development on riparian corridors from fragmentation.
8) Determine changes in flood zones due to the development of various subdivision typologies.

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BIOGRAPHICAL INFORMATION

Colt Yorek was born in Navasota, TX. He grew up raising and showing Santa Gertrudis Cattle. He has a love for the outdoors and from his summers growing up working for his Grandfather's lawn company, grew a great appreciation for Horticulture. He went to Sam Houston State University, in which he earned a B.S. in Agriculture – Horticulture and Crop Sciences. While at Sam Houston, Colt studied international agriculture techniques in China during the summer of 2006. He then proceeded to University of Texas at Arlington in which he is currently a Masters of Landscape Architecture candidate for fall 2010. Colt has interned at numerous landscape companies, including two stints for The Brickman Group, at their Dallas and The Woodlands locations. Professionally, Colt has worked as a designer, project manager, and sale associate for design/build companies in the Dallas – Fort Worth area, in which he has worked on residential, commercial, and municipal projects.