5-15-2009

Multitemporal Imagery Based Analysis of Urban Land in St. Tammany Parish in Conjunction with Socioeconomic Data

Jeffrey Joseph Varisco
University of New Orleans

Recommended Citation

Varisco, Jeffrey Joseph, "Multitemporal Imagery Based Analysis of Urban Land in St. Tammany Parish in Conjunction with Socioeconomic Data" (2009). *University of New Orleans Theses and Dissertations*. 943.
https://scholarworks.uno.edu/td/943

Multitemporal Imagery Based Analysis of Urban Land in St. Tammany Parish in Conjunction with Socioeconomic Data

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Arts
in
Geography

By

Jeffrey J. Varisco

B.A. University of New Orleans, 2005
M.A. University of New Orleans, 2009

May, 2009

Table of Contents

List of Figures

List of Tables

Abstract

The role of **urbanization** in the history of civilization is a profound and intricate part of human **geography**. By utilizing **socioeconomic** data and then integrating it with more technological innovations, such as **remote sensing**, the spread of sprawl and the **urban** corridor can better be mapped and quantified by researchers. Many different types of **socioeconomic** data were implemented in addition to the remotely sensed data. In this paper, six **Landsat** 5 TM images were used to create land cover classification maps of the developed or built-up land in St. Tammany Parish from 1984 to 2008. It was found that, in addition to St. Tammany expanding in population, the **urban** areas are becoming denser using a method called the '**remote method**.' This method is an advanced function of density that allows researchers to estimate consumption of the developed land.

Keywords: Urbanization, geography, socioeconomic, remote sensing, urban, Landsat, remote method

Chapter 1

Research Questions / Goals and Objectives

Urbanization would appear on the surface a natural course of creation by humans. Cities grow with populations; the idea seems clear yet there is more than just a growth in population that lies behind each unique city expansion. St. Tammany Parish, a suburb parish of New Orleans, Louisiana, that has its own distinct history like many other counties in the United States (with the exception that Louisiana counties are actually parishes, a leftover from Napoleonic Code). Early growth in St. Tammany Parish was slow; however, through a multitude of factors, it has become the fastest growing parish in the state and has the capability to become the most populous parish in the state if it maintains current growth patterns. This makes it an ideal choice for study using digital technology and census data. Both approaches have been masterfully approached by a variety of scientists and researchers to treat an abundance of issues and problems.

A twofold approach has been decided on; on the one hand, multi-temporal imagery from 1984-2008 will be processed to garner urban expansion. On the other, census data covering this same time period processed using various techniques to ascertain growth rates and growth trends in St. Tammany Parish. As will be discussed later, there is a large amount of academic debate as to the proper classification within satellite imagery; often, things on the ground do not specifically match the classification system designed by the researcher (Andersen *et. al.* 1976, Evans and Moran 2002). There is a considerable amount of error involved in the making of satellite imagery maps, but through more advanced imagery correction techniques, more accurate representations can be created. Density will be calculated for St. Tammany Parish over the study time period, and, it is hoped, a land expansion density formula will be calculated from the remotely sensed data by gauging the amount of expansion (urban) in the same years population has been recorded.

This research will ultimately find a way to prove the reality of majorly accepted datasets (census data) by using advanced techniques in remote sensing. Census data from the time periods observed via satellite data will help form a system of 'checks and balances.' This use of remote sensing emphasizes the statistics found through the use of readily available (and widely accepted as accurate) census data. This process is known as 'ground truthing.' There is no doubt that rapid urbanization has taken place in St. Tammany parish; however, census data, while useful, only comes out decennially. This may pose problems to land-use managers who wish to find better means of making short-term decisions regarding plans and resources. Thus, if remote sensing can show, relatively speaking, the same rates of expansion from above as is notated in census data, remote sensing could prove invaluable (and thus, given the repeat rate of new temporal data acquisition, almost function as an active census) to planners and resource managers.

To this end, it is hoped in this paper that the technology of remotely sensed satellite imagery, while not providing the in depth details offered by census data (the who and the why), can very well give local and state officials better estimates of expansion in their parish or county (the what, when and where).

Introduction to Urban Growth

The history of cities and people's tendencies to inhabit them embody a long and rich tradition in the history of the human race. As our cities have expanded, so too have the ways in which we define our propensity for urban dwelling. Cities, especially older ones, bear the marks of our history as humans. They ebb and flow much like a river does, ever changing but not on a daily basis. Rather, cities take on the aspects of the cultures and the technology that infuses them. As the old adage goes, "Rome wasn't built in a day" we can fully appreciate that sentiment in a different light if we come to understand that most cities are not what they were even 50 years ago. The expansion of the modern city is a testament to the modern society in which we live that makes us capable of living 50 miles from the city core and still be able to operate, at least during the day, in the city still. This would have been near impossible just 100 years earlier in any major city. Written in 1929, Derwent Whittlesey's essay on sequent occupance proves eerily clairvoyant in our modern times:

> Interruptions of the cultural order engendered by man occur even more commonly: shifts in political boundaries, revolutions, or often *mere enactment of laws* (added); movements of population which carry with them mores and attitudes novel to their new habitat, or create social friction; the introduction of new technology; changes in means of communication which alter physical and mental contact with outside regions; all these are capable of breaking or knotting the thread of sequent occupance (163)."

The processes and the inventions that drove this admittedly awe inspiring though ire inducing phenomena are nearly uniform across the modern American landscape. Terms such as suburbia, exurbia, new modernism, post modernism and the like have only come into the general lexicon within the last 50 years; yet their power and connotations are rampant on the tongues of nearly every academic. To this very point, scholar Anslem Strauss remarked nearly fifty years ago:

> Making sense of what was happening (America's urbanization) merged easily with complaints over the way things were going and with predictions and suggestions for the way things ought to go. The United States has had a very rich history of such ideological accompaniments to the objective facts of its urbanization (1960, 15).

Thus, there is an increasing need to prevent or mitigate known exposures, extrapolate environmental remediation knowledge, and share lessons of effective risk communication from industrialized countries with less developed areas of the world who are now experiencing their own immense rates of growth and will come to suffer many of the same problems that developed countries have been afflicted with for many decades now. At the same time, while we may be already committed to paths previous generations have laid out for our urban centers, the growth of technology has allotted us important new tools in restructuring our approach and understanding of our most human quality: growth. It is the purpose of this chapter to outline many of the issues associated with urban expansion, and to give a general overview of the mechanisms that shape the growth of cities. In addition, a brief overview of the evolution of the modern city will be undertaken. This does not begin an in-depth conversation of this tenet of our past; it does, however, allow for a transition into a more engaging conversation of urbanization in the twenty first century.

Ancient cities such as Rome and Edo (modern Tokyo) were estimated to have inhabitants in excess of one million denizens (Rozman 1974, Carcopino et al., 1991) at their peaks in the pre-industrial world. These large populations stressed the area that they encompassed and presented problems that smaller settlements would never encounter. For one, disposing of sewage and garbage was often critical while issues such as fire, especially in Japan where houses were almost always constructed of *tatami* and paper (Rozman 1974), were daily worries of the denizens of large pre-industrialist societies. There can be no doubt that much of city growth before the advent of industrialism was driven largely by the ability of the population to garner the services available in light of few transportation options. At the same time, poor building construction, potable water, and plague were a few more obvious concerns of the pre-industrial city; these were very real apprehensions that were inevitably tied to the growth patterns of such cities. As Stephen Grable (1979), during a brief tirade against blatant errors made in urban planning, says, "(planners) continue to work in an ahistorical manner, believing that the problems of the physical city can be solved without first investigating the developmental patterns responsible for them (49)." This particular research is concerned in two ways with the growth of cities: (1) the tangible expansion of the developed land and (2) the reasons why people move to suburban areas. Therefore, the approach of the research has taken on two separate but compatible concepts. It behooves this paper to first have a short discussion on the role of planning in cities and some definitions of modern urban design.

City Planning

Planning was nearly non-existent in early cities; this created disjunctive patterns that were often localized to prevailing conditions and geography (Efrat and Noble 1988). Modern cities such as Paris and London display wonderfully, like that of a cross section, how time has shaped their designs. On the inner ring, or what could be considered the old city, roadways are curvaceous and narrow, while on the outer rings more modern techniques of road building and planning were employed (wider and straight). Part of this shift in city planning reflects the creation of transportation networks within cities based on railways, and later on, the automobile. That people settle and live along major modes of transportation is no secret; one only has to look along American interstates to find powerful examples of population shifts along arterial corridors. In a study conducted on consuming and producing cities (those that are service oriented and those that are goods producing), Lo, Pannell and Welch (1977) noted that, "Politics and images aside, one common factor emerges that affects the physical structure of each city: heritage of city design. Urban development and growth must follow the existing street arrangement (283)."

There are various "modern" theories that suggest how cities form, of which probably the most famous is the concentric zone model created by Ernest Burgess in conjunction with Robert Park in 1925. His model consisted of the central business district (CBD) at the center of the circle (the city) with expanding rings outwards from the center that were inhabited by gradually more affluent denizens. The basic premise of his theory suggests that the more moneyed residents could afford to travel farther to work than the poorer, more centrally located inhabitants. Another important model is the Hoyt model (1939), or the sector model as it is commonly referred to in literature. This model suggests that cities grow along major corridors (such as rails and roadways) and that their growth emanated from the CBD along these arteries. Sector theory, as it is known, is based on early twentieth century transport and does not make allowances for private cars that enable commuting from cheaper land outside city boundaries (Rodwin 1950). These two theories underscore the growth of cities in the early 20th century, but do not exactly give a good idea of our cities today. The growth of the automotive industry, and its subsequent takeover of the American landscape, has transformed the modern city into an agglomeration of suburbs and a decayed central city (although, as will be noted, this trend has reversed in recent years in many major American cities). Another famous model, created by Harris and Ullman (1945), noted especially the marked change that automobiles were having on the modern-day city. While a city may have begun with the growth of a central business district, other additions to the city, such as an outlying airport that gave rise to hotels and restaurants, mark the growth of a city; also of note in Harris and Ullman's theory is the notion that experienced this change most directly from increased car ownership.

The models discussed above all have been shaped by urban growth in one way or another. It is not to be believed that any one of these models can accurately portray any of our modern cities precisely because, as mentioned before, the influences on our cities keep evolving. These influences vary from food availability to job creation and loss. Each city has a unique growth pattern associated with it, and within this unique growth is a large number of variables that shape the response of the human geography within that location. However, certain elements from each of these models do in fact show up repeatedly in studies of modern urban centers. The fact that these models are still a commonly cited source of urban expansion and explanation should speak to the inherent behavior of cities that they attempt to represent.

Metropolitan Areas and the Suburbs

We live in an increasingly urbanized world. At present, around 75% of the population in developed countries lives in dense urban or areas (Habitat, 2001). In the United States, an area is considered urban if it is a settlement of over 2,500 denizens, is considered part of a major metropolitan area, or if it is part of an extended network of settlements that comprises an urban area (US Census Bureau 1995). The Census Bureau first began this methodology in the 1950 census, and has since made adjustments concerning urban areas and their delineation; the reality is any area in the United States is one of two things: *rural* or *urban*. In 2002, urban land in the United States was less than 3 percent of total land area, but housed 79 percent of the U.S. population. Urban land area has quadrupled from roughly 15 million acres in 1945 to an estimated 60 million acres in 2002. The Census Bureau reports that the U.S. population nearly doubled over this same period. Thus, urban land area has increased at about twice the rate of population growth (USDA 2002, Mitchell 2001). Serious questions about sustainable growth have come about in the last couple of decades concerning the exponential growth of urban areas, particularly the suburbs.

In the United Kingdom, depending on the locale, there are three major ways of delineating urban space: It may be defined either in terms of the *built-up area* (the bricks and mortar approach); or, alternatively, it may be defined in terms of the area for which it provides services and facilities - the *functional area.* The *functional area* may embrace not only the *built-up* area but also free-standing settlements outside the urban area together with tracts of surrounding countryside if the population in these surrounding areas depends on the urban center for services and employment. A third method is to use *density* (either of population or of buildings) as an indicator of urbanization. However, implementation of any of these approaches involves some arbitrary decisions in drawing up boundaries because, in practice, towns tend to merge physically and functionally with neighboring towns and their hinterlands (UK Census 2001). Since much of our literature comes from either the United States or United Kingdom, it seems best to restrict this research to either of these two methods of defining the modern urban area. There are various other urban centers in other countries that are defined in other contexts (densely inhabited districts (DID) in Japan, for example) and differing amounts of population per square kilometer, but at the very core of it, societies are grappling with the idea of urbanization.

By most accounts, nothing moved the suburbs so efficiently toward sprawl as a certain stroke of President Dwight Eisenhower's pen, signing into law the Federal-Aid Highway Act of 1956, which launched a 41,000-mile interstate highway system. (Mitchell 2001). “Sprawl” can be understood as a pejorative term describing a certain type of land development most commonly associated with residential and light commercial zoning outside of densely populated urban cores. Sprawl is said to be unplanned and illogical development. It is criticized for being ugly, dehumanizing, and socially isolating (Yang and Jargowsky 2006). Ewing (1997) defined sprawl as “the spread-out, skipped-over development that characterizes the non-central city metropolitan areas and non-metropolitan areas of the United States (219).” These two definitions strive to highlight what is commonly seen as the suburbanization of America over the last 50 years which has been exacerbated by the easy attainment of automobiles and an increased quality of life by much of the population.

That people have been fleeing inner cities until recently is no small secret; a host of reasons exist for this exodus: crime, poor education opportunities, overcrowding, decreasing property values and pollution are a few of the more conspicuous offenses of the post-World War II city. Between 1880 and 1963 the metropolitan population living within 3 miles of city centers dropped from 88% to 24% (Ferguson 1997). A study in Canada found that:

> In view of these differences, it is not surprising to find that the greater the distance from the centre, the higher the proportion of people who
>
> used a car for at least one of their trips. Specifically, 61% of people living in a central neighborhood got behind the wheel, compared with 73% of people living between 10 and 14 kilometers from the city centre and 81% of people living 25 kilometers or more from the centre (Turcotte 2008).

A population shift from the city center is commonly known as the metropolitan density gradient. Density gradient in regional economics is a useful way of assessing whether or not a particular area has become more or less crowded over time. People have moved out of city centers (thus lowering the gradient) and have begun to populate suburbs in large numbers. Generally, suburbs contain a much lower density than cities because of the space each housing unit occupies (yard, driveway, garage, etc). The median lot size for U.S. single-family houses sold in the 1990s exceeded 9,000 square feet (Ferguson 1997). At the same time, this nearly unregulated spread of the American sub-urban city has created planning nightmares in the form of traffic (National League of Cities 2001, Baldassare 2002), water, fire and police efforts, to name a few. However, there are positive reasons for having moved to the suburbs for many residents who are escaping perceived (real or not) threats of the inner city: M. Senior (2006) suggested that older people and couples with young children were more likely to live in suburban areas with green space and garages for their cars.

It is here that we should begin our discussion of New Orleans and its growth as a city from its early days as a French (and later Spanish, and then French again) trading outpost on the Mississippi River to its modern day hub as an international port city. More important to our discussion, considering we are studying an outlying suburban parish (St. Tammany) of New Orleans, is the major population shift New Orleans experienced after World War II and the onset of two major episodes in American history: interstates (as was mentioned earlier) and segregation. Segregation, or the practice of keeping white and black students separate in many states, was officially outlawed in 1954 by *Brown vs. Board of Education*, which decided that "separate but equal" was, in fact, unconstitutional (Hoekstra 2004). Even after 1955, when the Supreme Court ruled that states must integrate schools with "all deliberate speed," few states took notice…in 1964, when Congress struck another blow against racism by passing the Civil Rights Act, less than 2 percent of Southern black schoolchildren attended mixed-race schools (*ibid* 2004, 2). Until the forcing of desegregation in the mid 1960's, many schools and neighborhoods remained completely segregated.

This trend is near universal in states that allowed segregation and is endemic of the phenomena termed “white flight.” Though sometimes shunned as a pejorative term in some circles, the sad truth is that demographic shifts in urban centers were drastically altered in the 1960’s by the ability of the largely middle class white community to ‘flee’ inner cities that were viewed increasingly as crime ridden and poverty stricken. It has been suggested (Clotfelter 1976, Renzulli and Evans 2005) that other pertinent factors added to increased suburbanization such as increases in median income, disenchantment with the inner city and increased mobility through an ever expanding highway system. The impact on downtowns was immense and doubly hard; there simply was an incredible collapse in tax revenue that worsened the plight of the inner city and accelerated the flight of the middle class out of central cities across the South and in many other states as well (22 states allowed segregation within their borders) (Hoekstra 2004).

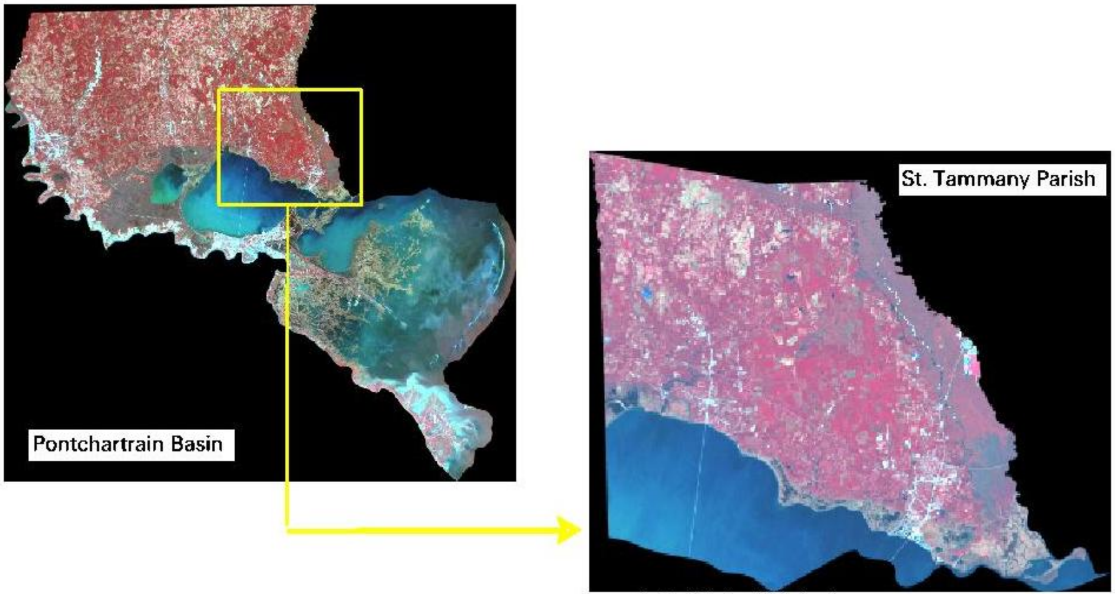
Between 1940 and 1990 the social geography of New Orleans under-went another drastic restructuring. The census figures for these two periods are deceptive; in both 1940 and 1990 approximately 496,000 people lived in the city. In 1940, 70 percent of the population was white, but by 1990 the percentage of white inhabitants had dropped to 35 percent. For the metropolitan area, 62 percent of the population was white in 1990 (Census Bureau 1995). Thus while the Orleans Metropolitan area had maintained a nearly static level of white inhabitants, the actual demographics of the city had shifted immensely. Hastened by the construction of the interstate highway system, the availability of federal home loans, perceived and real increases in inner-city crime, the institution of inner-city school desegregation and busing (practice of sending students to schools in different districts by means of city buses), and the promise of lower taxes in the suburbs, many white families moved from the city to newly built subdivisions in Jefferson, St. Bernard, and St. Tammany parishes, a migratory pattern that affected many parts of the United States shortly after World War II (Weiher 1989, Clotfelter 1976).

Study Area

The focus of this is St. Tammany Parish (see Figure 1 below), which lies to the north and north east of Orleans Parish across Lake Ponchartrain, in what was at one time an agriculturally dominated landscape. However, due to a confluence of factors affecting the metropolitan area, the population of St. Tammany parish has skyrocketed over the last 50 years (Carr *et. al*. 2006). This rapid rate of suburban expansion is not a local phenomenon; over the course of the last 50 years America has seen unparalleled growth in its suburbs. It is wholly accepted that urbanization is occurring at accelerating rates, though the recent impact of ever increasing transportation and fuel costs may yet hinder this unabashed growth. St. Tammany and neighboring parish Tangipahoa have both shown remarkable growth patterns during the last fifty years; St. Tammany's population has swelled from 26,998 in 1950 (LA Parish Profile 1989) to 230,605 in 2006 (US Census 2008), a staggering 435 percent increase in population in just over fifty five years. Whereas, Tangipahoa had a population of 53,218 in 1950 (LA Parish Profile 1989), but had more than doubled by 2006 to 113,137 (US Census 2008). Much of these population explosions was from in-state migrants; a Regional Planning Commission (RPC) document created by the state of Louisiana noted that in addition to the migrants being from Louisiana, "It has been estimated that about 98% of the 110,000 in migrants to the suburban parishes were white (Transit 81 2000, 21)." It is these exotic growth rates that make St.

Tammany (as part of the New Orleans metropolitan area) a prime area to study with remotely sensed data.

Figure 1.1 Landsat TM image of Ponchartrain Basin and the subset image of St. Tammany Parish.



Lodhi, M. A. Unpublished work

Souce: Lodhi, M. A. Unpublished work (2009)

Within the document excerpted in the above paragraph, the RPC also noted that, “While the suburban resident has in the past been able to freely move around, traffic congestion has started to restrain his movement and people are beginning to demand alternatives to the private automobile (2000, 24).” While people may have initially fled to the suburbs to ‘get away from it all (Berg *et al.* 2006),’ there were indeed new issues to deal with once relocated outside the core metropolitan area; as Hughes reminds us, “…the myth of suburbia—of isolated family-raising environments—is being increasingly challenged by the reality of its participation in an urbanizing region…the overall issues emerging are not going to fade away quietly, and since they involve so many diverse and competing interest groups, they will not be solved easily

(1975, 61-62)". And while large swaths of St. Tammany parish may have at one time been considered bucolic, core areas of the North Shore (a useful spatial term for the northern suburbs across Lake Ponchartrain that is generally used to describe St. Tammany parish and along with Tangipahoa to a lesser degree) such as the cities of Slidell, Covington and Mandeville can at times display traffic rivaling that of New Orleans or Metairie (a large, unincorporated suburb to the west of New Orleans that is the epicenter of metropolitan traffic nightmares). St. Tammany also has become increasingly more wealthy (see Figure below). The average median income in St. Tammany Parish, after calculating for dollar inflation, has increased over $20,000 in the last 40 years. This suggests that not only is St. Tammany growing (as population census suggests), but that the average family residing in St. Tammany is making more money than the state average ($40,926). Growth and income are regularly considered linked and this should therefore serve to reinforce the concept of growth in St. Tammany Parish.

Table 1.1 Median income for St. Tammany Parish, LA.

Median Income // Family	1970	1980	1990	2000
Income in St. Tammany parish (In actual dollars)	7469	21870	35033	55,346
http://www.measuringworth.com/ppowerus/result.php				
Money calculated to worth of money in the year 2000 using above website	33114	45715	46156	55,346
Change from 1970 - 2000				59.83%

Source: Census.gov; money calculations notated within chart. Change calculated by author.

Increasingly, the four major concerns of urbanization on the North Shore have come to the foreground of local and state government agencies: 1) Waste Water Treatment, 2)

Transportation, 3) Flood Protection and 4) Environmental Protection (RPC 1976). At the same time that these issues had been identified, local government turned to new methods of monitoring growth patterns of parishes around the metropolitan area, so that they might better be able to manage these four main problems, especially on the North Shore where development during the last fifty years has easily been the most pronounced. St. Tammany Parish, in the mid 1970s, turned to technology to help adapt to the growing population: the following is excerpted from a land-use report for the Parish in 1976, which states, "The primary source for land-use information was to be high-altitude aerial photography…a secondary source for land-use information was to be Landsat image" (1976, 8-9). This provides the groundwork for the next conversation concerning monitoring urbanization in other ways besides the more traditional methods of census and ground observation.

Remote Sensing and Urbanization

Mapping of the urban fringe (commonly defined as the transition zone between cities or their related urban areas and the surrounding uninhabited countryside) still remains an imperfect science and continues to impose certain difficulties for geographers and planners alike (Fesemmaier *et al.* 1979). The loss of agricultural land is assumed to be caused by the conversion of land to urban uses, and in the case of 'sprawl,' to low-density residential and commercial use. Rapid population growth and associated urban development have emerged as an important concern both at local and national levels alike (Theobald 2001); that the same problems that affect central cities have spread to suburban areas as well are even more problematic because of their political independence which does make long-term metropolitan planning and coordination very difficult (Scott 1975, Cozens and Hillier 2008).

These concerns are not entirely unfounded, given that many resources are needed to continually expand outwards from city cores; there is, of course, a multitude of literature concerning the negative aspects of unmitigated expansion (Hughes 1975, Scott *et. al.* 1975, Shihadeh and Ousey 1996). And while growth is primarily associated in business as good, it can be certainly argued from many other perspectives (environmental not being the least) that there are, in fact, repercussions for unchecked growth. Current issues with climate change, natural resource conservation and consumption dominate daily news headlines; certainly further expansion into the hinterland will come at a great price for future generations if current trends in transportation are not augmented or reconfigured.

This has raised questions as to how we are to classify urban areas, and again, how and what technologies we will use to identify urban areas. Urban areas are defined as an area with one or more census places and the adjacent settled areas—the urban fringe—that have at least 50,000 people. The Census Bureau defines the urban fringe as those areas that have densities of at least 1,000 people per square mile and that are within 1.5 road miles, or 5 road miles if separated by some undevelopable land or water body (U.S. Census Bureau 2000). An interesting aspect of studying the urbanization of St. Tammany parish over the last fifty or sixty years will provide a unique perspective of a landscape that was at one time mostly agrarian. Census data as well as remotely sensed data both confirm the expansion seen on the ground. Census data has long been considered the most useful method for researchers to track growth in development in an area of interest. However, decennial censuses are just that; they only occur once every ten years and, especially towards the end of a census cycle, researchers are often using out of date information concerning the areas they are studying. Thus, using remotely sensed data that is available at smaller time intervals allows researchers to study time periods with higher degrees of accuracy.

One of the newer methods of tracking the proliferation of urban features is from above; that is to say either by aerial photography or satellite imagery. This ‘bird’s eye view’ has offered geographers and planners alike a new and arguably more comprehensive method of understanding the spread of urban environs in a quicker manner. Integration of separate methodologies is often one of the progenitors of creation for research. It is hoped that the combining of remotely sensed data with socioeconomic data will offer researchers new and meaningful methods of quantifying the spread of urban land in a variety of situations.

Chapter 2

Land-use Analysis

Land-use and land-change are of enormous importance in modern day society. At the forefront of this striking regime of knowledge lies remote sensing and aerial photography. Change detection techniques are of utmost importance in many aspects of modern day remote sensing. Proper understanding of relationships and interactions at the earth's surface serve as a major benefit for all types of professionals in many different fields. The rapidly expanding field of remote-sensing, and of course the ever increasing technology of the instruments used to gather remotely sensed data, is most significant when data can be collected and examined and interpreted quickly and accurately. In this way, remotely sensed data allows professionals to both quickly realize trends in environmental and urban change as well as to gauge impact and damage from above. However, research of change detection techniques is still a dynamic topic that has to continue to evolve with the increasingly complex remotely sensed data that is available.

It is precisely these benefits of remote sensing and aerial photography that make it useful to study urban landscapes. This chapter intends to reflect the vast amount of literature that has been accumulated in journals by aerial photography and remote sensing when applied to urban settings; it is, in addition, the intent of this paper to track the methods and techniques used to accurately and adeptly interpret the data available on the most human of creations, cities. By studying the many avenues available to researchers in the field of land use and land cover, proper measures can be undertaken to create more useful and more accurate maps and conclusions.

Frequently, scientists and researchers are not just concerned about the human urban landscape, but also the fringe area between the city and the environment (if a delimited line could be drawn between the two) that is most commonly the area subject to land-use and land-change. Often times, researchers must view a period of 10, 15, or 20 years to show how change has affected an area (Maktav and Erbek 2005, Small 2005, Young and Wang 2001, *et al.*), whereas there are times when natural and human made disasters may alter the land dramatically in a short period of time. Events such as crop forecasting (MacDonald and Hall 1980) or the early warning of algal blooms in a watershed (Richardson 1996) provide a glimpse into the types of early warning that remote sensing is has been proven effective at tracking.

Urban environments are generally characterized by highly heterogeneous surface covers with substantial inter-pixel and intra-pixel changes. Data used for urban applications must meet certain conditions in regards to their temporal, spatial, spectral, and radiometric characteristics (Lo, 1986). Finer geometric resolution images are usually preferred for urban land use/cover change mapping. Useful sources of satellite data for these types of applications are imagery from Landsat Multi-Spectral Scanner (MSS) and Thematic Mapper (TM) (See Figure below for band configuration), and Systeme Probatoire pour l'Observation de la Terre (SPOT) High Resolution Visible (HRV), which have some of the highest periods of operation. Usefulness of a given type of imagery for urban applications should not be based solely on its spatial characteristics (Jensen and Cowen 1999). Specifically, in addition to spatial resolution, factors such as image quality, atmospheric haze, and contrast can affect the interpretability of an image (Leachtenaurer 1996). The issue of finding consistent and accurate data and methods of extracting such conclusions will be given much more attention further on in the review.

Figure 2.2 Landsat TM 5 series band configuration

Landsat 5 TM Band Descriptions

Band	Wavelength (um)	Spectral Region
1	0.45 - 0.52	Visible Blue
2	0.52 - 0.60	Visible Green
3	0.63 - 0.69	Visible Red
4	0.76 - 1.75	Reflective Infrared
5	1.55 - 1.75	Mid-Infrared
6	10.40 - 12.50	Thermal Infrared
7	2.08 - 2.35	Mid-Infrared

Data Selection

Beyond the enormous amount of data that can be analyzed in a change analysis project, there also lies the quandary of selecting proper data. Most commonly, this requires data from a singular satellite (or, from a family of satellites with similar calibration settings). Depending on availability or funding, a number of satellites have been used in urban studies. Each situation in change analysis generally requires a unique method of solving for any number of variables the researchers may come upon throughout the study period. To further illustrate this point, it is useful to compare the methods of two teams of researchers, one of which is on a local level and the other which is on a national/global level.

Maktav and Erbek (2005) use Ikonos XS+Pan, Landsat TM and Spot P in their analysis of urban growth in Istanbul. The experiment revolved around 14 administrative units (akin to the districts found in America) in Büyükçekmece, a governmental area in Istanbul that represents the size of a county or parish in America. Maktav and Erbek collected much of their census data regarding the populations for the area using data records accumulated by the government in order to plot growth not just by visible confirmation through satellite data, but also by confirming their findings with statistical growth rates of the administrative units. Some of the TM images were rectified to 1:25000 topographic sheets by a means of local correlation whereby a final pixel RMS of ±0.5 was achieved through the accumulation of over 1600 points. Maktav and Erbek also note that all Landsat TM data were classified separately from the other data using a supervised classification technique which used all bands except for the thermal band. The images were broken down into classes which included: settlements, fields, lake and sea, forest, stone quarries, and industrial sites. In all, 50 points were used as sample classes. After classification had been decided upon, methodology of interpreting the data was needed. Maktav and Erbek use a number of techniques to extrapolate conclusions, including: image differencing, image rationing, change vector analysis, and classification comparisons (Sunar 1998, Jurgens, 2000). In the course of their study, Maktav and Erbek assert that Band 3 of Landsat TM is the best band possible for extracting cultural/urban feature identifications. In this way, a type of normalized difference vegetation index (NDVI) was created by using the two Landsat TM dates (1984 and 1998). Band 3 (.63-.69µm) of the 1984 Landsat TM was subtracted/divided against the second Landsat TM image. Using these comparison techniques, Maktav and Erbek noticed a growth of nearly 40% or greater in many of the districts. At the same time, a loss or total loss of agricultural areas (e.g. fields) was also found to exist in many of the most rapidly growing districts. Maktav and Erbek conclude that, “monitoring of urban areas, land-use/cover changes, unplanned or informal structures, will greatly benefit from aerial photographs and high resolution satellite data (558)."

As opposed to the Maktav and Erbek experiment, since the target area was significantly larger (China is 9.6 million km^2), 8km Pathfinder data was employed, which is one of the most commonly used databases for global-scale research (James and Kalluri 1994). In order for the project to be economical, 1.1km data from Advanced Very High Resolution Radiometer (AVHRR) was expanded to 4.4km data in the effort to save money and time and the possibility of missing data from smaller swaths of land (it is of note that global area coverage (GAC) datasets have been resampled to even higher kilometer ranges such as 8, 16, and even 32km) (Goward et al. 1993). In addition to this, Young and Wang had to correct for atmospheric conditions and cloud cover, so they employed a technique they call maximum value composite (MVC) which uses a number of days (7-10 days usually) of AVHRR data or PAL data. The MVC is created on a pixel-by pixel basis where each pixel's NDVI value is the highest value over the period of time for which the data exists. Another problem that was addressed was the notion that certain calibration settings for AVHRR data led to erroneous conclusions (Agbu and James 1994), thus new algorithms were introduced (Rao and Chen 1994) and further revisions (Prince and Goward 1996, Smith et al. 1997) have helped to narrow down the problems associated with PAL and GAC datasets.

Normalized Difference Vegetation Index

Because the focus of Young and Wang's experiment lies primarily within the vegetative changes of China, the Normalized Difference Vegetation Index (NDVI) was chosen to be the indication of changes in productivity and land use across China. The NDVI, or 'greeness' index (near-infrared light – red light /near-infrared light + red light) (Tucker 1979) as it is known because of its measurement of healthy green vegetation, is a useful tool for discerning vegetation from the surrounding landscape. To assist in extracting land-cover change information from global scale data, a few digital imaging processing techniques were employed throughout the duration of the experiment. Univariate image of differencing, image deviation, change vector analysis, and principal components analysis (PCA (Eastman and McKendry 1991) were the primary techniques employed to garner reliable and informative data concerning the land-use/change cover of China.

By using the NDVI, or more precisely, by taking advantage of the correlation between photosynthetic activity (Dye 1996) and spectral reflectance, even large scale experiments such as the one in China are able to capture useful and meaningful data. AVHRR NDVI data has also been correlated with a number of other useful techniques such as land-cover classification (Townshend et al. 1991), spatial variability of vegetation activity at different scales (Justice *et al.* 1991), and the understanding of large-scale climatic effects on vegetation (Eastman and Fulk 1993). The previous list of techniques used with NDVI data is generally used on larger scale projects. There are, as one might expect, a number of smaller scale biophysical property indicators that can be assessed with AVHRR NDVI data. To foreshadow slightly, the author tried to incorporate the NDVI into the research but was unable to delineate certain farmland from urban areas, and thus only a cursory look at the NDVI has been afforded here.

Leaf Area Index

In addition to the aforementioned techniques, there exist other biophysical properties remote sensing is capable of detecting. The Leaf Area Index or LAI is the ratio of total upper leaf surface of a crop divided by the surface area of the land on which the crop grows. Potential evapotranspiration is a representation of the environmental demand for evapotranspiration and represents the evapotranspiration rate of a short green crop, completely shading the ground, of uniform height and with adequate water status in the soil profile. It is a reflection of the energy available to evaporate water, and of the wind available to transport the water vapor from the ground up into the lower atmosphere. Evapotranspiration is said to equal potential evapotranspiration when there is ample water (www.cimis.water.ca.gov 2007) (Box et al. 1989, Goward and Hope 1989, Thomas et al. 1989).

Both of these two experiments aim to classify land-use changes within a given environment. However, as Lambin (1999) reminds us, “the comparison of land-cover classifications of different dates does not allow the detection of subtle changes within land-cover classes.” Researchers who wish to avoid this pit-fall of remotely sensed data are generally required to check for changes through repetitive measurements of biophysical attributes that characterize the land cover. When attempting to accurately represent a land-cover feature, researchers must choose from a variety of methodologies. A discrete representation has the advantages of concision and clarity, but remains a very theoretical representation of the data. A continuous representation, in contrast, the biophysical variables vary continuously, not only spatially, but over a period of time (i.e. seasonally). These two approaches both contain flaws that may skew extrapolated data. Lambin (1999) has suggested that monitoring forest degradation by remote sensing requires a set of indicators of the surface, the seasonality of the attributes, and a fine-scale spatial pattern. The reason is to help discern between conversion and modifications of the landscape; restated, land-use/change at a pixel level is reliant upon the thresholds specified by researchers. Improper or faulty conclusions may be drawn upon data that has been augmented in illogical manners.

Resolution – Temporal and Spectral

Since the areas of dense human population and dense herbaceous life vary so greatly within the spectrum, it would appear on the outside a short task of discerning the two from above. However, the many factors photosynthetic life-forms react to in remote sensing include space and time, local environmental factors, climate variations, and human actions (Odum 1971, Waring and Running 1998). A major problem of defining forest types (or individual species), as noted by Maselli and Chiesi (2006), is the current lack of satellite data, which have both high spatial and temporal resolutions. There is, however, an abundance of satellite imagery that has high acquisition rates and is relatively inexpensive, but suffers from low spatial resolution sensors. This means that the all-important relevant pixel size can be anywhere from 30m to 1km in representative data. Conversely, satellite sensors that are characterized by high spatial resolution have infrequent acquisition times as well as being considerably more expensive (Bolle 1996). Thus, often times a researcher, one especially concerned with dense human populations and herbaceous environments must try to use data which contains the highest possible resolutions to attain a high degree of certainty regarding the data. However, due to budget or availability constraints, other methods have been developed to correct for these shortfalls.

To counter the problems associated with sensor imbalances and poor spatial resolution of certain types of data, many studies have been carried out with the intent to merge the different types of data into more useful and more accurate types of data. Studies aimed at merging useful data from different satellite sensors, such as Landsat TM and Enhanced TM, National Oceanic and Atmospheric Administration (NOAA) AVHRR and Spot Vegetation (VGT) (Maselli et al. 1998, Maselli and Rembold 2002). Bannari *et al.* (1995) suggests that there is great promise particularly for producing integrated datasets for the NDVI, because of its relation to essential vegetation properties such as the LAI and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR).

Often times, what is useful in urban-land use studies, within the data a researcher is trying to study is buried amongst layers of other data that is not pertinent. Thus, the decrease of redundant (unnecessary) information and preservation of the useful information depend on the transformation used (Törma 1996). As of now, there is no well-developed theory for feature extraction. Features tend to be application-oriented, bound by heuristic methods and interactive data. (Lampinen and Smolander 1996). The reasoning for feature extraction in classification problems is to extract the most congruous information while, minimizing the intra-class pattern variability while enhancing the inter-class pattern variability (Devijver and Kittler 1982, Özkan and Erbek 2005).

Principal Component Analysis

Principal component analysis (PCA) is a technique for removing or reducing the duplication or redundancy in multispectral images and for compressing all of the information that is contained in an original n-channel set of multispectral images into less than n channels or, more specifically, to their principal components. Principal components are then used for image analysis and interpretation. However, since principal components are ranked in terms of the amount of variance that they explain, they tend to show a markedly different spatial structure from one component to the next. Consequently, this new variable set is uncorrelated without *a priori* physical interpretation of the principal components (Eastman and Fulk 1993). In remote sensing applications, PCA has long been used as a data compression tool by discarding minor components with little explanatory value (Ricotta and Avena 1999).

Generally speaking, there are three major steps to creating a PCA:

1. compute the covariance matrix of data;
2. compute the eigenvalues and eigenvectors of the covariance matrix;
3. transform the input data into new feature space by using this eigenvector matrix (adapted from Özkan and Erbek 2005).

Quite often, the features defined by PCA are not optimum with regard to class separability. In feature extraction for classification, it is not the mean square error but the classification accuracy that must be considered as criteria for feature extraction (Cheng *et al.*

2006, Ricotta and Avena 1999). PCA can also use unstandardized components or standardized where every original band has equal weight in the creation of the new component bands (Singh and Harrison 1985, Eastman Fulk 1993, Young and Wang 2001).

Spectral Mixture Analysis

Another possibility when trying to classify pixel data is Spectral Mixture Analysis, which provides a systematic way to quantify spectrally heterogeneous urban reflectance. This method is based on the observations that, in many cases, radiances from surfaces with different reflectances mix linearly in proportion to area within the instantaneous field of view (IFOV) (Small 2005, Nash and Conel 1974, Singer and McCord 1979, Singer 1981). If a limited number of distinct spectral reflectance values are known *a priori*, it is possible to define a 'mixing space' within which mixed pixels can be described as linear mixtures of the 'endmembers.' Given sufficient spectral resolution, a system of linear mixing equations can be defined and the best fitting combination of endmember fractions can be estimated for the observed reflectance spectra (Boardman 1989).

Other Techniques in Remote Sensing

Other techniques that are used widely in urban change analysis include radiometric normalization to establish a common radiometric response among multi-date/multi-sensor data, an unsupervised image classification approach using image clustering and cluster labeling (which has been employed in this particular research), a GIS-based image spatial reclassification procedure to deal with classification errors caused by spectral confusion, and post-classification comparison with GIS overlay to map the spatial dynamics of land use/cover change. Different situations will warrant different approaches, but generally speaking, these are some of the more basic and widely used approaches to mapping land-use in satellite imagery.

Classification Techniques

Since the first satellites were launched for the purpose of searching for terrestrial resources, digital classification methods of remotely sensed images have acquired a growing importance in the automatic recognition of land cover patterns (Richards 2005). The general objective of the classification procedures is to categorize each pixel of an image into one of various land cover classes or themes. The resultant classified image is essentially a thematic map of the original image (Gonçalves *et al.* 2008). The nature and pace of technical developments in remote sensing are notable. However, if the science of remote sensing is to make significant contributions to the urban planning process, technological innovation must surpass conventional approaches (Walker and Blaschke 2008).

When classifying an urban change analysis project, researchers will tend to choose five or six categories into which the bulk of the spectral data can safely be assumed to fall. The first category is high-density urban use. This is when an area contains approximately 80 to 100% construction materials, e.g. asphalt, concrete, etc; typically commercial and industrial building with large open roofs as well as large open transportation facilities, e.g. large airports, parking lots, and multilane interstate/state highways; with low percentage of residential development residing in the city cores. The second category is low-density urban use. Approximately 50 to 80% construction materials; often residential development including most of the single/multiple family houses and public rental housing estate as well as local roads and small open (transitional) space as can be always found in a residential area; also may contain a certain percentage of vegetation cover (up to 20% or so). The third category contains cultivated and exposed land. These areas of sparse vegetation cover less than 20% of the pixel area and are likely to change or be converted in the near future to other uses which may include but are not limited to clear cuts, quarry areas, cultivated land without crops, and barren rock or sand along rivers, streams, or beaches. The fourth major land use classification is cropland or grasslands. These areas are characterized by high percentages of grasses and other herbaceous vegetation, and crops; including lands that are regularly mowed for hay and/or grazed by livestock, golf courses and city parks, and regularly tilled and planted cropland. The fifth major tenet of urban classification is forest cover. In order for data to register in this classification, there should generally be 90 to 100% forest cover. The final classification tends to be open water. These are areas of open water with greater than 95% cover water including streams, rivers, lakes, oceans, and reservoirs (Yang and Lo 2001).

Yang and Lo also mention two types of misclassification errors: the boundary error and the confusion in spectral classes representing two or more land use/cover types as described above. These errors can be substantially reduced with the use of spatial reclassification procedures. Boundary errors normally appear in the guise of what is generally termed *salt and pepper*. These misclassified areas are often small relative to areas of correct classification. These small areas should be removed and replaced with class values based on their surroundings. To this end, a contextual classification procedure could be used and it involves two stages: (1) identification of minimal areas and their subsequent declassification, and (2) re-labeling of declassified areas on the basis of their surrounding pixels(2001, 1782). A modal filter can be used to this end to achieve a fast approximation of these two stages in a once over on the image. On the other hand, spectral confusion refers to several land use/cover classes have similar spectral response, which is highly dependent upon imaging sensor characteristics (spatial, spectral, and radiometric resolutions) and scene contents. For an image in broad spectral band, spectral confusion is inevitable. In fact, as image spatial resolution increases, the number of *mixed pixels* increases, and thus the spectral confusion tends to be more serious. Therefore, it is highly advantageous to select unique classifications as well as a limited number of classes when reporting data. As was mentioned above, five or six classes is generally thought to be the best for showing urban land use features, especially when showing these changes over a period of time that uses multiple data sets from different imaging sources.

It stands then that when beginning a change analysis project, a researcher must have quite a few aims in mind. However, the overreaching necessities that ensure accurate and useful information will be formulated from satellite and aerial imagery must be taken into account along with the goals of the research. The success of the project lies within the careful selection of methods and practices that have been used in the past, but as a great deal of the research shows, often times different methods have been formulated to satisfy unique situations amongst the projects. Also, with ever increasing technology at the disposal of researchers, the science and the extraction of data within remote sensing is ever-expanding. New methods have to be developed on a near constant basis to keep up with the advanced imagery and advancements in data storage. Therefore, while certain methods may work for a number of related studies, there are certain climatic and local issues that may change the exact returns a researcher may get even if the very same experimental methods are followed. To this end, remote sensing requires researchers to be ‘hands-on’ with the material they are classifying. The ability to check for accuracy in land cover rests solely in the ability of the researchers to gather data that confirms what was assessed within the remotely sensed image. This is not always possible, and in many cases is not feasible due to time or money constraints.

Chapter 3

Socioeconomic Methodology

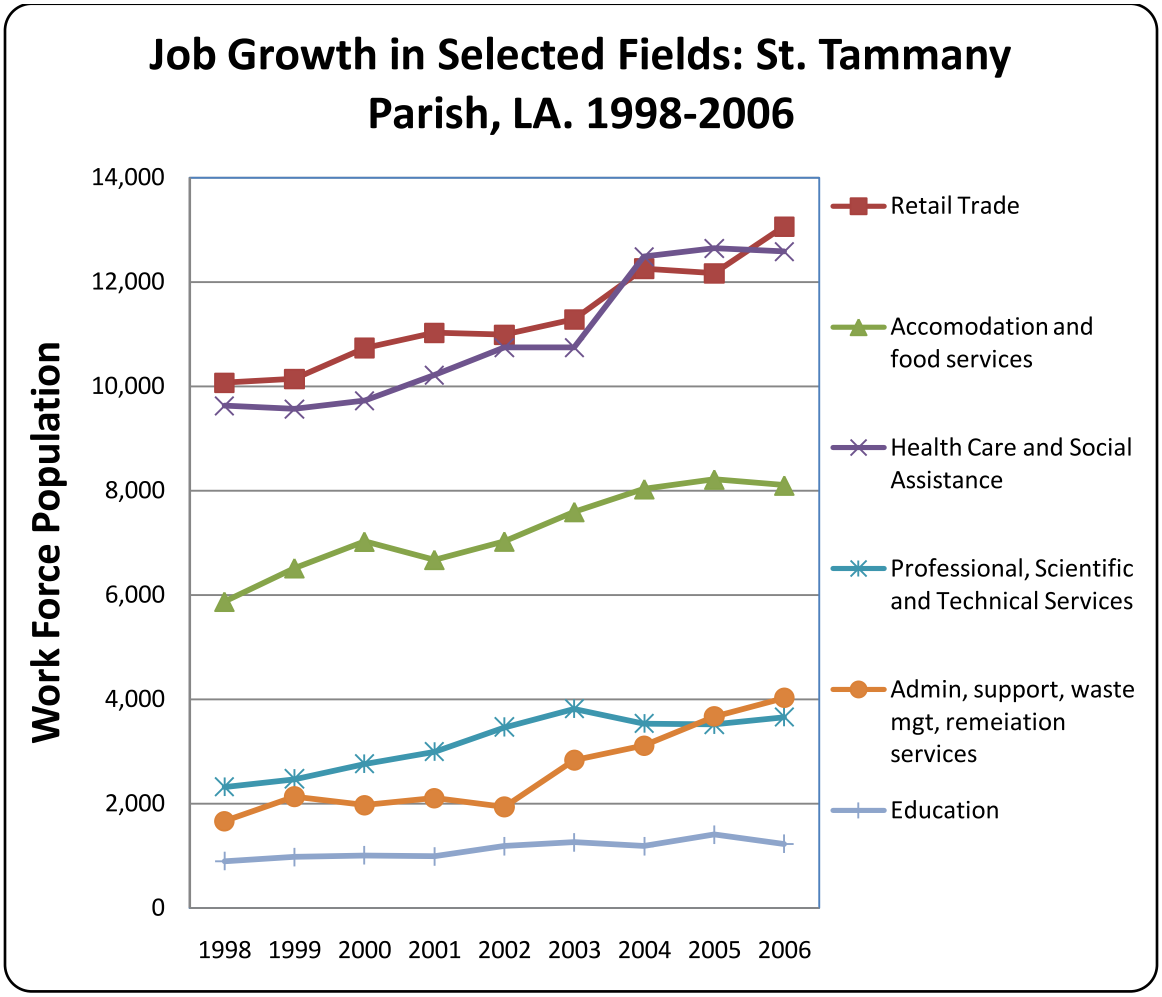
Because this paper entails both socioeconomic data and remote sensing data, the methods used to analyze data differ as well. Regarding the socioeconomic data, census data was obtained from the United States Census Bureau in decennial format. In addition, more precise information regarding business demographics was garnered by using census data from the North American Industry Classification System (NAICS 1998-2006) and the Standard Industrial Classification (SIC, 1993-1997). Population data, which can be acquired through census data as well (though not all of the decennial censuses contain parish specific content), is a telling feature of the growth of a given locale. Trends in population vary, but much of the literature surveyed in chapter 1 of this paper suggests that growth in suburban counties (and in this case a parish) has accelerated since 1950. At the same time, though not directly related to the present research, populations in inner cities have dwindled until recently (as was noted in Chapter 1). While population in the United States has increased for as long as census data has been recorded, St. Tammany Parish has recorded very large percentages of decennial growth over the last 100 years (35.9%), but even more so in the last 50 years (47.7%) (Census.gov). Comparatively speaking, the national population growth rate in the U.S. for 1900-2000 is 14.26%.

It was also useful to visit the American Factfinder (http://factfinder.census.gov) and USA Counties (http://censtats.census.gov/usa/usa.shtml) to find a variety of data useful in detailing growth of the actual urban landscape. Data on retail sales, building permits, and non-farm establishments were readily available in text format that was later assembled into excel charts.

Gathering data on these particular fields (in addition to population figures) was hypothesized as the most logically accurate way to check for urbanization through census data fields. Building permits are available on non-commercial buildings in St. Tammany Parish dating back to 1980 (a phone call to the St. Tammany Parish Permits and Regulations office confirmed the absence of data prior to 1980). Tracking permit issuances helps a researcher to do a number of things, but in this case, the number of permits suggests how much expansion we would expect to find across the parish in a given year (or over a given number of years).

Work force demographics were also collected from the NAICS to show, at least recently, the growth of certain job fields that would suggest of a burgeoning population and economy. The problem with using this particular field as a primary indicator of urban expansion, however, is that many of the jobs created in St. Tammany Parish may not be filled by denizens of St. Tammany Parish. Therefore, while the spatial expansion expected from the creation of many of these jobs does in fact exist, it cannot be said that you would expect all the people who have taken jobs in St. Tammany Parish to reside in St. Tammany proper. Similarly related, job increases through a number of professions that appear to be characteristic of a growing population were acquired using the 1970 census and the 2000 census. Construction, manufacturing, transportation, retail, finance, insurance, education and health were all selected because they directly reflect growth in the parish (especially jobs in construction, education, and health) (see Figure 3 below).

Figure 3.1 Job Growth in St. Tammany Parish by selected trade.



Source: National American Industry Classification System (NAICS)

A number of smaller data sets were collected to help reinforce trends within St. Tammany Parish. Among them are the national population from 1900-2008, growth of Orleans Parish and the growth of the Orleans Standard Metropolitan Statistical Area (SMSA). While these datasets in themselves are in certain ways unrelated to the focus of the research, St. Tammany Parish has proven itself as the place to move for citizens of Orleans Parish. By tracking population shifts in Orleans Parish, as well as the overall SMSA (which contains seven southern parishes, of which St. Tammany is one) population, the growth of St. Tammany can be better explained. Job growth in a number of fields were selected using NAICS data to show more recent growth in St. Tammany within a group of selected growth-oriented fields as was discussed above. Combining NAICS and SIC proved nearly impossible, considering fields were renamed or did not exist in both datasets. In addition, combining earlier decennial census data with NAICS data proved even more illogical; therefore, analysis of job growth was limited but was still possible given a few static categories (construction, manufacturing, education, retail, etc).

Remote Sensing Methodology

There are two basic approaches for land use/cover change detection and analysis (Singh 1989, Mundia and Aniya 2005) (1) post-classification comparisons, and (2) simultaneous analysis of multi-temporal data. As noted by Singh (1989), the first approach requires very good accuracy in the classification phase because the accuracy of the produced change map is a direct product of the accuracy ensured by the producer in the classification phase. Most of the original image dates, with the exception of the 2005 Landsat image (April), were taken on or near the same winter dates; these dates varied but were generally between October and January. However, after processing these images, it was decided that summer months would provide a better option for land use classification (distinction of certain land types was made more fluid in this manner). In addition, these months are the primary growing months and offer a better delineation between vegetation and urban expansion. This helped to ensure that a pixel was not accidentally identified as urban when it was in actuality a fallow field or a barren forest. This was done to ensure as Pilon *et al.* (1988) and Mundia *et al.* (2005) noted, “Selecting image acquisition dates as close as possible for the different years used minimizes problems related to the Sun position and vegetation health (2835)." In addition, it should be noted here that spectral confusion occurs regularly in remotely sensed data classification schemes; this confusion or misclassification of spectral classes is an inherent flaw of the method and is generally accepted in the literature (Andersen *et al.* 1976, Townshend *et al*. 1991)

Preprocessing of Satellite Data

All processed images that were gathered of the study area, St. Tammany Parish, are Landsat TM images. These 6 images were gathered from Earth Explorer (www.earthexplorer.usgs.gov), a web-based image distribution site maintained by the United States Geological Survey (USGS). These images were downloaded by requesting only Landsat 4-5 archival data with less than 20% cloud cover during the day. In addition, the swath the Landsat TM satellite takes every time is World Reference System (WRS) path 22, row 39 for the St. Tammany area helped during the search and retrieval of useful data. After the extraction ERDAS modeling tool was used to combine multispectral bands of Landsat-5 TM into a single file. From here the images were subset to 6 bands (the thermal band was excluded upon rendering) using an area of interest (AOI) file of St. Tammany Parish. This AOI cut out the extraneous land area of the rest of the image and also drastically reduced the file size that was used to do data analysis. Finally, each image was then subjected to an unsupervised classification algorithm, which is an iterative self-organizing data (ISODATA) analysis procedure described more fully in the next section.

Image Classification

There is no one ideal classification of land use and land cover, and, given the change in land and sensor calibrations constantly, it is unlikely to think a panacea ever will fit all classifications at all times. As suggested by Jensen (2005), "it is wise to use an established, standardized land-cover/land-use classification system for change detection (468)." In the course of this research, it was decided to follow Anderson's (1976) approach which is formally known by the USGS as the *Land Use/Land Cover Classification System for Use with Remote Sensor Data*. Given that the main concern of the research was urbanization, it has been modified to only 5 land use categories. The data itself (Landsat TM data) qualifies according to this approach as Class I (of IV). Anderson's classification system consists of 9 major categories and multiple sub-categories in certain instances. There are different perspectives in the classification process, and the process itself tends to be subjective, even when an objective numerical approach is used. There is, in fact, no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use and land cover patterns change overtime in conjunction with the need of natural resources (Anderson *et al.* 1976). That being said, some form of decorum in the process has been maintained and major categories have been dutifully selected to optimize and streamline the classification process.

An unsupervised classification approach was adopted because it allowed spectral clusters to be identified with a high degree of objectivity (Yang and Lo 2002). This method involved unsupervised clustering and cluster labeling. The ISODATA algorithms in ERDAS Imagine were used to identify spectral clusters. The ISODATA method uses a minimum spectral distance to assign a pixel to a cluster. The performance of this algorithm is sensitive to the sampling nature and clustering parameters (Vanderee and Ehrlich 1995). To avoid the impacts of sampling characteristics, the ISODATA algorithm was run without assigning predefined signature sets as starting clusters (Mundia and Aniya 2005). In addition, an NDVI and a PCA were both made of all five of the images for reference and experimentation. On all five of the images, the sixth band of Landsat TM (the thermal band) was excluded. Thus, only 6 bands were used in processing of the imagery. Only five classes were ascribed to the data: (1) open water, (2) marsh/watershed, (3) irrigation/farm, (4) forest (dense and light), and (5)urban or developed using both DOCQ's and local knowledge of the area to decide on the proper pixel brightness levels to ascribe to each category. In addition, the lower number of categories was hypothesized since the most critical element of the research is to decide how much urbanization, and thus density increase has occurred in St. Tammany Parish. Therefore, a truly accurate change detection map is unwarranted in this particular situation (namely, a truly accurate categorical change detection map). There are certainly more than 5 categories of land use in St. Tammany Parish; however, the simplification of the data was seen as paramount to achieving the most useful information on urban/built-up land

Spectral confusion, which occurs because several land use/cover classes have similar spectral response, is the major cause of inaccuracy in classifications based on spectral response. Yang and Lo (2002) noted that as image spatial resolution decreases, the number of mixed pixels increases and spectral confusion tends to be more serious. As was noted before, the research being used (Landsat TM image data) has a spatial resolution of 30m (i.e. pixel size). While this is considered medium resolution, there must be some spectral confusion expected in the analysis of coarse spectral resolution. Many land use studies have been successfully made using the Landsat imagery and the author believes that the data gathered was sufficiently accurate in any case.

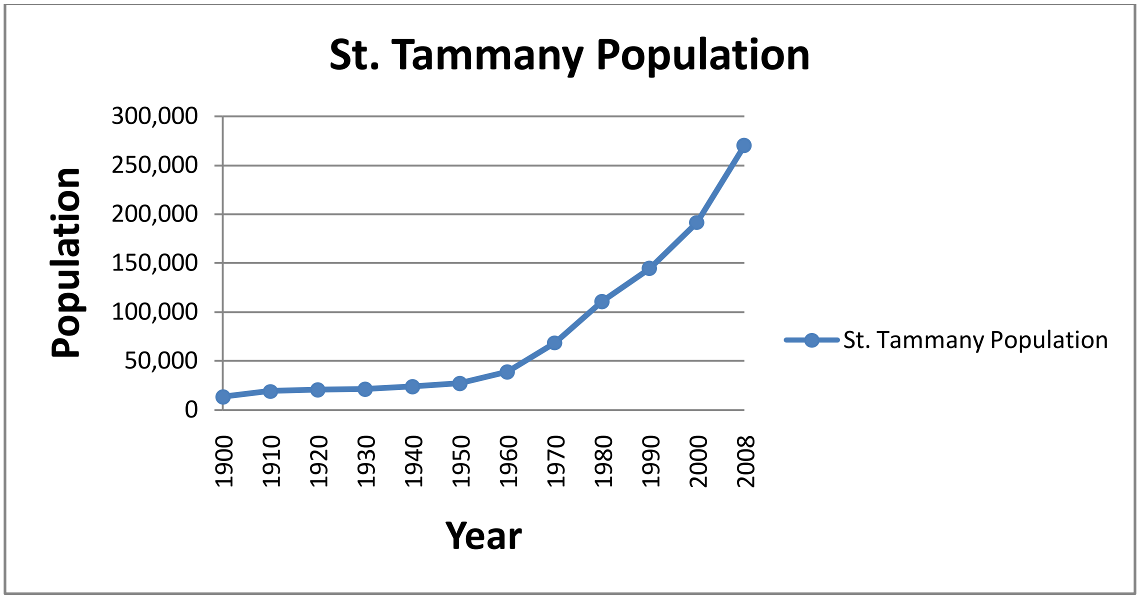
The final aspect of this research that must be noted is the combination of the census data (more specifically, the density of St. Tammany) with the remotely sensed data. It is hypothesized that per capita consumption of land can be measured by tracking the amount of urban area (gauged by remotely sensed data in sq. miles) divided by the total population of St. Tammany that year. Further explanation of this method will be undertaken in the next chapter, which focuses on analysis of the multivariate data collected during the course of this research. As was mentioned in Chapter 1, by accurately assessing the growth of the urban landscape, researchers and local planners should better be able to track the growth of the human environment. The benefit of seeing change from above are profound and many. By tracking the growth of the urban landscape with remotely sensed data, researchers can grasp the rate and the direction of growth in a much more efficient, rapid, cost effective and more accurate manner.

Chapter 4

Analysis of Data

Much of the socio-economic data required simple quantitative methods of analysis. Of special importance, however, is the concept of density in St. Tammany Parish. This was obtained by dividing St. Tammany's total population for a given year by its land area, 854.15 sq. miles (water excluded). By doing this, it was established that St. Tammany's density increased from 130 people per sq. mile in 1980 to 350 in 2008. Also of note is that St. Tammany's population increased by 159,131 people in those same years. Coincidentally, St. Tammany's estimated population of 270,000 (Chapple, 2008) is nearly the population of the historically larger Orleans Parish population (of which the city of New Orleans is situated entirely). St. Tammany's actual population has surged since 1900; the population in 1900 was 13,335 people. The most rapid ascent of the population, however, occurred in the last half century (see Figure 4 below). Chapter 1 spent a large amount of time discussing the role of suburbanization in the history of the United States. St. Tammany Parish is no exception to the growth of the suburbs in the United States over the last 60 years, and is in many ways a leading example of the phenomenon (given its high average population growth rate, which exceeds 30% per decade going back over the last century).

Figure 4 Error! No text of specified style in document.**.1 St. Tammany Population (1900-2008)**



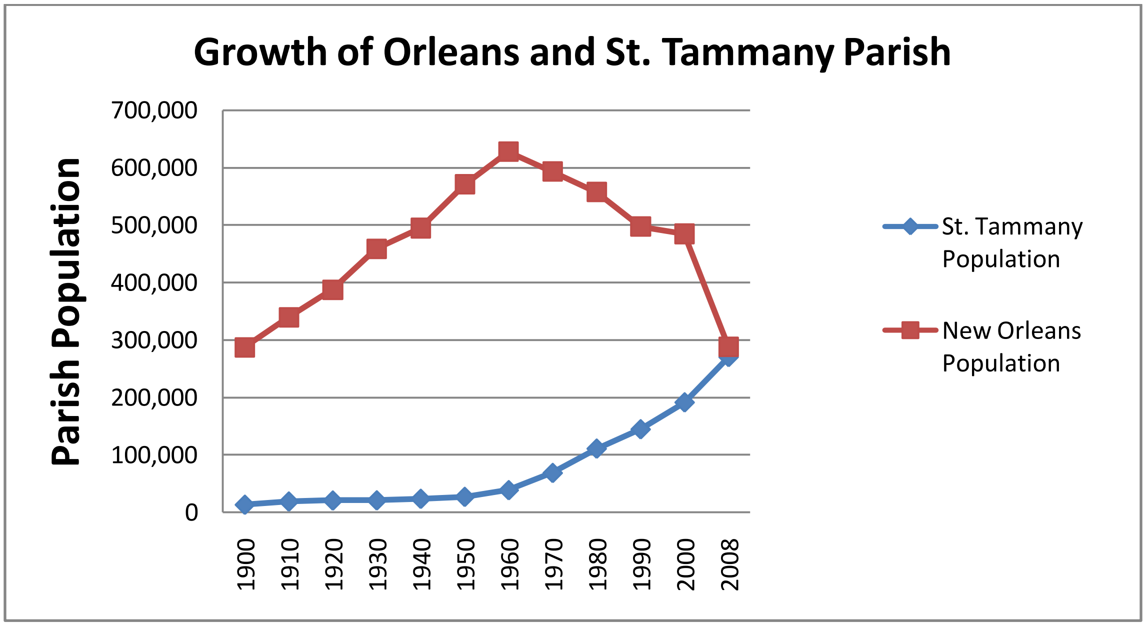
Source: Census.gov

The United States as a whole has also been expanding greatly as well. Since 1900, the U.S. has expanded its population from roughly 76 million , to 281 million in 2000 (U.S. Census 2000). The growth rate of the nation has averaged a decennial growth percentage of 14.26%. However, St. Tammany is, if taken as a microcosm of the nation, an outlier in terms of its population growth. Since 1900, St. Tammany Parish has averaged a growth rate of 22.9%. As was mentioned already, much of this growth has occurred in the last 50-60 years.

St. Tammany comprises a part of the Orleans Standard Metropolitan Statistical Area as well (SMSA). This SMSA (which is composed of 6 other parishes in the Greater New Orleans Metropolitan area) contained at its peak in 2003 1.33 million people. The largest share, until recently and in light of Hurricane Katrina, was composed of by Orleans Parish. Now, however, St. Tammany and Jefferson are the two largest parishes of the Orleans SMSA if current estimates are correct for St. Tammany. Large numbers of residents living on the southern shores of Lake Ponchartrain (i.e. Orleans, St. Bernard, and to a certain extent Plaquemines

Parishes) fled the city in the wake of Hurricane Katrina, many of them to the safety of the relatively higher base flood elevation of St. Tammany (for extra reference, see Figure 5 below).

Figure 4.2 Comparitive chart of Orleans and St. Tammany Parish populations (1900-2008)



The exodus of people is well documented and does not bear more than a cursory examination here in this research. It is of note that 2008 satellite imagery was acquired for the specific purpose of analyzing Katrina's impact on the acceleration of St. Tammany's urbanization. The population of St. Tammany parish was estimated at 220,480 immediately before Hurricane Katrina. In October of 2005, a mere two months after landfall of the most devastating hurricane to ever befall the United States, the population of St. Tammany Parish was 257,767 (an increase of 37,287 (16.9%) (www.louisianaspeaks-parishplans.org).

Therefore, it was considered desirable to see if this short term explosive growth could be documented using satellite imagery. St. Tammany's land area is 854 sq. miles. There are two types of density this research is concerned with: (1) arithmetic density which is the total population for a given time (e.g. 1980, 1990, 2005, etc.) divided by the total land area of the given area (in this case, 854 sq miles). The resulting number is the density per sq. mile of St. Tammany Parish (see Table 2 below). While the actual growth of St. Tammany between 2005 and 2008 in terms of arithmetic density grew 12%, the urban landscape increased only 5% according to analysis of the urban areas classified in the remotely sensed data. However, because many people may not have constructed new houses (due to a variety of economic factors such as overall failure programs such as Road Home (Reckdhall 2008), it is likely that many people moved in with relatives or friends in St. Tammany Parish and thus the lower growth of the urban landscape makes more sense. In addition, people may have moved into existing apartments or houses that were vacant before the storm. Housing was generally unavailable after the storm, and many people found themselves renting housing in the direct aftermath of the storm as they waited to return to Orleans and St. Bernard parishes.

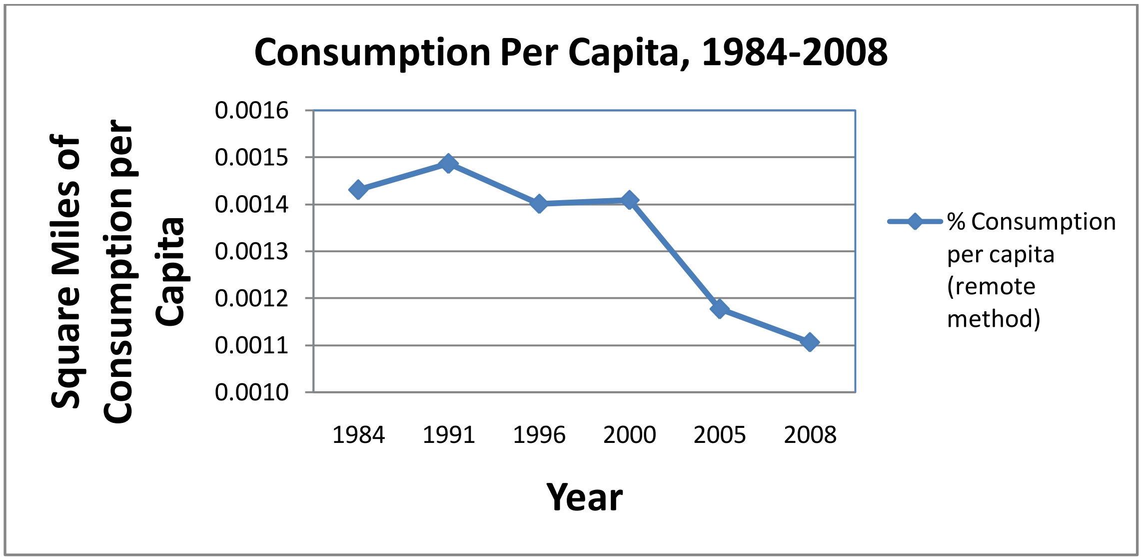
Table 4.1 Density (arithmetic) and Area Urban (from remotely sensed data) for selected years of study

St. Tammany Parish Density (Arithmetic and Area Urban)					
Year	Population	Density (arithmetic)	% Change from prior	Area Urban (From remotely sensed images)	% Change from prior
1984	124324	145.58		177.76	
1991	149184	174.69	20%	221.64	20%
1996	172564	202.07	16%	241.64	8%
2000	191268	223.97	11%	269.44	10%
2005	240478	281.59	26%	282.87	5%
2008	270000	316.16	12%	298.68	5%

Source: Census.gov

Interestingly enough, the remotely sensed data came back on the whole as was expected from the outset; that there would be growth of both the population and of the urbanized area. In some cases the area urban change percentage kept at or near the change in the arithmetic density. Another major component of the research was to see how much land each per consumed per capita of the area that was urbanized. This differs from the arithmetic density in that density, if a population increases, can only ever go up (assuming the land area of which the function of density is based on does not change). The urban area consumption changes differently as this research suggests (See Figure 6 below). When the urbanized area that is attained through the remote sensing techniques is divided by the population of the study area, this gives a consumption rate. The rate is small, but it does differ, and on a more intrinsically personal level, it gives an idea if the urban area is becoming more or less crowded. The consumption rate per capita in St. Tammany Parish was highest in 1991, with each person consuming 0.0015 sq. miles of urbanized land (41,817.6 sq. feet). This rate had dropped to 0.0011 (30,666.24 sq. feet) by 2008 (See Figure 7 below for a complete listing of growth and change according to socioeconomic data as well remotely sensed data).

Figure 4.3 Consumption Per Capita, 1984-2008 (in square miles)



Data Source: USGS.gov; calculations made by author

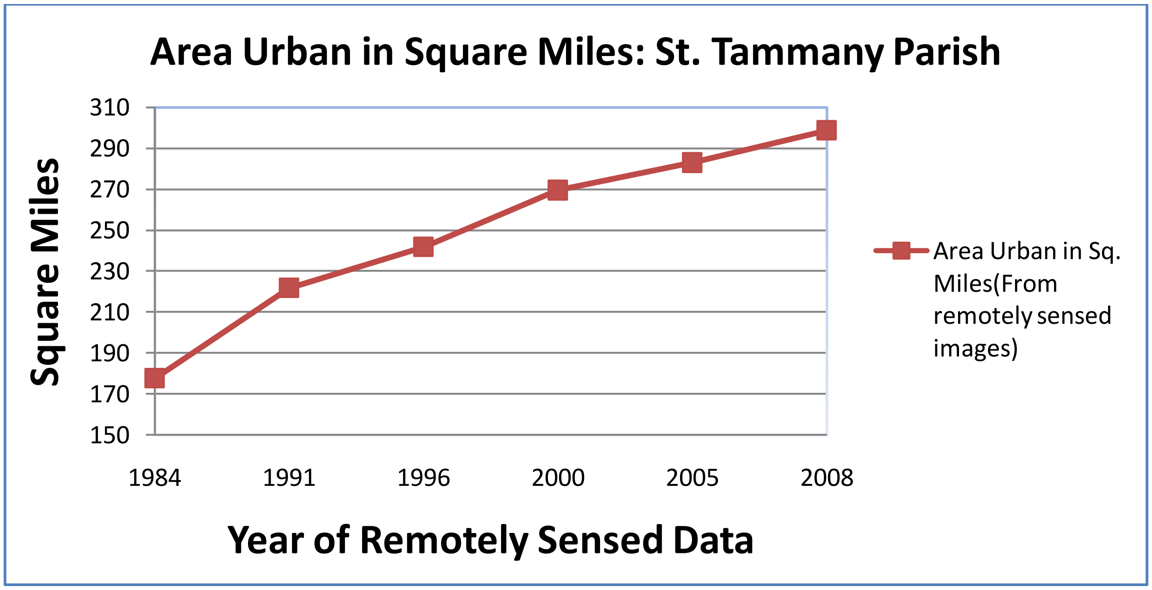
Table 4.2 Expanded chart on remotely sensed images; contains conversion to sq. feet.

			St. Tammany Parish Urban Area and Consumption			
Year	Population	% Change	Area Urban in Sq. Miles(From remotely sensed images)	% Change from prior	% Consumption per capita (remote method)	Conversion to sq. feet
1984	124324		177.76		0.0014	39,030
1991	149184	17%	221.64	20%	0.0015	41,818
1996	172564	14%	241.64	8%	0.0014	39,030
2000	191268	10%	269.44	10%	0.0014	39,030
2005	240478	20%	282.87	5%	0.0012	33,454
2008	270000	11%	298.68	5%	0.0011	30,666
Total	145676		120.92			

Data Source: USGS.gov; calculations made by author

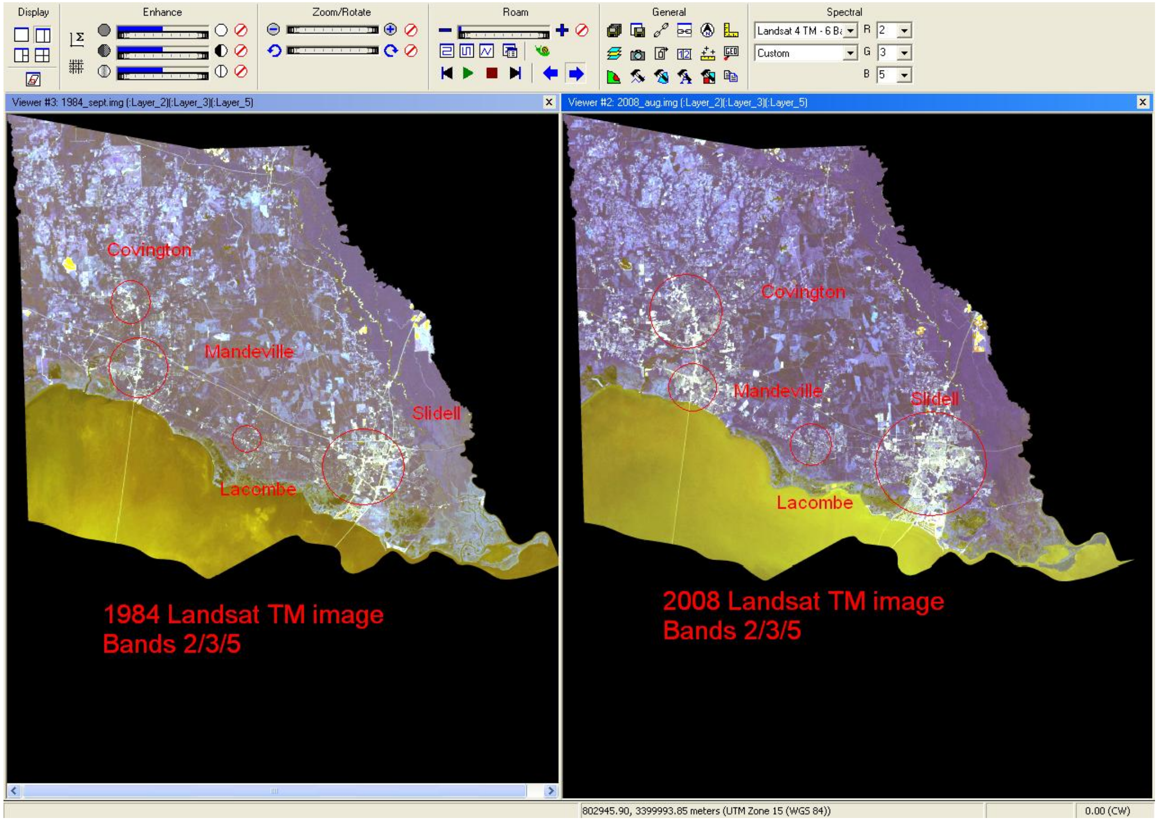
Even a peripheral examination of the 1984 and 2008 images without unsupervised classification (see Figure 9 below) makes obvious the growth of St. Tammany parish in just 24 years. Of special interest is the cities of Slidell, Mandeville, Lacombe, and Covington (circled in red), which are visibly much larger in 2008 than in 1984. Although visual inspection is not the goal of this research, the ideas for mapping this research began with this particular view of St. Tammany Parish in 1984 versus 2008. In addition, the sq. miles of urban land in St. Tammany Parish grew (in remotely sensed data) nearly 121 sq. miles (see Figure 8 below).

Figure Error! No text of specified style in document.**4.4 Area urban in St. Tammany Parish; acquired from remotely sensed data (1984-2008)**



Data Source: USGS.gov; calculations made by author

Figure 4.5 Visual growth of St. Tammany Parish using Landsat 5 TM imagery (Bands 2/3/5) 1984 & 2008



Source: USGS.gov; image created by author using ERDAS Imagine 9.2.

Besides the obvious differences in the visual realm of the digital imagery, a five class classification system was devised of the 25 class unsupervised classification images that were produced from the original unprocessed imagery. These classes were then colored and mapped using ERDAS Imagine software in raster attributes, the classification scheme is as follows: (1) open water (blue), (2) marsh/riverine (brown), (3) forest (dark green), (4) agriculture/light forest (light green) and (5) urban/developed (purple). A collection of these maps are included in the appendix of this paper. The sq. miles of the urban land was attained by creating a new column in the raster attributes of each Landsat TM image.

The area for each of the 6 images was then tallied and the result was logged in an Excel spreadsheet for computation. The classification was kept the same for each image in ERDAS as it was expected that the land cover classes selected would be sufficient to track urban land over the 6 datasets. The various pixel brightness that were assigned to each of the five classification categories were selected from a range of methods. In most cases, a true color view of the satellite image in another viewer or using the swipe function was used to qualify the area as one of the five (water being the most obvious and easy to classify) types of land cover. When this could not be determined from the relatively high spatial resolution of the Landsat TM pixels (30m), Google Earth and Louisiana DOQQs (downloaded from http://atlas.lsu.edu) were used to confirm or deny the existence of a particular land cover category.

Chapter 5

Conclusion and Discussion of Results

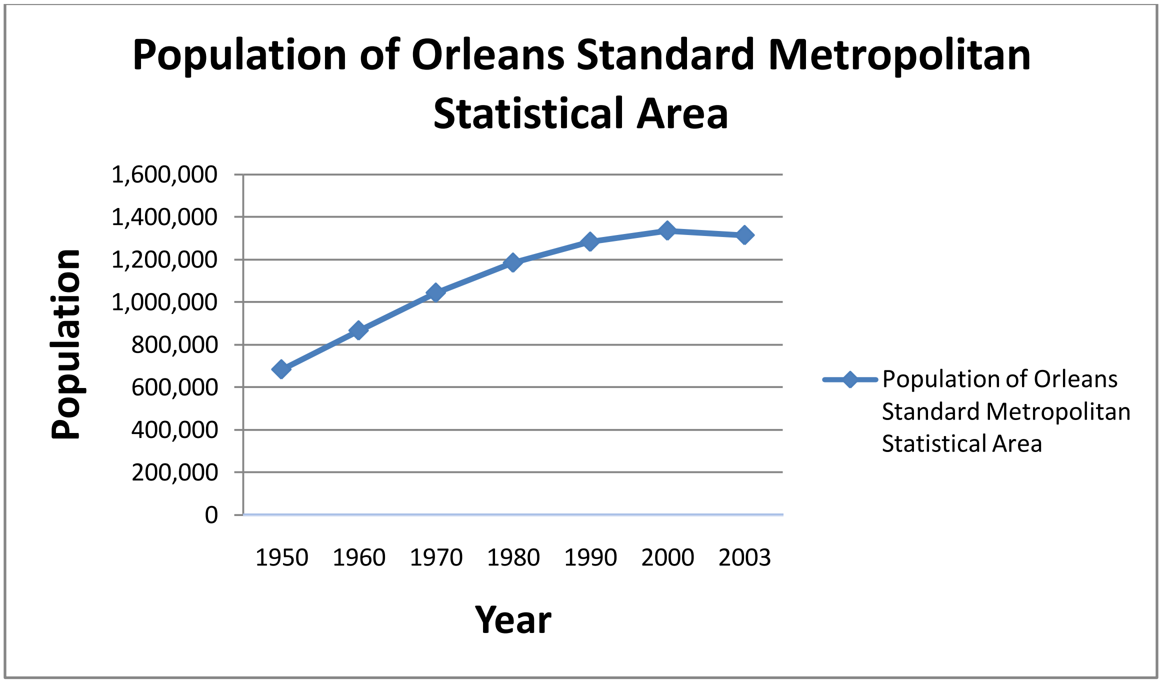
The results of the remotely sensed data confirmed the already established census data and the expansion of St. Tammany Parish. What this research did find was that St. Tammany's consumption of land per person is shrinking, which suggests that while the density is ever growing, people are clustering together more in the already urbanized areas of the parish. This suggests that St. Tammany, while suburban for all intents and purposes, is beginning to develop central city characteristics. To be sure, the urbanized area has grown nearly 121 sq. miles (an expansion of 3.3 billion sq. feet) during the period of 1984-2008, a huge gain in such a short amount of time. This equates to nearly 14% gain in urban land in relation to the total size of St. Tammany Parish; overall, the remotely sensed data suggests that 34.9% of the parish is urbanized according to the classification system used in the study.

To be sure, remotely sensed data does provide local and regional planning agencies with a promising method of tracking the expansion of the urbanized land. If, for instance, even higher spatially resolute data had been used in this research (such as IKONOS 1m resolution), a much higher degree of certainty of land use/ land cover could be acquired. However, high resolution data such as IKONOS takes enormous amounts of data storage and is often expensive to purchase. Landsat TM imagery, on the other hand, offers moderately resolute data that can be very useful, especially over large areas such as entire parishes or counties. The issue is twofold in this manner: (1) how much money does the researcher have at his or her disposal to purchase imagery and (2) what is the size of the study area (as larger study areas will warrant, most likely, a smaller resolution so that the larger area can be generalized).

The expansion of the urban area in St. Tammany Parish was also more fully explained through secondary census data references, such as non-farm establishments (i.e. businesses), retail trade, and permit issuances for residential building. All three of these categories increased significantly over the study period. In particular, non-farm establishments rose from 2,000 to 6,000 between 1982 and 2008. The worker population of St. Tammany Parish rose from 38,000 (1994) to 63,000 (2006). The trouble with these statistics, while they are very telling of the growth experienced by St. Tammany, do not gauge where the workers or business owners reside. However, as they are directly linked to the urban expansion of St. Tammany, they provide a good backdrop of which to measure

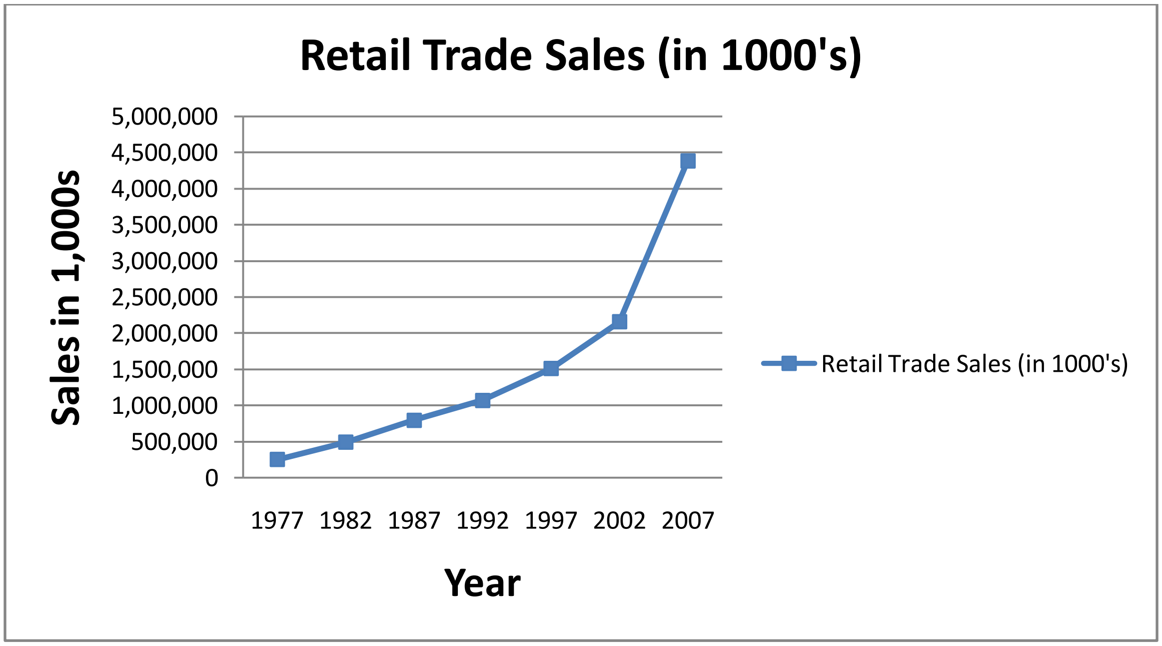
Retail trade, especially in the last few years, has curved upwards exponentially (see Figure 10 below) in St. Tammany Parish, and this suggests a burgeoning population that has a higher median income that can sustain spending and growth. The growth of St. Tammany Parish is remarkable; as has been noted several times throughout this paper, the growth rate of St. Tammany Parish is much higher than the average in the United States. In addition, St. Tammany Parish also has now become a major population hub of the New Orleans SMSA. While the overall population of the metropolitan area has suffered a slight decline since 2000 (See Figure 11 below), St. Tammany continues to stem the decline with its own growth. Part of this can be attributed to Hurricane Katrina, which bears special mention in the course of this research.

Figure Error! No text of specified style in document.**5.1 Population of Orleans SMSA (1950-2003)**



Source: Census.gov

Figure 5.2 Retail trade sales, St. Tammany Parish (1977-2007)



Source: Census.gov and NAICS/SIC

Katrina and St. Tammany Parish

On August 28, 2005, Hurricane Katrina caused considerable damage to the Gulf Coast region. It is easily the most costly hurricane in the history of the United States in terms of damage caused to infrastructure. In the aftermath, New Orleans population was halved as people fled to various adjacent parishes and out of state, many never returned. The case of Katrina is a unique episode in American history: simply put, there is no other disaster that has caused such a widespread diffusion of population. Owing to this fact, it serves as a unique chance for researchers to track the human dispersion immediately after the storm.

One of the chief recipients of the evacuees from the southern shores of Lake Ponchartrain was St. Tammany Parish. Part of the reason 2008 was selected as a data point was to do a small scale study on the effects of Katrina on the urban expansion of St. Tammany Parish. Between April 2005 and August 2008, St. Tammany Parish expanded nearly 16 sq. miles in urban area. This was a 5% increase in urban land expansion in only 3 years. Given the author's own personal experiences with automotive density in St. Tammany, it seems hardly surprising that the roadways are more congested than ever in St. Tammany Parish. Local governments are scrambling to catch up with the boom in expansion in St. Tammany along with the increased traffic created by new denizens of the parish. While the true impacts of Katrina on St. Tammany's population and economy may not be able to be fully grasped and quantified, satellite analysis of the parish suggests a burgeoning expansion fueled primarily by the exodus of Orleans and St. Bernard parishes.

Problems and Observations

While the primary objective of the research was to map the urban areas of St. Tammany Parish, a problem began to appear once ground surveying of sites was undertaken. Many homes in parts of St. Tammany Parish exist under the canopy of oak and pine trees throughout the parish (see Images 1 and 2 below). Given that the study images were taken from the growing season, it is certain, at least in a few circumstances, that certain urban areas were improperly mapped as forest or light forest. Though this isn't the kind of thing that reduces the accuracy of the unsupervised classification, it did indeed bear mentioning; suburbs of Slidell that the author has lived in showed up as light forest. The characteristic of highly heterogeneous surface covers with substantial inter-pixel and intra-pixel mixing in urban environment increase the difficulty in identifying land-use changes (Deng *et al.* 2008). St. Tammany exemplifies this problem; spectral confusion is an accepted minor error within medium-resolution data such as Landsat 5 data.

Figure 5.3 Tree canopy in Covington, Louisiana (St. Tammany Parish) covers developed land and possibly reflects in classification system improperly.

Source: Jeffrey Varisco

Figure 5.4 Tree canopy in Abita Springs, Louisiana (St. Tammany Parish) covers developed land and possibly reflects in classification system improperly.

Source: Jeffrey Varisco

The area where the majority of pictures taken by the author were taken of houses that would reflect as forest in a remotely sensed Landsat TM image comes from Abita Springs and Covington. However, considering there was a fair bit of misclassified pixels in the northern area of the parish (fields with very high reflectance), the cancellation of urban area for forested area seems to be near negligible since the core areas grow according to population estimates in each of the remotely sensed images. The interesting thing about St. Tammany Parish is the emphasis in a lot of communities of keeping trees as part of the subdivision in many cases (the author lived adjacent to one in his younger days). These particular subdivisions would have no chance of being identified as urban (and they may well not deserve to be classified as such) in a Landsat TM image. However, this does not represent St. Tammany planning in general. A more likely scenario can be seen off Highway 21 (see Image 2 below) in Covington. This particular construction is endemic of American construction in suburban areas; large parking lots and low rise buildings dominate St. Tammany Parish.

Figure 5.5 Land development near Interstate 12 in Covington, Louisiana (St. Tammany Parish). Large developments such as this 'resort' are cropping up all along major corridors in St. Tammany Parish, especially along I-12.

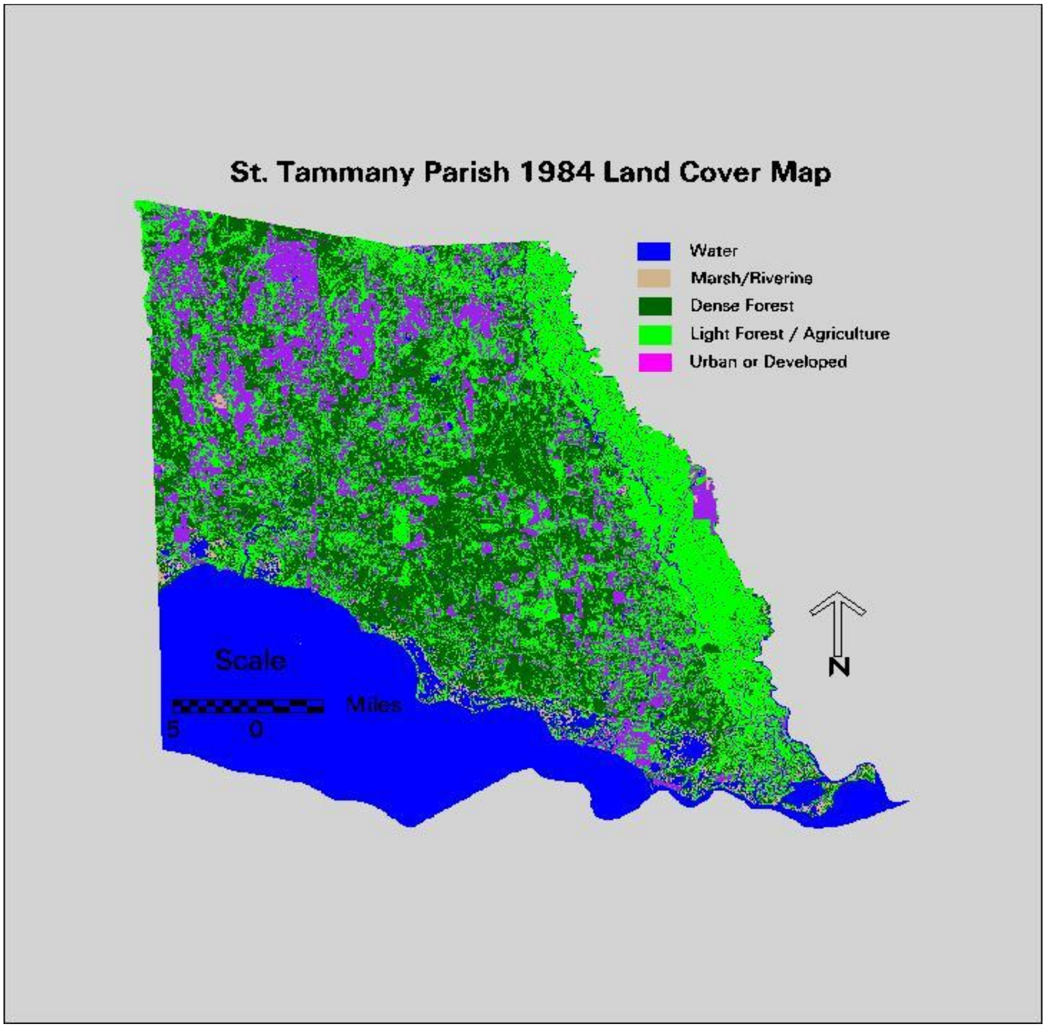
Source: Jeffrey Varisco

While St. Tammany keeps expanding, the interesting result of the research presented within this thesis is that the actual land consumption per capita, has reduced. And while this amount may not seem like much (a .0004 reduction per capita of the total sq. miles urban), this actually equates to over 10,000 sq. feet less per capita consumption of urbanized land. This means that St. Tammany, though it is still sprawling, has begun to be inhabited more densely in the areas that are urban. In many cases, it could mean that more families inhabit single-family housing or that apartment complexes have begun to be built to make for the burgeoning population.

Another striking feature of the growth of St. Tammany is the purely exponential growth in every category of census data. Jobs, income and population have skyrocketed in the area over the last 25 years. Another boon to St. Tammany has been its proximity to New Orleans, and it enjoys great benefits as a neighbor (with a large watery fence) to Orleans Parish. St. Tammany, it could have been argued at one point, could not have existed without Orleans Parish (Mandeville was a vacationing spot for denizens of Orleans looking to 'get away from it all' in the mid 1900's). In fact, not much was there pre 1960; the majority of the population was agriculturally bound to the land. As was mentioned earlier, segregation and the automobile have profoundly shaped the American landscape in the last 50 years, and St. Tammany is one of the best research opportunities available to a modern research. Compounded by this is the exciting (though regrettable) opportunity to study the effects of Katrina on the population and economy of St. Tammany Parish. Katrina caused a record exodus in Orleans Parish's population but caused an overwhelming growth in St. Tammany as a direct result.

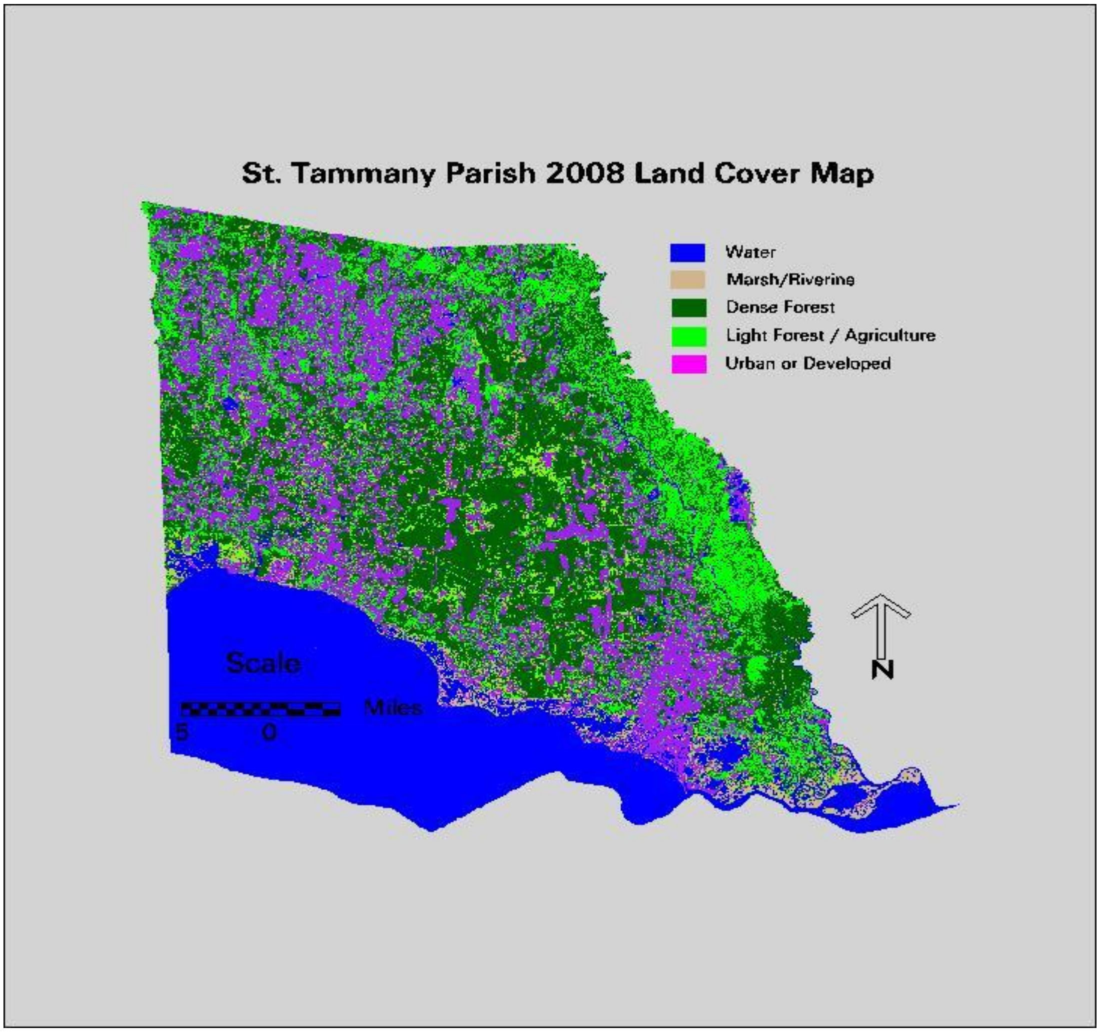
With remotely sensed imagery, the power to map these changes exists in a nuanced way. Remotely sensed data cannot tell us alone *why* people have moved there or why urbanization is occurring; it can only tell us *where* and at what rate. The background to St. Tammany Parish's growth is unique in its own way. It grew as a suburb in the 1960's through 1990's as a suburban trend of America. In the last 10 years, it can be safely argued, it has grown as a safe haven from hurricanes and the associated storm surge that has beleaguered coastal parishes such as Orleans and St. Bernard. St. Tammany has seen a renaissance in its growth and there are few reasons to believe that it will stop growing at all. The one major gnawing factor that seems to doom St. Tammany is that its population has grown so much that traffic has reached critical mass in many places. Much of St. Tammany was and still is transected by one lane highways. While remote sensing cannot change certain realities on the ground, it does offer local and state government tools which can help plan for growth more effectively in the future (see Figures below that are the color classified maps created by the remotely sensed data).

Figure 5.5 Land-use classification map of St. Tammany Parish (1984)



Data Source: USGS.gov, image created in ERDAS Imagine 9.2 by author.

Figure 5.6 Land-use classification map of St. Tammany Parish (2008)



Data Source: USGS.gov, image created in ERDAS Imagine 9.2 by author.

General Conclusions and Recommended Future Research

Having used Landsat imagery to map St. Tammany Parish, it seems that future urban studies can and should be used in conjunction with socioeconomic data. Landsat 5 series imagery is freely available, and there is so much of it available online, that any sort of low-level classification scheme can be effectively mapped. The essence of this research is useful to a variety of planning and governmental agencies. Because so much of modern research is grounded in past endeavors, the ability to quickly map a land area and infer density patterns is not only practical, but efficient. Coupled with the economy of quickly classifying land-use patterns (at the larger spatial scale), there is really no doubt that the future of urban-planning will at some point be used in conjunction with remotely sensed data.

When dealing with urbanization, recent trends suggest that, much like the findings of this particular research, that people are adopting more sustainable methods of urbanization. This particular backlash against rampant 'sprawl' has been termed 'New Urbanism.' It was conceived as a reform movement emphasizing physical design as a tool to improve the quality of life of urban and suburban areas. Advocates of New Urbanism have been promoting housing and urban development projects to mitigate sprawl, to facilitate infill development, to support regional development patterns that facilitate walking and transit, and to encourage sustainable growth (Garde 2006).

sensitive to environmental quality, economy and social equity.

This research helps contribute to the already larger existing body of work that has focused on land-use in urban areas. However, unlike much of the research, the integration of socioeconomic data was a new development in many regards. Although this usage is not indoctrinated as accurate, there are many good reasons to believe that this adds a new dimensionality to the density component. The remote method creates new depth into an otherwise mundane statistic: arithmetic density. This new dimensionality helps to add a more human and thus more readily digested statistic into the urban and environmental planning lexicon. Consumption of urban land is at first maybe an odd way to view urbanization;

however, it allows researchers to gauge the actual density of the urban land, which in turn helps to signify the growth type of the city or urban corridor at hand.

Further research into these methods will be of immense help to future planners and researchers. While there are plethoras of growth indicators for growing populations, it is often time consuming and not easily obtained. Once all this information has been obtained, say by a local government, then it can be easily modified to track growth on a variety of levels and will afford better and more concrete results in conjunction with remotely sensed data. Certainly, a system that uses not only census data for results, but is combined and integrated with remotely sensed data will serve to create more useful and more efficiently graded data. This sparks hope that this particular research has been more than useful and will serve as a potential wellspring for future research questions and work.

References

Agbu, P. A., and M.E. James, 1994. *The NOAA/NASA Pathfinder AVHRR Land Data Set User's Manual* (Greenbelt, Maryland: Goddard Distributed Active Archive Center Publication).

Anderson, R., E. E. Hardy, J. T. Roach, and R. E. Witmer, 1976, A land use and land cover classification system for use with remote sensor data. USGS Professional Paper 964, Sioux Falls, SD, USA.

Baldassare, M., 2002. *PPIC Statewide Survey: Special Survey on Land Use. San Francisco, CA*: Public Policy Institute of California.

Bannari, A., D. Morin, F. Bonn, A. R. Huete, 1995. A review of vegetation indices. *Remote Sensing Reviews,* **13**, 95-120.

Boardman, J. W., 1989, Inversion of imaging spectrometry data using singular value decomposition. *Proceedings of the 12th Canadian Symposium on Remote Sensing.* Vancouver British Columbia, 2069-2072.

Bolle, H. J., 1996. The role of remote sensing in understanding and controlling land degradation and desertification processes: the EFEDA research strategy. In *The Use of Remote Sensing for Land Degradation and Desertification Monitoring in the Mediterranean Basin. State of the art and future research*, J. Hill and D. Peters (Eds), Directorate-General Science, Research and Development, European Commission, 45-77.

Box, E. O., B. Holben, and V. Kalb, 1989. Accuracy of the AVHRR vegetation index as a predictor of biomass, primary productivity and net CO^2 flux. *Vegetatio*, **80**, 71- 89.

California Irrigation Management Information System., Department of Water Resources, Office of Water Use Efficiency. Accessed online at http://wwwcimis.water.ca.gov/cimis/welcome.jsp July 9th, 2007.

Carcopino, J., translated by E. R. Lorimer, edited by H. T. Rowell, 1991. *Daily Life in Ancient Rome: The People and the City at the Height of the Empire*. Penguin BooksLtd, 13-26.

Carr, J. B., S. Bae, W. Lu., 2006. City-County government and promises of economic development: a tale of two cities. *State & Local Government Review*, **38**, 131-141.

Chapple, C. "St. Tammany population too low, say parish officials." The Times Picayune [New Orleans] 11 May. 2008: **B3.**

Cheng, Q., L. Jing, and A. Panahi, 2006. Principal component analysis with optimum order sample correlation coefficient for image enhancement. *InternationalJournal of Remote Sensing*, **20**, 3387-3401.

Clotfelter, C. T., 1976. The Detroit decision and "white flight." *The Journal of Legal Studies*, **1**, 99-112.

Cozens, P., and Hillier, D., 2008. The shape of things to come: New urbanism, the grid and the cul-de-sac. *International Planning Studies*, **13**, 51-73.

Deng, J. S., K. Wang, Y. H. Deng and G. J. Qi, 2008. PCA-based land-use change detection and analysis using multitemporal and multisensor satellite data. *International Journal of Remote Sensing*, **29**, 4823-4838.

Devijer, P.A. and J. Kittler, 1982. *Pattern Recognition: A Statistical Approach* (London: Prentice Hall International).

Dye, D., 1996. Satellite monitoring of terrestrial vegetation and vegetation-climate regions. In *Elements of change 1995, Session 1: changes in Global Vegetative Patterns and their relationship to Human Activity*, edited by S. J. Hassol and J. Katzenberger (Aspen, Colorado: Aspen global Change Institute), 25-27.

Eastman, J.R., and J. McKendry, 1991. *Explorations in GIS technology. Volume 1, change and Time Series Analysis* (Geneva: UNITAR and Clark University).

Eastman, J. R., and M. Fulk, 1993. Long time series evaluation using standardized principal components. *Photogrammetric Engineering and Remote Sensing*, **59**, 991-996.

Efrat, E., A. G. Noble, 1988. Planning Jerusalem. *Geographical Review*, **4**, 387-404.

Evans, T. P., and Moran, E. F., 2002. Spatial integration of social and biophysical factors related to landcover change. *Population and Development Review,* **28**, 165-186.

Ewing, R., 1997. Is Los Angeles-style Sprawl Desirable? *Journal of the American Planning Association*, **63**, 107–126.

Garde, A., 2006. Designing and developing new urbanist projects in the United States: insights and implications. *Journal of Urban Design*, **11**, 33-54.

Goward, S. N., D. G. Dye, S. Turner, and J. Yang, 1993. Objective assessment of the NOAA global vegetation index data product. *International Journal of Remote Sensing,* **14**, 3365-3394.

Goward, S. N., and A. S. Hope, 1989. Evapotranspiration from combined reflected solar and emitted terrestrial radiation: preliminary FIFE results from AVHRR data. *Advances in Space Research*, **9**, 239-249.

Ferguson, T. W., 1997. Down With the Burbs. *Forbes*, **159**, 9.

Fesenmaier, D. R., M. F. Goodchild, and S. Morrison, 1979. The spatial structure of the rural-urban fringe: a multivariate approach. *Canadian Geographer*, **23**, 255-265.

Franques, S. A., B. D. Keim, and A. E. Mosher, 1995. Downtown Dynamics, *Geographical Review*, **4**, 497-517.

Gonçalves, M. L., M. L. A. Netto, J. A. F. Costa and J. Zullo Júnior, 2008. An unsupervised method of classifying remotely sensed images using Kohonen self- organizing maps and agglomerative hierarchical clustering methods. *International Journal of Remote Sensing*, **29**, 3171-3207.

Grable, S. W., 1979, Applying urban history to city planning: a case study in Atlanta. *The Public Historian*, **1**, 45-59.

Habitat, 2001. *State of the world's cities report 2001*. Nairobi: United Nations Center for Human Settlements.

Harris, C., E. Ullman, 1945. The nature of cities, *The Annals of the American Academy of Political and Social Science*, **242**, 7-17.

Hughes, **J. W.,** 1975. Dilemmas of suburbanization and growth controls. *Annals of the American Academy of Political and Social Science*, **422**, 61-76.

Hoekstra, J., 2004. Segregation's End. *Carlton College Voice*, **3**, 1-3.

Hoyt, H., 1939. *The Structure and Growth of Residential Neighbourhoods in American Cities*, Washington, Federal Housing Administration.

Hutchinson, N., B. Perry, 1996. The future/s of the North American city. *Geodate*, **9**, 4.

James, M.E., and S. N. V. Kalluri, 1994. The Pathfinder AVHRR land data set: an improved coarse resolution data set for terrestrial monitoring. *International Journal of Remote Sensing*, **15**, 3347-3364.

Jensen, J. R. Introductory Digital Image Processing. Upper Saddle River: Prentice-Hall. 2005

Jensen, J. R., D. C. Cowen, 1999. Remote sensing of urban/suburban infrastructure and socio-economic attributes. *Photogrammetric Engineering and Remote Sensing*, **65**, 611-622.

Jurgens, C., 2000. Change detection: erfahrungen bei der vergleichenden multitemporalen satellitbildauswertung in Mitteleuropa. *Photogrammetric, Fernerkundung, Geoinformation (PFG)*, **1**, 5-18.

Justice, C, O., J. R. G. Townshend, B. N. Holben, and C. J. **Tucker**, 1985. Analysis of the phenology of global vegetation using meteorological satellite data. *International Journal of Remote Sensing*, **6**, 1271-1381.

Lambin, E, F., 1999. Monitoring forest degradation in tropical regions by remote sensing: some methodological issues. *Global Ecology and Biogeography*, **8**, 191-198.

Lampinen, J., S. Smolander, 1996. Self-organizing feature extraction in recognition of wood surface defects and color images. *International Journal of Pattern Recognition and Artificial Intelligence*, **10**, 97-113.

Leachtenauer, J. C., 1996. National Imagery Interpretation Rating Scales overview and product description, *Proceedings of ASPRS-ACSM Annual Convention*, edited by American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland (Bethesda, Maryland: American Society for Photogrammetry and Remote Sensing), **1**, 262-272.

Lo, C, P., 1986, *Applied Remote Sensing* (New York: Longman).

Lo, C. P., C. W. Pannell, and R. Welch, 1977. Land use changes and city planning in Shenyang and Canton. *Geographical Review*, **3**, 268-283.

Louisiana Regional Planning Commission, 1981. *Transit 81*. Louisiana Government Document.

Louisiana Regional Planning Commission, 1976. *Planning for Future Growth and Development*. Regional Planning Commission for Jefferson, Orleans, St. Bernard, and St. Tammany Parishes for the Louisiana commission on Intergovernmental Relations.

Louisiana Sites and Resources, 1989. *Parish Profile 1989*. Louisiana Department of Economic Development.

Maktav, D., F. S. Erbek, and C. Jürgens, 2005. Remote sensing of urban areas. *International Journal of Remote Sensing*, **26**, 655-659.

Maselli, F., F. Rembold, 2002. Integration of LAC and GAC NDVI data to improve vegetation monitoring in semi-arid environments. *International Journal of Remote Sensing*, **23**, 2475-2488.

Maselli, F., M. Chiesi, 2005, Integration of multi-source NDVI data for the estimation of Mediterranean forest productivity. *International Journal of Remote Sensing*, **10**, 55-72.

Maselli, F., M. A. Gilabert, and C. Conese, 1998. Integration of high and low resolution NDVI data for monitoring vegetation in Mediterranean environments. *Remote Sensing of Environment*, **63**, 208-218.

Mitchell, J., 2001, Urban sprawl. *National Geographic*, **200**.

Mundia, C. N., M. Aniya, 2005. Analysis of land use/cover changes and urban expansion of Nairobi city using remote sensing and GIS. *International Journal of Remote Sensing*, **26**, 2 831-2849.

Nash, E.B., J. E. Conel, 1974. Spectral reflectance systematics for mixtures of powdered hypersthene, labradorite and ilmenite. *Journal of Geophysic Research,* **79**, 1615-1621.

National League of Cities, 2001. *The State of America's Cities: The Seventeenth Annual Opinion Survey of Municipal Elected Officials*. Washington, DC: National League of Cities.

Odum, E. P., 1971. *Fundamentals of Ecology*, 3rd ed. (Philadelphia, PA: W. B. Saunders).

Office for National Statistics, 2001. [http://www.statistics.gov.uk/census2001/pdfs/urban_area_defn.pdf].

Özkan, C., S. F. Erbek, 2005. Comparing feature extraction techniques for urban land-use classification. *International Journal of Remote Sensing*, **26**, 747-757.

Pilon, P.G., P. J. Howarth, R. A. Bullock, and P. O. Deniyi, 1988, An enhanced classification approach to change detection in semi-arid environments. *Photogrammetric Engineering and Remote Sensing*, **54**, 1709-1716.

Prince, S. D., S. N.Goward, 1996. Evaluation of the NOAA/NASA Pathfinder AVHRR Land Data Set for global primary production modeling. *International Journal of Remote Sensing*, **17**, 217-221.

Renzulli, L. A., L. Evans, 2005. School choice, charter schools, and white flight. *Social Problems*, **3**, 398-418.

Reckdhall, K. "Road Home falls short." The Times Picayune 20 Aug. 2008 : A1.

Richardson, L, L., 1996. Remote sensing of algal bloom dynamics. *BioScience*,**46**, No. **7**, pp. 492-501.

Ricotta, C., G. C. Avena, 1999. The influence of principal component analysis on the spatial structure of a multispectral dataset. *International Journal of Remote Sensing*, **20**, 3367-3376.

Rodwin, L, 1950. The theory of residential growth and structure, *Apprasial Journal*, 18, 295-317.

Rozman, G., 1974. Edo's importance in the changing Tokugawa society. *Journal of Japanese Studies*, **1**, 91-92.

Shihadeh, E. S., G. C. Ousey, 1996. Metropolitan expansion and black social dislocation: the link between suburbanization and center-city crime. *Social Forces*, **2**, 649-666.

Scott, T. M., 1975. Implications of suburbanization for Metropolitan Political Organization. *Annals of the American Academy of Political and Social Science*, **422**, 36-44.

Senior, M.L., C. J. Webster, N. E. Blank, 2006. Residential relocation and sustainable urban form: statistical analyses of owner-occupiers' preferences. *International Planning Studies*, **11**, 41-57.

Singer, R. B., 1981. Near-infrared spectral reflectance of mineral mixtures—systematic combinations of pyroxenes, olivie and iron oxides. *Journal of Geophysical Research*, **86**, 7967-7982.

Singer, R. B., T. B. McCord, 1979. Large scale mixing of bright and dark surface materials and implications for analysis of spectral reflectance. *Journal of Geophysical Research*, 1835-1848.

Singh, A., 1989. Change detection in the tropical forest environment of northeastern India using Landsat data. In *Remote Sensing and Tropical Land Management*, M.J. Eden and J.T. Parry (Eds), 237-254 (London: Wiley).

Singh, A., A. Harrison, 1995. Standardized principal components. *International Journal of Remote Sensing*, **6**, 883-896.

Small, C., 2005. A global analysis of urban reflectance. *International Journal of Remote Sensing*, **4**, 661-681.

St. Tammany Parish Government Document, 1976. *St. Tammany Parish Land-Use Report Summary 1976*, Louisiana Regional Planning Commission.

Strauss, A., 1960. The Changing Imagery of American City and Suburb. *The Sociological Quarterly*, **1**, 15-24.

Sunar, F., 1998. Analysis of changes in multidate data set: a case study in Ikitelli Area. Istanbul, Turkey. *International Journal of Remote Sensing.* **19**, 225-235.

Theobald, D. M., 2001. Land-Use Dynamics Beyond the American Urban Fringe. *Geographical Review*, **3**, 544-564.

Thomas, I. L., R. W. Saunders, and D. L. Croom (eds), 1989. Applications of AVHRR data: Special issue. *International Journal of Remote Sensing*, **10**, 597-936.

Torma, M., 1996, Self-organizing neural networks in feature extraction. *International Archives of Photogrammetry and Remote Sensing*, ISPRS XVIII congress in Vienna, Austria, Part B2 xxxi, 374-379, July 1996.

Townshend, J. R. G., C.O. Justice, W. Li, C. Gurney, and J. McManus, 1991. Global land cover classification by remote sensing: present capabilities and future possibilities. *Remote Sensing of Environment*, **35**, 243-256.

Tucker, C. J., 1979. Red and photographic infrared linear combination for monitoring vegetation. *Remote Sensing of Environment*, **8**, 127-150.

Turcotte, M., 2008, Dependence on cars in urban neighborhoods. Supplemental Government Document, 20-30.

United States Census Bureau, *Urban and Rural Definitions*, [http://www.census.gov/population/censusdata/urdef.txt]

---------, 2000. *Geographic Areas Reference Manual*. [http://www.census.gov/geo/www/garm.html].

---------, 2006. *State and County Quick Facts* [http://quickfacts.census.gov/qfd/states/22/22071.html].

Van den Berg, A. E., T. Hartig, H. Staats, 2007. Preference for nature in urbanized societies: stress, restoration, and the pursuit of sustainability. *Journal of Social Sciences*. **63**, 79-96.

Vanderee, D., D. Ehrlich, 1995. Sensitivity of ISODATA to changes in sampling procedures and processing parameters when applied to AVHRR time-series NDVI data. *International Journal of Remote Sensing*, **16**, pp. 673–686.

Walker, J. S., and T. Blaschke, 2008. Object-based land-cover classification for the Phoenix metropolitan area: optimization vs. transportability. *International Journal of Remote Sensing*, **29**, 2021-2040.

Waring, H.R., S. W. Running, 1997. A continental phenology model for monitoring vegetation responses to interannual climatic variability. *Global Biogeochemical Cycles*, **11**, 217-234.

Weiher, G. R., 1989. Public Policy and Patterns of Residential Segregation. *The Western Political Quarterly*, **1**, 651-677.

Whittlesey, D., 1929. Sequent Occupance. *Annals of the Association of American Geographers*, **19**, 162-165.

Yang, R., P. A. Jargowsky, 2006. Suburban Development and Economic Segregation in the 1990s. *Journal of Urban Affairs*, **28,** 253-273.

Yang, X., C. P. Lo, 2002. Using a time series of satellite imagery to detect land use and cover changes in Atlanta, Georgia. *International Journal of Remote Sensing*, **23**, 1775–1798.

Yang, X., C. P. Lo, 2001. Using a time series of satellite imagery to detect land use and land cover changes in the Atlanta, Georgia metropolitan area. *International Journal of Remote Sensing*, **9**, 1775-1798.

Government and Web Resources

http://library.uno.edu/
http://www.jstor.org/
http://www.taylorandfrancisgroup.com/
www.esri.com
http://edcsns17.cr.usgs.gov/EarthExplorer
www.usgs.gov
http://atlas.lsu.edu
www.usda.gov
www.census.gov
www.doi.gov
www.dotd.louisiana.gov
http://earth.google.com
www.stpgov.org
http://factfinder.census.gov

Appendix A

Table 1 St. Tammany Population and percent increase

St. Tammany Population and Percent Increase by Decennial Census (1900-2008)

Year	Population	% increase
1900	13335	N/A
1910	18917	29.51%
1920	20645	8.37%
1930	20929	1.36%
1940	23624	11.41%
1950	26988	12.46%
1960	38643	30.16%
1970	68585	43.66%
1980	110869	38.14%
1990	144508	23.28%
2000	191268	24.45%
2008	270000	29.16%

Source: Census.gov

Table 2 Retail Trade Sales, St. Tammany Parish (1977-2007).

	Retail Trade Sales (in 1000's)	% Growth
1977	250,747	N/A
1982	492599	49.10%
1987	796003	38.12%
1992	1070000	25.61%
1997	1511469	29.21%
2002	2155481	29.88%
2007	4384900	50.84%

Source: NAICS, SIC, and Census.gov

Table 3 St. Tammany Parish non-farm establishments 1980-2006 (business permits)

St. Tammany non-farm establishments (by permit)	
Year	**# of establishments**
1980	1662
1981	1751
1982	1969
1983	2425
1984	2662
1985	2898
1986	2919
1987	2898
1988	2814
1989	2875
1990	2958
1991	3081
1992	3240
1993	3411
1994	3645
1995	3812
1996	4132
1997	4361
1998	4433
1999	4510
2000	4635
2001	4744
2002	4950
2003	5039
2004	5265
2005	5479
2006	5659
Source:	censtats.census.gov

Table 4 St. Tammany Parish selected job field growths between 1970 and 2000

Occupation		**St. Tammany selected occupation increases**	
	1970	2000	1970-2000 % change
Construction	2073	8044	288.04%
Manufacturing	4020	6866	70.80%
Transportation	873	4308	393.47%
Retail	3259	11423	250.51%
FIRE	850	6045	611.18%
Health	1160	10399	796.47%
Education	1462	7421	407.59%

Source: NAICS and Census.gov

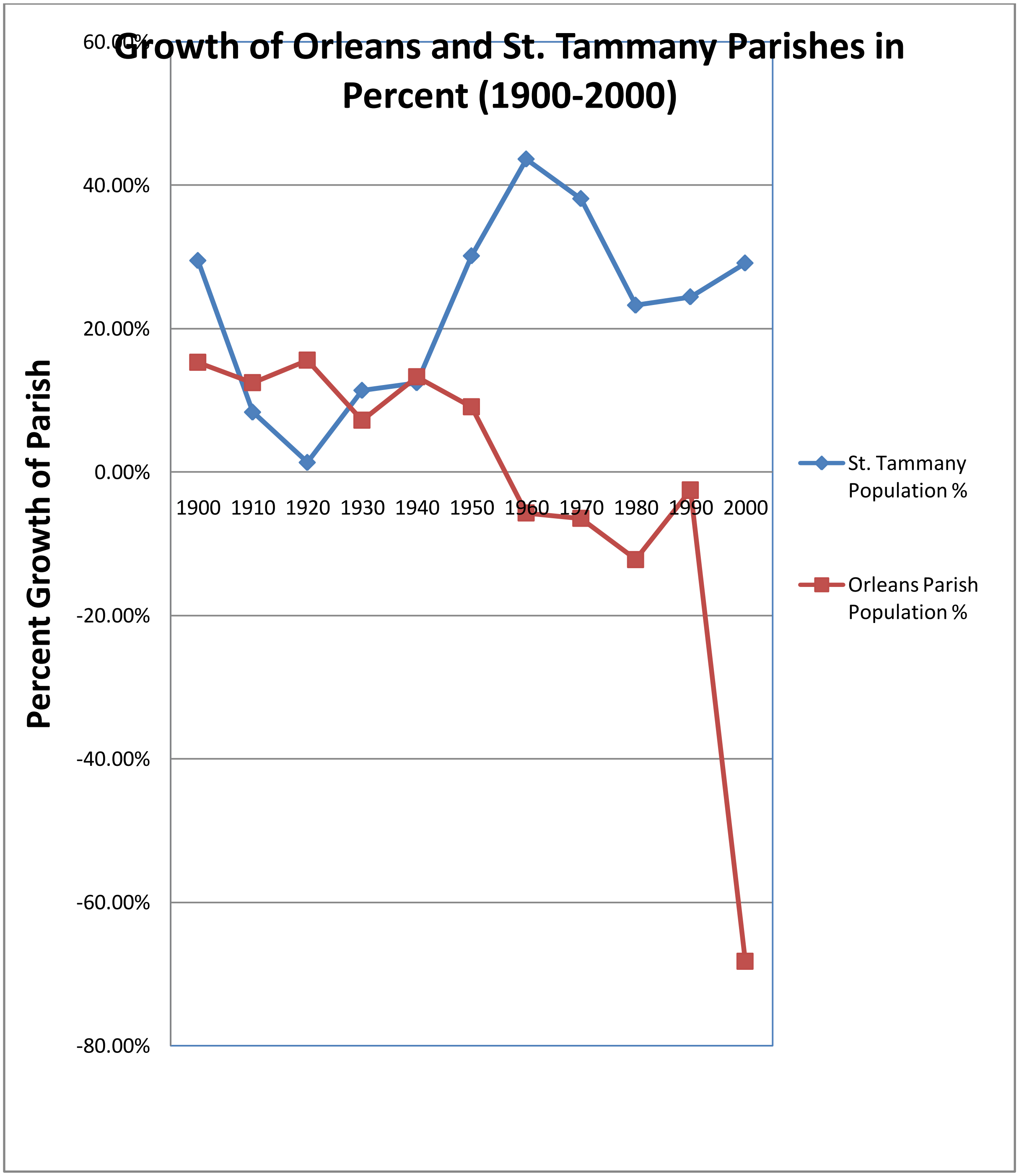
Table 5 St. Tammany selected occuptaion increases (1970-2000)

Occupation	**St. Tammany selected occupation increases**		
	1970	2000	1970-2000 % Change
Construction	2073	8044	288.04%
Manufacturing	4020	6866	70.80%
Transportation	873	4308	393.47%
Retail	3259	11423	250.51%
FIRE	850	6045	611.18%
Health	1160	10399	796.47%
Education	1462	7421	407.59%

Source: NAICS and Census.gov

Appendix B

Figure 1 Growth percentages of Orleans and St. Tammany parishes



Source: Census.gov

Figure 2 St. Tammany non-farm establishments as listed by permit per year (business class)

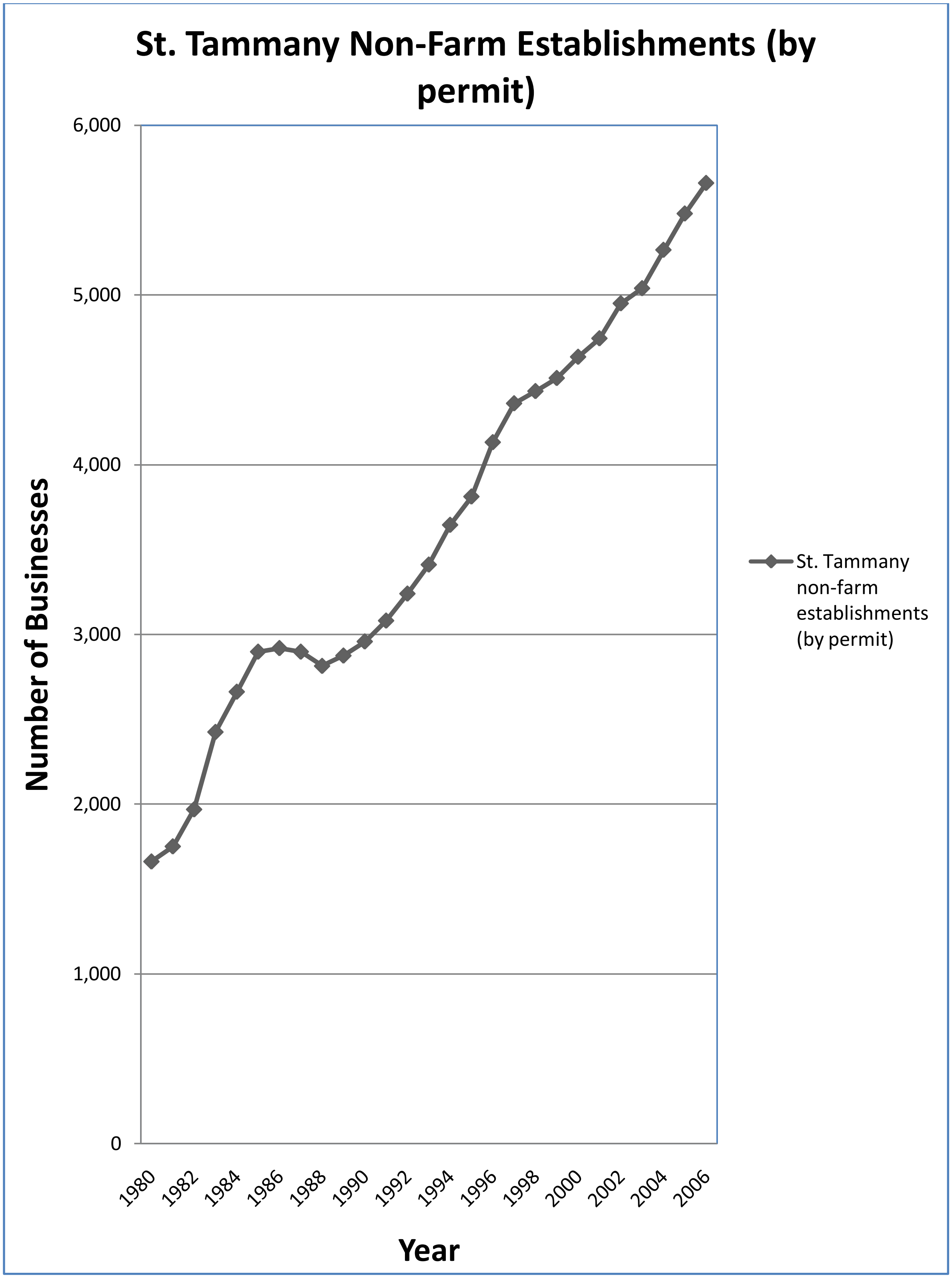
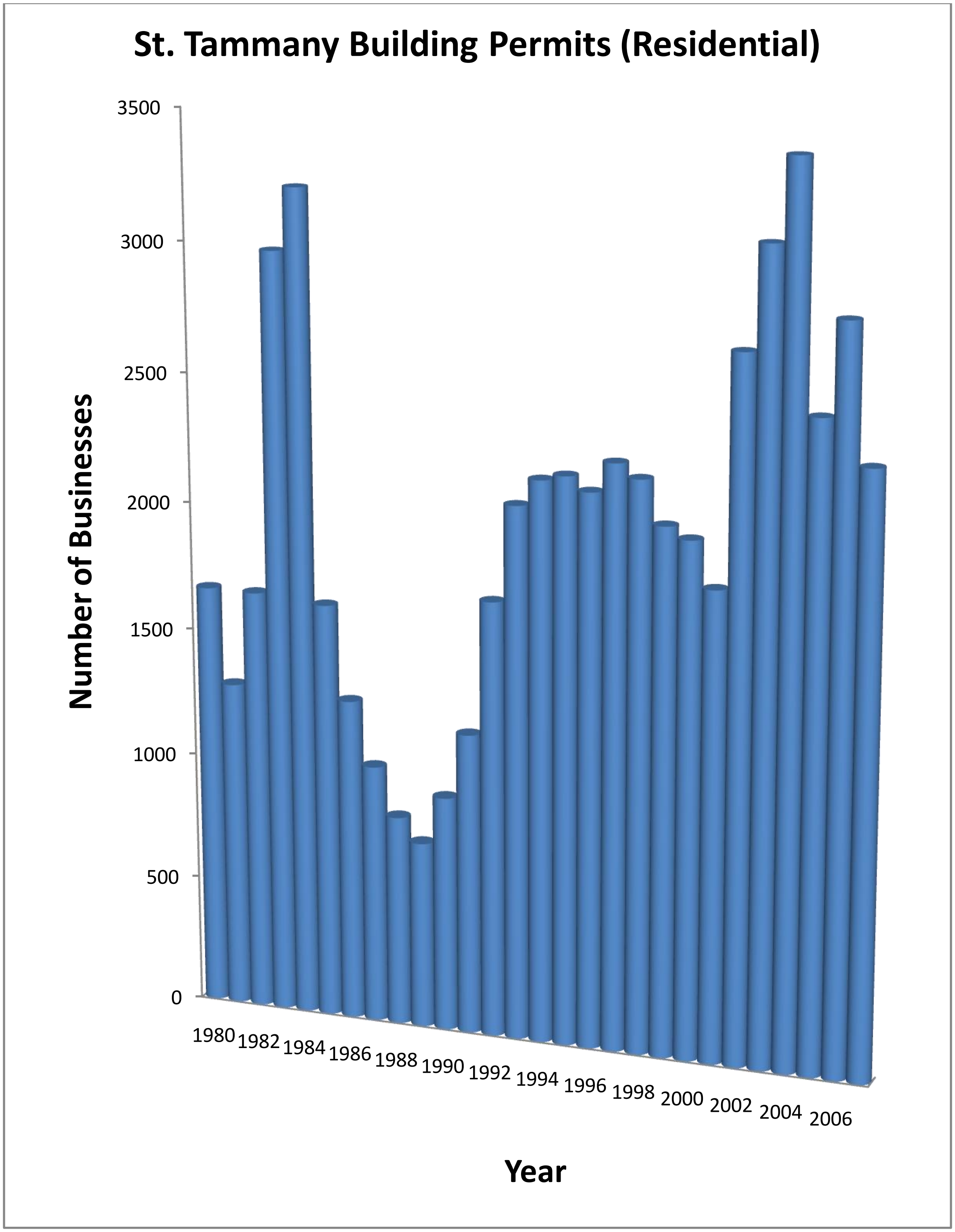
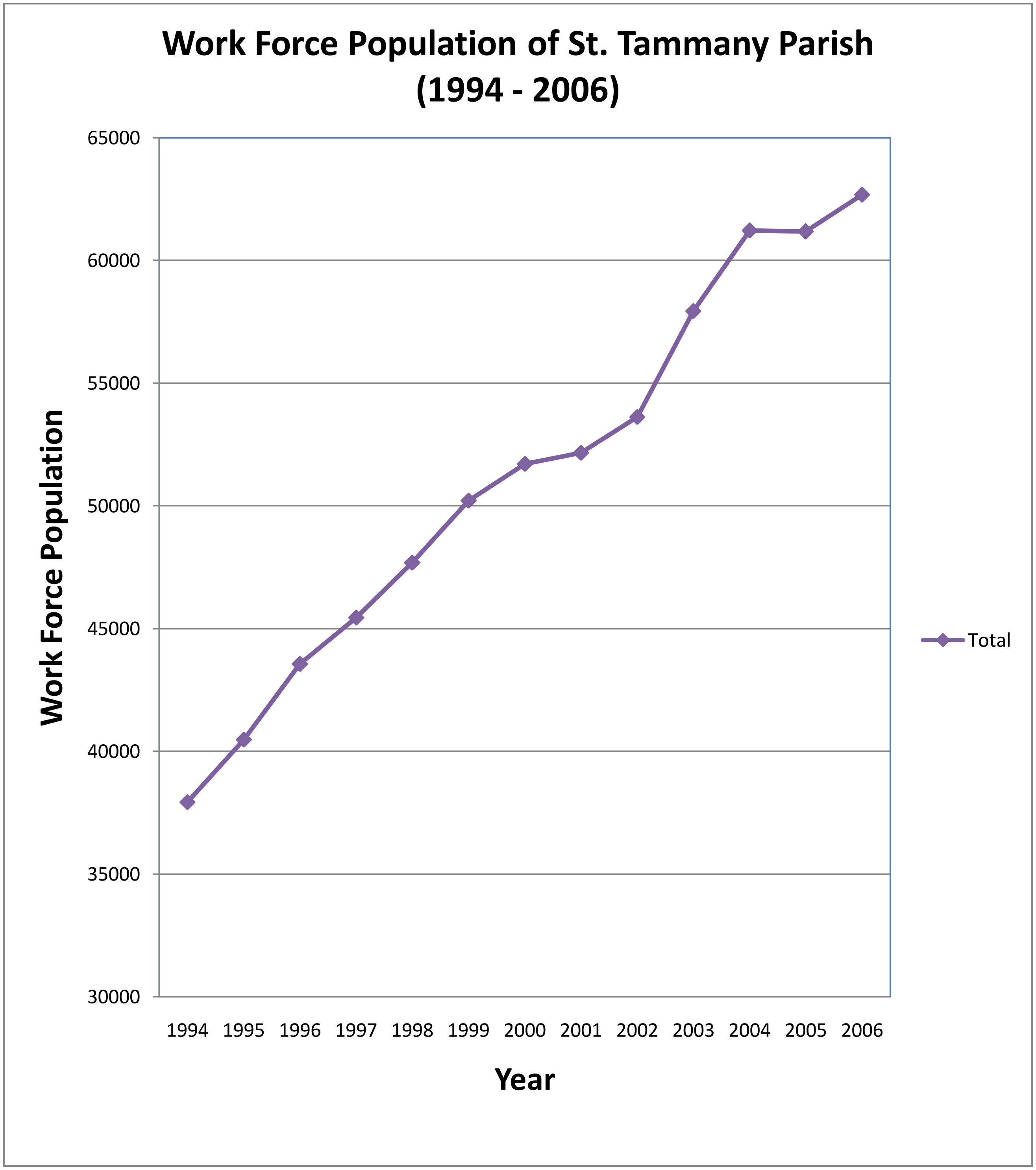


Figure 3 Building permits issued for residential buildings in St. Tammany Parish



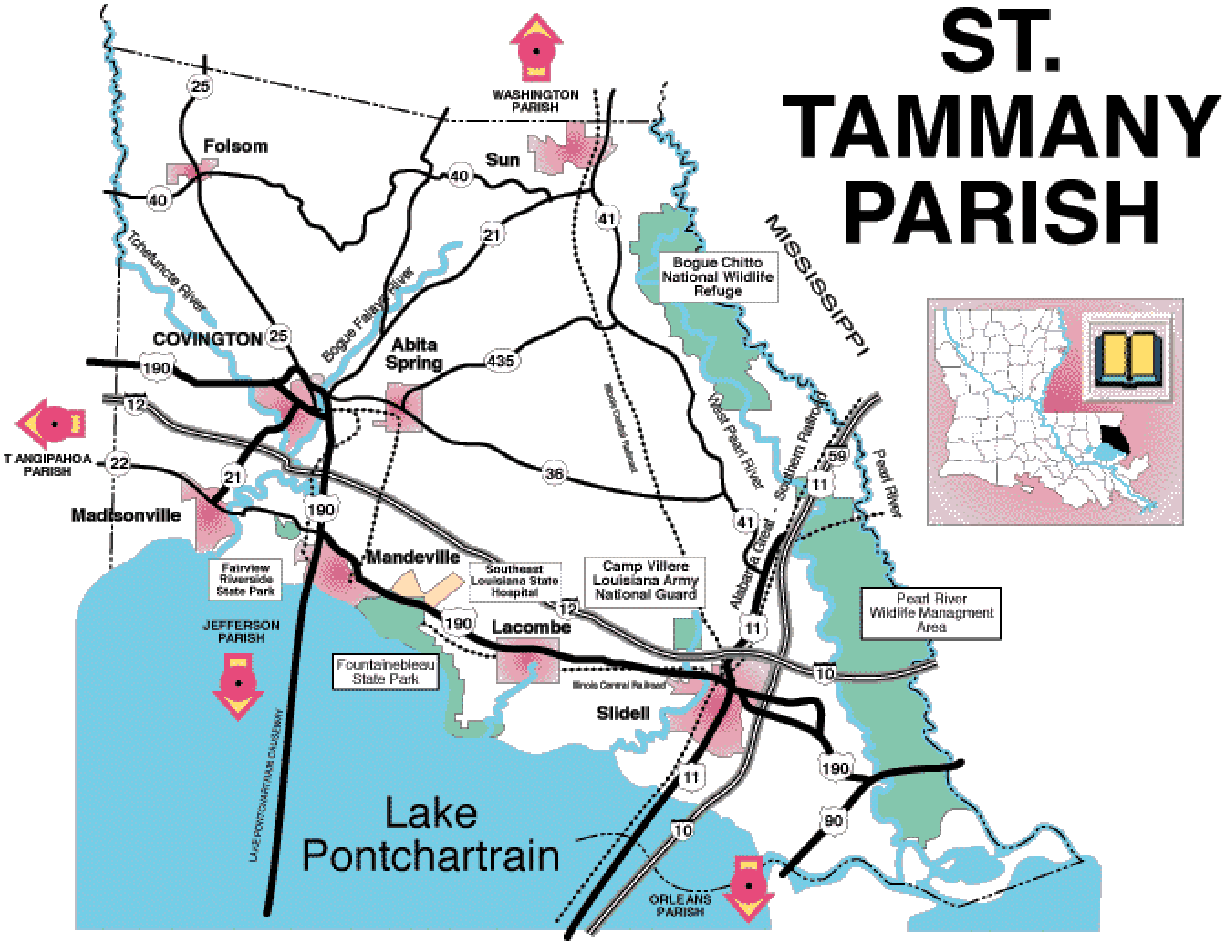
Source: Census.gov

Figure 4 Worker population of St. Tammany Parish (1994-2006)



Source: Source: SIC (1994-1997) and NAICS (1998-2006)

Figure 5 Detailed map of St. Tammany Parish. Urban areas are shaded light pink/red



Source: Encyclopedia Louisiana, www.enlou.com (2009).

Vita

Jeffrey Varisco was born in Slidell, Louisiana to an admittedly suburban family. He graduated from Andrew Jackson Fundamental High School in 2000. He then went to the University of New Orleans first as Computer Science major, then English, and finally finished with a B.A. in Philosophy in the Spring of 2005. It was during the last two years of his B.A. that Jeffrey began taking courses in Geography; this would be the catalyst for his decision to return as a graduate student in Geography.

Jeffrey resumed studies in the fall of 05’ focusing on technical and urban aspects of geography. However, in August 2005, only 1 week had passed in the semester of his inaugural graduate year before Hurricane Katrina shuttered the university for the fall semester of 05’. Jeffrey evacuated to Atlanta, GA, and later Osaka, Japan. Technically speaking, Jeffrey did not begin his master’s studies until the spring of 06’. In order to satisfy his graduate studies minor, Jeffrey enrolled in a number of planning courses, both urban and environmental. This would serve as the frame work for the graduate thesis ultimately.

When not in school, the author is involved in multiple hobbies: tennis, electronic music composition, bartending (more like a job but it still remains *fun*), fine wine consumption, epicurean affairs and sailing on yachts make for a busy and fulfilling life outside of graduate studies. Jeffrey plans to eventually use this master’s thesis as a bridge to higher studies in a related field such as urban planning.