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Thomas A. Green
Minnesota State University - Mankato

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Determining Exurbia: Is It Really Its Own Entity or Merely An Extension of Americas Growing Suburbia

By
Thomas Green

A Thesis Submitted in Partial Fulfillment of the Requirements for a
Master of Science Degree
In
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Determining Exurbia: Is It Really Its Own Entity or Merely An Extension of Americas Growing Suburbia

Thomas Green

This thesis has been examined and approved by the following members of the thesis committee.

Dr. Fei Yuan, Advisor

Dr. Jose Lopez

Dr. Brenda Kayzar

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Abstract

The purpose for studying exurbanization is to evaluate the spatial spread of metropolitan areas into their immediate hinterlands through remote sensing satellite imagery. This includes addressing scholar's inability to define exurbia, along with plausible reasons people move into exurbia. In addition, determination will include consideration on the possibility that exurbia has become an extension of America's growing and increasingly independent suburbia or; recognize that exurbia exists, but within various geographic locations. In return to the former, an analytical approach was taken to investigate scholar's inability to provide a definition to this phenomena; as well as inconsistent results on the push and pull factors behind people's desire to move further outward. Therefore, the need for remote sensing, GIS analysis that includes statistical implementation is necessary to determine the potential location of exurban developments.

This includes three study areas, which are St. Louis, Twin Cities and Los Angeles. Each city were evaluated through 1990 and 2000 census data information and satellite imagery. The level of impervious verses non-impervious land area for selected census tracts were determined, as the main findings indicate a substantial increase of urban sprawl within St. Louis and Twin Cities. As for Los Angeles, this area maintained a level of compact urban development from 1990 and 2000 census tract data, satellite imagery and geospatial analysis. These findings indicate two different results: (1) Los Angeles has a high probability that exurbia is an extension to suburbia; (2) St. Louis and Twin Cities experienced substantial increase of urban sprawl that suggests the possibility of continued exurban existence.

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1. INTRODUCTION

Exurbia was first introduced by Auguste C. Spectorsky in his (1955) book publication "The Exurbanites." According to Spectorsky, exurbia is defined as being rural and mostly located inside agricultural areas ten or more acres in size. Those that reside within these areas are usually the wealthy, which maintain a strong connection to the city. This strong connection to the city, yet residing in rural areas, is what Spectorsky suggests as an exurbanite. These exclusive communities Spectorsky refers to, while based on New Yorkers settling in New Jersey rural areas, have become common place throughout much of the United States and abroad. The purpose of this analysis is to investigate exurbia's existence, with the possibility that its existence is reliant on certain geographic locations as temporal analysis of all three study sites will provide differences of historical development and urban sprawl patterns. Therefore, an applied research basis will be conducted and divided into three parts. First, discussion of common characteristics many scholars have agreed upon as exurbia and exurban development. Second, a systematic random processes of census tracts of three separate study areas will be investigated through the usage of remote sensing and GIS techniques; as well as statistical analysis of entropy that should provide evidence that exurbia has become an extension of suburbia, but only within certain geographic locations. Finally, once the entropy along with two one-way ANOVA's and a Tukey Test to support the entropy have been completed; a determination on the difference of each study area and the potential existence of exurbia with certain geographic locales can be represented. Overall, the three components of this investigation will provide evidence and reasons to the difficulties in the study of exurbia.

1.1 Statement of Problem

As mentioned before, Auguste C. Spectorsky (1955) has been credited as introducing the term "exurbia" and presenting a description to the American public the idea of an "exurbanite;" however, overtime scholar's attempt to analyze and understand exurbia has resulted in numerous inconsistent findings and definitions toward this phenomenon. While a portion of this is due to the changes in urban development patterns, partially from technological factors, such as the automobile. A second issue toward inconsistent results is from the increase amount of Americans that have left the city in search for the ideal lifestyle as depicted by Spectorsky, and supported by Lance (1972, Nelson (1992), Whitelegg (2002). This in turn has resulted in some scholar's, such as Arthur Nelson (1988), that have suggested the possibility that exurbia is perhaps merely an extension of America's growing suburbia and should not be classified or regarded as a separate entity of urban growth.

By keeping this in mind, the methodological approach to this study will include implementation of the Shannon's Entropy, along with one-way ANOVA and the tukey test; together all three geospatial techniques should determine the existence of exurbia, particularly within the St. Louis and Twin Cities study areas. As for the intensification of urban infill within the Los Angeles study area, evidence should indicate that exurbia has become an extension of suburbia; therefore supporting the claim that exurbia does exist, but its existence is reliant on certain geographic locations. In return, this will provide explanation on why scholars and private non-profit organizations have resorted to approaching exurbia through various techniques. As it has become clear scholars for the past half century have failed to reach a consensus on the differences, and spatial boundaries between exurban to rural and suburban to exurban. In light of these issues, techniques that have been implemented to analysis the location and existence of exurbia include social identifiers; as well as, theorizing environmental concerns, which includes the use of computerized techniques, such as GIS and remote sensing satellite imagery.

The approaches of studying exurbia, while extensive, have uncovered several different factors based on regional differences of its existence. Even though, studies by Arthur Nelson (1988) have found convincing support to the claim that exurbia is nothing more than an extension to suburbia. These claims by Arthur Nelson, however, have been contradicted by his own studies later re-suggesting the possibility that exurbia does exist (Nelson 1992). Therefore, a proposed careful analysis will be conducted that will include a brief analysis of social identifiers on why people re-locate to exurban areas; the possibility that exurbia is merely an extension of suburbia; and finally, the implementation of statistical interpretation along with remote sensing and GIS techniques, in order to determine the potential location of exurban areas.

With implantation of remote sensing, GIS and United States Census tract data, an additional concern arises in regards to accuracy and the question of ecological fallacy.

According to Jargowsky (2004), an ecological fallacy is “the assumption that relationships between variables at the aggregate level imply the same relationships at the individual level.” This definition and others similar to the above present the concern of skewed results in regards to socio-economic, race and ethnicity within census tract data; however, the presence of ecological fallacies with United States census data will likely continue as the federal law does not allow the release of individual information of census count recipients specified under title 13 of the U.S. code (Zayatz 2005). Therefore, the census bureau must release data within a group format, thus presenting the potential of outliers with census block, tract, county, state and national level data.

1.2 Background

The terms, “exurbia,” “exurbanite,” “exurban” and “exurbanization” are credited as being first introduced by Auguste C. Spectorsky in his (1955) book “The Exurbanites.” Even though Spectorsky was presented in reference to New Yorkers settling into the New Jersey country-side, this concept is used today by many current scholar’s that investigate exurban areas, such as, David M. Theobald, Jill Clark and Arthur Nelson. Their contribution to our understanding of exurbanization, has unfortunately, produced more questions than answers.

Many scholar's throughout their analysis of exurbia and exurban development patterns have conflicting views as to define this phenomenon; to some, it is merely an extension of suburbia (Kirsten and Ross 1968; Nelson 1988; Whitelegg 2002 & Sutton et. al 2006) or seen as some phenomena uniquely different (Barnes et al. 2001; Theobald

2001, 2004 and 2005; Larsen et al. 2007; Clark et al. 2009; Taylor 2009). The latter scholar's that view exurban development as a unique and different phenomena, additionally analyze the environmental consequences of exurbanization. Nonetheless, these conflicting views have left the study of exurbia to become one of the most complex and undetermined phenomena's in the realm of Geography, as well as other social science disciplines.

Despite increased growing speculation to some scholar's that exurbia may be an extension to suburbia, evidence has been introduced that exurbia does exists as its own entity. This existence though depends on geographic locations. The evidence that exurbia can be classified as its own entity has basis that most exurban development areas are formed by the wealthy. Even though these select groups of people have situated themselves among agricultural and natural forested settings, their connection to the city is strong. They have chosen to commute far from urban central core areas to avoid urban congestion, pollution and crime.

Nonetheless, since Auguste C. Spectorsky's book, three common characteristics have appeared in most manuscripts, theses, monographs, and journal articles concerning exurbanization. The most common characteristic of exurbia is: low density (mostly residential, with light commercial development), or low density residential discernment without any commercial development. The demographics of these exurbanites are predominately wealthy, mostly Caucasian, middle aged Americans that have the tendency to be heavily connected to the city; but prefer the remote tranquility of open spaces.

Some have argued though, that all three characteristics are nothing more than the stereotypical suburban sprawl; white Americans, heavily dependent on their automobiles, prefer to live outside of urban areas as a means of avoiding the common pitfalls of urban settlement, such as crime, congestion and noise (Apel 2008).

Beginning in the last quarter of the twentieth century, the focus of exurban studies shifted from trying to understand what type of people are moving to exurbia to newer concerns. These new foci include the loss of habitat and biodiversity (Hart 1976; Daniels and Nelson 1986; Camagni et al. 2002; Theobald 2001, 2004, 2005; Clark et al. 2009) as well as concerns over suitability of water management practices (Barnes et al. 2001; Stefanov et al. 2001; Yin et al 2005). This shift in focus is due impart to the rapid growth of global cities centralized in water deficient areas, and their insatiable appetite for natural resources. Presently, the main goals of exurban studies is to map exurban areas using remote sensing and GIS technology and somehow give exurbia a clear working definition, one that separates it from suburbia.

The problems behind using remote sensing and GIS to analyze and evaluate exurbanization, indicates the ambiguity of this phenomena. In fact, exurbanization is ambiguous as the concept of urban sprawl. The way exurbanization and urban sprawl should be defined is debatable as mentioned by Ban and Ahlqvist (2009). For example, Barnes et al. (2001) and Whitelegg (2002) provide agreement that exurbia is a form of urban sprawl as low-density leapfrog or scattered development occurs that includes a lesser connection with the immediate urban central core area. This is additionally presented with many scholar's agreeance that exurbia is possibly a component of 'white flight,' as upper-middle to elite status Caucasian Americans flee to more tranquil environments for child rearing, low crime and traffic congestion (Vance 1972; Barnes et al 2001; Whitelegg 2002).

Since defining exurbanization has become a hindrance to scholars, many have resorted to the utilization of remote sensing and GIS techniques as an inexpensive way to analyze potential locations of exurban development; but most importantly, it is an attempt to define and differentiate the areas that are rural or non-rural. In return, researchers could determine the extent of urban sprawl, along with measuring the extent of exurban development and its existence (Qiu et al. 2003; Alberti et al. 2004; Yuan el al. 2005; Yin et al. 2005; Torrens 2005; Ji et al. 2006; Sutton et al. 2006; Burube et al. 2006; Jat et al. 2008; Brown et al. 2008; Dewan and Yamaguchi 2009; Ban and Ahlqvist 2009; Poelmans and Rompaey 2009).

1.3 Study Area

The analysis of exurbanization and the possibility of its existence within certain geographic locations will be represented with three study areas. These three study areas are the metropolitan areas of St. Louis, Missouri, Twin Cities, Minnesota and Los Angeles, California (Figure 1.1).

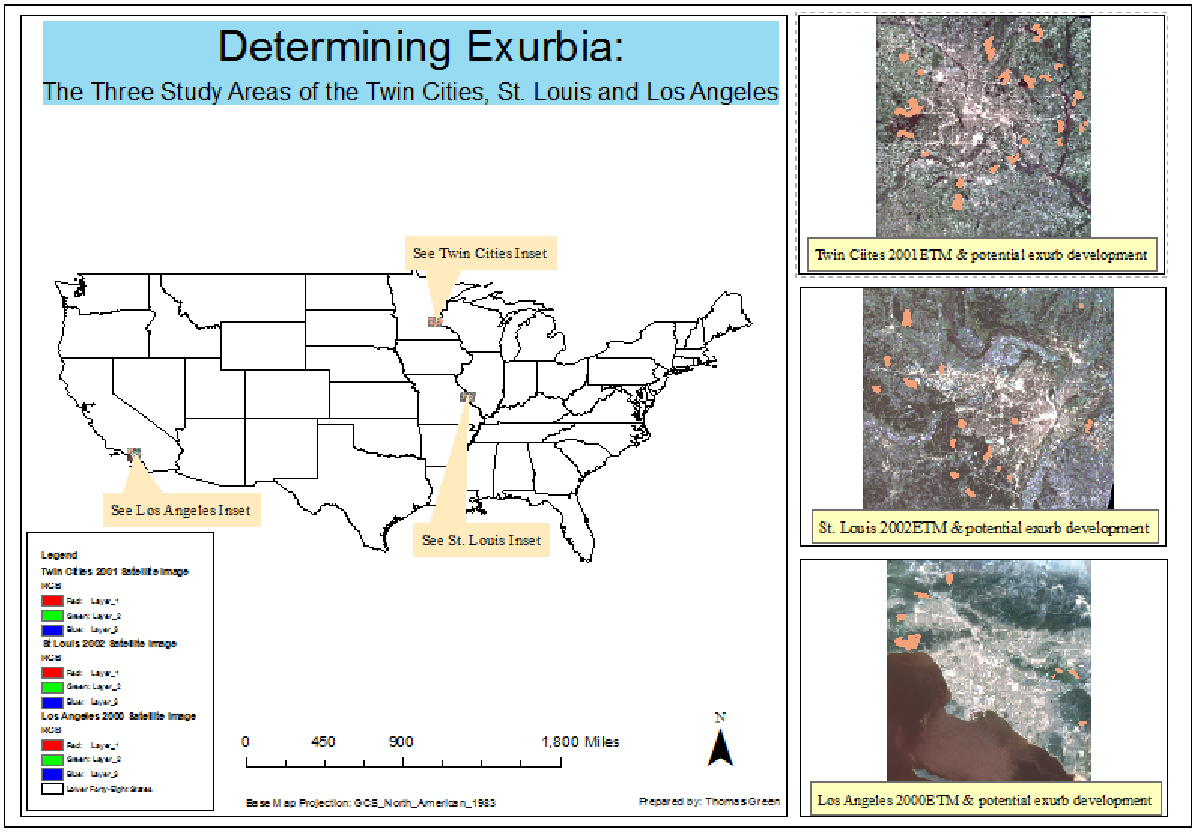

Figure 1.1: Map of the lower forty-eight conterminous United States with inset and caption of the three metropolitan areas that are featured in this study.

As seen in Figure 1.1, all three study areas have the potential of exurban development; however, it is imperative to acknowledge their geographic and economic environments. The Twin Cities and St. Louis areas are comparable in terms of metropolitan land area and population. In addition to the previous, both are situated within the Mississippi River watershed and are absent of topographic or political boundary obstacles that will alter urban sprawl outward from their respective central core areas. On the other hand, the Los Angeles study area is much larger in both land area and population when compared to St. Louis and Twin Cities. This alternatively includes the temporal urban development existing timeframe of Los Angeles that has experienced rapid urban sprawl much longer than either St. Louis or Twin Cities study areas.

Aside from the spatial differences Los Angeles has from the other two study sites, which includes temporal and population factors; another contrast between these three study sites is the former is handicapped by its geographical location in terms of topography and political boundaries. This handicap is due to the extensive urban sprawl the city had already experienced throughout much of the latter half of the twentieth century that has caused the metro to be blocked on all four sides. These geographic and political obstructions include the Pacific Ocean to its west and southwest, the San Gabriel Mountains to the north, the Santa Ana mountains to the east, and finally; Camp Pendleton Marine Base to the south, which additionally separates the Los Angeles Metropolitan Area from the San Diego Metropolitan Area.

Even though the Los Angeles study area is different in scale, size and includes geographic obstacles that prevent further urban sprawl, all three metropolitan areas will assist to determine the potential effects urban sprawl has on defining exurban development. In the case of Los Angeles, California, the significant increase of urban sprawl, particularly within suburbia, has resulted in a transformation of exurban areas to become an extension of suburbia. This extension, in turn, has caused exurbia to have similar characteristics to suburban areas, as evidence has indicated on the increase of independence suburbia has obtained from the original central core, because of cheaper land values that are more appealing to commercial and industrial development; as well as, America’s present reliance on the automobile (Kersten and Ross 1968, Vance 1972 & Whitelegg 2002). Even with the possibility that exurbia has become an extension to suburbia in the case of Los Angeles; there is however, the likelihood this is not the case for the Twin Cities and St. Louis areas.

In discussion of St. Louis, Missouri and Twin Cities, Minnesota Metropolitan Areas, these two study areas will be used to evaluate the continued existence of exurbia. These two areas, at present, have not experienced the high level of excessive outward growth that other United States metropolitan areas have witnessed, such as, Los Angeles, California throughout the 1960’s and 1970’s or Atlanta, Georgia throughout the 1990’s; nor have these two final study areas have sprawled enough to find their metropolitan areas hugging or overlapping with adjacent metropolitan areas, as the case of Los Angeles.

2. LITERATURE REVIEW

The literature reviewed has been separated into three sections. This has been done with the intent of producing a clear perspective on the historical significance of exurbanization, who are exurbanites, the issues with defining exurbia, and the problems with delineating the spatial location of these areas. The three sections are: understanding exurbia, the possibility exurbia is merely an extension of America's growing suburbia, and the geospatial techniques used to analyze exurbia.

2.1 Understanding Exurbia

In order to understand exurbanization a number of approaches have been conducted, which include, the implementation of social identifiers, spatial proximity measurements from the central core areas to the outer fringe, and environmental concerns. The extent of analyzing exurbanization through numerous fields of study have resulted in more ambiguities, inconstancies, and differing views to the location of this phenomena; along with the possibility that exurbanization is merely an extension to America's growing suburbia (Davis et al. 1994; Nelson 1992 and 1997; Barnes et al. 2001; Crump 2003; Hansen et al. 2005; Berube et al. 2006; Ban and Ahlqvist 2009).

The implantation of social identifiers has become the most common attempt to evaluate and analyze exurbanization as it has become central to many scholars' interpretations toward the phenomena, such as, the investigative approaches taken by

Jackson (1985), Daniels & Nelson (1986), Davis et al. (1994) and Gillman (2002). However, to return to Spectorsky, he defined an exurbanite as someone of White European ancestry, with an upper-middle class background that wanted to live outside of the central core area; as well as, being located outside of the suburban periphery to escape urban congestion, pollution and crime. These people basically wanted a tranquil natural environment far outside the central core, but close enough to maintain the conveniences of city life. This perception of who are exurbanites and the reasons behind their influence to live outside immediate metropolitan areas continues at present.

In the latter quarter of the twentieth century to present, exurbanization analyses have gone through numerous fields of science and social science inquiries, which have all yielded divergent views due to the different scientific methodological approaches. These approaches of analysis toward exurbanization include social identifiers that have been altered and elaborated on by Jackson (1985), Daniels and Nelson (1986), Nelson (1988, 1990 and 1992), and Taylor (2009). In fact, Taylor (2009) highlights that America went on to embrace the ideal lifestyle that was first established by affluent New Yorkers that were involved with the financial, advertisement and entertainment industries. "These New Yorkers published books, articles and magazine ads of the ideal lifestyle and in return, presented evidence of Spectorsky's dark-side of exurban living" (Taylor 2009). This 'dark-side' toward exurbia suggests that overtime more Americans would want the taste of the ideal Jeffersonian lifestyle. In return, as more American's moved outward to be a part of this ideal lifestyle, environmental consequences would ensue as people would eventually destroy this very ideal.

Aside from the social identifiers that have been determined to be useful in the extent of emphasizing a basic understanding of people that are potential exurbanites, it has become clear this alone will not suffice; therefore, the implementation of statistical methods and spatial parameters become a required component in the analysis of locating the potential areas of exurbia, in relation to suburban and urban areas. The implementations of statistics, as well as, social identifiers on the analysis of exurban areas have some scholar's giving credit to Arthur Nelson. Even though, Nelson is quoted as rejecting the usefulness of statistical analysis, his contribution has laid down the ground work for future scholars, such as Berube et al. (2006) and Brown et al. (2008). These credits given to Arthur Nelson, with his continued attempts to characterize exurbanization suggest the relentless determination scholar's have in defining exurbia (Taylor 2009).

The implementation of statistical analysis, however, has become better supported impart to the advancement of computerized technology and software programs. These computer software programs include the capabilities to view and interpret satellite imagery, such as ERDAS™ and IDRISI™; or the ability to calculate statistics, one of many components within ArcGIS™. In the past fifteen years, the practices of using remote sensing techniques have provided contribution to the continual analysis of exurbanization. Scholar's that have implemented remote sensing and GIS to determine exurban development include, the contributions of Theobald (2001, 2004 and 2005), Carrion-Flores and Irwin (2004), Yuan et al (2005) and Clark et al. (2009).

Even though implementation of statistical analysis or the use of remote sensing and GIS techniques have pushed the study of identifying exurbia through technical processes, it's important to recognize the continued implementation of social identifiers. Social identifiers that were formally introduced by Spectorsky, were altered by later scholars such as, Hart (1976), Daniels and Nelson (1986), Nelson (1988 and 1992) and Theobald (2001). These scholars began to define exurbanites as former urbanites that would purchase large land lots within agricultural or forested environments to escape urban life. At times, exurbanites where additionally defined as the purchasers of old or abandoned farms that on occasion were utilized as a small farm itself (Jackson 1985; Daniels and Nelson 1986).

The elaboration of socially identifying present differences between an exurbanite and suburbanite, which additionally required the implementation of spatial parameters, resulted in an expanded definition of exurbanization. In turn, this ultimately skewed the lines between rural and exurban areas, in relation to exurban and suburban areas. Unfortunately, the debate on who are and who are not exurbanites, and whether or not exurbia is merely an extension to America's growing suburbia began to become suggested, even by Arthur Nelson (Nelson 1988, 1994 and 1997; Taylor 2009).

Nonetheless, the implantation of setting spatial parameters and statistics to assist in understanding and determining the location and extent of exurban developments has opened the door to numerous interpretations of its existence. Current analysis within the realm of social identifying exurban areas, along with statistics and spatial parameters include case studies, regional planning policies, and one on one interviews with spatially defined boundaries. These studies have included the contribution of many scholars within various fields of study, such as, Lamb (1983), Crump (2003) and Cadieux (2008). While Lamb (1983) approaches the study of exurbanization through statistical methods similar to Arthur Nelson, Crump (2003) and Cadieux (2008) on the other hand; have conducted their case study analysis, with the first on Sonoma County, California; and the second, Christchurch, New Zealand.

These case studies, by Crump (2003) and Cadieux (2008) took a questionnaire approach, which was based on defined parameters set by previous scholar's interpretation of suburban and exurban areas. The purpose of both studies was to define exurbanites, along with differentiating them from suburbanites, as the case of Crump's (2003) analysis of Sonoma County, California. Crump's (2003) study found several similarities and differences between those defined as suburbanites and exurbanites. According to the results of Crump's case study, both suburbanites and exurbanites had a close percentage of wanting the convenience of nearby open spaces; along with low crime and job opportunities. On the other hand, the study found four major differences of opinion in regards to level of important amenities a suburbanite and exurbanite expected. These differences found most suburbanites considered easy access to major transportation road networks and higher cost of housing as extremely important to their choices of living location. As for exurbanites, they mostly considered high level of privacy and clean air as essential to their living environments.

The latter claim of exurbanites essential desire of clean air and privacy as being considered highly imperative for their living environments, are supported through additional exurbanization analyses from numerous scholars of various fields of study. These analyses, in return, incorporate their environmental concerns of agricultural lands, biodiversity, and the pollution of water resources. In order to determine these effects, scholars have conducted soil and water pollutant samples, as well as the tracking of wildlife both migratory and non-migratory with the purpose of evaluating differences of habitat. The various studies conducted, with many determining inconsistent results, there has been found support to the claim that exurbanites are possibly destroying the natural settings they enjoy (Barnes et al. 2001; Maestas et al. 2001; Camagni et al. 2002; Hansen et al. 2005).

Aside from scholar's divergent views and suggested findings that exurbanites are perhaps destroying the natural settings they enjoy, some studies have found evidence of the contrary. An example of one study comes from Larsen et al (2007) where a case study of a former Colorado ranching valley is used to determine the attachment exurbanites have on the natural environment. The objective of Larsen et al (2007) study wanted to investigate whether or not exurbanites were absent of place perception; and therefore, had minimal to complete absence of social interaction with neighbors both long term or short term. This study found convincing evidence however, that exurbanites within this study location had constant contact with long term and short term residents of the area. These short term residents, many of which were considered exurbanites, were aware of minimal water resources, as well as providing their own concern over threatening environmental hazards.

2.2 Is Exurbia merely an extension of Suburbia?

The findings of who are and who are not exurbanites through social identifiers, along with various statistical and spatial approaches suggesting that exurbia is merely an extension of America's growing suburbia. This suggestion will be examined through various techniques that will include three study areas. These three study areas, as mentioned earlier, will represent the existence of exurbia; along with indication that erratic and excessive urban sprawl can result in exurban developments in becoming a part of America's growing suburbia. Therefore, all three study areas included in the analysis will determine exurbia's existence, but within certain geographic locations.

Even though the purpose of this study includes determining the present existence of exurbia, under certain geographic locations, scholars have argued the contrary. The agreement that exurbanization is simply an extension of suburbia can be seen in several monographs and journal articles. These monographs and journal articles have analyzed exurbanization through various detailed statistical and spatially defined approaches; as well as socio-economic and regional urban land-use planning analysis. Kersten and Ross (1968), Taaffe et al. (1980), Landis (1983) Jackson (1985), Davis et al. (1994), Nelson and Sanchez (1997 and 2005), Gillham (2002), Whitelegg (2002), Echeique and Homewood (2003) and Landis (2009) have all suggested exurbanization is simply an extension of America’s growing suburbia, or has examined the changes of rural environments into semi-urban to urban environments as part of urban sprawl.

These author’s have either considered the possibility that exurbia may perhaps be its own entity; however, their analyses have classified this phenomena as typical urban sprawl that is attributed to various causes of urban outgrowth. Therefore, some scholar’s have suggested the implementation of urban containment practices and policies. For instance, Kersten and Ross (1968) and Whitelegg (2002) evaluated the de-centralization of America’s major cities, since the end of the Second World War. In their analysis they detailed the excessive re-location of commercial and industrial areas from the central core to suburban areas. This, in return, results in secondary business districts that are distinct from the original business district. In result to the re-location of both commercial and industrial areas, this has allowed people to move further away from the original central business district (CBD) and commute to the much closer secondary CBD.

The analysis by Kersten and Ross (1968) and Whitelegg (2002) can be supported by Vance (1972) Taaffe et al. (1980) and Echenique and Homewood (2003) that the automobile has assisted in the spread of people further outward from the central core areas. While these scholar’s have determined the automobile as a technological factor that has allowed people to move further outward; the re-location of commercial and industrial facilities to suburban areas due to cheaper land values has additionally allowed further dispersion outward from central core areas (Kersten and Ross 1968; Vance 1972; Taaffe et al. 1980; Gillman 2002; Landis 2009). This, in turn, has resulted in various exurbanization investigators to suggest that exurbia is a component of urban sprawl; and therefore, is an extension to America's growing suburbia.

Some of the exurbanization investigators that have suggested the possibility that exurbia is simply an extension of suburbia, include Arthur Nelson. Nelson and Sanchez (1997 and 2005) investigate the causes to the rise of exurbia, where they determine influences that have attributed to this phenomenon. The influences indicated in Nelson and Sanchez (1997) discuss post-industrial, cultural, technological and political pull factors that have resulted in population dispersion further out from the central core area. Furthermore, these influences that have been supported by public and private organizations have caused metropolitan areas to increase substantially in population and land acreage, with noticeable central core population decrease (Kersten and Ross 1968; Taaffe et al. 1980; Gillman 2002 and Landis 2009).

The argument that exurbia is merely an extension of suburbia is well supported. Nonetheless, many scholars, including Arthur Nelson, finds himself contradicting his previous findings with the suggested possibility that exurbia is its own entity that is distinct from suburbia. This continued perception that exurbanization itself is simply another component of America's urban sprawl, results in the current analysis of this phenomena. As past and present debate by scholars on finding the location of exurbia has resulted in this study to address the existence of exurbia through geospatial technical analysis. The reason behind investigating exurbia through geospatial techniques, presents the understanding on the inability of successfully defining exurbia, and the ways this component of urban sprawl differs from ordinary suburbia. Therefore, the remainder of this study will represent the technical aspects applied to determine the location of exurban development patterns and its potential existence within certain geographic locations through geospatial analysis.

2.3 Geospatial Techniques to Analyze Exurbia

The geospatial techniques that were applied to the study came exclusively from ArcGIS 9.3™ and remote sensing ERDAS Imagine™ software. Geospatial techniques provided from these software systems have become, in essence, the central backbone to analyze and investigate urban sprawl and urbanization spatial patterns. While analysis have included social identifiers and possible environmental and wildlife concerns, the usage of GIS data and remote sensing satellite imagery have assisted in delineating spatial parameters of exurban and suburban areas. Unfortunately, exurbia has become difficult to define as some scholar's have referenced this phenomenon as a component of urban sprawl; this inconsistency has thereby resulted in divergent results through spatial analysis techniques. The differences in interpretation are at times due to different fields of study and their varied methodological approaches (Taylor 2009); another reason for inconsistency is geographic location (Sutton et al. 2006). The latter concern of geographic location indicates that some areas have succumbed to extreme urban sprawl, particularly in the conterminous United States eastern seaboard of the mid-Atlantic region. This area has experienced such intense urban sprawl, the argument that exurbia has become more suburbia in nature exists.

As remote sensing and GIS have become intensely used, particularly within the last ten to fifteen years; many studies will indicate its usefulness toward the analysis of land cover and land use change. However, these two separate geospatial software applications were used for the purpose of this investigation to delineate the areas that may potentially have exurban development. As utilization of these two software systems with intent to delineate urban sprawl or exurbanization can be seen in previous scholarly works as Sutton et al. (2006), Jat et al. (2008), Ban and Ahlqvist (2009), Poelmans and Rompaey (2009), Bhatta et al. (2010) and Shrestha and Conway (2010). In various applications, scholars have evaluated analytical and empirical approaches to determine the rate of urban sprawl or exurbanization. The analyses of both exurbanization and urban sprawl are similar with their concern over the environment, reduction of forested and non-forested lands, water resources and migratory and non-migratory habitat concerns (Qiu et al. 2003; Alberti et al. 2004; Yin et al. 2005; Yuan et al. 2005; Ji et al. 2006; Dewan and Yamaguchi 2009).

These various spatial analysis techniques that have been additionally analyzed for their level of accuracy can be seen through Wentz et al. (2006), Jat et al. (2008), Shrestha and Conway (2010) and Bhatta et al. (2010). Wentz et al. (2006) discusses three different methodological approaches and determined the usefulness of all three, in relation to conditions of usage. The three methodological approaches analyzed was the usefulness of aerial photography, satellite imagery, and ground observation, with the purpose to determine accuracy of land use and land cover mapping in arid urban environments (Wentz et al. 2006). In addition, Wentz et al. (2006) found that satellite imagery was the most useful in terms of classifying land coverage; however, the inclusion of aerial photography and ground observation are valuable to assist in classification procedures to provide higher accurate results.

Jat et al. (2008) and Bhatta et al. (2010) both included the Shannon Entropy method to analyze and monitor urban sprawl. This approach measures the degree of impervious areas in relation to, non-impervious areas on a scale from zero to $\log_e$. The range of scale from zero to $\log_e$ provides the investigator a mathematical and visual pattern of urban sprawl; and therefore, the closer the variable is to zero indicates compact impervious areas. On the other hand, if the variable is closer to $\log_e$, then this indicates wide dispersion of impervious areas, which supports the spatial measurement of urban sprawl.

The process of delineating exurban development by Shrestha and Conway (2010) included the usage of SPOT satellite imagery, along with a Normalized Difference Vegetation Index (NDVI), in relation to a Normalized Difference Built-up Index (NDBI) method. This approach additionally included an unsupervised classification and implementation of thresholds, in regards to the NDVI image. Accuracy assessment results were poor; comparatively, the NDVI process had the highest percentage of overall accuracy. A post-classification assessment was performed to improve the overall classification accuracy. This latter process has become essential in the analysis of urban sprawl as high levels of error are common, due to similar spectral reflectance of urban areas and bare soil (Yuan et al. 2005 and Jat et al. 2008).

The various interpretations of exurbia are clearly recognizable through previous analysis, which are additionally presented with implementation of GIS and remote sensing techniques. Even though divergent and inconsistent results are present, these have to do with ambiguously defined spatial parameters of exurbia. Nonetheless, exurbia is strongly examined for its social, political, economic, and its spatial distribution in reference to central core areas. Therefore, the provided literature of social identifiers, statistical analysis, and data interpretation within various disciplines has the potential to determine the current existence of exurbia, in relation to specific geographic locations.

3. METHODS AND RESULTS

The methodological approaches for this study include similar process analyses that have been utilized in previous studies, in regards to determining the spatial location of exurbia. These techniques initiated are from ERDAS Imagine 9.3, and ESRI ArcGIS 9.3 software, two of the most powerful and widely used systems. These two separate software systems will be utilized to analyze the three selected study areas. A basic step by step approach was taken that included, data collection, pre-processing, classification, and post-classification within ERDAS Imagine 9.3 (Figure 3.1). The study area of Los Angeles entailed additional pre-processing, along with the basic processing and post-classification. As for the other two study areas, the additional pre-processing that was initiated for Los Angeles was not necessary for the analysis.

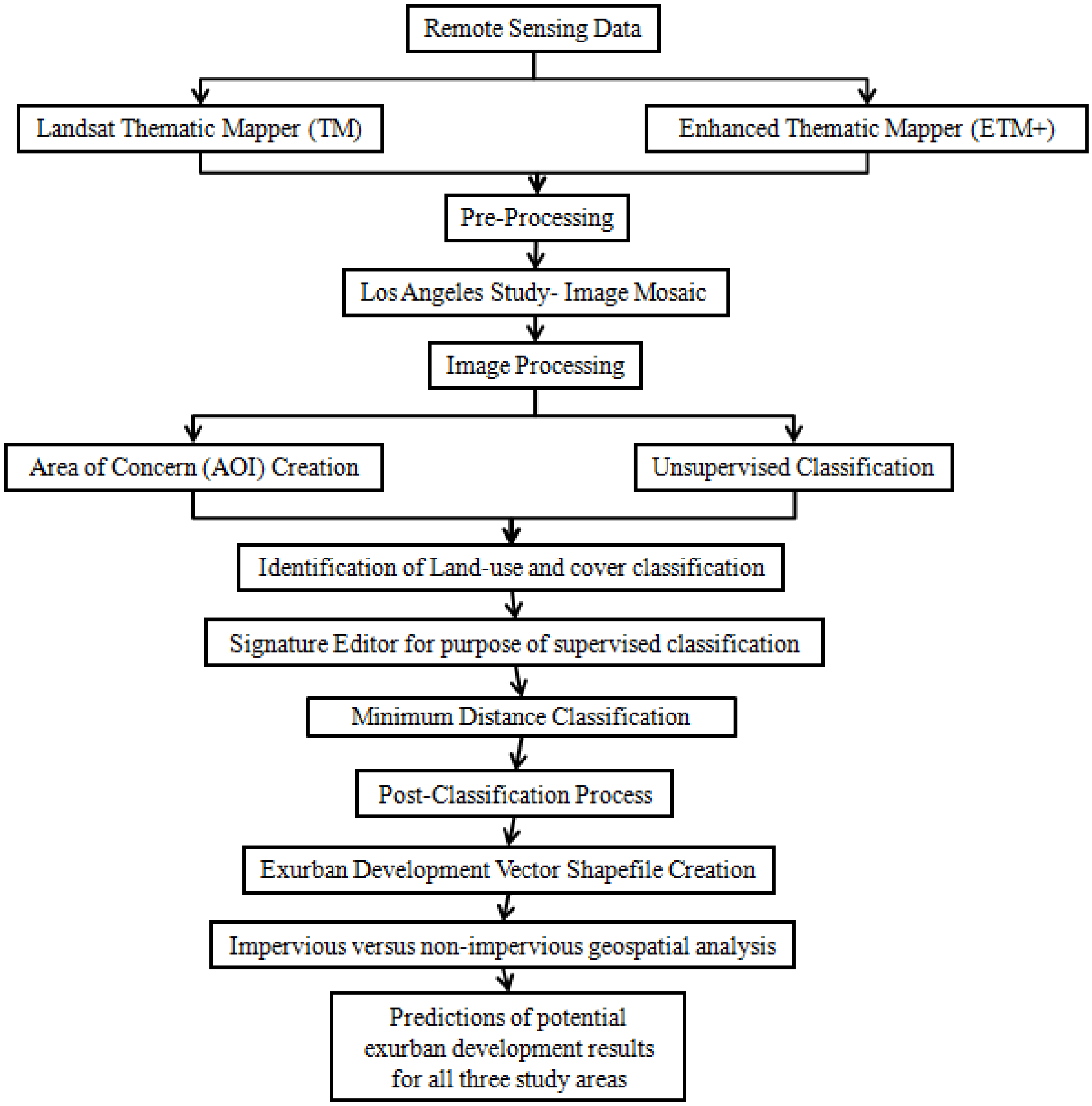

Figure 3.1: Flow Chart that represents the collection of data and analysis process that followed, which lead to the final results of this study.

3.1 Data Acquisition and Pre-Processing

Satellite imagery was acquired exclusively from the United States Geographical Survey (USGS) website for all three study areas. The acquisition of data for these study areas includes both Landsat Thematic Mapper (TM), and Enhanced Thematic Mapper(ETM+) imagery. These satellite images that were downloaded, particularly for Los Angeles, had different years available for public access; the satellite images from different years would result in presenting inconsistent spectral reflectance values. Therefore, the additional pre-processing technique necessary for the Los Angeles study area was a mosaic of two satellite images taken one year apart from the other, which in turn, resulted in some minor differences in spectral reflectance. The minor difference in spectral reflectance consisted of one satellite image having a minimal brighter quality than the other.

It is imperative to clarify however, that prior to conducting an image mosaic for the Los Angeles study area, the data that was acquired from USGS for all three study areas had to be converted from its default of TIFF format to ERDAS.img. This pre-process was conducted in ERDAS 9.3 model builder. Once each study area was converted from TIFF format to image, then pre-processing of each study area could begin. This pre-process, as mentioned earlier, included additional analysis for the study areas of Los Angeles. The situation with the Los Angeles study area required a mosaic of two separate satellite images in order to incorporate the entire Los Angeles Metropolitan Area.

The mosaic of the Los Angeles area, once completed, a process of drawing an Area of Interest (AOI) around the three separate study areas began. This process of AOI creation for all three study areas of St. Louis, Missouri, Twin Cities, Minnesota and Los Angeles, California was required for both the 1990 and 2000 satellite images for the intent to shrink the file sizes of each study area to a more manageable interpretation (Figures 3.2 and 3.3).

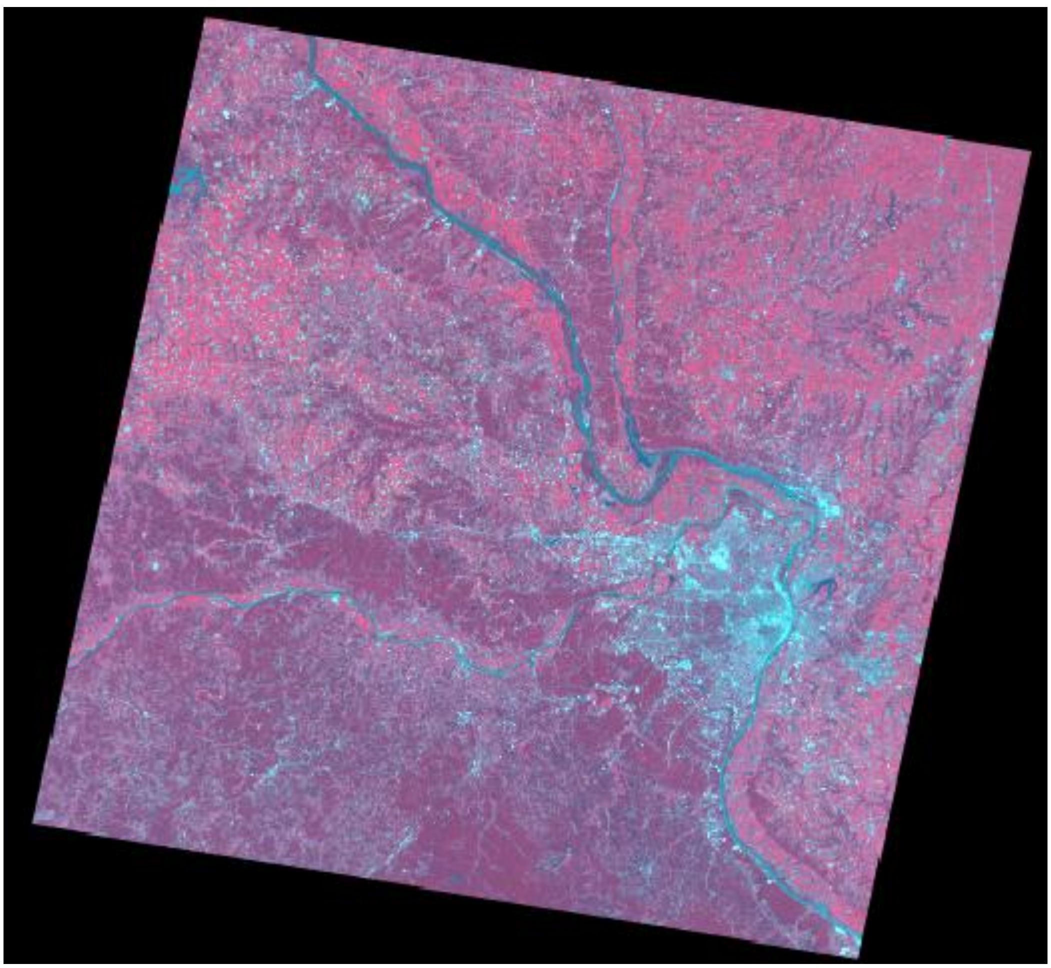

Figure 3.2: This is the original downloaded 1990 image of St. Louis, one of three study areas, prior to the implementation of an AOI to extract the immediate metropolitan area; as well as; create a smaller file for improved accuracy of classification.

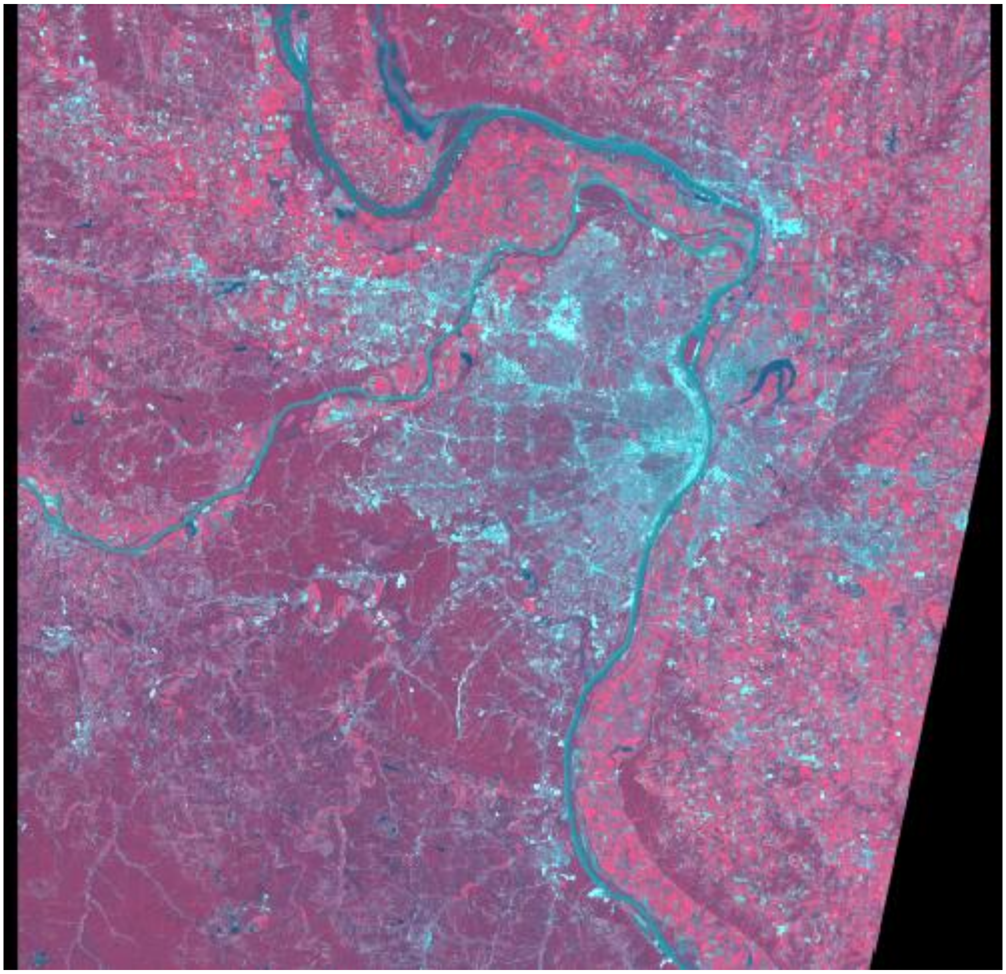

Figure 3.3: The 1990 St. Louis Metropolitan Area following the implementation of an AOI, which was in return saved as the new original base image for classification and post-classification analysis.

After the mosaic and subset process an additional processing technique was applied to the Los Angeles image, which was the inclusion of band 6 (thermal band). This band was included in attempt to differentiate snow cover from cloud cover, which had similar reflectance coloration over the San Gabriel Mountains and Pacific coastline. The inclusion of band 6 (thermal band) for the study area of Los Angeles proved to be un-necessary, however. This determination was found (Schowengerdt 2007), where snow and cloud spectral reflectance are noticeably different.

According to Schowengerdt (2007), clouds give off a white to bluish white color in the 4-3-2 false color composite; whereas, snow cover typically gives off a black to dark color. Nonetheless, Figure 3.4 displays the Los Angeles area with its cloud coverage along the Pacific coast; as well as, following the implementation of data mosaic and AOI new image creation.

Figure 3.4: The Los Angeles Metropolitan area1989 image as downloaded through USGS and converted into image format through ERDAS. There is clear cloud coverage along the Pacific coastline, which was classified separately to distinguish its spectral reflectance from the other classifications.

3.2 Image Classification

Image classification is a basic process necessary for the analysis of remotely sensed data. The entire purpose of image classification is to create themes of various land cover types off the pixels values that are included within a satellite digital image. These themes of different land cover classes are represented to enhance image quality and provide easier analysis of land cover features. How are these pixels classified into the land cover classes? This occurs through the spectral reflectance wavelength all satellite data are embedded within its images. All of the pixels are identified with a digital number that in turn, allows the image to be classified based on digital value. Therefore, as classification occurs these digital values become clumped together to create a single unique class, hence water bodies or vegetation.

Aside from the basic understanding of image classification, it is important to note the various different image classification techniques available, in reference to the techniques utilized for this study. Some of the classification techniques available through ERDAS Imagine 9.3 is supervised and unsupervised, as well as, maximum likelihood, minimum distance, and parallelepiped classification. The final three, which were not used for this study, are defined somewhat on the basis of their names. Maximum likelihood takes a statistical approach to the pixel values within an image and could provide the most accurate classification of land coverage; however, this is dependent on the level of signature accuracy that was provided by the analyzer that should not be relied on. Minimum distance classification, on the other hand, utilizes the mean vector of each signature segment, and this too can provide error if the data does not have the Gaussian distribution; which is, the standard normal bell-shaped curve as seen in Figure 3.5 (Campbell 2007).

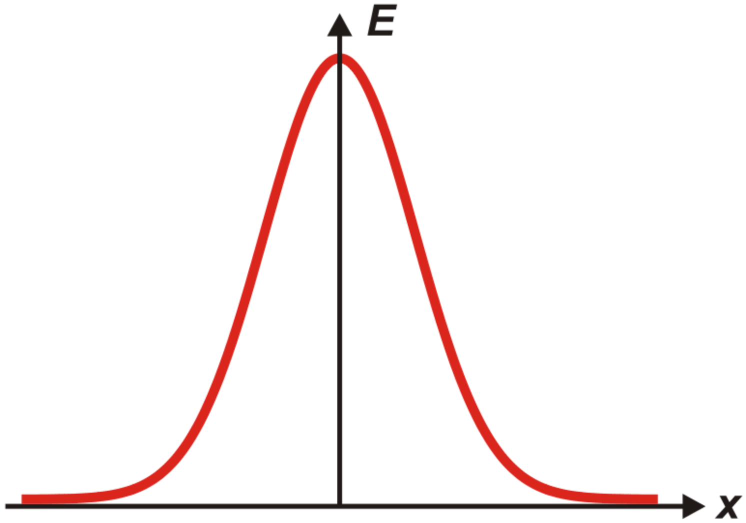

Figure 3.5: Illustration of the Gaussian distribution, which is an example of a normal curve that provides assistance in classifying accuracy when analyzing satellite imagery.

Finally, the parallelepiped classification, as representative of its name, classifies the pixel values that are within the limits of a parallelepiped. The problem with this image classification process is some pixel values can fall into more than one class, or may not fall within the boundaries of any class that generates a poor accuracy assessment (Campbell 2007).

As for the image classification techniques that were utilized for this study; the supervised and unsupervised classification techniques represent the most commonly implemented techniques for image classification. The image classification scheme conducted for this study began with an unsupervised, followed by a supervised; and finally, a post-classification process to ensure the most accuracy possible for each study area.

3.2.1 Unsupervised Classification

The unsupervised classification allows the user to define a minimum amount of parameters in order to disclose statistical patterns, which are already imbedded inside the data. Even though, these statistical patterns may not be explicitly equivalent toward the characteristics within the data; an unsupervised classification, however, allows an algorithm process to get as close as possible to the distribution of the images digital number values.

While two basic unsupervised methods exist, the Red, Green, Blue (RGB) clustering and the Iterative Self-Organizing Data Analysis Technique (ISODATA), the latter was implemented for this study. The parameters of the ISODATA clustering procedure began by setting the number of classes to forty. Throughout the ISODATA algorithm process it is important to note the first iteration mean value is decided upon arbitrarily, where "n" is representative of the amount of clustering designated by the user. As each iteration process runs a new mean value is calculated in relation to, the actual spectral location of the pixels in the cluster. This iteration process will cease once the maximum amount of iterations have been met that were set by the user, or the convergence threshold of 0.95 has been reached.

The reason it is critical to set a maximum number of classes, and a convergence threshold prior to running the ISODATA cluster technique is to ensure that the unsupervised classification process will not run forever. Once the ISODATA process is complete, the forty spectral classes were re-coded into five information classes: water, high density urban, low density urban, agriculture/bare soil and vegetation. These five classes will determine the location of existing high density urban, in relation to potential exurban areas; particularly, within low density urban and agriculture or forested areas. The reason these five classes were selected has to do with the inability to directly classify exurbia patterns because of their ambiguous nature.

Even though an un-supervised classification can assist the user to analyze separate classes for each area, the accuracy is unfortunately poor as spectral reflectance of high density urban has close similarity to agriculture and barren rock (Yuan et al. 2005; Jet et al. 2008; Dewan and Yamaguchi 2009; Ban and Ahlqvist 2009; Bhatta et al. 2010 & Shrestha and Conway 2010). As previous studies indicate the similarities of spectral reflectance, a supervised classification will assist to improve the level of accuracy for all study areas.

3.2.2 Supervised Classification

The supervised classification process began with the creation of AOI's within the signature editor located in the classifier tab of ERDAS Imagine 9.3. Once all AOI's were created, the image was classified to the same five information classes of: water, high density urban, low density urban, agriculture/bare soil and vegetation (Figure 3.6); a minimum distance classification was initiated.

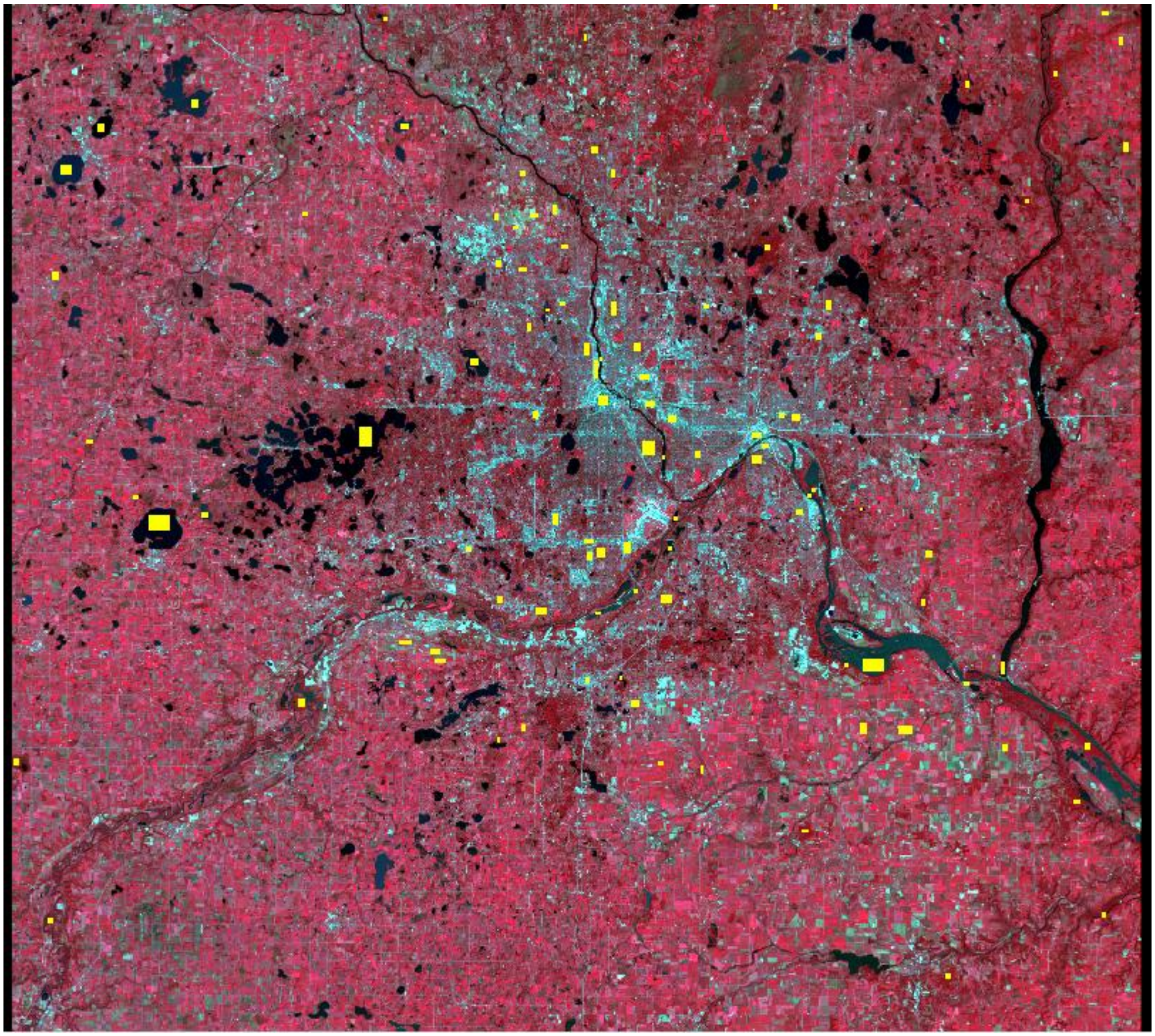

Figure 3.6: Screen capture of Area of Interest (AOI) of the Twin Cities metropolitan area, which includes the additional supervised classification AOI's of all five designated classes for the study of land use change.

The reason a minimum distance classification was initiated for the Twin Cities and St. Louis areas, instead of a maximum likelihood classification, was due to the absence of the thermal band. On the other hand, it is imperative to emphasize for the Los Angeles study area, the thermal band (band 6) was include for its analysis. Even though, the inclusion of the thermal band for the Los Angeles study area proved to be useless in the attempt to delineate cloud cover along the Pacific shoreline from snow located in the San Gabriel Mountains; this still resulted in a maximum likelihood classification to occur exclusively for this study area.

This being said, however, the difference between a maximum likelihood and minimum distance classification is extremely limited; as well as subjective to the analyzer (Schowengerdt 2007 & Short 2010). When comparison is made from the Los Angeles study area to both the Twin Cities and St. Louis study area satellite images, there is a certain level of brightness within the five information classes. For example, the Los Angeles study area reflectance levels resulted in certain areas along the Pacific coastline to be clustered through the ISODATA procedure as high density urban, instead of water. In addition to the errors uncovered within Los Angeles, the Twin Cities and St. Louis study areas have issues as well (Figure 3.7).

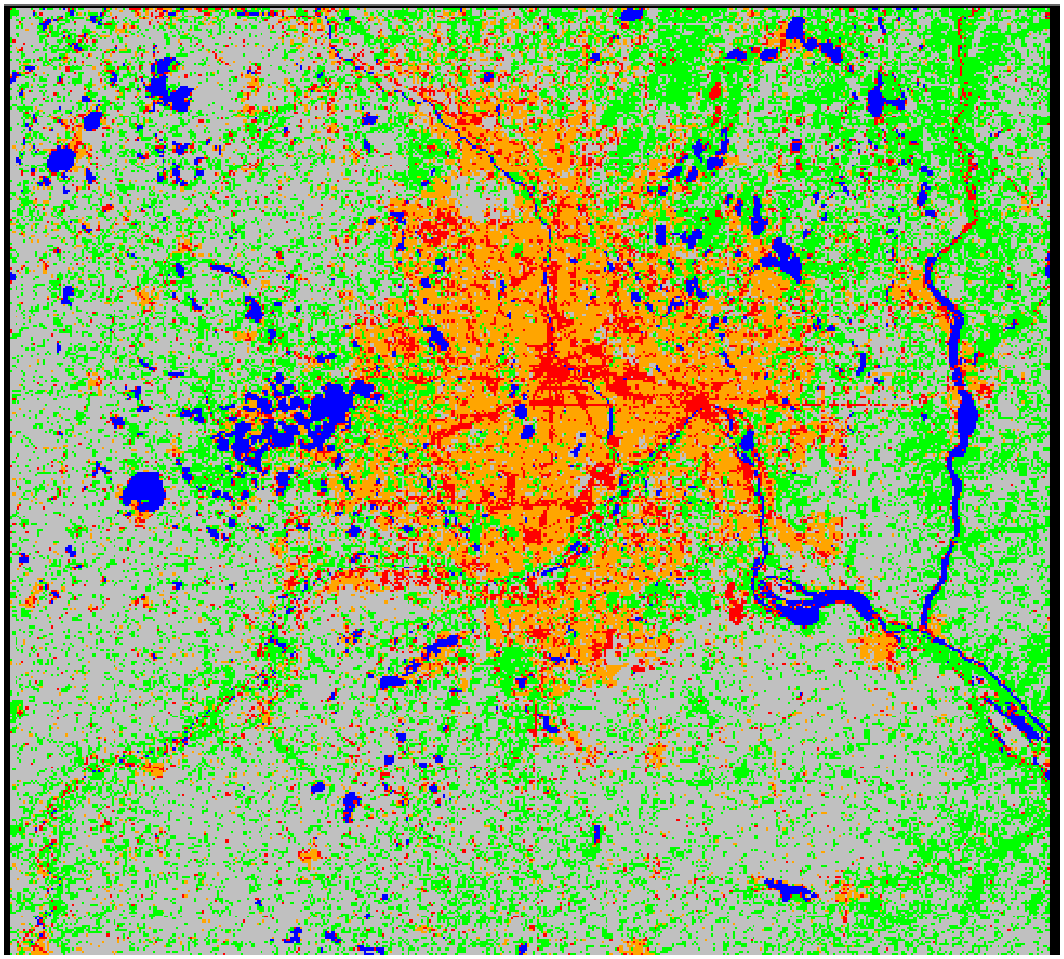

Figure 3.7: Twin Cities metropolitan area supervised classification conducted in ERDAS 9.3.

While a supervised classification can improve the accuracy of the image, there is clear evidence of spectral values that have been in-correctly classified through the minimum distance classification process, as seen in Figure 3.7. The analyzer can see the supervised classified image of the Twin Cities Metropolitan Area, and can clearly identify in-correct classification along the St. Croix River. This river that borders the Twin Cities Metropolitan Area to the east has been classified as high density urban. A possible reason for this inaccuracy could be due to shadow effects within the original satellite TM image. While this error could have been avoided through a process of removing dark objects from the image, a post-classification to improve accuracy is necessary. The processes of post-classification vary from interpreter's discretion, and the direction of the analytical or empirical outcome. In this case, the purpose of this study is to locate potential exurban areas; as well as determine that exurbia has the likelihood of becoming an extension of suburbia within certain geographic locations. Therefore, a manual post-processing approach was exercised in order to correct the image, and improve accuracy.

3.2.3 Post-Classification

In order to conduct a manual post-classification process, an additional viewer window is opened with the original image. This will allow a side-by-side comparison to ensure appropriate re-classification. A tie between the original image to the supervised classification image is conducted, along with navigation to the seed properties window located in the aoi tab of the viewer window to set and change default settings. For the purpose of this analysis, the default settings within the seed properties were changed with distance being set to 0.0 from 1.0, and maximum pixels were moved from 1,000 to 10,000. Once these manual changes were implemented the manual post-classification began commencement.

The overall procedure of this manual post-classification increased the accuracy of the image (Figure 3.8). Aside from the numerous possibilities of alternative post-classification processes, this manual technique allowed an increase of hands on interaction with the data; and therefore, this process is subjective to the analyzer. In

Figure 3.8, visual analysis clearly indicates the improvement of accuracy, specifically along the St. Croix River, east of the Twin Cities Metropolitan Area.

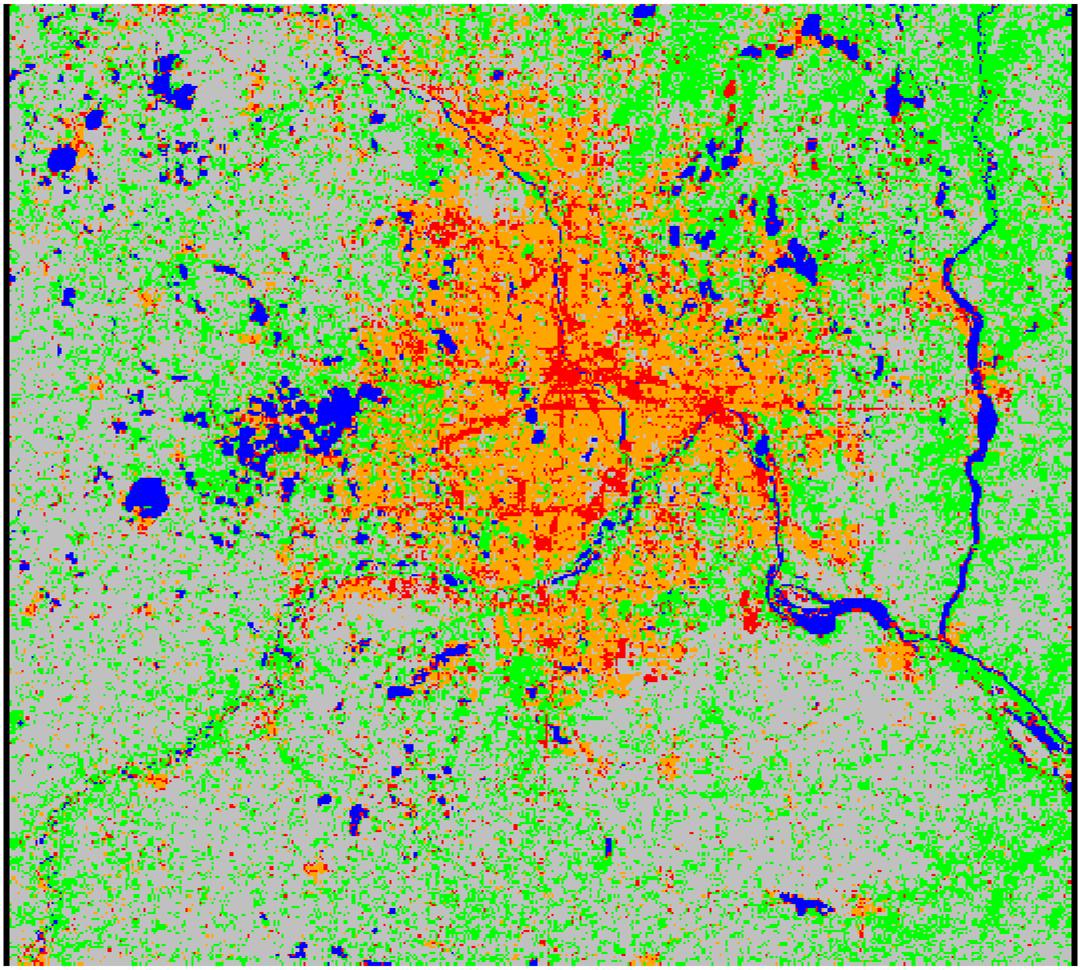

Figure 3.8: Twin Cities 1992 classified image following manual post-classification process.

3.3 Exurban Development Delineation

Exurban developments were evaluated through the usage of both ERDAS Imagine 9.3 and ArcGIS 9.3. While the former was used to create the vector shapefiles off of the original image that are considered to be exurban developments; the latter software were used to process the census tract data. The usage of census tracts will improve the accuracy, in regards to the location of exurbia, as county-wide census data has the potential of being spatially too large or small depending in the geographic location (Berube et al. 2006).

There are concerns with census data, in general, as suggested by Berube et al. (2006); however, the analysis of delineating exurban areas through vector shapefiles (Ji et al. 2006), and the implementation of statistical analysis, such as, correlation and linear regression will support the findings of exurban developments. Before discussion can occur in the implemented statistical methods utilized for the study, it is imperative to shed detail on the preparation of the data.

3.3.1 Data Prepping for Implementation of Statistical Analysis

Aside from the Shannon's entropy and the supportive statistical analysis of one-way ANOVA and the tukey test, the process of setting the data for this analysis involved further technical process through ArcGIS 9.3. Once the vector shapefiles were created in ERDAS 9.3, the satellite imagery and vector shapefiles were opened and overlaid on top of each other in ArcMap. At this time, the data went through a series of additional processes in order to determine square miles of census tracts, in relation to the square miles of impervious land.

The process in ArcGIS 9.3 began with re-classifying the original raster layer that was created in ERDAS 9.3 into five separate raster layers. This was followed with a vectorization where the separate raster layers were converted into polygons. Once the data was converted into vector format, the attribute table was edited by adding two fields, the first was titled ‘name’ to represent the vector layer being either high or low density urban, and the other being ‘area.’ The latter was created for the purpose to calculate the area of compact high and low density urban development polygons into square miles.

This vectorization and overlay on the original base raster image additionally involved the overlay and re-projection of United States Census data of select census tracts that are believed to have potential exurban developments. These 1990 and 2000 selected census tracts were first downloaded and placed within the ArcGIS image, and re-projected, in order to match the projection of the original raster and vector layers that were initially created in ERDAS 9.3. Census tracts that have potential locations of exurban developments were selected and exported.

Once the entire selected census tracts were overlaid onto the map a clip was conducted to clip together the selected census tracts to the high and low density urban polygons that were within their boundaries. This process then allowed the calculation and data table creation to begin, in order to uncover the square miles of selected census tracts, and compare these numbers to the square miles of impervious and non-impervious areas with all three study areas.

While each study area had the high and low density clipped into the selected census tracts, additional data tabulation had to be conducted prior to statistical analysis and documentation of results. This additional data tabulation had to do with the FIPS code change from 1990 to 2000 for some census tracts. The numbers of some census tracts were changed slightly from the designated number value they received during the

1990 census, in relation to the 2000 census. Therefore, the change in census tract numbers were documented to ensure that even though some census tracts may have been divided into two or more newly created census tracts, they were still recognized as the same selected census tract or tracts of the 1990 census data (Tables 3.1, 3.2 & 3.3).

Census Tract Number in 1990	Census Tract Number(s) in 2000	Total Area of Census Tracts
501501	501501	1.45967 sq miles
501502	501502	1.32184 sq miles
502404	502404	9.85176 sq miles
503401 is the same as	503411 and 503412	10.29444 sq miles
503402	503402	7.1229 sq miles
221402 is the same as	221421 and 221422	21.13865 sq miles
221500 is the same as	221501, 221502 and 221503	47.41177 sq miles
221602 is the same as	221621, 221622 and 221623	39.36951 sq miles
700106 is the same as	700107, 700108 and 700109	24.97291 sq miles
700201 is the same as	700203, 700204 and 700205	20.5468 sq miles
700301 is the same as	700303 and 700304	15.11219 sq miles
311800 is the same as	311801 and 311802	10.2216 sq miles
312100 is the same as	312102	10.1944 sq miles
312202	312202	57.535099 sq miles

Table 3.1: This table explains the change in census tract identification numbers from 1990 to 2000 for the St. Louis study area.

Census Tract Number in 1990	Census Tract Number(s) in 2000	Total Area of Census Tracts
502.04 is the same as	050223, 050224, 050228	19.8342 Sq miles
502.05 is the same as	050225, 050226, 050227	10.6312 Sq miles
502.06 is the same as	050218 and 050219	10.3461 Sq miles
502.07 is the same as	050217, 050220, 050221, 050222	22.3025 Sq miles
502.12 is the same as	050215, 050216	21.723 Sq miles
508.12 is the same as	050814, 050815	17.149099 Sq miles
406.01 is the same as	40601	9.34821 Sq miles
710.05 is the same as	071017 and 071018	19.8342 Sq miles
605.04 is the same as	060508 and 060509	17.8256 Sq miles
607.07 is the same as	060739 and 060740	5.62751 Sq miles
260.12 is the same as	026017 and 026018	13.714935 Sq miles
267.09 is the same as	026714, 026715, 026716	14.4763 Sq miles

Table 3.2: This table explains the change in census tract identification numbers from 1990 to 2000 for the Twin Cities study area.

Census Tract Number in 1990	**Census Tract Number(s) in 2000**	**T_Area of Cen Tracts**
262601	262601	7.8720 sq miles
8001 is the same as	800101 and 800102	23.294 sq miles
800502	800502	8.8151 sq miles
800501	800501	10.513 sq miles
106603	106603	4.5686 sq miles
920303	920303	19.449 sq miles
101	101	13.301 sq miles
102	102	34.544 sq miles
32025	32048, 32049 and 32050	4.8744 sq miles
52414 is the same as	52426, 52427 and 52428	23.868 sq miles
62619	62619	0.8104 sq miles
62620	62620	1.2506 sq miles
62607 is the same as	62632, 33, 34, 35, 36, 37, 38, 39, 40 and 41	13.439 sq miles
42204 is the same as	42205 and 42206	2.9759 sq miles
42105 is the same as	42111 and 42112	4.8745 sq miles

Table 3.3: This table explains the change in census tract identification numbers from 1990 to 2000 of the Los Angeles, California study area.

3.3.2 Shannon's Entropy

This approach uses the total area of the 1990 and 2000 census tract boundaries as the base value to determine the level of impervious verse non-impervious. The Shannon Entropy has been utilized by numerous scholars' within the field of geography or related disciplines in previous studies to determine levels of imperviousness. The formula used for this analysis is shown below:

$$H = - \sum p_i \log(p_i)$$

This formula allows the evaluation of impervious verses non-impervious areas, in order to determine the significance of urban sprawl within a particular metropolitan area. The process of utilizing this formula defines p_i as "the probability of a phenomenon (variable) occurring in the $_{ith}$ zone" (Bhatta et al. 2010). In addition to this, the $\log_e$ within the equation represents the scale of zero to $\log(p_i)$, where zero represents impervious, in other words "the distribution of built-up is very compact" (Bhatta et al. 2010); whereas, if the value is closer to $\log(p_i)$, meaning the $_{ith}$ variable that is arbitrary "reveals that the distribution of built-up areas is dispersed" (Bhatta et al. 2010).

In this study, all three study areas had the entropy procedure implemented; however, in order for this procedure to work a base value is required. The selected census tracts that were downloaded were adjusted into square miles and used as base values in order to find the square miles of high and low density urbanization. Entropy was used for this study because of its successful implementation by previous scholars where their studies indicated significant levels of leapfrog and scattered outgrowth surrounding a central core area (Sudhira et al. 2003; Ji et al. 2006; Jat et al. 2008; Bhatta et al. 2010 & Verzosa and Gonzalez 2010), which in turn, is evident within the study areas of St. Louis and the Twin Cities.

After the entropy is calculated, the value alone is not sufficient enough to support the claim; therefore, it is critical to find a threshold value. A threshold value was found to represent all three study areas. The set threshold value for all three study areas was set at 3.65, which was calculated by finding the mean of all six entropy values for each separate study area (Table 3.4).

Shannon Entropy Values	
	3.738328772
	4.11232278
	3.912288024
	4.902342484
	2.470451192
	2.793588679
Threshold	3.654886989

Table 3.4: Represents Entropy Values for all three study areas with threshold calculation.

3.3.3 One-Way ANOVA

The entropy values collected for all three study areas additionally need support to validate the findings, which resulted in two more statistical techniques: one-way ANOVA and the tukey test (pronounced too-key). First, the one-way ANOVA is similar to statistical analysis of other scholar's work, such as, the correlation and regression analysis conducted by Jat et al. (2008), to determine the amount of urban sprawl away from the central core area. In Jat et al. (2008) study, the correlation and regression analysis evaluated urban sprawl for their study assessment.

During implementation of the one-way ANOVA, two separate one-way ANOVA's were conducted as each study area included two different years of satellite imagery and census tract data. The process included the creation of two descriptive tables (Tables 3.5 & 3.6), as well as two one-way ANOVA tables (Tables 3.7 & 3.8) that are representative for 1990 and 2000 census data and satellite imagery analysis. These results, as indicated in the preceding four tables, all were calculated through the SPSS (Statistical Package for the Social Sciences).

	1990 Descriptives Table based on 95% Confidence Interval for Mean							
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	MIN	MAX
Twin Cities	12	0.31146	0.0479982	0.0138559	0.280962	0.341955	0.1723	0.3515
St. Louis	14	0.27939	0.0506193	0.0135286	0.250166	0.30862	0.2192	0.3664
Los Angeles	15	0.16464	0.0516394	0.0133332	0.136043	0.193237	0.0692	0.2915
	41	0.2468	0.0809752	0.0126462	0.221236	0.272354	0.0692	0.3664

Table 3.5: SPSS descriptive table based on 1990 one-way ANOVA analysis in determining the F Value.

		2000 Descriptives Table based on 95% Confidence Interval for Mean						
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	MIN	MAX
Twin Cities	12	0.34265	0.0386008	0.0111431	0.318124	0.367176	0.2558	0.3678
St. Louis	14	0.350114	0.159018	0.0042499	0.340933	0.359296	0.3057	0.3675
Los Angeles	15	0.1862	0.0592819	0.0153065	0.153371	0.219029	0.0867	0.2555
	41	0.287961	0.0886257	0.013841	0.259987	0.315935	0.0867	0.3678

Table 3.6: SPSS descriptive table based on 2000 one-way ANOVA analysis in determining the F Value.

One-Way ANOVA for 1990 Census Data					
Area	Sum of Sq	df	Mean Sq	F(Value)	Significance
Between Groups	0.166	2	0.083	32.918	0
Within Groups	0.096	38	0.003		
Total	0.262	40			

Table 3.7: The one-way ANOVA procedure conducted for all three study areas in relation to 1990 census data and satellite imagery courtesy of the United States Census Bureau and the United States Geological Society.

	One-Way ANOVA for 2000 Census Data				
Area	Sum of Sq	df	Mean Sq	F(Value)	Significance
Between Groups	0.245	2	0.123	67.666	0
Within Groups	0.069	38	0.002		
Total	0.314	40			

Table 3.8: The one-way ANOVA procedure conducted for all three study areas in relation to 2000 census data and satellite imagery courtesy of the United States Census Bureau and the United States Geological Society.

In reference to Tables 3.7 and 3.8, the sum of squares was reflective of the total square miles of land within all selected census tracts for all three study areas. Then comes the analysis of finding the between groups (BG) and within groups (WG) to determine the F value, which includes the total degree of freedom value found for both one-way ANOVA's. The BG was calculated by relying on the assumption that the data value within each study area matches to its mean value. Therefore, the standard deviation is squared in relation to the study area sample size. As for the process of the WG, this involves taking the random error residual found from the BG calculation as every single data value that represent a study area never fully matches its actual mean value. This places each sample independent from each other, as comparisons are made with no relation to other samples within the study.

After data was tabulated for each census tract year, the process was run through SPSS where the F values of 32.918 and 67.666 were found for the census years of 1990 and 2000, respectively. However, in order to know what these values for each study year means, the critical value had to be assessed through the F table. The critical value found for both one-way ANOVA's were based on a 95% confidence level, which in turn provided a critical value of 3.245. This critical value of 3.245, when compared to the Shannon's Entropy values found differences within all three study areas. These differences that will be elaborated further, found the Los Angeles study area as being compact in urban structure for both respective years. On the other hand, St. Louis was calculated as being dispersed in urban structure for both respective years of analysis; whereas, calculation of the Twin Cities resulted in the metropolitan area having compact urban structure for 1990, but experienced extreme levels of urban sprawl that resulted in the study area being dispersed for 2000 results.

This result found however, does not mean all three study areas experienced a decrease of imperviousness. Instead, the one-way ANOVA that is utilized to support the entropy value rather indicates the amount of urban sprawl all three study areas have experienced from 1990 to 2000, in reference to satellite imagery and census tract data. In fact, it is possible if all three study areas each had a separate one-way ANOVA calculation, there is indication the results would be different as no study area would be compared to the other. The process would then consist of comparing a single study area to its selected census tracts, in relation to the square miles of land that was classified as impervious; which could present an entire different F value for each study area. Therefore, as the one-way ANOVA represented all three study areas as being different it was imperative to implement the tukey test.

3.3.4 Tukey Test

The Tukey Test is a single-step test that compares multiple comparisons, that is commonly utilized to supplement the one-way ANOVA, in order to uncover the possibility of a different mean value for all represented study areas (Table 3.9).

Tukey Test	
M1 vs M2	non-signifcant
M1 vs M3	P < .01
M2 vs M3	P < .01

Table 3.9: The Tukey Test calculation that was conducted in conjunction with the one-way ANOVA tests for the purpose to find a difference between mean values for all three study areas.

As seen in Table 3.9 the 'M' symbol represents each study area where M1 and M2 stand for the Twin Cities and St. Louis; whereas, M3 is designated for Los Angeles. As indicated in Table 3.9, it has been determined there is no significant difference in mean values for either the Twin Cities or St. Louis study areas. As for Los Angeles, the mean value for this study area was in fact different from the other two separate study areas. In return, the tukey test calculation presents supports, not only for the one-way ANOVA, but provides support to the Shannon Entropy as well.

4. DISCUSSION AND ANALYSIS

The process of data interpretation through ERDAS Imagine 9.3, ArcGIS 9.3, and the implementation of statistical analysis can be best analyzed with an understanding of the concepts to interpret the potential location of exurban development, in relation to 1990 and 2000 census data, satellite images and statistical analysis. This presented results that indicated either slight or strong differences, or similar structure in regards to the implementation of statistical analysis. The discussion of results will be addressed through each specific study area on an individual basis.

4.1 St. Louis, Missouri Study Area

Data from this study area, along with spatial and statistical analysis in ArcGIS found an extreme case of urban dispersed development patterns based on the entropy values found for both the 1990 and 2000 census tract data. This was determined through calculation of square miles of impervious land, in relation to the selected census tracts that were considered to be the location of potential exurban developments (Tables 4.1 & 4.2). These selected census tracts were all calculated as being dispersed in urban structure as defined by the entropy method and set threshold (3.65) for both study years; which means, these selected census tracts are recognized as being potential locations for existing exurban developments.

Census Tract	Total Area of Impervious in 1990	Total Area of Census Tracts	÷ A to Impervious	ln(P)	Final Results
501501	0.1798 sq miles	1.45967 sq miles	0.1231	-2.094758246	-0.25786474
501502	0.1222 sq miles	1.32184 sq miles	0.0924	-2.3816283	-0.22006245
502404	3.3125 sq miles	9.85176 sq miles	0.3362	-1.090049058	-0.36647449
503401	1.5332 sq miles	10.29444 sq miles	0.1489	-1.904480339	-0.28357712
503402	1.1006 sq miles	7.1229 sq miles	0.1545	-1.867561183	-0.2885382
221402	2.3254 sq miles	21.13865 sq miles	0.11	-2.207274913	-0.24280024
221500	6.588 sq miles	47.41177 sq miles	0.1389	-1.974001029	-0.27418874
221602	4.4013 sq miles	39.36951 sq miles	0.1117	-2.191938573	-0.25645681
700106	3.0616 sq miles	24.97291 sq miles	0.1225	-2.099644249	-0.25720642
700201	3.6489 sq miles	20.5468 sq miles	0.181	-1.709258248	-0.30937574
700301	1.4283 sq miles	15.11219 sq miles	0.0918	-2.388142981	-0.21923153
311800	2.9722 sq miles	10.2216 sq miles	0.2907	-1.235463471	-0.35914923
312100	2.7294 sq miles	10.1944 sq miles	0.2677	-1.317888328	-0.35279871
312202	5.5092 sq miles	57.535099 sq miles	0.0957	-2.346536981	-0.22456359
			Shannon's Value		**3.912288024**

Table 4.1: The lower right corner of the table indicates the level of imperviousness within the selected census tracts according to 1990 census data for the St. Louis study area where entropy is much closer to zero, in comparison to, table 4.2.

Census Tract	Total (A) of Impervious (2000)	Total (A) of Census Tracts	÷ of Area	ln(P)	Final Results
501501	0.4561 sq miles	1.45967 sq miles	0.3124	-1.163470861	-0.363468297
501502	0.6346 sq miles	1.32184 sq miles	0.48	-0.733969175	-0.352305204
502404	4.9275 sq miles	9.85176 sq miles	0.5001	-0.692947201	-0.346542895
503411 and 412	2.4502 sq miles	10.29444 sq miles	0.238	-1.435484605	-0.341645336
503402	2.9123 sq miles	7.1229 sq miles	0.4088	-0.89452924	-0.365683553
221421 and 422	5.5496 sq miles	21.13865 sq miles	0.2625	-1.337504197	-0.351094852
221501, 502 and 503	11.409 sq miles	47.41177 sq miles	0.24	-1.427116356	-0.342507925
221621, 622 and 623	9.287 sq miles	39.36951 sq miles	0.235	-1.448169765	-0.340319895
700107, 108 and 109	6.709 sq miles	24.97291 sq miles	0.268	-1.316768298	-0.352893904
700203, 204 and 205	6.1109 sq miles	20.5468 sq miles	0.297	-1.21402314	-0.360564873
700303 and 304	2.6601 sq miles	15.11219 sq miles	0.176	-1.737271284	-0.305759746
311801 and 802	4.2394 sq miles	10.2216 sq miles	0.414	-0.881889305	-0.365102172
312102	5.0954 sq miles	10.1944 sq miles	0.499	-0.695149183	-0.346879442
312202	20.313 sq miles	57.535099 sq miles	0.353	-1.041287222	-0.367574389
			Shannon's Value		**4.902342484**

Table 4.2: The lower right corner of the table indicates the level of imperviousness within the selected census tracts according to 2000 data of the St. Louis study area where entropy is much further away from zero, in comparison to, table 4.1.

As the potential existence of exurban development within the St. Louis study area exists. The findings shown in Tables 4.1 and 4.2 indicate the increase between 1990 and 2000 entropy values as the latter has moved much further away from zero. These two separate values of 3.912 and 4.902 are representative of the constant leapfrog and scattered development patterns that are in continuum within the selected census tracts, as well as, the entire metropolitan area. However, as the entropy value had a serious increase away from zero, the levels of imperviousness within the selected census tracts did increase in percentage value. This mean, as these selected census tracts increased in imperviousness, the levels of dispersed development continued to move further outward from the central core area. Therefore, the possibility of exurbia does exist with the St. Louis metropolitan area, but these developments are likely no longer within the selected census tracts. Instead, these development patterns have moved further outward, which supports the definition of exurbanites being less connected with a central core area than their suburbanite counterparts (Crump 2003).

The claim that existing exurban developments may have easily moved further outward, and are perhaps no longer with the selected 1990 census tracts is supported through Figures 4.1 and 4.2. These figures represent the St. Louis metropolitan area through 1991 and 2000 satellite imagery overlaid with 1990 and 2000 selected census tracts of potential exurban developed areas. When comparison is made between both satellite images, it becomes evident on the increase of urban sprawl, particularly with St. Charles and portions of St. Louis Counties; as well as, Madison County, Illinois.

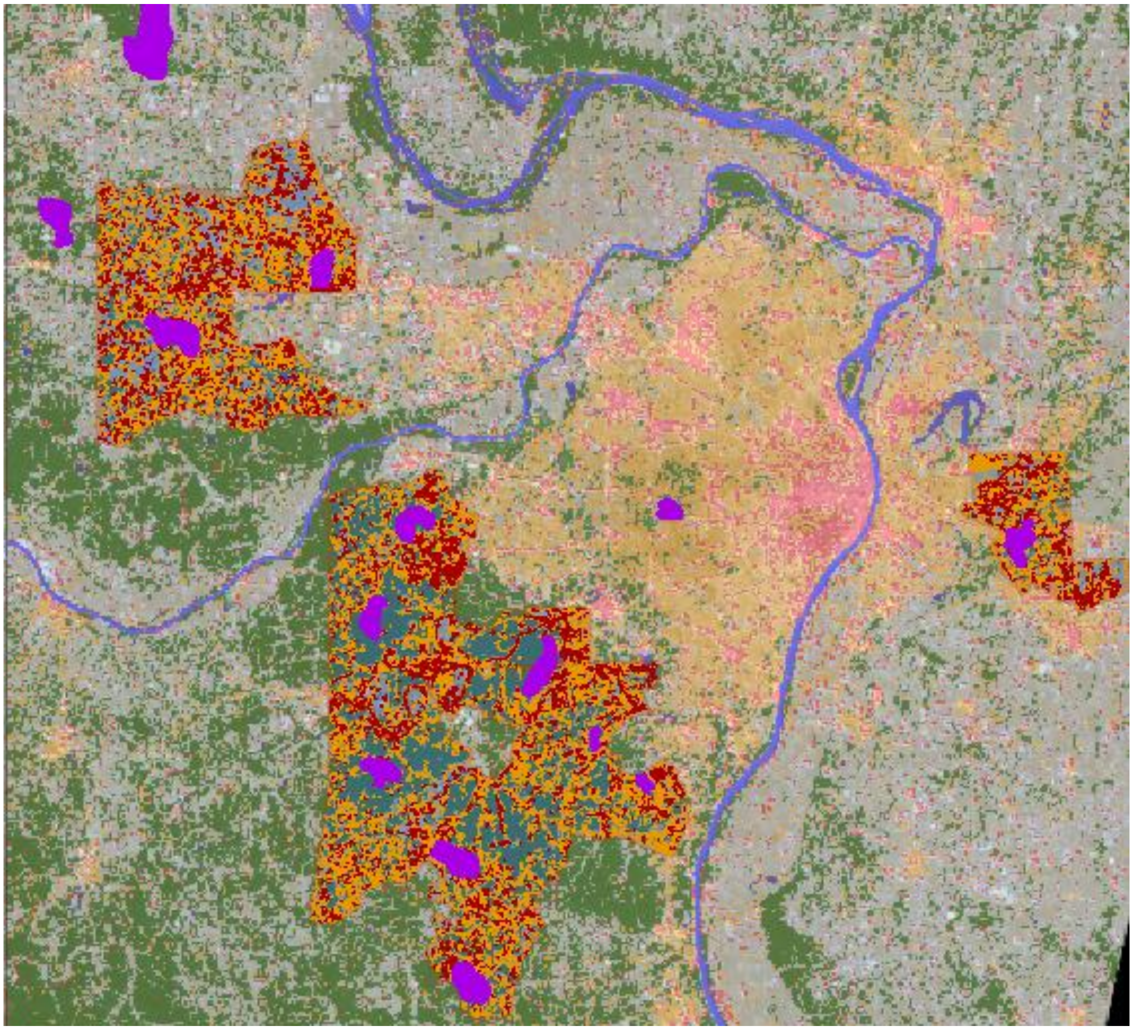

Figure 4.1: Screen capture represents the 1990 Census tracts, provided by the United States Census Bureau website, overlaid on the St. Louis Metropolitan Area. This additionally includes ERDAS created shapefile polygons of the delineated exurban areas that surrounds St. Louis based on 1992 TM Satellite Imagery.

Figure 4.1, visually illustrates the compact development St. Louis had in 1990. This is additionally supported by its Shannon's Entropy value of 3.912, when compared to the entropy value of 4.902 and the 2000 St. Louis satellite image shown in Figure 4.2.

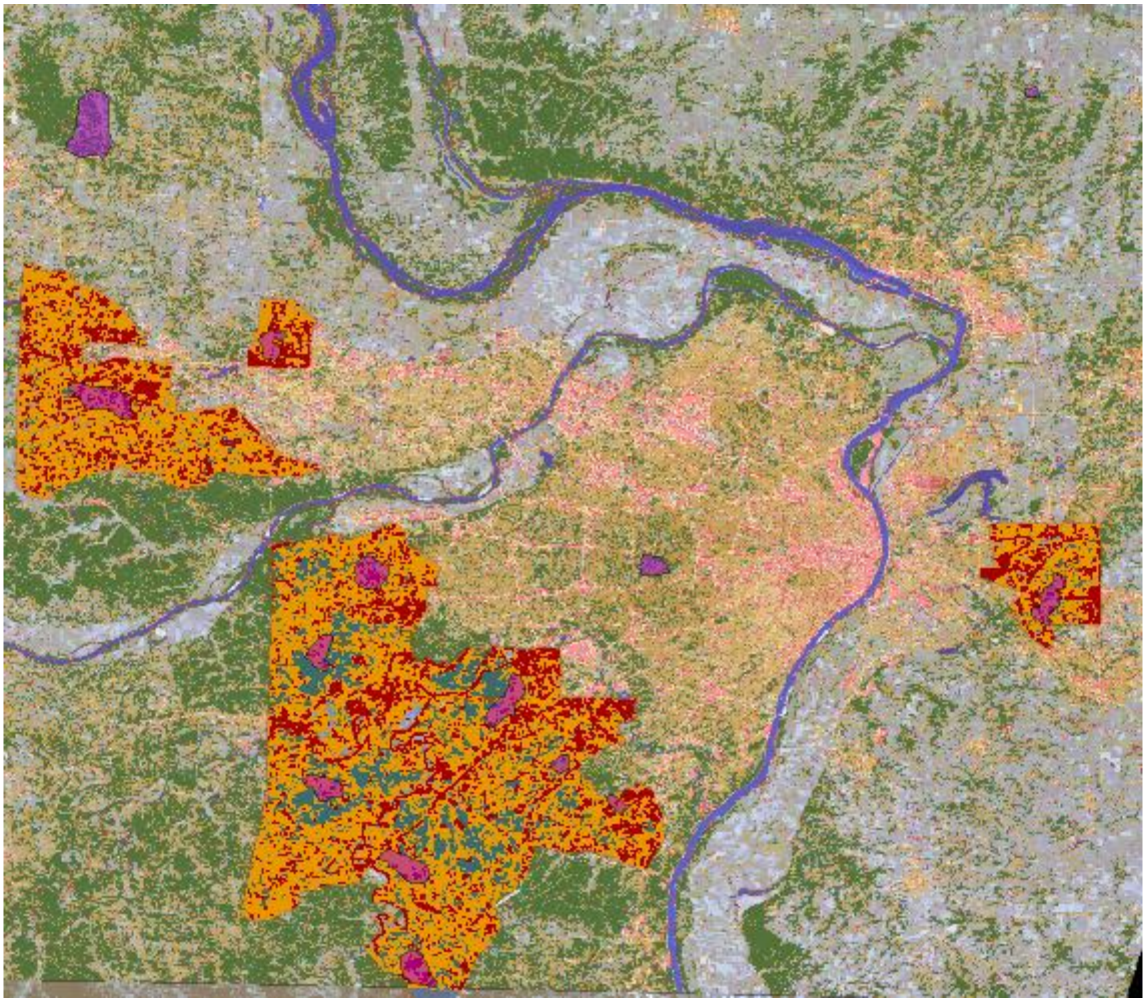

Figure 4.2: Screen capture represents the 2000 Census tracts, provided by the United States Census Bureau website, overlaid on the St. Louis Metropolitan Area. This additionally includes ERDAS created shapefile polygons of the delineated exurban areas that surrounds St. Louis based on 2002 ETM Satellite Imagery.

Even though the Shannon's Entropy method successfully supported the claim on the possibility that exurbia exists within certain geographic locations it is imperative to examine the two remaining study areas; as well as, implement two additional statistical methods to support the entropy values of both years and its findings. This supportive methods utilized was one-way ANOVA and the Tukey Test. As mentioned earlier, the one-way ANOVA is a very basic statistical approach where a critical value is found based off of the F table.

The procedure of one-way ANOVA, as stated earlier in the methodology, was calculated through SPSS to support the entropy results found for all three study areas. This calculation resulted in a critical value set at 3.245, while lower than the found entropy threshold value; both midpoints were close enough to present similar findings for the study areas. In reference to St. Louis the one-way ANOVA results found both study years to be calculated as being dispersed in urban structure, a finding that directly supported the entropy value based on its 3.65 threshold. This direct support between these separate statistical techniques allow presents conclusive evidence the St. Louis metropolitan area maintained constant urban leapfrog and scattered development practices from 1990 to 2000.

Aside from the utilization of one-way ANOVA, which presented very strong support to the entropy results, the tukey test was implemented. The statistical technique is extremely common in support to the one-way ANOVA, as the tukey test finds the difference with mean values within a one-way ANOVA calculation. The results for tukey test, however, will be elaborated on further following the analysis of the other two study areas. This will allow each study area to be clearly analyzed through the Shannon's Entropy and one-way ANOVA, prior to comparing difference in mean values, if any.

4.2 Twin Cities, Minnesota Study Area

In the second study area, the Twin Cities Metropolitan Area results indicated a similar consistent pattern as seen in the St. Louis study. The results for the Twin Cities found the study area had experienced an increase of urban sprawl outward from the central core area, which is identical to the results of St. Louis. On the other hand, the amount of urban sprawl within the Twin Cities was substantially lower than the findings indicated for St. Louis.

In return to the former, the Twin Cites entropy calculation generated the values of 3.738 and 4.112 for 1990 and 2000 census tract data and satellite imagery (Tables 4.3 & 4.4). These two separate values represent the level of impervious surface distribution in regards to compact urban development. This does not mean the findings suggest the Twin Cities became less impervious, rather the entropy indicates an extreme increase of urban sprawl from 1990 to 2000. The results of the selected census tracts represent dispersed development rather than compact infill development.

Census Tracts	Total (A) Impervious 1990	Total (A) of Census Tract	÷ of A of Impervious	ln(P)	Final Results
502.04	4.642006	19.8342	0.234	-1.452434164	-0.3398696
502.05	2.804067	10.6312	0.264	-1.331806176	-0.3515968
502.06	2.4141068	10.3461	0.233	-1.456716825	-0.339415
502.07	4.756569	22.3025	0.213	-1.546463113	-0.3293966
502.12	3.25017	21.723	0.15	-1.897119985	-0.284568
508.12	3.357717	17.149099	0.196	-1.62964062	-0.3194096
406.01	1.55133	9.34821	0.166	-1.795767491	-0.2980974
710.05	1.238118	19.8342	0.062	-2.780620894	-0.1723985
605.04	3.432923	17.8256	0.193	-1.64506509	-0.3174976
607.07	2.87023	5.62751	0.51	-0.673344553	-0.3434057
260.12	2.492139	13.714935	0.182	-1.703748592	-0.3100822
267.09	3.170031	14.4763	0.219	-1.518683549	-0.3325917
			Shannon Value		**3.73832877**

Table 4.3: The lower right corner of the table indicates the level of imperviousness within the selected census tracts according to 1990 census data for the Twin Cities study area where entropy is much closer to zero, in comparison to, table 4.4.

Census Tracts	Total (A) Impervious 2000	Total (A) of Census Tract	÷ of A of Impervious	ln(P)	Final Results
502.04	5.716629	19.8342	0.288	-1.2447948	-0.358500902
502.05	5.182553	10.6312	0.487	-0.71949116	-0.350392193
502.06	4.258829	10.3461	0.412	-0.88673193	-0.365333555
502.07	9.314046	22.3025	0.418	-0.87227385	-0.364610468
502.12	8.150533	21.723	0.375	-0.98082925	-0.36781097
508.12	6.766111	17.149099	0.395	-0.92886951	-0.366903458
406.01	2.736771	9.34821	0.293	-1.22758267	-0.359681722
710.05	5.691141	19.8342	0.287	-1.24827306	-0.358254369
605.04	7.304998	17.8256	0.410	-0.89159812	-0.25588866
607.07	3.783109	5.62751	0.672	-0.39749694	-0.267117942
260.12	6.656537	13.714935	0.485	-0.72360639	-0.350949098
267.09	7.225351	14.4763	0.499	-0.69514918	-0.346879442
			Shannon Value		**4.11232278**

Table 4.4: The lower right corner of the table indicates the level of imperviousness within the selected census tracts according to 2000 data for the Twin Cities Study Area where entropy is much further away from zero, in comparison to, table 4.3.

As Figures 4.3 and 4.4, along with the Twin Cities side-by-side comparison in Figure 4.5 show some of the selected census tracts became extremely impervious, particularly those selected in the northwestern and southeastern side of the metro. These findings indicate the areas that have experienced the most urban development, as well as the direction the Twin Cities grew outward from the central core. In addition to the previous statement, the findings further indicate the potential existence of exurbia as these developments clearly moved further outward, and away from the central core area.

The results from the Shannon's Entropy method alone, indicates the Twin Cities is comparable to the St. Louis study area. However, according to the set threshold value of 3.65 for the Twin Cities study area, results suggest the metropolitan area as a whole was more compact in 1990 than found through its 2000 census tract data and satellite imagery in reference to urban development structure. This determines the amount of urban sprawl that has occurred throughout the metropolitan area as the 1990 Shannon value was 3.738, and in 2000 increased to 4.112. On the other hand, when these results are compared to the St. Louis study area, differences are made apparent as the former study areas' Shannon's value were both above the set threshold of 3.65. The comparison of St. Louis and Twin Cities alone identifies how the former is far less compact in urban development, then the latter.

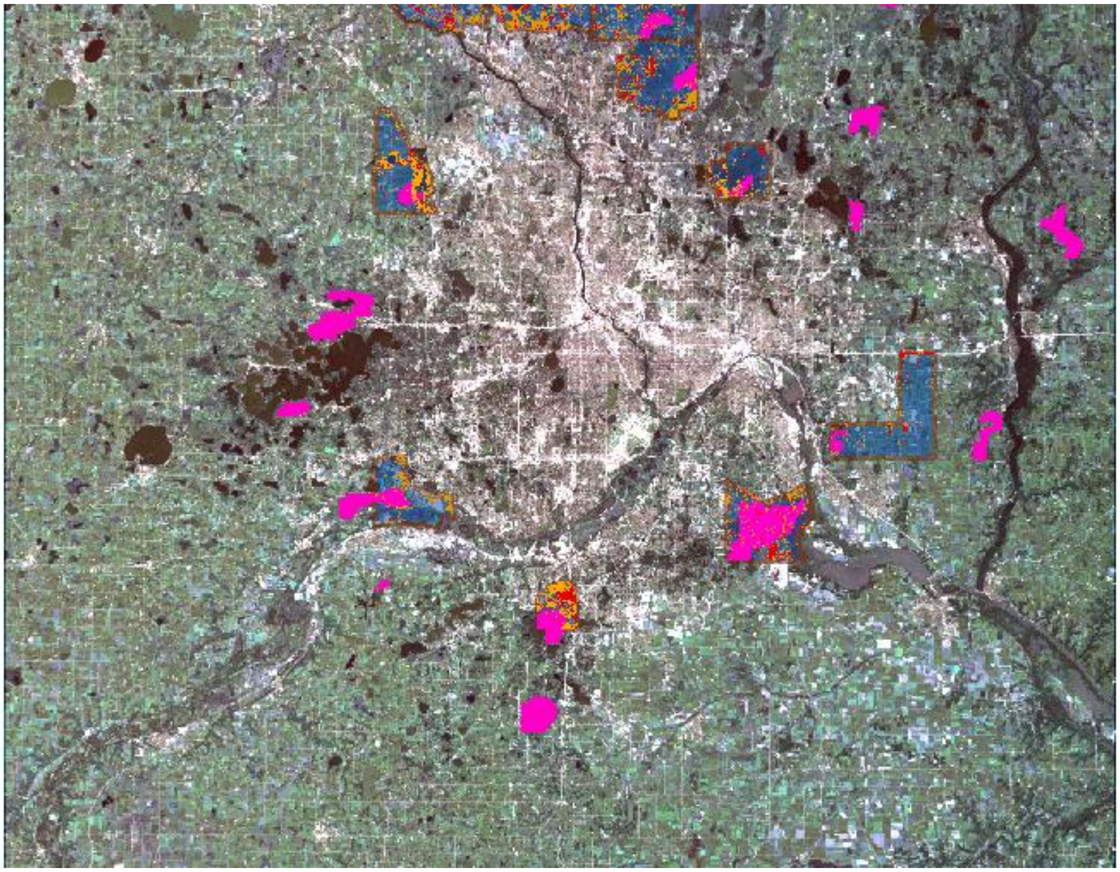

Figure 4.3: Screen capture represents the 1990 Census tracts, provided by the United States Census Bureau website, overlaid on the Twin Cities Metropolitan Area. This additionally includes ERDAS created shapefile polygons of the delineated exurban areas that surrounds Minneapolis/St. Paul based on 1992 TM Satellite Imagery.

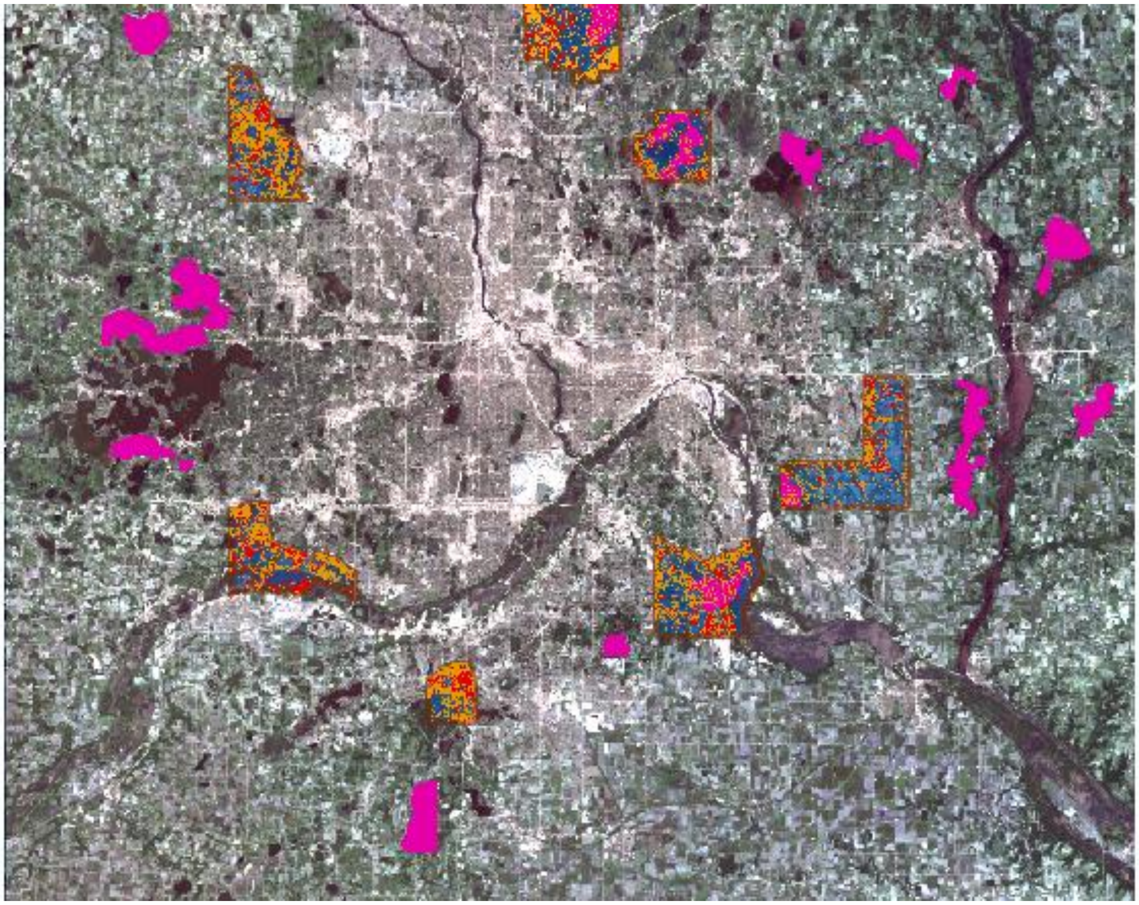

Figure 4.4: Screen capture represents the 2000 Census tracts, provided by the United States Census Bureau website, overlaid on the Twin Cities Metropolitan Area. This additionally includes ERDAS created shapefile polygons of the delineated exurban areas that surrounds Minneapolis/St. Paul based on 2001 ETM Satellite Imagery.

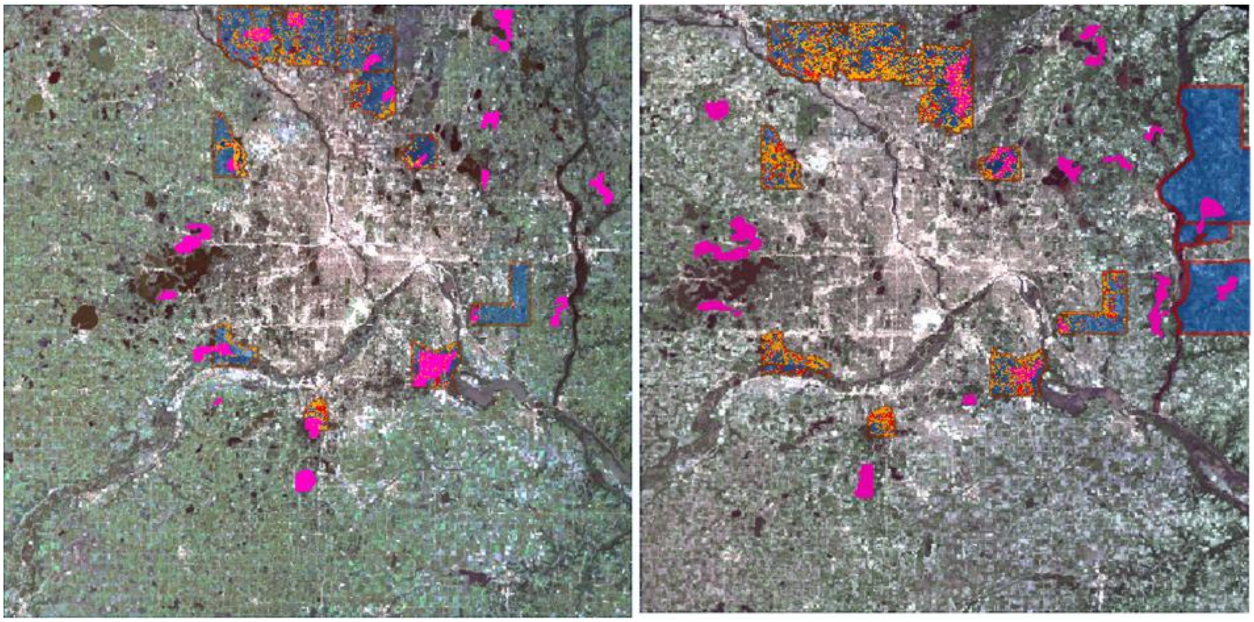

Figure 4.5: Side-by-side satellite image comparison of the Twin Cities in relation to existing exurban developments between 1992 and 2001. This includes the effects of urban sprawl within suburbia that has caused the disappearance of some exurban areas with further outward creation of new developments.

While the Shannon's Entropy and satellite imagery analysis provide convincing evidence that exurbia does potentially exist within the Twin Cities Metropolitan Area; these results cannot stand alone and therefore, requires the additional statistical analysis of a one-way ANOVA to provide support. This additional statistical analysis, however, presents a slight difference within the Twin Cities study area in comparison to St. Louis. As previously mentioned, the results for St. Louis calculated the study area as being dispersed in urban development for both entropy analysis. The Twin Cities, on the other hand, found to be compact through its 1990 selected census tracts and satellite imagery in urban development patterns; whereas, its 2000 selected census tract data and satellite imagery results found the opposite as the study area had become more dispersed in urban development patterns in relation to the 3.65 Shannon's threshold value.

Unfortunately, the entropy value was not consistent with the one-way ANOVA supportive test. In the case of the Twin Cities, the study site was considered dispersed in urban form for both 1990 and 2000 census tract data information as the critical value for the one-way ANOVA was set at 3.245. Even though, the one-way ANOVA found both study years being calculated as dispersed in urban structure patterns, finding still present the increase of sporadic development patterns occurring within the metropolitan area from 1990 to 2000. This in turn, additionally identifies the potential possibility both St. Louis and Twin Cities consist of exurban development patterns around their periphery. However, these exurban developments have possibly re-located further outward from their respective central core areas based on evidence seen through satellite imagery indicating the increased outward growth of suburbia.

While both the Shannon's Entropy and one-way ANOVA methods indicate some correlation between the St. Louis and Twin Cities, the Tukey Test was implemented as well. As previously mentioned, the result of this analysis determines if there is any significant difference between all three study areas. Thus far, the Tukey Test found no significant difference between the first two study areas of St. Louis and Twin Cities; however, the final study area may possibly result in a different determination.

4.3 Los Angeles, California Study Area

Similar to the Twin Cities study area in terms of levels of impervious land area, the Los Angeles study area also had some exceptions when compared to both the St. Louis and Twin Cities study sites. The 1990 census tract data and satellite imagery represents a metropolitan area that consists of both a higher population of people, and a greater square mileage of urban land area. This difference of scale, in terms of urban infrastructure and metropolitan land area, in comparison to the study areas of St. Louis and Twin Cities was picked intentionally to highlight the possibility that under certain exceptions exurbia may have become an extension of America's growing suburbia. In fact, the city of Los Angeles has experienced such rapid growth throughout the 1950's well into the 1980's that much available land has been either annexed for future development or has already been utilized for commercial, industrial and residential growth.

The Los Angeles Metropolitan Area has expanded to an extent to where it has reached geographic obstacles that prevent for further outward development, and therefore; the city of Los Angeles has become blocked on all four sides. These geographic and political obstructions are the Pacific Ocean to its west and southwest, the San Gabriel Mountains of the North, Camp Pendleton Marine Base to its south, and the Riverside/San Bernardino Metropolitan Area to its east, where all the above leaves the city with no alternative but to practice infill development.

This infill development practice of Los Angeles and its surrounding metropolitan area provides little room for the possibility of exurban development. Evidence seen in Figure 4.6, illustrate the already existing compact urban structure of Los Angeles based on census tract data and satellite imagery. Even with the possibility that exurbia may not exist within the surrounding periphery of Los Angeles, a process of delineating vector polygons on the potential location of exurban developments were still implemented for the study site. Figures 4.6 and 4.7 both illustrate the amount of urban infill development that has occurred within the selected census tracts. Where levels of urban infill practices within Los Angeles is more recognizable in Figure 4.8.

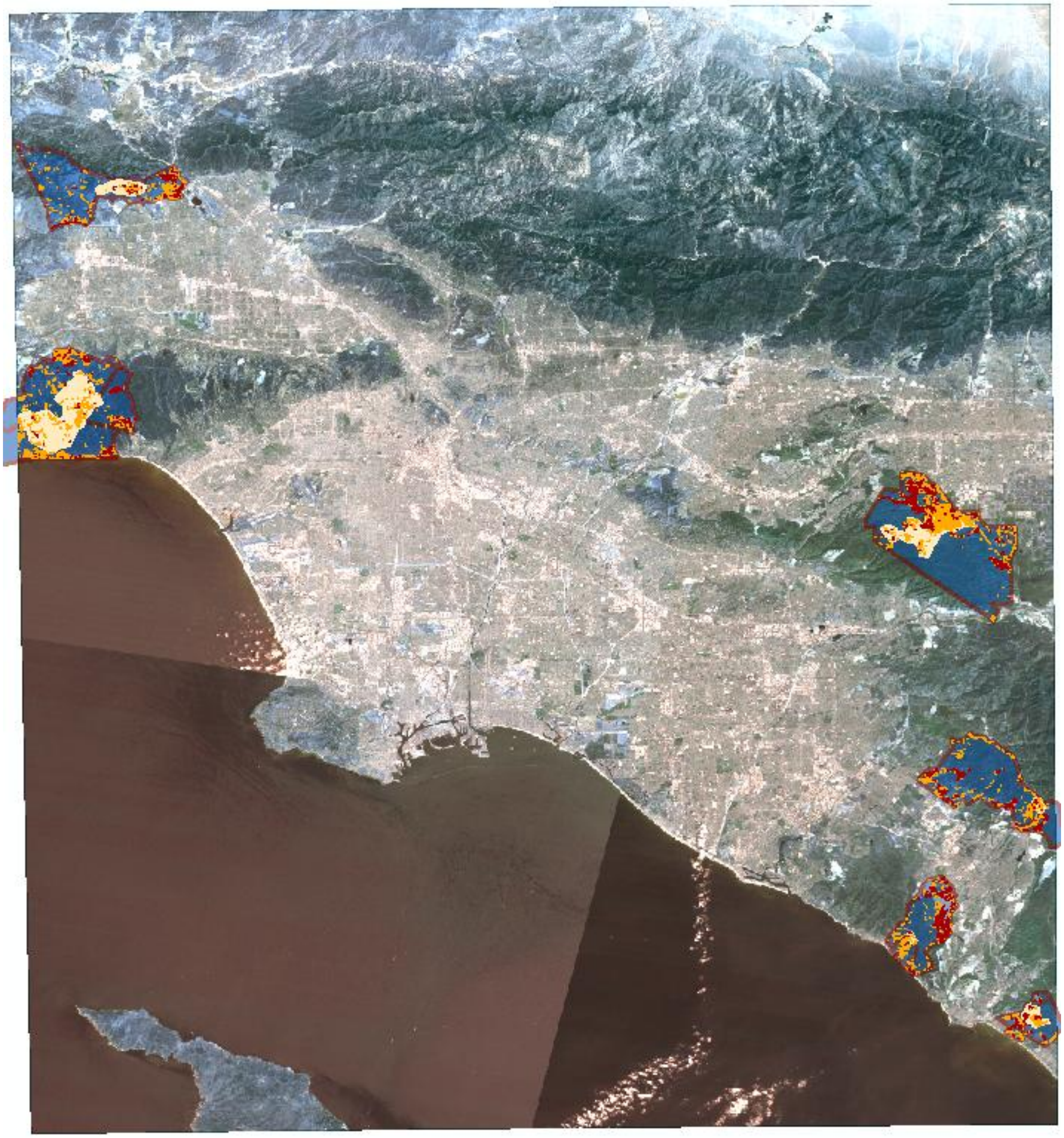

Figure 4.6: Screen capture represents the 1990 Census tracts, provided by the United States Census Bureau website, overlaid on the Los Angeles Metropolitan Area. This additionally includes ERDAS created shapefile polygons of the delineated exurban areas that surrounds Los Angeles based on 1989 TM Satellite Imagery.

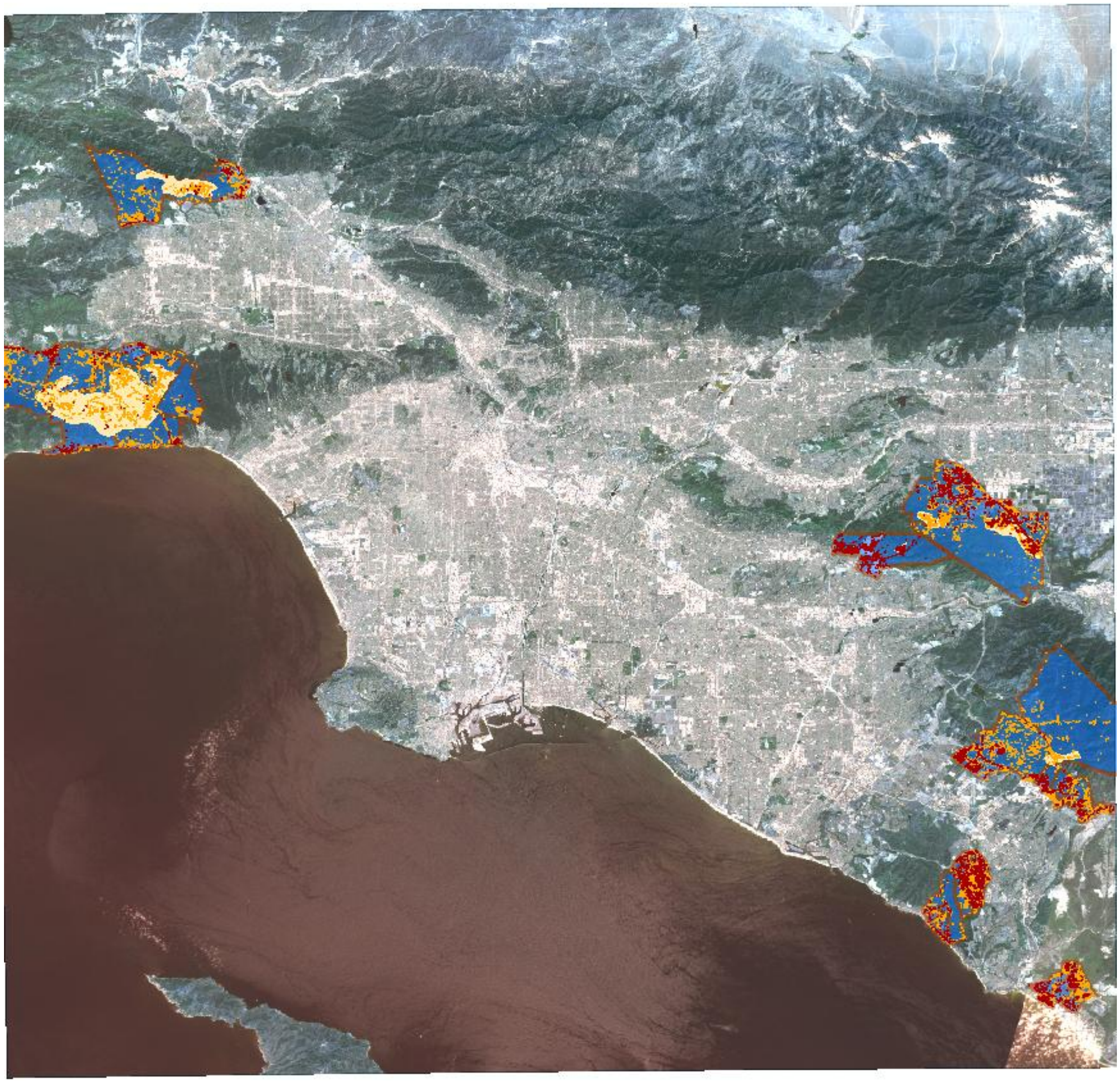

Figure 4.7: Screen capture represents the 2000 Census tracts, provided by the United States Census Bureau website, overlaid on the Los Angeles Metropolitan Area. This additionally includes ERDAS created shapefile polygons of the delineated exurban areas that surrounds Los Angeles based on 2000 ETM Satellite Imagery.

This side-by-side comparison of Figure 4.8 clearly identifies the amount of compact urban development particularly within the Santa Ana Mountains at the cross sections of the Los Angeles, Riverside, San Bernardino and Orange county lines.

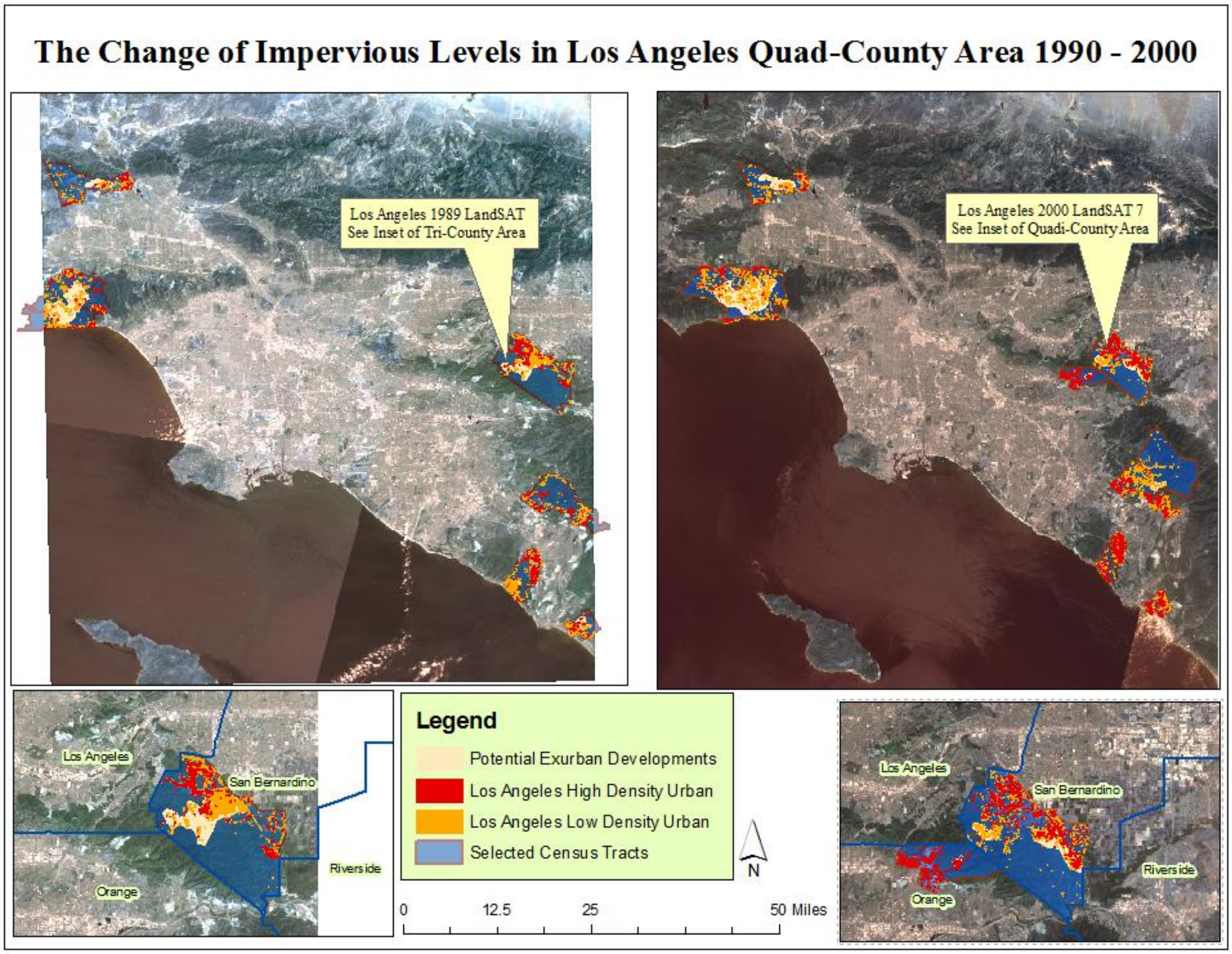

Figure 4.8: Side-by-side satellite image comparison of Los Angeles in relation to existing exurban developments between 1989 and 2000. This includes the effects of urban sprawl within suburbia that has caused the disappearance of some exurban areas with further outward creation of new developments.

These satellite images of the Los Angeles study area, visually details the amount of urban sprawl, along with the increase of urban infill of already annexed and developing areas within the metro. Unfortunately, visual representation cannot stand alone, and therefore statistical analysis must be implemented to verify the results. As seen in the two previous study areas, the Los Angeles study area too went through a Shannon's Entropy; as well as one-way ANOVA to assist in supporting the visual claims being made on the possibility that exurbia has become an extension to suburbia, at least under certain geographic conditions.

What was found in the results is similar to the 1990 Twin Cities study area, where the Los Angeles area had a 2.47 Shannon's value (Table 4.5), with a threshold value of 3.65.

Census Tract	**Total Area of Impervious in 1990**	**Total Area of Census Tracts**	**÷ of Area**	**ln(P)**	**Final Results**
262601	0.5339 sq miles	7.8720 sq miles	0.067	-2.70306266	-0.181105198
8001	1.3166 sq miles	23.294 sq miles	0.056	-2.882403588	-0.161414601
800502	0.324 sq miles	8.8151 sq miles	0.036	-3.324236341	-0.119672508
800501	0.5916 sq miles	10.513 sq miles	0.056	-2.882403588	-0.161414601
106603	0.6982 sq miles	4.5686 sq miles	0.152	-1.883874758	-0.105496986
920303	0.333 sq miles	19.449 sq miles	0.017	-4.074541935	-0.069267213
101	2.1077 sq miles	13.301 sq miles	0.158	-1.845160246	-0.291535319
102	2.9593 sq miles	34.544 sq miles	0.085	-2.465104022	-0.209533842
32025	0.2013 sq miles	4.8744 sq miles	0.041	-3.194183212	-0.130961512
52414	1.02 sq miles	23.868 sq miles	0.042	-3.170085661	-0.133143598
62619	0.0539 sq miles	0.8104 sq miles	0.066	-2.718100537	-0.179394635
62620	0.0829 sq miles	1.2506 sq miles	0.066	-2.718100537	-0.179394635
62607	0.8905 sq miles	13.439 sq miles	0.066	-2.718100537	-0.179394635
42204	0.2433 sq miles	2.9759 sq miles	0.081	-2.513306124	-0.203577796
42105	0.2874 sq miles	4.8745 sq miles	0.058	-2.847312268	-0.165144112
			Shannon Value		**2.470451192**

Table 4.5: The lower right corner of the table indicates the level of impervious within the select census tracts according to 1990 census data for the Los Angeles Study Area where the entropy value is slightly further away from zero, in comparison to, table 4.6.

This value was additionally supported with the one-way ANOVA that had a critical value of 3.245 for both 1990 and 2000 census data. In terms of the critical value of the one-way ANOVA, compared to the Shannon's entropy value of 3.65, the Los Angeles study area selected census tracts would be considered compact in urban structure; which means, the potential existence of exurban developments within the selected census tracts is low. The reason for this assumption is due to the amount of urban sprawl Los Angeles has already experienced; as well as, census tract data and satellite imagery that clearly identifies the geographic obstacles. This gives the Los Angeles area no alternative but to utilize land within its existing boundaries. Therefore, as infill has become more recognizable within Los Angeles, the possibility that exurban development being an extension of America's growing suburbia is likely.

Aside from this, the Shannon's Entropy and one-way ANOVA statistical techniques that were implemented resulted in direct support to each other. The comparative results of these two methods determined that Los Angeles was compact in urban form for both 1990 and 2000 census tract data and satellite imagery. As for direct comparison toward the previous study areas of St. Louis and Twin Cities, Los Angeles found similarities with the latter.

According to the results of the Twin Cities, both Los Angeles and Twin Cities were found to be compact in urban development around their central core areas (Table 4.5). On the other hand, the Los Angeles study area saw a minor increase of urban sprawl based on the 0.32 higher entropy value in reference to 2000 data (Table 4.6). This slight increase within the entropy value, however, did not result in Los Angeles being calculated as being dispersed in urban form; instead the study area remained being classified as compact. The Twin Cities, on the other hand, found a change in entropy value high enough to be calculated as dispersed in urban development for its respective 2000 data. This in turn, represents the latter became more dispersed in urban form, even though its selected census tracts increased in levels of imperviousness. Thereby, this recognizes the absence of geographic obstacles surrounding the Twin Cities, which in turn allows the metropolitan area to continue its practice of leapfrog and scattered development further outward from its central core area.

As for the comparative results between Los Angeles and St. Louis, the findings indicate the latter as being more dispersed in urban structure for both 1990 and 2000 census tract data and satellite imagery, in comparison to the former. The differences suggest St. Louis and Twin Cities are more similar, in relation to urban dispersion patterns, when compared to Los Angeles that is highly more compact as evident through the Shannon's Entropy value as seen in Tables 4.5 and 4.6. These tables show the 1990 entropy value at 2.47, and the 2000 entropy value as 2.79 with a calculated threshold of 3.65 determines completely different results for Los Angeles from the two previously analyzed areas.

Census Tract No.(s)	Total (A) of Impervious 2000	Total (A) of Census Tracts	÷ of Area	ln(P)	Final Results
262601	0.2718 sq miles	7.8720 sq miles	0.034	-3.381394754	-0.114967082
800101 and 102	1.2631 sq miles	23.294 sq miles	0.054	-2.918771232	-0.157613647
800502	0.8334 sq miles	8.8151 sq miles	0.094	-2.364460497	-0.222259287
800501	0.3619 sq miles	10.513 sq miles	0.034	-3.381394754	-0.114967422
106603	0.4185 sq miles	4.5686 sq miles	0.091	-2.396895772	-0.218117515
920303	0.4752 sq miles	19.449 sq miles	0.024	-3.729701449	-0.089512835
101	1.2327 sq miles	13.301 sq miles	0.092	-2.385966702	-0.219508937
102	2.3879 sq miles	34.544 sq miles	0.069	-2.673648774	-0.184481765
32048, 49 and 50	0.4343 sq miles	4.8744 sq miles	0.089	-2.419118909	-0.215301583
52426, 27 and 28	1.7758 sq miles	23.868 sq miles	0.074	-2.603690186	-0.192666538
62619	0.0193 sq miles	0.8104 sq miles	0.023	-3.772261063	-0.086762004
62620	0.1525 sq miles	1.2506 sq miles	0.121	-2.111964733	-0.255547733
62632-41	1.5837 sq miles	13.439 sq miles	0.117	-2.145581344	-0.251033017
42205 and 06	0.3602 sq miles	2.9759 sq miles	0.121	-2.111964733	-0.255547733
42111 and 12	0.4386 sq miles	4.8745 sq miles	0.089	-2.419118909	-0.215301583
			Shannon Value		**2.793588679**

Table 4.6: The lower right corner of the table indicates the level of impervious within the select census tracts according to 2000 census data for the Los Angeles Study Area where the entropy value is slightly closer to zero, in comparison to, table 4.5.

The entropy and one-way ANOVA results for Los Angeles, based on 1990 and 2000 census tract data and satellite imagery, where calculations of both techniques presented identical results of compact urban structure; the Tukey Test was completed, in order to determine if any significant difference existed between all three study areas. The Tukey Test found a significant difference between Los Angeles, in comparison to St. Louis and Twin Cities. On the other hand, the latter two study sites were found to have no significant difference. A potential reason for this, as mentioned earlier, has to do with Los Angeles being much large in land area and population density; as well as being geographically obstructed by political and topographical entities. These political and geographical obstacles have resulted in Los Angeles to begin implementing urban infill development, a practice the other two study areas are not necessarily implementing as heavily in reference to their respective satellite images and census tract data trends.

5. CONCLUSIONS

5.1 Summary of Results

The overall results of the study suggest many similarities and differences between all three study areas; as well as, the margin of error that occurs with such an analysis. First, in terms of margin of error, the problem with classifying land coverage classification process is the likelihood of poor accuracy. This poor accuracy includes both unsupervised and supervised classification assessments, where classes are typically incorrectly classified do to similar spectral reflectance of land coverage. A second margin of error comes through the ambiguous and inconsistent definitions applied to the understanding of exurbia, which leads to the analyzers inability to classify exurbia through a remote sensing image classification process.

In regards to margin of error in terms of statistical analysis, the Shannon's Entropy method is extremely limited as its approach is a black and white view of urban sprawl. This in short means the Shannon Entropy does not determine the possibility of gray areas; the calculation either represents the study area as either compact or dispersed. This becomes a problem for any study that is trying to identify patterns of urban sprawl. Even though, the Shannon's Entropy method provides a black and white answer to its findings it was implemented for this study for the following reasons: (1) the purpose of the study was to evaluate selected census tracts based on 1990 and 2000 census data, in relation to satellite imagery; and (2) recognize if these selected census tracts would be classified as being dispersed in urban structure patterns or compact within a spatial context.

By utilizing the Shannon's Entropy method, the findings for all three study areas concluded similar results, with exception to one study area. The two study areas that yielded similar findings were St. Louis and Twin Cities. These two study areas were considered more compact in urban structure in regards to 1990 data. As for 2000 data findings, this presented that both study areas had become more dispersed in urban structure; even though the levels of imperviousness within the selected census tracts indicated some significant increases.

In addition to these findings, both St. Louis and Twin Cities were considered to have a higher likelihood of being surrounded with exurban development. These exurban areas, however, would have moved further outward as evident through satellite image analysis of both St. Louis and Twin Cities. As these two separate study sites both experienced extreme leapfrog and scattered development further outward from their respective central core areas. This in turn, leads to the conclusion that as some of the selected census tracts became more compact, the existence of exurban developed areas could have become an extension of suburbia.

This does not mean that exurbia does not exist, as satellite imagery analysis determines the continued existence of leapfrog and scattered development around the periphery of St. Louis and Twin Cities. Therefore, exurban development patterns may no longer be within the 1990 selected census tracts; instead they may have potentially moved further outward as exurbanites are defined as being less attached to central core areas.

As for the final study area, Los Angeles did not consist of similar findings, in relation to St. Louis and Twin Cities. This study area consisted of different results that were possibly contributed to its geographic location; as well as, its substantial higher population and land area, in comparison to the former study areas. These findings determined that Los Angeles was compact in both study years of 1990 and 2000, as calculated through the Shannon’s Entropy and one-way ANOVA. This presents the conclusion that Los Angeles has remained level with its compact urban development patterns due to its geographic location; as the metropolitan area deals with its political and topographic obstacles that prevent further outward development.

Overall, the Los Angeles study area was determined as being different from the St. Louis and Twin Cities study areas; a finding that was expected based on the historical urban developmental sprawl aspect of Los Angeles, in relation to the other two study sites. This is validated by the Shannon's Entropy method that concludes exurbia has the potential to exist, but within certain geographic locations. These certain geographic locations could be represented within the St. Louis and Twin Cities study areas. As findings indicated some of the selected census tracts were recognized as being more dispersed in urban structure, in comparison to other selected census tracts within the metropolitan area that were recognized as being more compact.

As for the results from the one-way ANOVA and Tukey Test, these findings presented an overall support to the entropy method; as well as, emphasizing the assumption that Los Angeles is definitely different from the other two study areas was an accurate determination. This being stated however, one additional point that needs to be highlighted. Following each statistical analysis, the Shannon Entropy was determined as being un-necessary for the study as the one-way ANOVA and Tukey test presented enough statistical analysis to determine as significant difference between the Los Angeles study area to the St. Louis and Twin Cities study areas.

5.2 Benefits

In analyzing potential benefits to the study, findings showed several. These benefits include the implementation of ERDAS Imagine and ArcGIS software services, census tract data, geospatial techniques and collective literary sources to assist in understanding the concept of exurbia, exurban development and those that are potential exurbanites. The latter, is emphasized through scholarly work on case study classification on the differences between a suburbanite and exurbanite; and together all of these benefits assisted in delineated potential exurban areas from satellite imagery.

The implementation of ERDAS allowed detailed analysis of land cover and classification to be conducted for all three study areas, which in turn was overlaid with census tract data courtesy from the United States Census Bureau. Once data was converted, processed, and post-classified, geospatial techniques were implemented to find areas of impervious verses non-impervious that would assist in determining the location of potential exurban development. Therefore, if a selected census tract would be calculated as dispersed (non-impervious) the possibility of exurbia existing within that particular census tract is high. On the other hand, the opposite outcome could occur, and would thereby result in a high level of compact (impervious) development suggesting the potential possibility of exurbia existing to be low for a particular selected census tract.

Therefore the overall benefits to this approach, are perhaps useful for future analysis on urban sprawl; as the possibility to identify the potential location of exurban developments were successful. This further includes the visual representation of how all three study areas have grown outward from their central core areas, and thus allows projections of how these areas may continue to grow in the future.

5.3 Limitations

Aside from the benefits to the study, limitations exist as well. These limitations are present and were briefly elaborated on within earlier sections. For instance, the ability to define and identify exurbia has proved to be very complex, and extremely difficult to determine. The complexity and difficulty of this issue has to do with inconsistent conclusions by scholars, as well as poorly defined spatial perimeters of its existence. This in turn, has lead to numerous scholars' to resort to analyzing and attempting to define exurbia spatially through the process of remote sensing and geospatial processes.

These remote sensing and geospatial process have encountered limitations to the findings as well. Some of these limitations include image classification, statistical error, and ecological fallacy; the latter being in regards to census data analysis. The problems with image classification is neither ERDAS Imagine nor the user can ever accurately define information classes of land cover. This inability to accurately define information classes of land coverage based on satellite imagery has to do with similar spectral reflectance values that can occur within an image. For instance, spectral reflectance of high density urban can resemble reflectance values of agriculture/bare soil. This problem indicates the level of accuracy for a potential study area is misleading, as it becomes dependant on the interaction of supervised and post-classification techniques to improve accuracy that too will present discrepancies, such as, dark objects and atmospheric obstruction.

The statistical analysis presented in the study has its limits as well; such as, the Shannon's Entropy, as mentioned earlier calculates its findings in either being compact or dispersed. This limitation results in some areas to be perhaps compact, but because of the square miles of the census tract the results could calculate the selected census tract as being dispersed. In light of this issue, the St. Louis study area presented this limitation, as some of the metropolitan study areas' selected census tracts were much larger in square miles, in relation to, the selected census tracts of the Twin Cities and Los Angeles study area. Unfortunately, this difference may have presented a higher value in the Shannon's Entropy value, and thus illustrates the margin of error to this approach.

In addition to the utilization of the Shannon's Entropy for future research of urban sprawl, it would be beneficial to incorporate urban planning, urban morphology and to elaborate further on the issues of social, economic and political concepts. The addition of these concepts mentioned, would allow an increased understanding of the people that live within exurban areas, and could reduce the level of ecological fallacies that are apart of census data.

Finally, in regards to ecological fallacy, this becomes a limitation when incorporating census tract data. While an ecological fallacy is defined as assuming there is a relationship between variables at a group level, in regards to the relationship to an individual. This definition assumption results in socio-economics, race and ethnicity within census tract data to become skewed; however, as mentioned earlier, the presence of ecological fallacies with United States census data will likely continue as the federal law does not allow the release of individual information of census count recipients. Therefore, the census bureau must release data within a group format, thus presenting the potential of outliers with census block, tract, county, state and national level data.

5.4 Suggestions for Future Research

The methods used for this study have overall presented their benefits and limitations; however, they have proven to be useful for future research for alternative study areas. For example, the Shannon's Entropy was successful at determining what selected census tracts had become or remained compact, in relation to those that were calculated as dispersed. This statistical process can assist in evaluating the level of urban sprawl within a metropolitan study area, along with being able to project the direction of future growth.

This further includes the continuation of implementing satellite imagery, and geospatial techniques provided through ArcGIS. The usage of remote sensing has become extremely beneficial toward the study of urban sprawl and exurban development analysis. Remote sensing has allowed geographers and others in related disciplines to evaluate and assess the levels of land cover change that have occurred overtime within a certain geographic location. This in turn, has allowed potential threats to the environment to be analyzed and assessed on hypothetical ideas on ways to curb potential hazards; as well as, project the potential direction a metropolitan area is more likely to grow outward from the central core area. These mentioned usages of remote sensing, while are only representative of a few highlight investigative strategies within the field of geography, along with other disciplines of study have presented the need for the implementation of this technology indicating the continual need it provides.

Finally, the additional usage of 2010 satellite imagery and census tract data would provide a two decade timeframe comparison for all three study sites. This implementation of 2010 data would present a possible conclusion that exurbia does exist within certain geographic locations, or present an opposite result to the present initial findings toward this study. Nonetheless, the incorporation of 2010 data for all three study sites could provide further insights on the scope, direction and continuation of urban sprawl that is effecting these study locations. This in turn, could present foundation to investigate other metropolitan areas within the United States, and how these trends from 1990 to 2010 may have respects on the existence of exurban development.

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