QUANTIFYING SPATIOTEMPORAL PATTERNS OF PAST AND FUTURE URBAN TRENDS IN EL PASO, TX AND THEIR IMPACT ON ELECTRICITY CONSUMPTION USING NLCD DATA AND THE CA-MARKOV MODEL

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Dedication

This dissertation is dedicated to my Lord and Savior, Jesus Christ, for all his blessings; and my family. I want to thank my grandfather, Wilbur, for his example of hard work and love. I want to especially thank my Dad, William, for his prayers, encouragement, and unfailing love. I could not have accomplished this without my Dad. My brother, Jim, for his prayers and love during this process and always. My sister, Donna, for making me promise to continue my education and her love. My sister, Nancy, for being my example as the first in our family to graduate college and her love. I would also like to thank my friends for their encouragement.

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by

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Abstract

As cities continue to grow, their urban form continues to evolve over. Understanding this evolution allows for planners, engineers, and decision makers to plan for a sustainable community. Change analysis was conducted for El Paso, Texas county to determine the areas of growth within the past 15-years (2001-2016). The results indicate that growth has primarily occurred within the city of El Paso, in particular Districts 5 (east side), 1 (west side), and 4 (northeast), with District 5 experiencing substantial growth. Developed sub-categories medium and High intensity experienced the fastest growth, which represents single-family housing and compact/commercial areas. However, landscape metrics indicate that the dominating land-use is single-family housing (low and medium intensity). Landscape metrics suggest as the districts continue to grow, fragmentation and shape irregularity of developed areas decrease. The metrics also indicate a diverse sub-category landscape, which may suggest mixed-use within developed areas.

Using past growth trends, CA-Markov is employed to predict 2031 land-use. The counties' projected growth is evenly contributed to El Paso city and outside city limits. Growth outside city limits is expected within Plan El Paso's potential annexation areas (City of El Paso 2012), with the exception of projected growth adjacent to District 1. Similar trends for city growth are suggested in 2031 land-use, with Districts 1, 4, and 5 dominating the cities' growth. The landscape metrics suggest as Districts 1 and 5 continue to expand, there is a decline in fragmentation. However, District 4 indicates an increase in fragmentation as the districts' developed areas expand. Panel data analysis was performed to investigate the relationship between landscape metrics and electricity consumption. The results indicate that the developed mean patch area is positively correlated with consumption, provided the metric does not remain

constant. The findings suggest that future growth continues to be directed within Districts 1 and 4, with fragmentation discouraged through city policies. The vast growth concentration within single-family housing should be redirected to compact housing within the high-intensity sub-category. Though these categories have experienced the fastest growth, high intensity comprises the smallest area of the districts' landscape. Further research should be conducted to include metrics that describe the interconnection of developed patch areas and an increase in time observations to provide a better understanding of the landscape metrics and electricity consumption relationship.

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Chapter 1: Introduction

1.1 Problem Statement

Urbanization has become an increasing concern to planners, engineers, decision-makers, and the public in recent years. Urban growth is a necessary process to meet the needs of a growing population through housing, roadways, and commercial buildings; which are examples of what encompasses urban growth. The patterns and rate of urban expansion have been studied extensively in various cities of the United States through the use of remote sensing and geographic information system (GIS). However, minimal research has been conducted to understanding the urbanization growth of El Paso, Texas in the past 15 years. Understanding El Paso's past urban growth patterns allows for a basis to predict future trends of urbanization. Understanding future urban growth patterns allows decision-makers and stakeholders to plan accordingly for a sustainable El Paso. According to the El Paso Comprehensive Plan (Plan El Paso), "managing El Paso's outward expansion is perhaps the most complex and difficult strategy…" (City of El Paso 2012). Landscape metrics are a means to understand various aspects of urban growth patterns including fragmentation, sporadic growth, infill, or outward sprawl. Understanding growth patterns allows informed policy creation to plan for smart communities, which consist of dense development to limit transit times, reduce infrastructure costs, and are environmentally conscious. Urban growth has also placed a strain on resources such as energy consumption. Residential and commercial sectors account for 40% of U.S. energy consumption. Relating El Paso's urban growth patterns to electricity consumption allows decision-makers and the public to make informed decisions based on scientific analysis for policies and urban planning strategies.

1.2 Objectives

The following objectives illustrate the focus of this dissertation:

1) Provide an understanding of El Paso's past growth from 2001 – 2016 utilizing change analysis.
2) Utilize landscape metrics to analyze El Paso's urban dynamic growth patterns.
3) Predict future land-use within El Paso County for 2031 utilizing CA-Markov and apply landscape metrics to understand growth patterns.
4) Examine the relationship between El Paso's landscape metrics and electricity consumption.

1.3 Significance of Research

"The proper design and management of the physical environment-both the natural and man-made realms – will determine if we can provide an even better El Paso to our children and grandchildren than the one we know today," from El Paso's City Comprehensive Plan. The purpose of this study was to provide decision-makers and stakeholders with an understanding of El Paso's urban growth patterns within the last 15-years, project and analyze future growth patterns, and its' subsequent impact on electricity consumption in order to make informed decisions. Cities typically consist of an urban center that consists of the cities' nucleus from which employment, entertainment, and government resources are centered. Thus, a cities' growth is centered around the urban centers. The urbanization analysis of such cities' focus on growth trends from the urban center. However, El Paso's growth has dispersed into three main wedges due to El Paso's unique geographical setting consisting of urban growth constrains. The constraints include a countries' border (Mexico), state border (New Mexico), largest urban park in the United States (Franklin Mountains State Park), and military reservations; which dictate El Paso's urban expansion locations. These constraints have forced urban expansion beyond El

Paso's urban center (City of El Paso 2012). This study focused on specific districts within the county that possessed the majority of urban growth within the study period. Minimal research has been conducted on El Paso's urban growth trends and consequential patterns. Therefore, this study adds to the existing research and provided an analysis of El Paso's urban growth trends from 2001-2016, and utilized landscape metrics to quantify the resulting urban dynamic patterns. CA-Markov was incorporated to project 2031 future growth to understand where urban development is projected to occur within El Paso county and analyze its' projected landscape patterns. Urbanization demands an increase in resources, such as electricity, to meet the needs of a growing community. According to Plan El Paso, the sustainable energy goal consists of "promote behavioral changes and consumption pattern that conserve energy…" (City of El Paso 2012). Due to data availability, this study focused on El Paso's urban dynamic patterns impact on electricity consumption, a secondary source of energy, within El Paso's fastest-growing areas within the last 15 years (2001-2016). Lessons learned from this relationship will provide decision-makers, urban planners, and residents a statistical basis for making informed decisions on how to expand El Paso to provide the optimum quality of life for the residents. This study is an example for urban areas, like El Paso, which possess constraints that influence urban growth patterns, and how these areas impact electricity consumption. El Paso is also a case study for cities who exhibit growth within specific regions of the city and wish to have an understanding of the growth characteristics.

1.4 Organization

This dissertation begins with the literature review of topics such as the application of remote sensing in understanding urban development, landscape metrics for dynamic urban growth patterns, predictions of land-use, and the relationship between electricity consumption

and urban growth. The methodology adopted and data collection for this study are discussed in Chapter 3. This chapter discusses the location of the study area, land-use change analysis implemented along with the landscape matrices utilized, land-use prediction for 2026, and the role of electricity consumption in urban growth. Chapter 4 discusses the results of the analysis, including the change analysis, the accuracy of the data utilized in the study, landscape matrices and their findings, future prediction of land-use for 2026, and the relationship between urban patterns and electricity consumption. A summary of the study, concluding remarks, limitations, and recommendations are presented in Chapter 5 of this dissertation.

Chapter 2: Literature Review

2.1 Background

The world's population is estimated to grow by approximately one billion people within the next decade, reaching 8.5 billion by 2030 (United Nations 2017). According to the United Nations, 3.5 billion people, half of the world's population, currently reside within cities and is expected to increase to 5 billion by the year 2030 (United Nations 2016). This results in "60% of the world's population will live in cities by 2030 (United Nations n.d.)." The term "cities" is commonly referred to as incorporated areas that have legal jurisdiction to conduct governmental activities, such as collecting taxes, within "legally defined geographic boundaries" (U. C. Bureau 2015). The U.S. Census Bureau defines urban areas as "a cluster of densely settled census blocks that together have a population of at least 2,500 people" (U. C. Bureau 2015). Thus, the term "urbanization" refers to the spatial distribution of former rural areas into urban, built environments (United Nations 2018). In 1990, the U.S. possessed 86 cities with a population of 300,000 or more. The number of cities grew to 144 in 2018 and is projected to contain 158 cities with a population of 300,000 or more in 2030 (United Nations 2018). Within the past eight years (2010 – 2018), the United States has experienced an approximate 6% population increase, with Texas ranked first in population growth at nearly 3.6 million people added (U. C. Bureau 2015). In 2001, 79% of the US population lived in urban areas. The percentage increased to 82% in 2016 and is projected to increase to 85% by 2031 within the US (United Nations 2018). Metropolitan areas are designated by the U.S. Office of Management and Budget, and may consist of one or several counties, an urban center of a minimum of 50,000 people, and may include additional cities that rely on the urban center for their economic and social benefits (U. C. Bureau 2015). Cities are the center of economic prosperity and advancement opportunities. As

a result, population growth is considered an indicator of projected city growth to accommodate the needs of residences such as drinking water and wastewater, transportation, and housing. As cities continue to expand, it is vital to plan and manage expansion wisely and not randomly. El Paso County is expected to reach a population of over 1 million by 2030, which has continuously expanded outward since 1873 (City of El Paso 2012). Understanding past and future urban growth and their patterns are vital in planning and designing sustainable and efficient future development. To ensure a sustainable environment, consideration of energy efficiency within new development is a priority under the Energy goal in Plan El Paso. Meeting the energy needs for the present without compromising future El Pasoan's resources, is the goal of understanding the relationship between urban growth and electricity consumption. Providing an analysis of past and future land-use within the region, and how these patterns affect energy consumption will provide decision-makers and stakeholders vital information to make informed and sustainable decisions.

2.2. Understanding Urban Development Utilizing Remote Sensing

As a result of city expansion, land cover is rapidly changing to accommodate the needs of a growing population (Tv, Aithal, and Sanna 2012). Urbanization incorporates land cover and land-use change in and around metropolitan areas. Land cover pertains to the current land features (Sudhira, Ramachandra, and Jagadish 2004; Tv, Aithal, and Sanna 2012), which can include the natural environment (Chen Liping, Sun Yujun, and Saeed 2018), while land-use relates to human dwellings and resulting modification of land cover (Chen Liping, Sun Yujun, and Saeed 2018; Sudhira, Ramachandra, and Jagadish 2004; Tv, Aithal, and Sanna 2012). Land-use and land cover (LULC) change refers to the transformation of one land classification to another. This transformation occurs during urbanization when the native land cover is

transformed to built-up urban areas. Urbanization is the fastest growing classification of land-use (United Nations 2016). Synonymous with impervious surface cover, urbanization includes road, residential/commercial buildings, and structures. LULC change of cities exhibits various growth patterns and size over time. This spatial-temporal relationship has played a critical role in monitoring and mapping urbanization trends. The tools used in analyzing and understanding spatial-temporal trends are Remote Sensing (RS) and Geographic Information Systems (GIS). The coupled relationship between RS and GIS application has been well-documented for its effective use in mapping and analyzing urban development. This relationship incorporates satellite imagery to perform LULC changes and ultimately a change detection analysis (Aburas et al. 2017). Change detection analysis provides both, a visual and quantitative analysis, as to the amount of change that has occurred over a specified length of time. It is primarily used to measure, monitor, and evaluate LULC changes that have occurred within a study area (Aburas et al. 2017). The stages of change detection analysis are data acquisition and processing, accuracy assessment, mapping, and identifying occurrences of change (Aburas et al. 2017; Alkan et al. 2013; Suribabu, Bhaskar, and Neelakantan 2012). Data acquisition is dependent upon the desired study and availability of data.

An error matrix and kappa index are popular accuracy assessments conducted for verification of data. Various maps are then created to identify and analyze land-use change. The final product consists of maps and statistical information to provide a visual and quantitative understanding of land-use change (Aburas et al. 2017). Change detection analysis is vital in understanding the characteristics and processes of city growth.

2.2.1 Urban Development Analysis within Arid Regions/El Paso

Earlier research studies have been conducted to understand urban dynamics for metropolitan areas centered within wooded or agricultural rich regions within the United States (US), including Washington, D.C. – Baltimore and Minneapolis-St. Paul (Sexton et al. 2013; Yuan et al. 2005). These studies discuss the effects of urbanization on deforestation and farmlands. On the contrary, for arid urban environments, research has incorporated Phoenix, AZ as a study area , where the region is used for a proposed expert land cover classification system (Stefanov, Ramsey, and Christensen 2001). Phoenix Metropolitan area has also been the study area to examine possible land fragmentation due to rapid urban growth, and examine the accuracy of land cover data by the National Land Cover Database (Shrestha et al. 2012). A comparison of spatiotemporal patterns among Phoenix, AZ and Las Vegas, NV was conducted to compare growth patterns of the vastly growing urban areas (Wu et al. 2011). Urban growth patterns have focused included Tucson, AZ to measure the effects of urbanization (DiBari 2007).

El Paso, Texas is one such city located within an arid environment. Numerous research articles have included a discussion of El Paso's growth using remote sensing. However, these articles focus on a larger study region which includes the entire El Paso Del Norte Region. Few urban dynamic studies focused solely on the City of El Paso to provide an extensive understanding of its' spatiotemporal patterns and drivers. Remote sensing technology has been utilized for analyzing critical areas within El Paso-Juarez for flood control as a result of the extreme weather events (such that occurred in 2006 (Barud-Zubillaga 2011)), evaluating extreme rainfall scenarios and subsequent runoff due to land-use change and studying its' impact on watersheds within El Paso (Neelam 2018). Studies also incorporated remote sensing to analyze air pollutants within the region (Mahmud 2016), nighttime urban heat retention and subsequent health effects within El Paso (Amaya et al. 2016), and land-use change effects on the ecosystem (Miyazono, Patiño, and Taylor 2015). Land-use change analysis was conducted for the Middle Rio Grande Basin along a 16km swath of either side of the Rio Grande River, which includes