THE RELATIONSHIP BETWEEN LAND USE AND TEMPERATURE CHANGE

IN DALLAS COUNTY, TEXAS

A Thesis

by

HEE JU KIM

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF URBAN PLANNING

August 2009

Major Subject: Urban and Regional Planning

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Approved by:

Chair of Committee,	Samuel D. Brody
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ABSTRACT

The Relationship between Land Use and Temperature Change in Dallas County, Texas.

(August 2009)

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Chair of Advisory Committee: Dr. Samuel D. Brody

This study examines the relationship between land use and temperature change in Dallas County, TX. The purpose of this research is to analyze the relationship between temperature and land use and to identify the primary factors contributing to the formation of urban heat islands based on different categories of land use. Specifically, this research analyzes the elements that contribute to the urban heat island effect in Dallas County using temperature data provided by remote sensing imagery and parcel-based land use data using Geographic Information System (GIS) technique and a correlation analysis method, which was employed to analyze the relationship between temperature and land use.

The results of this study showed that every land use category has different temperature averages and those patterns were observed similarly in both 2000 and 2005. Parking, airport, commercial, industrial, and residential areas have relatively high temperatures. In contrast, water, undeveloped area and parks showed relatively low temperatures. Another major finding was ratio of land use composition affected the temperature of census tracts. Correlation analyses of land use and temperature in 2000 and 2005 indicate that various types of land use categories have significant relationships with temperature. Among them commercial, industrial, residential, parking, and infrastructure, are positively associated with temperature, while undeveloped, parks, water, and dedicated areas are negatively associated with temperature. Areas with a high ratio of commercial use showed the highest and undeveloped areas showed the lowest relationship. Furthermore, through the analysis of the relationship between land use and temperature change for five years (2000-2005), this study finds that temperature change depends on the ratio of each land use category change.

The results of this study can help local planning and policy decisions which are related to urban land use planning concerning temperature change such as zoning, environmental regulations and open space preservation.

DEDICATION

To my husband, Taeho

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CHAPTER I

INTRODUCTION

1.1 Research Background

A considerable amount of research has been conducted on acute natural hazards such as hurricanes, floods and earthquakes, but comparatively few studies have been done on slow-onset hazards such as climate change. Environmental hazards not only produce acute disasters but also chronic problems such as urban heating and environmental pollution. These chronic environmental hazards have accumulated for many years, making it difficult to overcome their adverse effects -- death, accelerated desertification and threats to public health.

Urban heating is the one of most serious chronic hazards facing local communities. According to the EPA, "the annual mean air temperature of a city with one million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings. In the evening, the difference can be as high as 22°F (12°C). Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality."[1] Built-up urban areas with deforestation concentrate the heating effect.

Urban heat islands are urban areas with air and surface temperatures higher than the ambient temperatures that are associated with their surrounding rural areas (Streutker,

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This thesis follows the style of and format of *Journal of the American Planning Association*.

[1] EPA website "http://www.epa.gov/*heatisland*/"

2003; Aniello et al., 1995). This effect has become well-recognized since the 1960s when research h an increase in the annual high temperatures for the City of Los Angeles. When planted spaces and natural vegetative cover were replaced with buildings, parking lots, roads, and industrial and commercial complexes, the average temperature in the downtown area of Los Angeles increased by approximately 1°F each decade from the 1930s to the present (LBNL, 2004; Aniello et al., 1995). Many geographical and climatological studies regarding urban heat islands and urban land surface changes have been performed (Voogt & Oke, 1997). However, the urban heat island effect has only recently gained serious attention in the field of urban planning and public health (Stone & J. M. Norman, 2006). Thus, it is important to study this Urban Heat Island phenomenon with its accompanying environmental problems and try to develop solutions from a planning perspective.

1.2 Research Objective and Scope

Many large cities are experiencing problems with urban heat island effects because of increased development including residential, business and industrial areas, and loss of open spaces -- water and green areas. Even though the urban heat island effect creates numerous physical and social problems, there have been few concerns and policies to deal with the negative impacts of this phenomenon.

There are various causes of increasing urban heat island effect such as population, city size, land use/land cover, etc. Based on the urban heat island effect, land use/land cover can be a main factor affecting regional temperatures. To establish policies or action for decreasing the urban heat island effect it is necessary to know which characteristics of land use significantly increase or decrease temperature in terms of microclimate. Thus, the purpose of this research is to analyze the relationship between temperature and land use and identify the primary factors contributing to the formation of urban heat islands based on different categories of land use. Specifically, this research examines the elements that contribute to the urban heat island effect in Dallas County using temperature data provided by remote sensing imagery [2] and parcel-based land use data using GIS (Geographic Information Systems).

Therefore, the objectives of this research are to:

1) Examine urban heat islands effect at a regional-scale using remote sensing data and GIS techniques

2) Analyze the relationship between land use and temperature based on census tracts

3) Analyze the relationship between land use change and temperature change

4) Examine planning and policy implications regarding temperature change associated with land use change

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[2] Landsat TM band6 (*Thermal*), USGS

CHAPTER II

LITERATURE REVIEW

2.1 Urban Heat Island Effect

The urban heat island effect was first documented by Luke Howard in his climate study of London over 180 years ago. This phenomenon is one of the most powerful elements increasing temperatures as a result of urban development (Landsberg, 1981). Based on "Recent advances and issues in meteorology", the urban heat island is detailed as "an area of higher temperatures in an urban setting compared to the temperature of the suburban and rural surroundings. It appears as an "island" in the pattern of isotherms on a surface map (p. 264)." This effect may be measured as both surface and atmospheric phenomena. The temperature profile shown in Figure 1, for example, illustrates a very generalized distribution of near-surface (measured 1-2 meters from the ground) air temperatures across varying intensities of urbanized land use (Stone, Jr., Michael O. Rodgers, 2001).

The heat island is a reflection of the totality of microclimatic changes brought about by man-made alterations of the urban surface. Even a single building complex will show a different microclimate than an equal-sized piece of land in its natural state (Landsberg, 1981). Urban heating can negatively impact the economy and human health (Lo & Quattrochi, 2003). High profile killer heat waves such as experienced recently in

Chicago (1995)[3] and France (2003)[4] resulted in the potential for heightened numbers of deaths (Rosenzweig et al., 2005). Moreover, higher temperature from urban heat islands prompt increased use of energy for air conditioners, which send significant amounts of heat energy into the urban environment (Jensen, 2000).

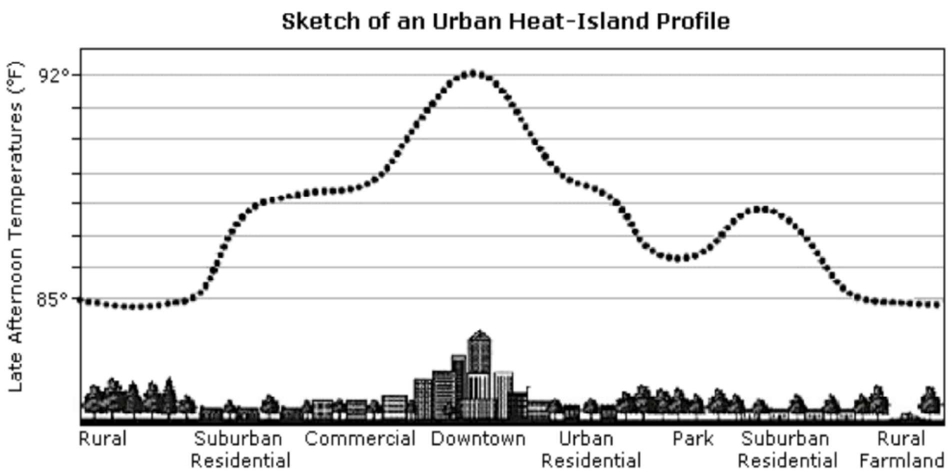


Figure 1. Sketch of urban heat island profile
(Source: http://eetd.lbl.gov/HeatIsland/HighTemps)

Many factors contribute to the urban heat island effect. Oke (1973) argued that city size and urban heat island effect are related and he explained that restricted land use in large cities can reduce climate change. He also explained in his book, *Boundary Layer Climate* (1987) that urban construction and deforestation is great enough to raise the

[3] In the case of Chicago, it sustained a heat wave that resulted in more than 600 excess deaths and 3300 excess emergency department visits (Jane E. Dematte, 1998).
[4] "France recorded 11,435 extra deaths during a heat wave in the first two weeks of August when temperatures soared over 40 degrees Celsius (104 Fahrenheit) according to officials." (CNN, Friday, August 29, 2003)

average temperature of a city by several degrees over that of peripheral nonurbanized regions. Rosenziweig et al. (2005) explained that population shifts, urban and suburban growth, land-use change, and production and dispersal of anthropogenic emissions and pollutants interact with regional climate as well as with the frequency and intensity of specific weather events. In addition, heat islands develop in areas that have a high percentage of non-reflective, water-resistant surfaces and a low percentage of vegetated and moisture-trapping surfaces. In particular, materials such as stone, concrete, and asphalt can trap heat at the surface (Landsberg, 1981; Oke, 1982; Quattrochi et al., 2000). Increasing amounts of dark and impervious surfaces that absorb relatively more sunlight can be one significant cause of the urban heat island effect (Streutker, 2002). Takahashi et al. (2004) pointed out that diminished green areas, low wind velocity due to high-building density and change of street surface coating materials are the main factors which increase air temperature.

Researchers have studied the relationship between surface characteristics and heat island effects (temperature) through various data. For example, Kalnay and Cai (2003) examined the impact of urbanization and land use change on climate. Their research revealed that the diurnal temperature range with land-use change is at least twice as high as urbanization alone. Jenerette et al. (2007) studied the relationship between mean surface temperatures, vegetation density, and socioeconomic characteristics across census tracts in metropolitan Phoenix, AZ. This research established a statistically significant link between vegetation density and daytime surface temperature.

Many analyses have used thermal remote sensing data to examine land surface characteristics. Remote sensing data provide researchers with the ability to examine large areas of terrain in greater and greater detail (Jensen, 2000). For example, Lo et al. (1997) used remote sensing techniques to compare the urban heat island effect with vegetation coverage that is often measured by NDVI (Normalized Difference Vegetation Index). Alexander Velazquez-Lozada (2006) explained that the urban LCLU modifies mass and energy exchanges between the surface and the low atmosphere reflected in low relative humidity and high temperatures in urban areas when compared to rural areas.

Steve et al. (2007) studied the influence of land use on the urban heat island in Singapore and found that each different land use type has a different temperature profile. The result of this study found differences between day and night time temperatures. During the day, industrial areas and airport/port areas have the highest surface temperatures because of their open concrete areas. Commercial and business areas follow industrial areas, and park areas have the lowest surface temperature. On the contrary, at night, commercial and business areas have higher temperatures than industrial areas released due to the heat trapped inside the urban canyon being slowly released into the environment. Last, Stone et al. (2006) studied residential parcel design and surface heat island formation in a major metropolitan region of the southeastern United States. They argue that parcel-based research surface warming can lead to parcel-specific land use policies such as zoning regulations, subdivision regulations, and building codes.

2.2 Land Cover and Land Use

The term "land-cover" is associated with the form or materials covering land surface: forest, water, homes, crops and asphalt. "Land-use" refers to the functional use of land surface: agriculture, commerce, residential, etc. Many different land-cover types can be present in one land-use type (Jensen, 2005). Urban land use change will continue to cause the biggest human impact on the terrestrial environment (Kaufmann et al., 2007).

Research has shown that land use changes can adversely affect natural environments. Land use is another key factor controlling the water balance of ecosystems and associated river runoff. Land use changes have already impacted the terrestrial water cycle and will continue to do so in the next century (Shilong Piao et al., 2007). Different urban land use patterns and population densities have been used as measures and indices of different GHG (Regional Greenhouse Gas) profiles (Gaffin, 1998). Land use and land cover changes can be the criteria for urban development to provide change in land use in urban areas. Changes in urban surfaces have altered the radiative, thermal, moisture and aerodynamic properties of the environment (Oke, 1987).

Many researchers have proved that urban land and climate are connected. For example, Menne et al. (2004) argue that "urbanization and other changes in land use have an impact on surface air temperature (p.214)." Through their analysis the authors showed through their analysis that land use change makes a difference of 0.147C. They explained that "this result also indicates that land-use change accounts for two-thirds of the warming over the past four decades (p. 214)." Similarly, Robert C. Hale et al. (2006) observed significant temperature change associated with land use/land cover change; 95% of the stations analyzed in their study showed warming trends. Cai and Kalnay (2003) explained that reforestation, saturation of urban heat-island effects, and more regulated land-use change could be primary factors in decreasing temperatures. In same context, the areas contain a high percentage of non-reflective, water-resistant surfaces and a low percentage of vegetated and moisture-trapping surface contribute to urban heat island effect. Especially, materials such as stones, concrete, and asphalt tend to trap heat at the surface (Landsberg, 1981; Oke, 1982) and lack of vegetation covers are directly connected with temperature increasing (Lougeay et al., 1996).

CHAPTER III

RESEARCH DESIGN AND METHODS

3.1 Conceptual Research Framework

The general approach and methodology for establishing the relationship between land use and urban temperature are illustrated by the flow chart in Figure 2. After preparing parcel-based land use data and temperature data from Landsat5 TM, Thermal band, Landsat 5 TM thermal band was converted from DN (Digital Number) value to temperature (Kelvin); land use data were categorized and aggregated by land use characteristics based on a land use category made by NCTCOG (North Central Texas Council of Governments). In the case of remote sensed image in 2005, clouds were removed because the presence of clouds in the image would have contaminated the heat island effect. Thus, cloud pixels were removed by virtue of their low relative temperature[5] (Streutker, 2002). Using prepared data, I overlaid both sets of data with census tracts using ArcGIS 9.3. Next, to show varying temperatures following each different land use category, a correlation analysis[6] was conducted using the percentage of each land use category and average temperatures were then calculated in the census tracts. Last, I examined the relationship between land use change and temperature change over five years (2000-2005) through correlation analysis[7] to show that land use change can be one

[5] In this study, the pixels that have temperature below 297K (Kelvin) are removed because of clouds.
[6 ,7] Pearson's product moment correlation

of the elements which change temperature. This result is a valuable resource for future land use planning.

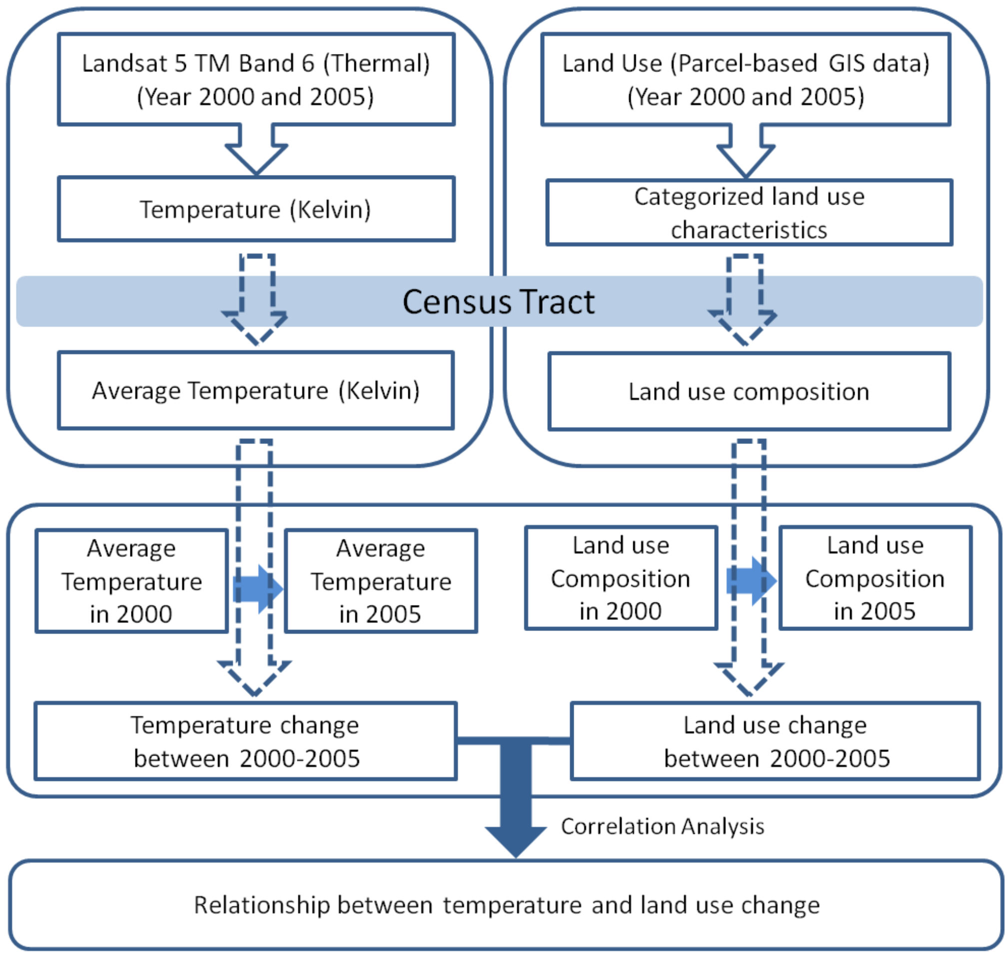


Figure 2. Approach and methodology flow chart

3.2 Study Area

Dallas County in north central Texas, as shown in Figure 3, is bordered by Kaufman and Rockwall counties to the east, Tarrant County to the west, Denton and

Collin Counties to the north, and Ellis County to the south. Its county seat is Dallas, which is also the largest city in the county, the third-largest city in Texas, and the ninth-largest city in the United States. Dallas County is the most populous county within the metropolitan area and contains the largest of its principal cities. Dallas County has 879.6 square miles of land area and, as of 2007, the county had an estimated population of 2,366,511, it is now the ninth most populous county in the United States. (US Census Bureau, 2008)

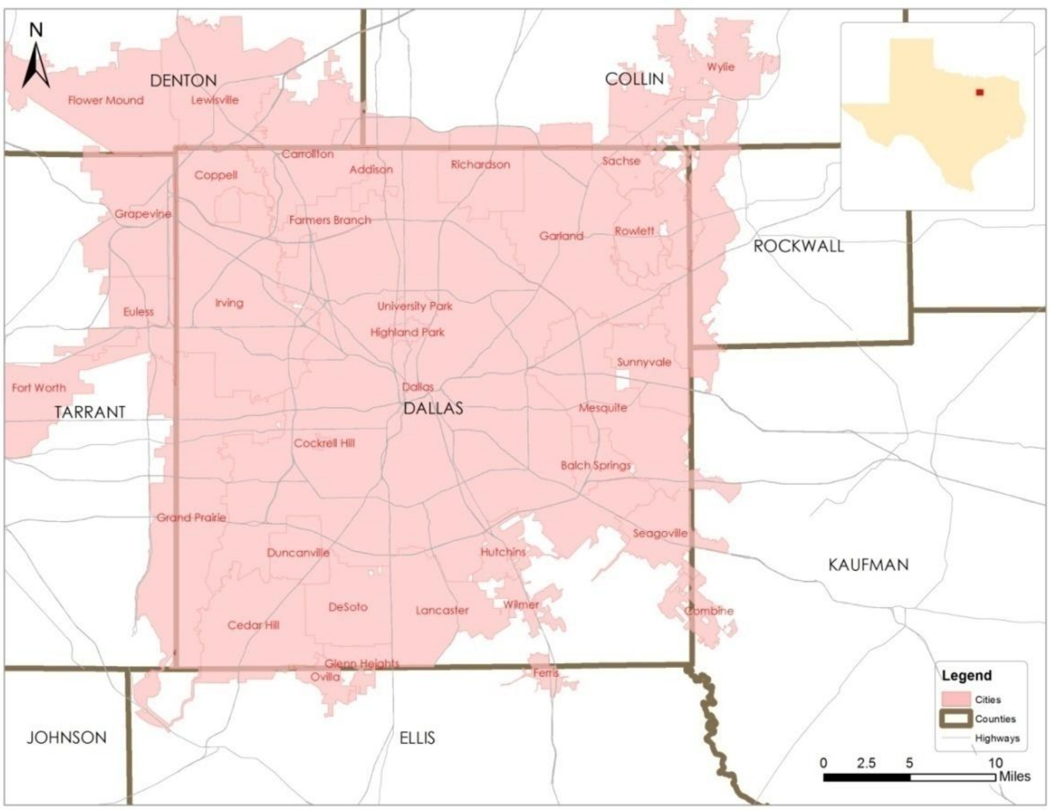


Figure 3. Study area: Dallas County

Growth in urban population and land development has increased impervious surfaces and regional temperatures. For this reason, nearly all of the larger cities in the world have problems with public health and energy use. The Dallas-Fort Worth metro region is the 9th largest metropolitan area in the United States in terms of population. The population growth of the Dallas-Fort Worth PMSA (Primary Metropolitan Statistical Area) was 29.3% between 1990 and 2000, which is more than double that of the national growth rate of 13% (US Census Bureau, 2000). Due to this trend, urbanization has also rapidly accelerated. Changes in urban surfaces have altered the radiative thermal, moisture and aerodynamic properties of the environment (Oke, 1987; Givoni, 1998). Urbanization and deforestation are two major human impacts which have altered the patterns of land-use and land-cover (LULC).

Dallas County is located in the North Central Texas climate division; the temperature change in this climate zone between 1970 and the present was 1.05F. (See Figure 4)

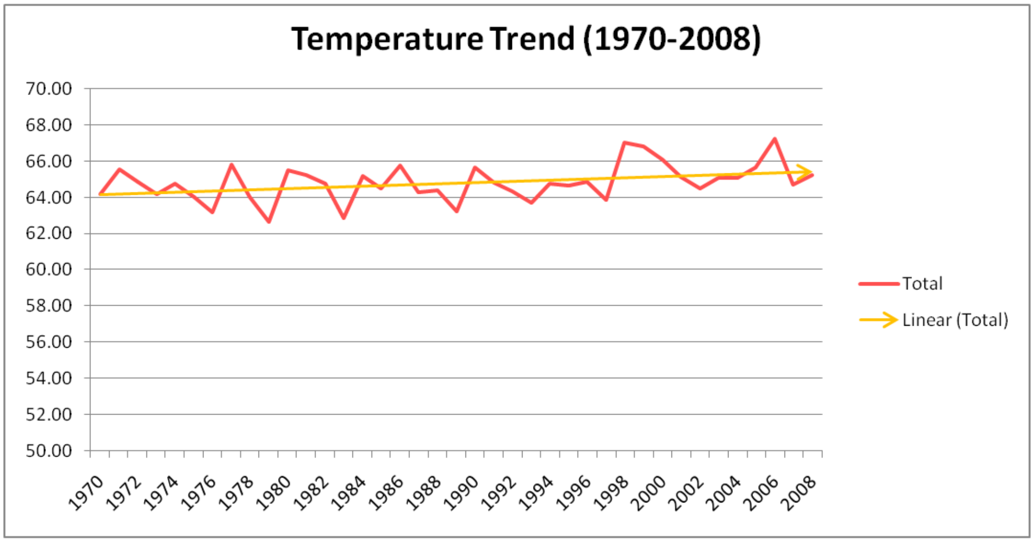


Figure 4. Temperature trend of North Central climate division between 1970-2008

3.3 Data Sources

The following data were used to analyze the relationship between temperature and land use change. 1) The 2000 and 2005 Land use data from NCTCOG were mapped based on parcels with a data format of Shape (Vector). 2) Census tract shape file from NCTCOG presents the census tract boundary which contains the population related attribute and physical characteristics attribute (Area, parameters) as well. 3) Two sets of Landsat 5 TM imageries from USGS (U.S. Geological Survey) were acquired July 10, 2000 and July 8, 2005, with a thermal band (10.4-12.5µm) at a spatial resolution of 120 meters. Table 1 provides detailed information about each of the data sources used in this study.

Table 1. Data sources

	Description	Year	Data format	Source
Land use	Parcel-based Land use	2000 2005	.Shp (vector)	NCTCOG
Census tract	Census tract boundary	2000	.Shp (vector)	NCTCOG
Temperature	Landsat 5 TM band 6(Thermal band) Spatial resolution: 120m	July 10 2000 July 8 2005	.Tiff (raster)	USGS

3.4 Concept Measurement

3.4.1 Dependent Variable: Temperature

The dependent variable is the temperature in 2000 and 2005 within Dallas County. To observe temperature change, I used the Landsat 5 TM imagery from the USGS which was acquired July 8, 2005 and July 10, 2000 with a thermal band (10.4-12.5mn) at a spatial resolution of 60 meters since the urban heat island effect can be readily observed in summer (Landsberg , 1981).

The digital number values from the thermal band of the Landsat 5 TM data were converted to temperatures using the following two steps (Chander et al., 2003):

1) Digital number value of the thermal band was converted into radiance values (L) using the following equation:

$$1.\ \text{Radiance}(L_\lambda) = L_\lambda = \left(\frac{LMAX - LMIN}{Q_{cal\,max}}\right) Q_{cal} + LMIN_\lambda$$

where

L_λ Spectral radiance at the sensor's aperture in $W/(m^2 * sr * \mu m)$;

Q_{cal} quantized calibrated pixel value in DNs;

Q_{calmin} minimum quantized calibrated pixel value (DN=0) corresponding to $LMIN_\lambda$;

Q_{calmax} maximum quantized calibrated pixel value (DN=255) corresponding to $LMAX_\lambda$;

$LMIN_\lambda$ spectral radiance that is scaled to Q_{calmin} in $W/(m^2 * sr * \mu m)$;

$LMAX_\lambda$ spectral radiance that is scaled to Q_{calmax} in $W/(m^2 * sr * \mu m)$;

Table 2 shows band-specific $LMAX_\lambda$ and $LMIN_\lambda$ parameters used at different times for the NLAPS processing system. λ parameters used at different times for the NLAPS processing system. This equation and parameters were needed to convert DN value to Radiance value. (Dhander et al., 2003)

Table 2. L-5 TM postcalibration dynamic ranges for U.S. processed NLAPS data

Spectral Radiances, $LMIN_\lambda$ and $LMAX_\lambda$ in $W/(m^2 * sr * \mu m)$				
Processing date	From March 1, 1984 To May 4, 2003		After May 5, 2003	
Band	$LMIN_\lambda$	$LMAX_\lambda$	$LMIN_\lambda$	$LMAX_\lambda$
1	-1.52	152.10	-1.52	193.0
2	-2.84	296.81	-2.84	365.0
3	-1.17	204.30	-1.17	264.0
4	-1.51	206.20	-1.51	221.0
5	-0.37	27.19	-0.37	30.2
6	1.2378	15.303	1.2378	15.303
7	-0.15	14.38	-0.15	16.5

1) The radiance values (L) were converted to effective at-satellite Kelvin temperature (T) by using the inverse of Planck’s equation of radiation. The conversion formula is

$$2. \quad T = \frac{K2}{\ln\left(\frac{K1}{L_\lambda} + 1\right)}$$

where

T effective at-satellite temperature in Kelvin;

K2 calibration constant 2 in Kelvin;

K1 calibration constant 1 in Kelvin;

L_λ spectral radiance at the sensor’s aperture

In this study, K1 and K2 constants for Landsat 5 are 607.09 and 1260.56, respectively. This remotely sensed temperature data is not surface temperature but at-satellite temperature. Thus, it is necessary to calibrate using in-situ ground truth data to get the surface temperature. However, the focus of this study was to compare regional temperature change between two years. Thus, it is not necessary to get exact surface temperatures.

Figure 5 shows Dallas County displayed with Kelvin temperature which was converted from thermal band data from Landsat TM imagery (2000). In this picture the urban heat island effect can be observed around the city of Dallas.

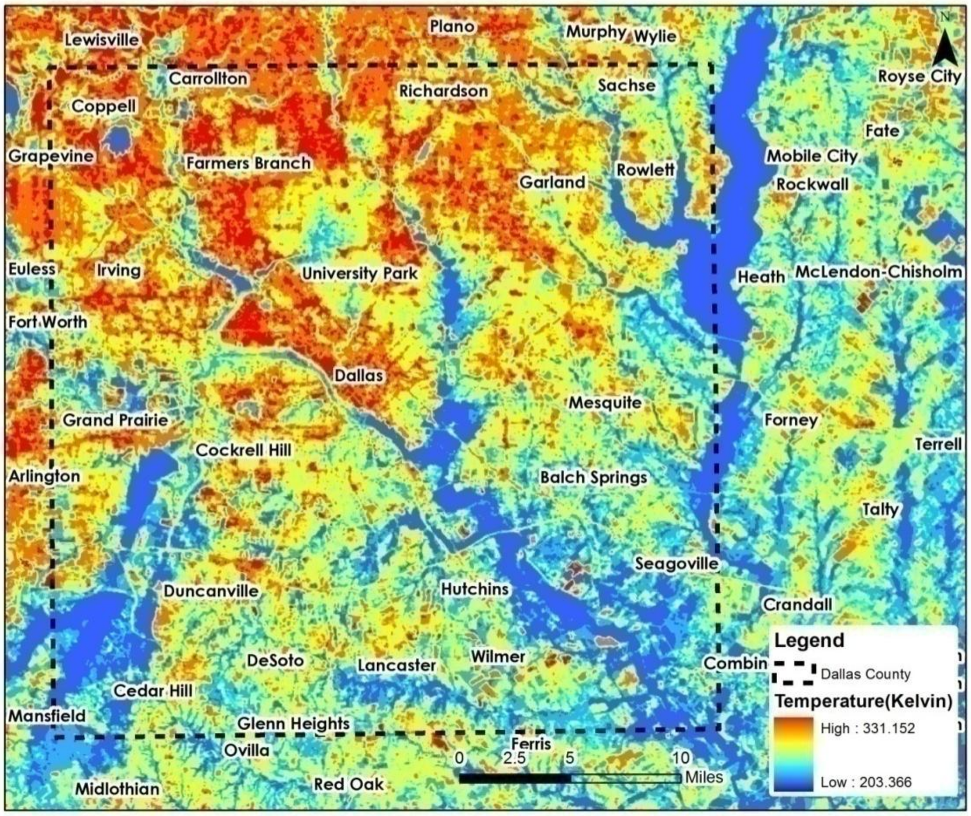


Figure 5. Temperature (Kelvin) of Dallas County (July 8, 2000)

3.4.2 Independent Variable: Land Use

In the literature review above, many variables, including land use, determined temperature. This study assumed that the other variables can be controlled by regional characteristics. For example, weather variables such as wind speed and precipitation can be controlled by climate division (in this study, Dallas is included in the North Central Texas climate division); urban features such as buildings and impervious surfaces can be controlled by regional structural patterns. Based on these assumptions, I measured Land Use as the independent variable for this study. I used parcel-based Land use data (2000 and 2005) downloaded from NCTCOG (North Central Texas Council of Governments) which has 9 categories with 25 land use characteristics. I examined land use changes based on these categories except for parks and parking because these areas can effectively increase/decrease the temperature of surrounding areas. I used 11 categories: Residential; Government/Education; Commercial; Industrial; Infrastructure; Airports; Dedicated; Parks; Parking; Undeveloped; and Water. Table 3 shows various land uses (land use code) under 11 land use categories and Figure 6 shows land use of Dallas County which displayed based on above 11 categories.

Table 3. Land use category in Dallas County

Category	Land Use(Land Use Code)
Residential	Single Family (111), Multi Family (112), Mobile Homes (113)
Government/Education	Group Quarters (114), Institutional (123)
Commercial	Office (121), Retail (122), Hotel/Motel (124), Large Stadium (147), Mixed Uses (160)
Industrial	Industrial (131)
Infrastructure	Transportation (141), Roadway (142), Utilities (143)
Airports	Airports (144), Runway (146)
Dedicated	Landfill (172), Flood Control (171), Parks (172)
Undeveloped	Parking Garage (145), Under Construction (173), Vacant (300), Parking(CBD) (306), Expand Parking (308)
Water	Water (500)

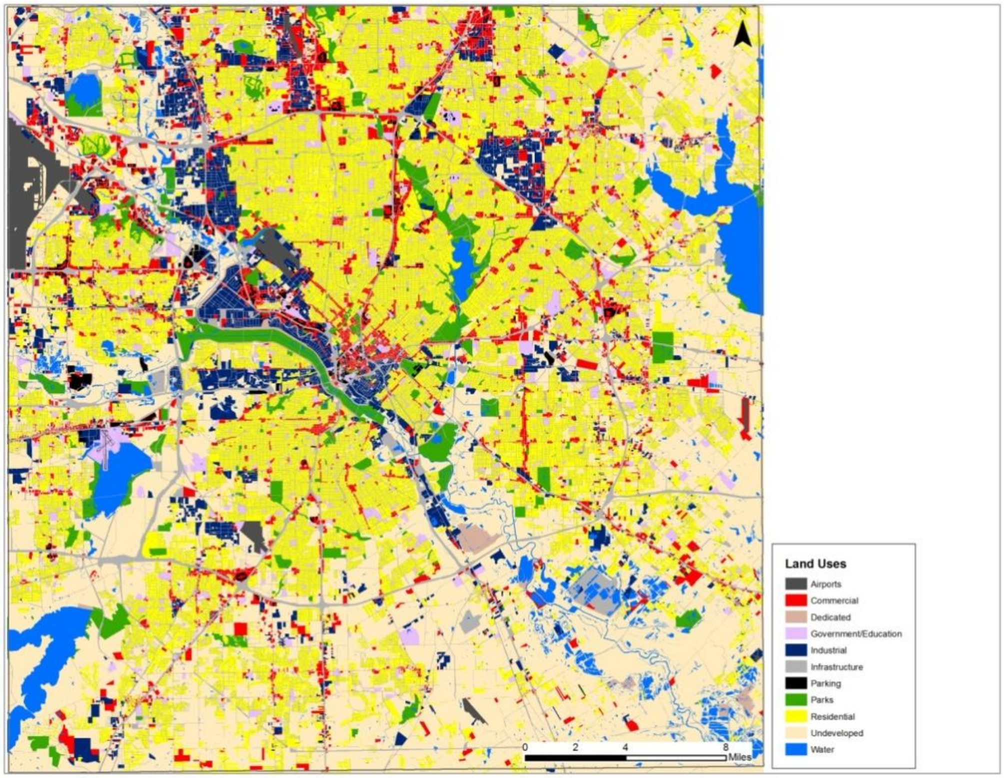


Figure 6. Land use in Dallas County (2000)

3.5 Unit of Analysis: Census Tracts

To compare land use and temperature changes between 2000 and 2005, census tract was used as a unit of analysis. Average temperature and land use composition of each census tract was calculated. Figure 7 shows land use and temperature with census tracts. Each census tract is made up of various land uses and temperatures. High temperatures observed near industrial areas and low temperature observed near parks and water.

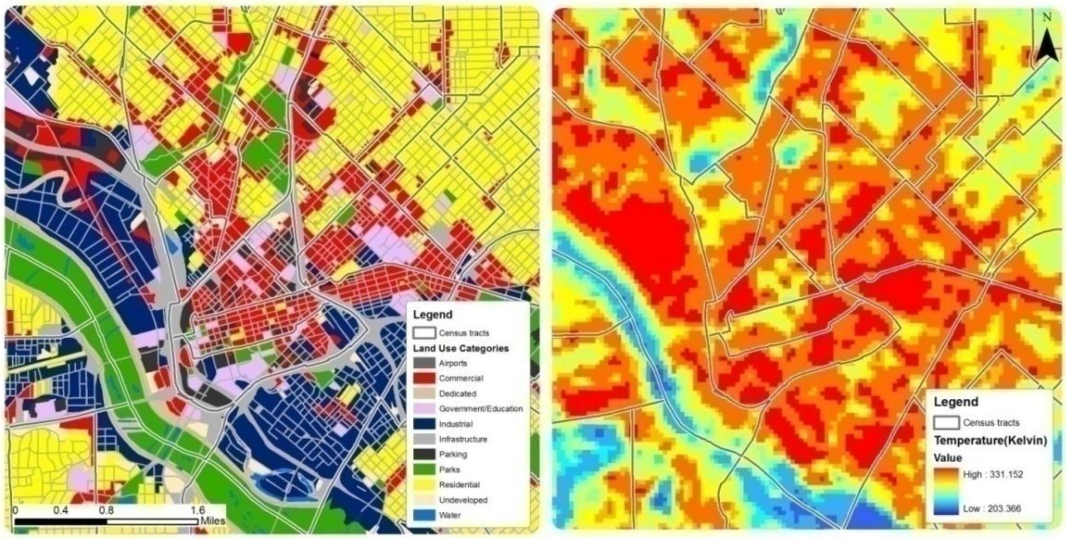


Figure 7. (a) Land use with census tracts (b) Temperature of census tracts

Dallas consists of 487 census tracts. Each census tract has several land uses which were calculated by percentage (%) of census tracts because the area of census tracts varies. To calculate land use composition, I overlaid the map with land use data and census tract data using the union function in Arc GIS 9.3. For example, land use composition of census tract '0001.00' is 48% of the residential area, 23% of the park area, 16% of infrastructure, 13% of water, etc. (See Figure 8-a, b)

(a) 

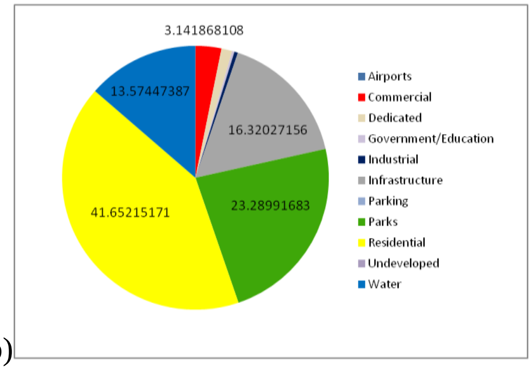
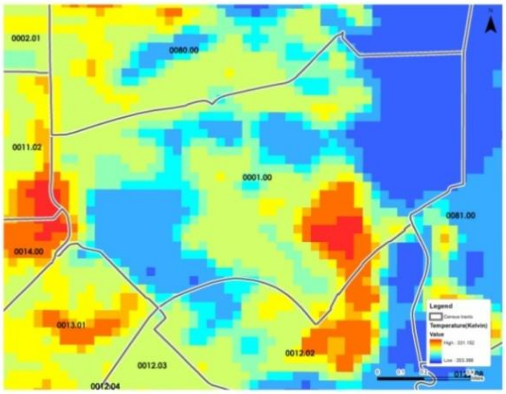
(b) 

Figure 8. (a) Land use in census tract '0001.00' (b) Land use composition of census tract '0001.00'

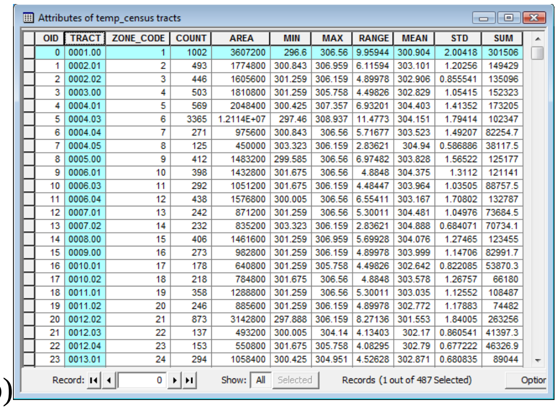
The average temperature of each census tract was calculated. As shown in Figure 9-a, census tract '0001.00' has varied temperatures. To calculate average temperature in each census tract, I used Zonal statistics tool[8] under spatial analyst in ArcGIS 9.3. After conducting this analysis, I found the general statistical values of census tracts in terms of temperature -- minimum, maximum and average temperature. (See Figure 9-b) Using this result, temperatures were distributed and displayed in the study area. (See Figure 9-c)

[8] This tool provides statistical calculation by taking a value raster as input and calculating for each cell a function or statistic using the value for each cell and all cells belonging to the same zone. (Arc GIS help)

(a)



(b)



Attributes of temp_census tracts

OID	TRACT	ZONE_CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
0	0001.00	1	1002	3607200	296.6	306.56	9.95944	300.904	2.00418	301506
1	0002.01	2	493	1774800	300.843	306.959	6.11594	303.101	1.20256	149429
2	0002.02	3	446	1605600	301.259	306.159	4.89978	302.906	0.855541	135096
3	0003.00	4	503	1810800	301.259	305.758	4.49826	302.829	1.05415	152323
4	0004.01	5	569	2048400	300.425	307.357	6.93201	304.403	1.41352	173205
5	0004.03	6	3365	1.2114E+07	297.46	308.937	11.4773	304.151	1.79414	102347
6	0004.04	7	271	975600	300.843	306.56	5.71677	303.523	1.49207	82254.7
7	0004.05	8	125	450000	303.323	306.159	2.83621	304.94	0.586886	38117.5
8	0005.00	9	412	1483200	299.585	306.56	6.97482	303.828	1.56522	125177
9	0006.01	10	398	1432800	301.675	306.56	4.8848	304.375	1.3112	121141
10	0006.03	11	292	1051200	301.675	306.159	4.48447	303.964	1.03505	88757.5
11	0006.04	12	438	1576800	300.005	306.56	6.55411	303.167	1.70802	132787
12	0007.01	13	242	871200	301.259	306.56	5.30011	304.481	1.04976	73684.5
13	0007.02	14	232	835200	303.323	306.159	2.83621	304.888	0.684071	70734.1
14	0008.00	15	406	1461600	301.259	306.959	5.69928	304.076	1.27465	123455
15	0009.00	16	273	982800	301.259	306.159	4.89978	303.999	1.14706	82991.7
16	0010.01	17	178	640800	301.259	305.758	4.49826	302.642	0.822085	53870.3
17	0010.02	18	218	784800	301.675	306.56	4.8848	303.578	1.26757	66180
18	0011.01	19	358	1288800	301.259	306.56	5.30011	303.035	1.12552	108487
19	0011.02	20	246	885600	301.259	306.159	4.89978	302.772	1.17883	74482
20	0012.02	21	873	3142800	297.888	306.159	8.27136	301.553	1.84005	263256
21	0012.03	22	137	493200	300.005	304.14	4.13403	302.17	0.860541	41397.3
22	0012.04	23	153	550800	301.675	305.758	4.08295	302.79	0.677222	46326.9
23	0013.01	24	294	1058400	300.425	304.951	4.52628	302.871	0.680835	89044

Record: 0 Show: All Selected Records (1 out of 487 Selected) Optior

(c)

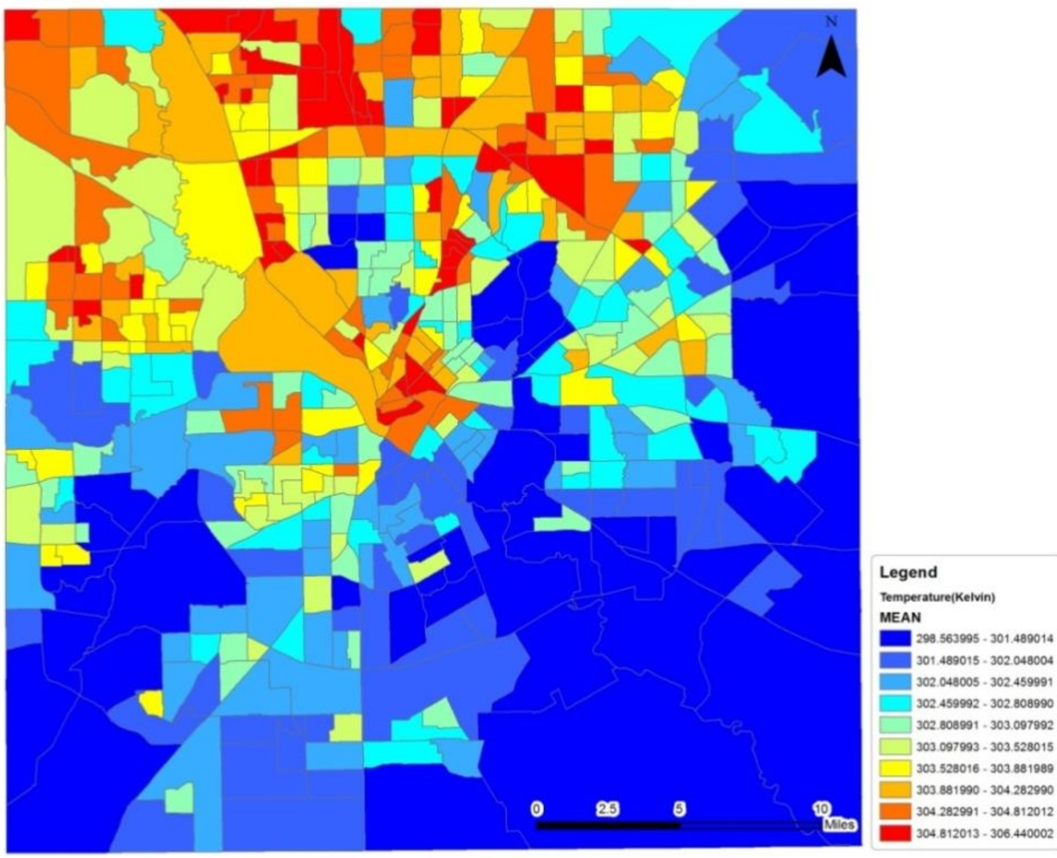


Figure 9. (a) Various temperatures of Census tract '0001.000' (b) Statistical summary table of census tracts by zonal statistical tool (c) Average temperature of census tracts (2000)

To determine the concepts of analysis, there are several limitations. First of all, this study used Landsat 5 TM imagery with 120m- spatial resolution to detect temperature. It is not real-temperature which people feel but air-temperature data. Gallo et al. (1996) suggested weather station data considered on a human scale can be better than remote sensed data. However, when I used weather station data, it had problems covering the regional scale.[9] Second, as stated in the literature review, there are various elements which increase the urban heat island effect such as density of development, surface matters, etc. However, this study is focused on the regional temperature change pattern based on land use change. Thus, micro-scale characteristics are not considered.

3.6 Correlation Analysis

The data were analyzed in two phases with Pearson's product moment correlation analysis. "Pearson's product moment correlation analysis is the most popular correlation analysis method. "The Pearson product moment correlation, named after its developer, Karl Pearson, provides a single numerical index of the degree to which paired observations vary together (Abrami et al, 2001, p.416)." The range of values for the correlation coefficient is presented from -1 through 0 to 1. In here, -1 means perfect negative or inverse linear relationship, +1 means a perfect positive linear relationship.

First, I examined the relationship between land use characteristics (land use categories) and average temperatures based on census tracts for each year (2000 and

[9] Dallas County has 34 weather stations but each weather station can cover the area below 100m2 from the station. Thus, it is hard to find the relationship between land use change and temperature change because of the small sample number and covered areas.

2005). The result of the first step allowed me to move to the next step to show the relationship between land use characteristics and temperature. To observe the relationship between land use and temperature change, a correlation analysis was conducted. Independent variables are the 11 land use categories: Airports, Commercial, Dedicated, Government/Education, Industrial, Infrastructure, Parking, Parks, Residential, Undeveloped and Water. The dependent variable is temperature. Independent variables are calculated as a percentage of each land use based on each census tract because each census tracts has a different size of area. Thus, sample size is determined by the number of census tracts in Dallas County (487 tracts).

Second, correlation analysis estimated the effect of land use changes on temperature change over the five-year study period (2000~2005). In this analysis, dependent variables are the percentage of each land use change in the census tracts. The amount of land use change is also calculated by the percentage of each land use category within a census tract. Independent variable is the change of temperature.

CHAPTER IV

LAND USE AND TEMPERATURE ANALYSIS

In this chapter, results will be presented in three sections. The first section shows the descriptive statistics of land use and temperature in the study area. The second section presents relationship between land use and temperature for the years of 2000 and 2005 separately. The last section presents the relationship between land use change and temperature change over the five year study period. To show the relationship between land use and temperature, correlation analysis—Pearson's product moment-- was conducted.

Several statistical tests for reliability were conducted to ensure data validity. The result revealed no violation of correlation assumption.

4.1 Descriptive Analysis

Urban land areas have various characteristics; land use is one of the standards which represent these characteristics. In this study, 487 census tracts were analyzed in Dallas County with different land use compositions. Shown in Figure 10, each land use category is associated with a specific average temperature. The chart shows the average temperature of each land use: parking areas have the highest temperature followed by industrial and airports. In contrast, water, parks and undeveloped areas showed relatively lower temperature than other categories.

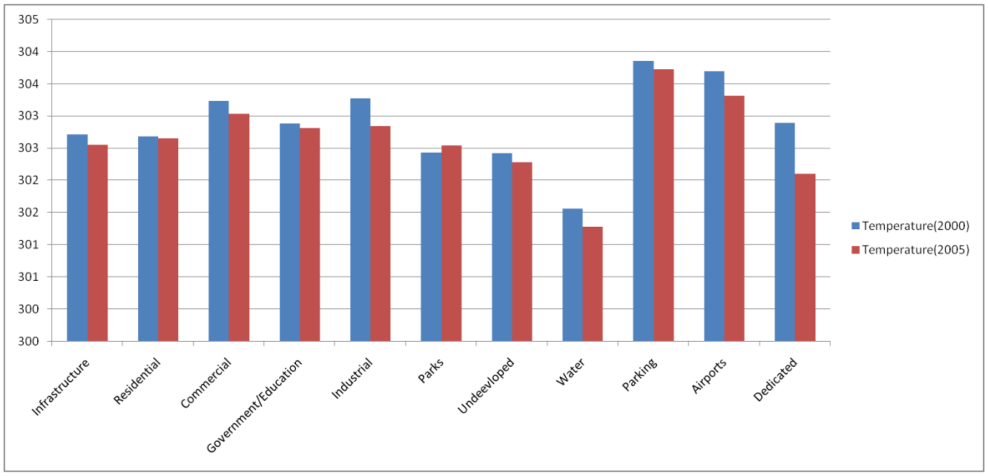


Figure 10. Average temperature of land use categories

Figure 11 shows the profile of temperatures following their land use characteristics in 2005. Parks, water and undeveloped areas showed relatively low temperatures and industrial and commercial areas showed high temperatures compare to other land uses.

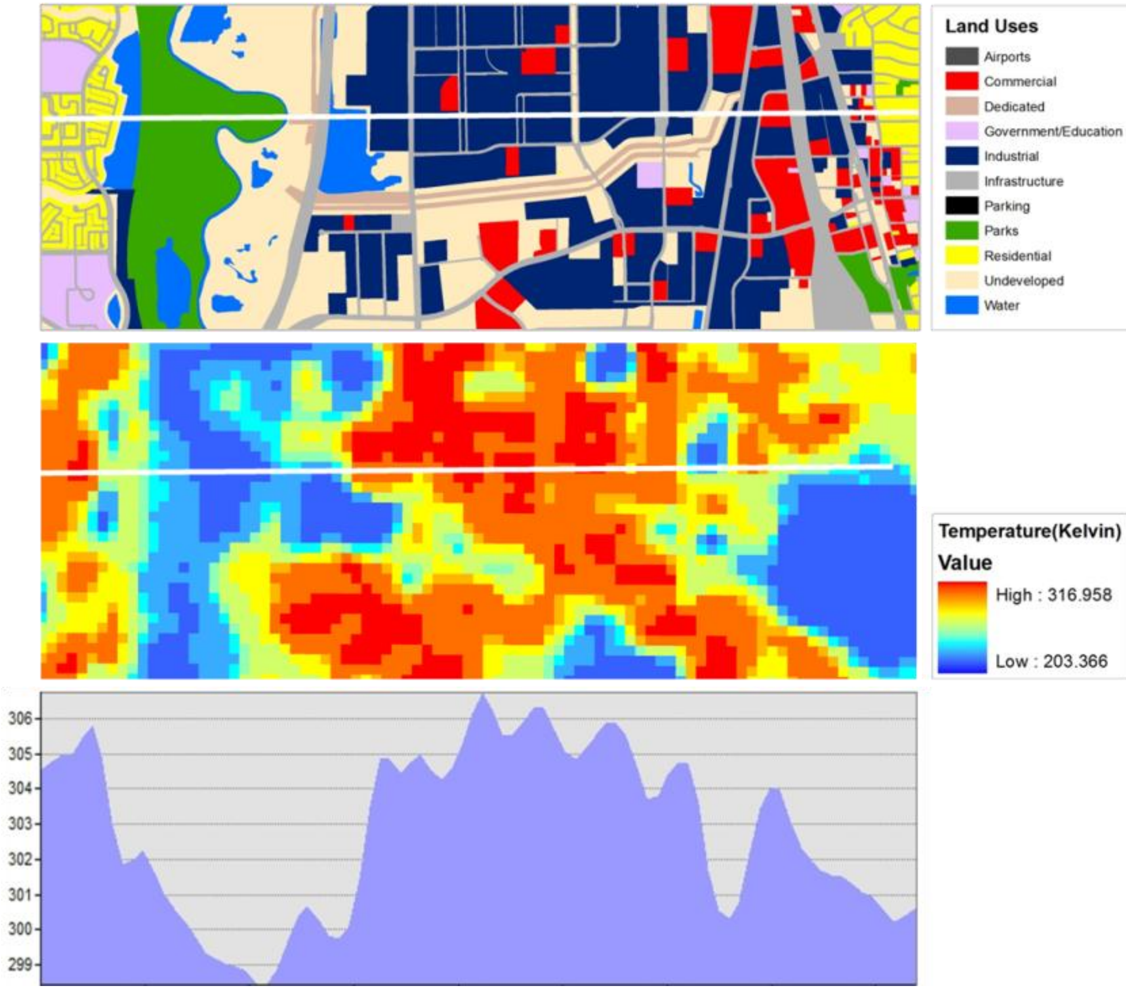


Figure 11. Temperature profile of land uses (2005)

4.2 Correlation Analysis between Land Use and Temperature (Year 2000 and 2005)

4.2.1 Land Use

As in Figure 6 and 12, undeveloped and residential areas are the dominant land use types in Dallas County. Industrial and commercial areas are usually located together and commercial areas exist along the major highways and roads. In general, the northwest of Dallas County, near the airport, has more industrial and commercial development than the southeast.

Changes in land use for 2005 were in many instances based on the expansion of existing land use categories in 2000. For example, the northeast is fully covered by industry since developed areas are expending towards the northeast side. In the southwest near the bodies of water, large parks have emerged. As shown in land use map in Figure 12, industrial areas moved from central areas to outside. Many amounts of industrial areas located in central area were taken off and outside industrial areas densely filled in.

4.2.2 Temperature

The temperature pattern of Dallas County in 2000 shows that the northwest portion with large industrial and commercial areas, experience higher temperatures. In addition, some linear features presenting high temperatures consist of the major highways and roads. On the other hand, water and undeveloped areas show lower temperatures, and parks show relatively lower temperatures than other land use types. Shown in Figure 12, every census tract has its average temperature calculated from remote sensed temperature data which is used as a dependant variable. It shows similar patterns to the temperature distribution in Figure 12.

In the remote sensing image of 2005, some clouds showed up presenting low temperatures because remote sensors detected clouds temperature not air temperature. Thus, the areas with clouds were excluded when calculating average temperatures of census tracts. In Figure 12, clouds are represented by white. Overall temperature distribution patterns changed. Compare to 2000 heating areas are evenly distributed in whole areas that are concentrated in the northwest. The northeast, which added some industrial areas, gained more heat and the southwest with new parks had decreased temperature.

4.2.3 Correlation between Land Use and Temperature

Correlation analysis provides an understanding of major land use characteristics affecting the temperature. Table 4 shows correlations between temperature and several land use categories.

As many former studies have showed, undeveloped, water, parks and dedicated areas have negative relationships with temperature. However, except for the previous four land use types, other developed land use categories have positive relationships with temperature. Commercial areas in particular show a significant positive relationship (where, $P<0.01$) which can be expected because of relatively large building lots with parking areas. Infrastructure which includes roads, and parking areas have a comparatively high relationship because of its surface material (concrete or asphalt).

Common land developed types such as residential, industrial and government/education areas also have significant positive relationships with temperature but among these land use types, residential and government/education have a relatively low positive relationship because usually houses and schools have more open space than industrial areas.

Table 4. Correlations for land use and temperature

Variables(Land use)	2000		2005	
	Coefficient	Sig. (2-tailed)	Coefficient	Sig. (2-tailed)
Airport	0.033	0.462	0.034	0.449
Commercial	.519**	0.000	.411**	0.000
Dedicated	-0.08	0.079	-.105*	0.021
Government/Education	.139**	0.002	.125**	0.006
Industrial	.257**	0.000	.161**	0.000
Infrastructure	.396**	0.000	.292**	0.000
Parking	.312**	0.000	0.021	0.644
Parks	-.194**	0.000	-.234**	0.000
Residential	.163**	0.000	0.081	0.073
Undeveloped	-.510**	0.000	-.322**	0.000
Water	-.426**	0.000	-.276**	0.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

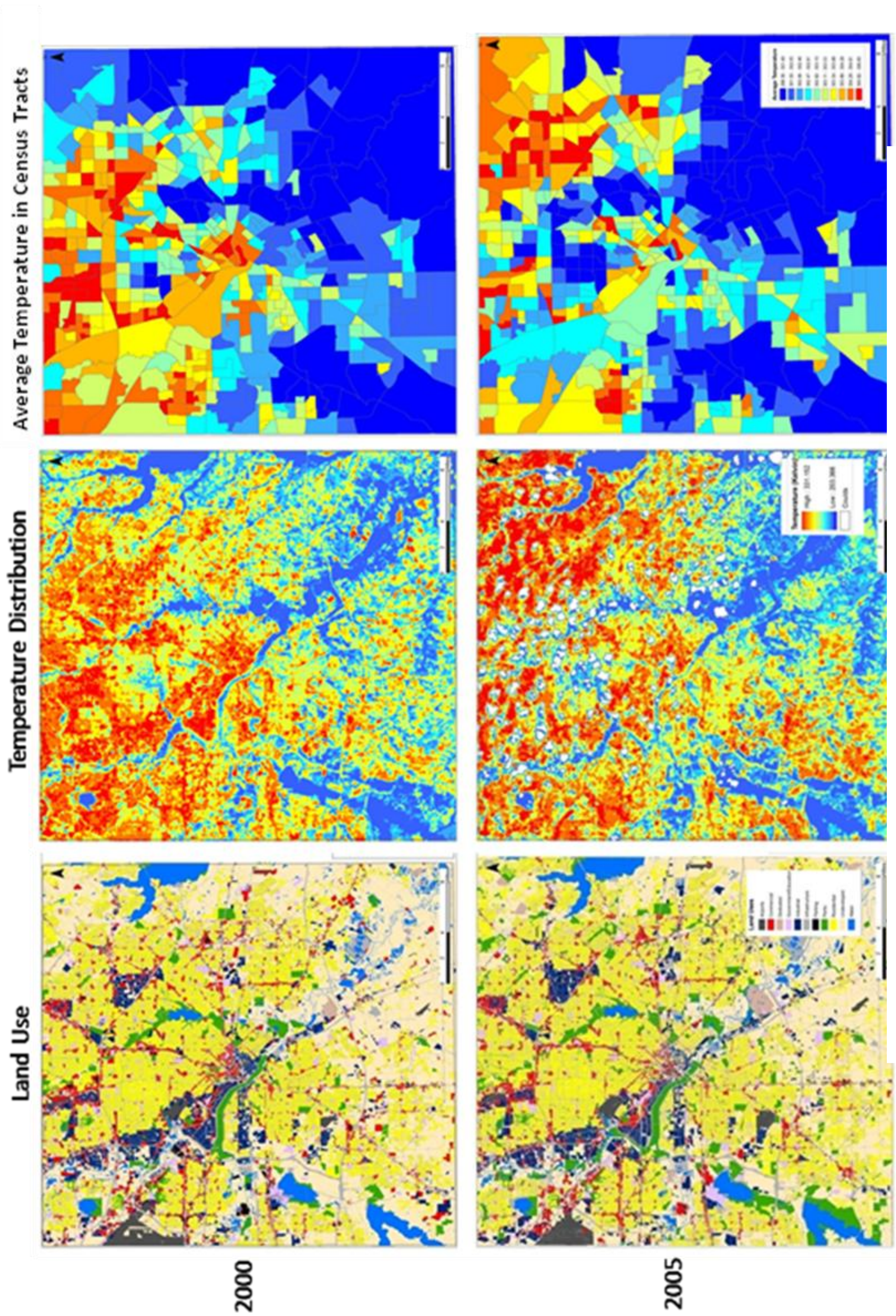


Figure 12. Land use and temperature distribution in 2000, 2005

4.3 The Relationship between Land Use and Temperature Change

4.3.1 Land Use and Temperature Change

According to the land use data, Dallas County had a 59.78% developed area (land use categories: undeveloped and water) in 2000 and a 66.13% developed area in 2005.(See Figure 13) Shown in Figure 5, residential, parks and infrastructure had relatively large increases between 2000 and 2005. Even though overall developed areas increased, this cannot be directly connected to increased temperatures because each land use has an individual effect. (See Figure 7, 10 and 11) Thus, we need to determine which specific land use characteristics can affect temperatures negatively or positively for future land use planning in regard to urban temperature.

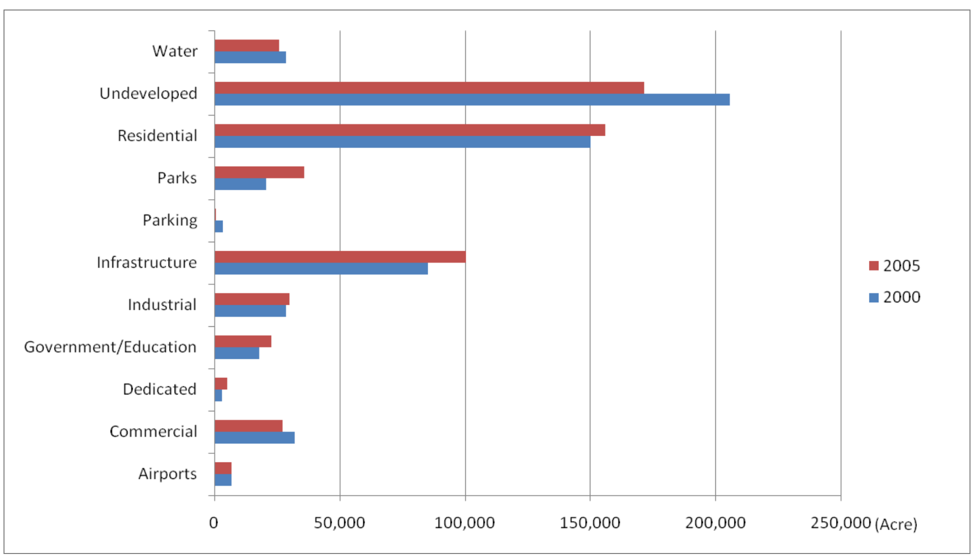


Figure 13. Land use change (2000-2005)

As analyzed in the above section, there is a relationship between land use categories (land characteristics) and temperature; namely, each land use category has a different temperature. Based on this relationship, I have analyzed the relationship between land use and temperature change. Every census tract has changed in terms of land use and temperature over five years (2000-2005). Thus, this study hypothesizes that "land use change will drive temperature change." To analyze this relationship, correlation analysis is conducted; the results are shown on Table 5. Results indicate that three land use variables—parks, residential and undeveloped—show a significant relationship to temperature but other variables are not statistically significant. As expected, undeveloped areas are negatively associated with temperature and residential areas (the most increased land use type for five years) which are positively correlated to temperature. Airports, commercial, industrial and parking areas have positive relationships with temperature that are similar to the correlation analysis in Section 4.2.3.

However, dedicated, government/education, infrastructure, parks and water show different results (See Table 5), which can be interpreted as follows. First of all, each census tract does not have just one category of change but various land use changes. Even though dedicated areas were added into census tracts which showed a negative correlation with temperature in the above correlation analysis (See Table 4) but if the same census tract added more commercial or industrial areas, the final temperature that is detected by the remote sensor might be increased. Next, in the case of parks which showed a positive relationship to temperature, there were two predicted reasons— 1) Depending on the characteristics of parks or types of parks, usually, parks are highly vegetated with many trees but some parks such as zoos, golf courses and playgrounds, etc. do not have enough trees or vegetation to decrease the temperature; 2) After examining the analyzed land use for two years (2000 and 2005), some areas which were designated as undeveloped became designated as parks although there were no changes. In Dallas County large lots near bodies of water were designated as parks with no physical changes, so, even though they changed their land use category they retained the same physical characteristics.

Table 5. Correlations for land use and temperature change

Variables (land uses)	Coefficient	Sig. (2-tailed)
Airports	0.002	0.957
Commercial	0.058	0.198
Dedicated	0.077	0.09
Government/Education	-0.036	0.424
Industrial	0.058	0.199
Infrastructure	-0.038	0.397
Parking	0.073	0.105
Parks	.124**	0.006
Residential	.207**	0
Undevloped	-.252**	0
Water	0.061	0.176

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

CHAPTER V

CONCLUSIONS AND DISCUSSION

This chapter concludes by summarizing the important findings from this study and by discussing the land-use planning implications based on the major findings. Then, study limitations and future research are discussed.

5.1 Summary of Key Findings and Conclusions

There have been many factors considered in land use planning such as population, land suitability or transportation, etc. However, most of these factors are related to physical and social aspects of urban characteristics. As a result of these planning trends, many environmental problems have arisen. Environments are essential elements for sustainable land development. Thus, this study has explored the relationship between temperature (one of the environmental elements) and land use using GIS and Remote sensing data with correlation analysis. Following are the key findings of this study based on an analysis of the relationship between land use and temperature in Dallas County, Texas.

The key finding of this study showed that there are relationships between land uses and temperature. Many previous studies used land cover (vegetation, urban area and agricultural areas) with surface characteristic but did not include the land functions. Thus, this study analyzed land use as variables that influence temperature. As a result of this analysis, every land use category has different temperature averages and those patterns were observed similarly in both 2000 and 2005 (See Figure 10 and 11). Parking, airport, commercial, industrial and residential areas have relatively high temperatures. In contrast, water, undeveloped area and parks show relatively low temperatures. Thus, each land use category has its own physical characteristics which influence temperature.

Another major finding showed that ratio of land use composition affected the temperature of census tracts. Correlations analyses of land use and temperature in 2000 and 2005 indicate that various types of land use categories have significant relationships with temperature (See Table 4). Among them commercial, industrial, residential, parking and infrastructure are positively associated with temperature, and undeveloped, parks, water and dedicated areas are negatively associated with temperature. Areas with a high ratio of commercial use showed the highest and undeveloped areas showed the lowest coefficient in both years.

Furthermore, this study also analyzed the relationship between land use and temperature change for five years. The results showed temperature change depends on the ratio of each land use category change. Not surprisingly, expanding the ratio of residential, commercial, industrial and parking areas increased temperature. Especially, residential areas showed high positive relationship with high statistical significance. On the contrary, some land use categories showed unexpected results. For example, parks showed a positive relationship with temperature. By observing the change of land use in 2000 and 2005, this result was made by disregarding detailed characteristics of parks. Generally, other land uses have homogeneous characteristics but parks include various types of uses such as golf courses, zoos and playgrounds. Based on the above findings from analyses in this study, the following summary points can be made about the relationship between land use and temperature in urban areas.

5.2 Planning Implications

Many large cities in the United States are experiencing serious environmental problems resulting from climate change, especially urban heat island effect caused by reckless development. Thus, in recent years, the relationship between urban land use and environmental quality has received increased attention in both planning research and practice (Stone et al., 2001).

This study analyzed the relationship between land use and temperature to examine which land use categories have affected temperature changes. The results of this study could help local planning and policy decisions which are related to urban land use planning concerning temperature change such as zoning (maintaining development permits), environmental regulations and open space preservation. Following are detailed suggestions utilizing the results of this study.

First, it is necessary to maintain and control permits for development. For example, when a city receives a request for constructing new industrial, it should consider the composition of land use near the requested area in terms of temperature characteristics. If the surrounding areas have sufficient water, undeveloped area or parks with vegetation, the government can permit the development of an industrial district. However, if that area is already fully developed with other land uses that create high temperatures, the government should not give permission.

Second, developing incentive policies can be suggested. Shown in this study, there are land use categories that help to decrease urban temperatures such as water, parks and dedicated areas. If new developments are planned with these temperature-decreasing land use categories, the government could give advantages and incentives.

As discussed so far, the results of this study not only provide scientific basis for zoning regulations in regional planning but also specify land use controls for site planning.

5.3 Study Limitations and Future Research

This study has several limitations. Although this study provides a fundamental understanding of the relationship between land use and temperature, it is hard to arrive at a simple relationship. Since, in the real world various elements such as rainfall, humid and wind speeds, determine temperature. Future studies which consider various aspects that contribute to formatting temperature will provide more detail and precise analysis.

A second limitation may exist in the spatial resolution of Remote Sensing data. This study used thermal band of Landsat 5 TM imagery, which is widely available with 120m of spatial resolution. It is enough to examine the regional scale temperature but more high-resolution thermal data such as landsat ETM+ (60m) or ATALAS (5 to 10m) is needed as temperature data to analyze temperature at the neighborhood level.

Third, this study did not consider the interacting relationships with each land use. Namely, in the correlation analysis of land use and temperature change, this study analyzed each land use category change and temperature change. However, in fact, changes of several categories were combined for the five years (2000-2005). Thus, results can be improved by considering interacting changes between each land use category.

Based on the results and limitations of this study, future study should deal with various elements affecting temperature that were not considered here with high-resolution data. Moreover, through analyzing the relationship between land use and temperature, researchers can study air pollution, human health issues and energy consumption which are connected with urban land use development and temperature.

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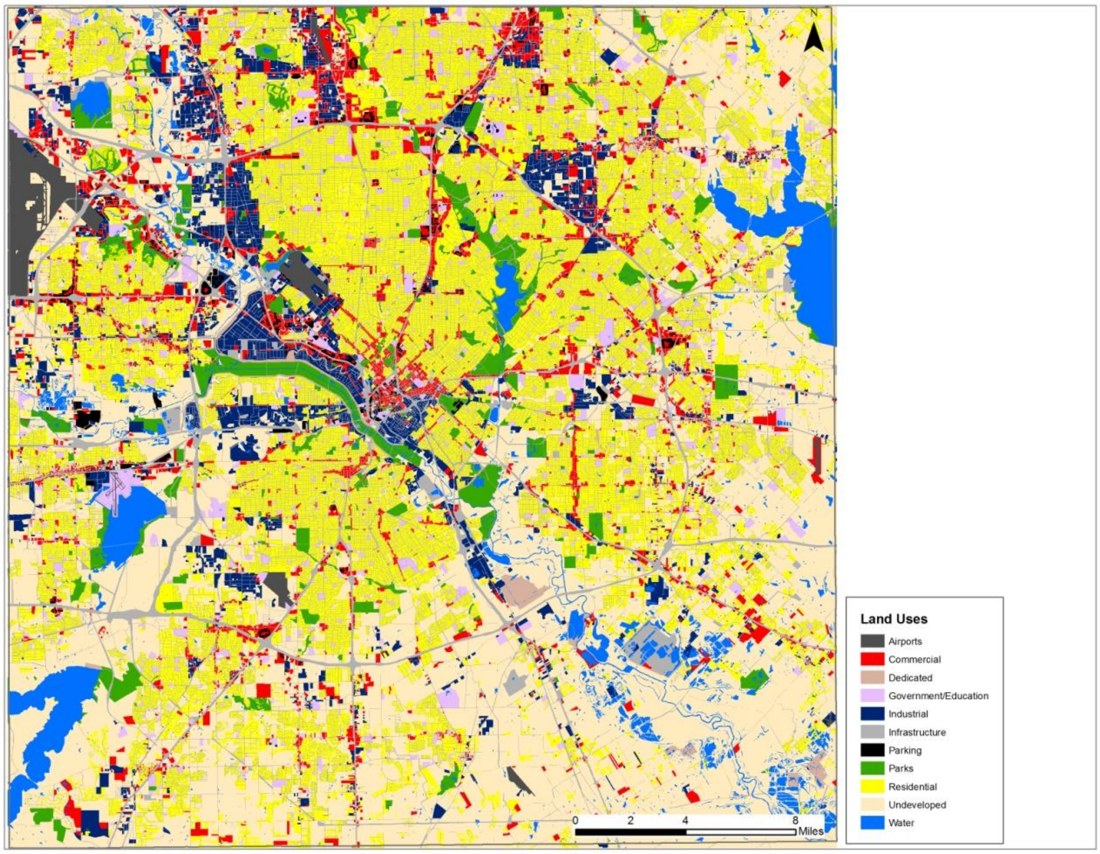
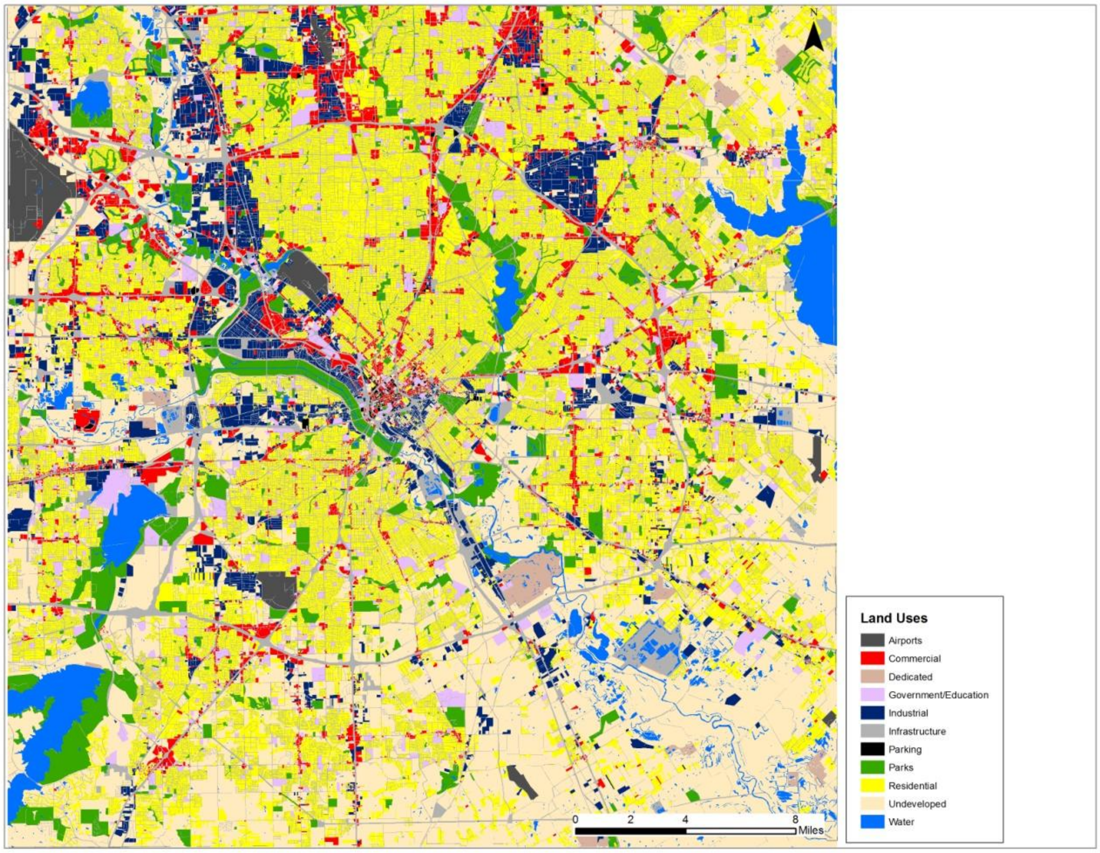
APPENDIX A

LAND USE IN DALLAS COUNTY (2000)



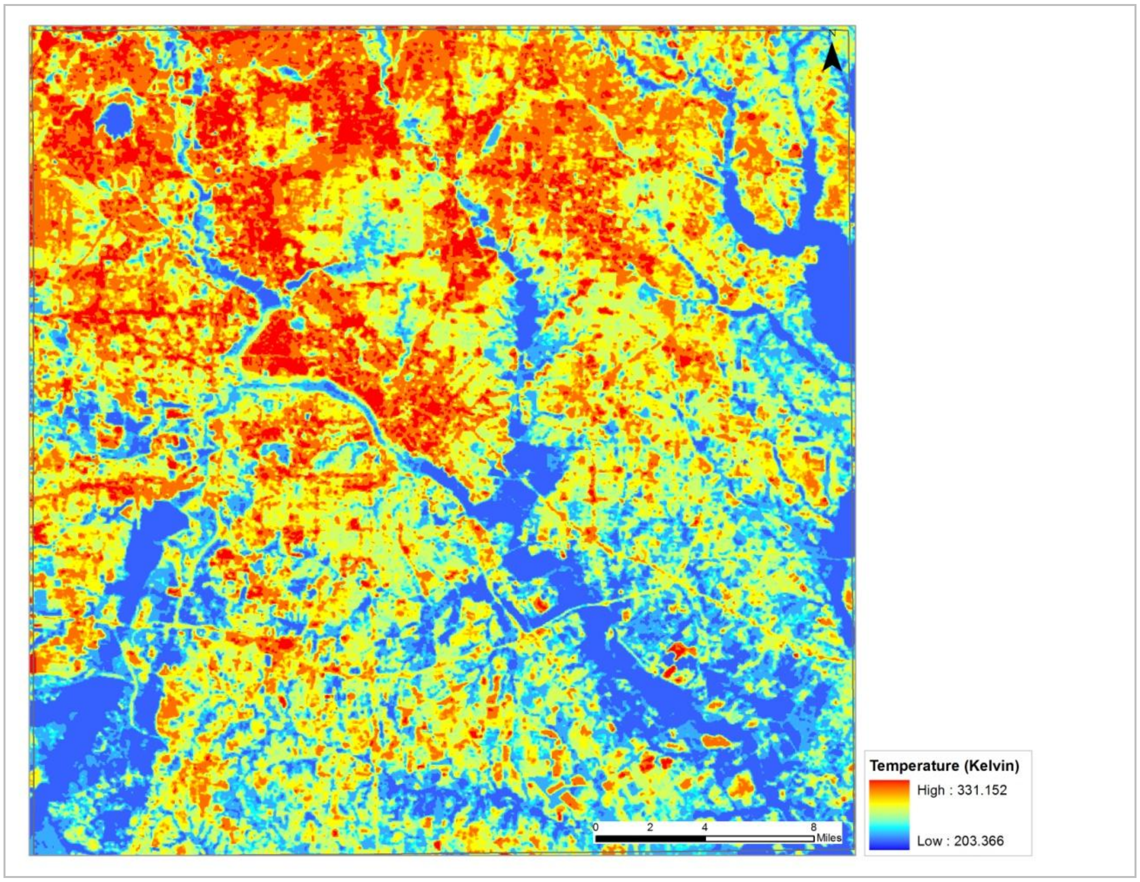
APPENDIX B

LAND USE IN DALLAS COUNTY (2005)



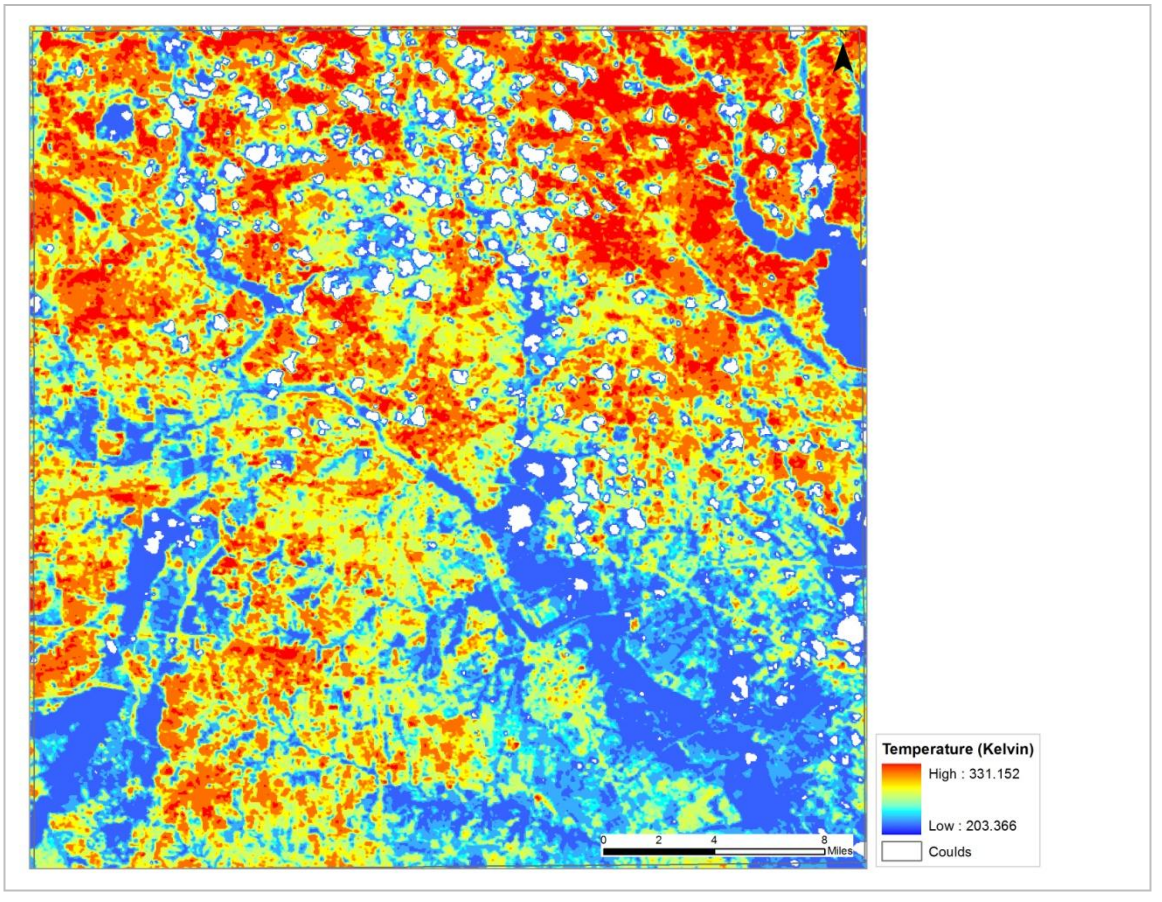
APPENDIX C

TEMPERATURE DISTRIBUTION IN DALLAS COUNTY (2000)



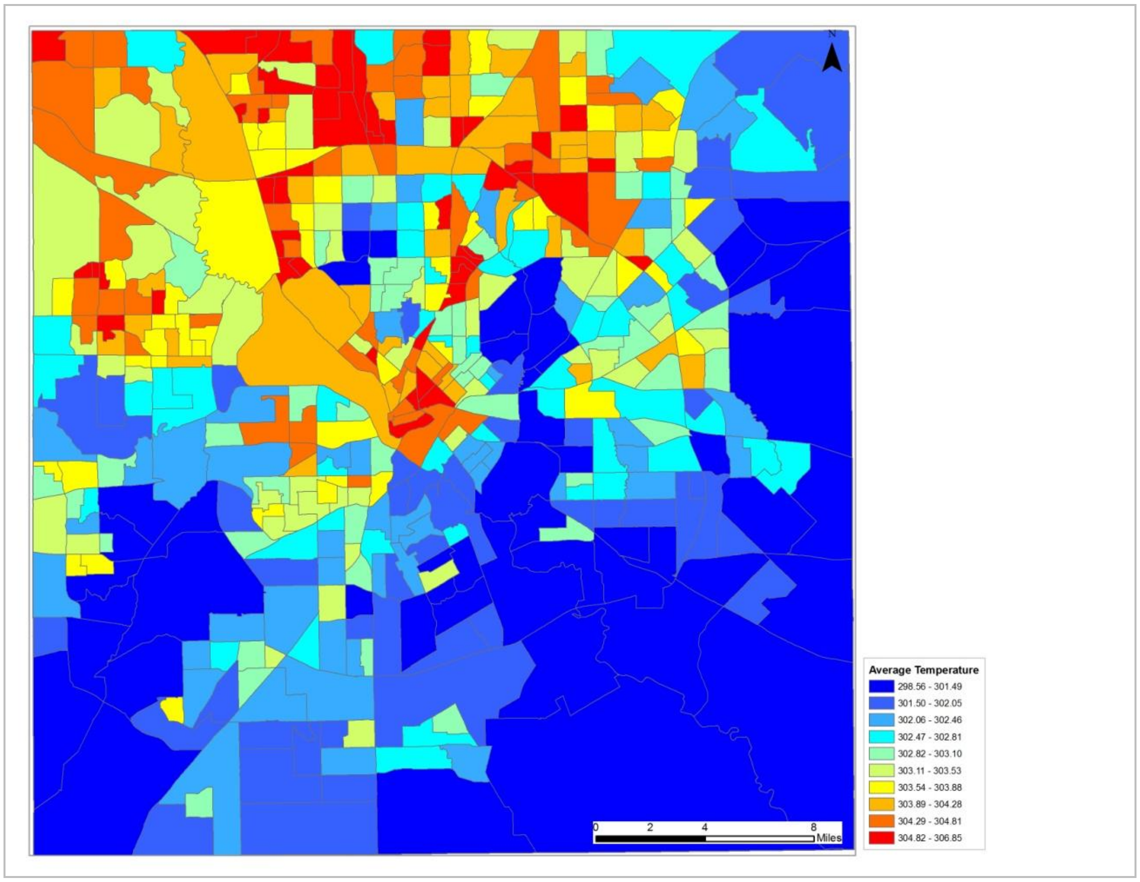
APPENDIX D

TEMPERATURE DISTRIBUTION IN DALLAS COUNTY (2005)



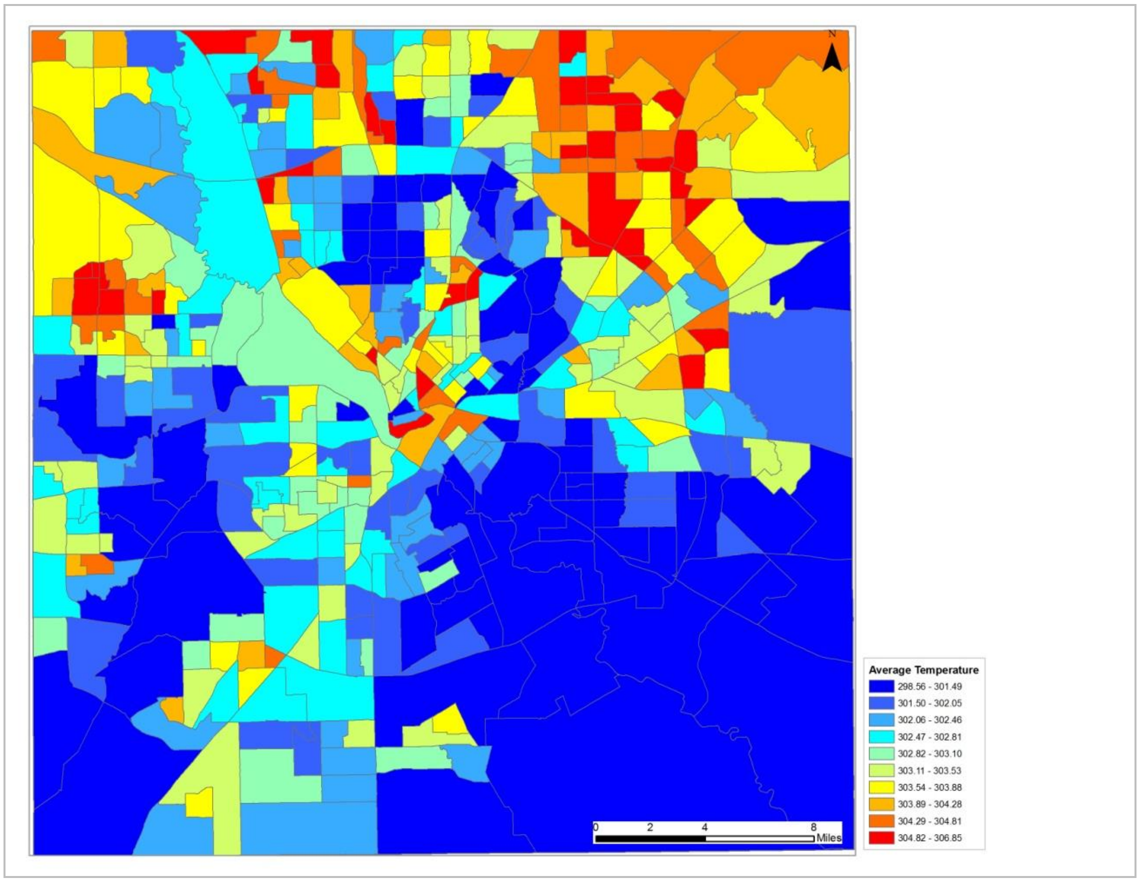
APPENDIX E

TEMPERATURE DISTRIBUTION IN DALLAS COUNTY WITH CENSUS TRACTS (2000)



APPENDIX F

TEMPERATURE DISTRIBUTION IN DALLAS COUNTY WITH CENSUS TRACTS (2005)



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