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VARIATIONS IN DIURNAL TEMPERATURE RANGE IN THE SOUTHEAST UNITED STATES DUE TO LAND USE/LAND COVER CLASSIFICATION, 1995-2004

By

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VARIATIONS IN DIURNAL TEMPERATURE RANGE IN THE SOUTHEAST UNITED STATES DUE TO LAND USE/LAND COVER CLASSIFICATION, 1995-2004

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Daily temperature variations across an area can often be attributed to differences in land use/land cover (LULC). This study focuses on the relationships between the diurnal temperature ranges (DTRs) of 145 weather stations, classified as urban, agriculture, evergreen forests, deciduous forests, pine forests, and mixed forests. Paired samples t-tests were employed to test for significant DTR differences due to LULC type, season, and air mass type.

Conflicting with previous research, agricultural areas reported the lowest DTRs, which may be due to the vegetation or to other physiographic variables. The forest types showed very few significant DTR differences. All of the LULC types experienced an annual bimodal DTR pattern, with peaks in April and October. Results of this study show that air mass has the largest influence on DTR (over LULC and season), therefore, the annual variability of air mass occurrence is most likely cause of the bimodal pattern.

DEDICATION

I would like to dedicate this research to my loving and supportive family back in Maryland- my grandmother "H," my mother Jude, my father Barry, and my big brothers, Billy and Brent.

ACKNOWLEDGEMENTS

The author would like to recognize the many people who supported the production of this thesis. First, sincere thanks go to my committee for their unyielding support and influential friendships throughout the pursuit of my degree. Grady− I deeply appreciate your dedicated assistance, and oh-so-blunt honesty during this two year adventure. Not only did you teach me to embrace my “inner redneck,” but your friendship really helped a “yankee” feel at home in the South. Mike− Thanks to you, I now understand and appreciate black coffee, Airborne®, and what it takes to survive in the Plains. Keep people’s hands off my shelf after I leave! D. Rodg− Without you and your infinite supply of mints and wit, I wouldn’t have been able to survive two years of GIS labs, crazy students, and this thesis. Appreciation is also given to Dr. Brent Skeeter of Salisbury University, who encouraged my further study in the field of meteorology, as well as Dr. Charlie Wax and Dr. Jamie Dyer for continuing my interest in meteorology at the master’s level. Finally, thanks go out to those inhabitants of the “bat cave,” who helped keep each other sane by sharing food and grad school horror stories. This includes my partner in crime, Ashley Mac, who constantly reminded me to “get it together,” and my office mate Justyn Jackson, who always managed to let me know how happy he was that his thesis was already completed.

TABLE OF CONTENTS

CHAPTER

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Variations in daily temperature across an area can often be ascribed to processes in surface and atmospheric interactions related to differences in land use/land cover (LULC) throughout a region. Many studies involving deviations of temperature due to LULC rely on the presence of an urban heat island, which was first researched nearly two centuries ago in London (Howard 1833). More recently, researchers have found that many other LULC types can influence the climate of an area, including agriculture and different forest types (Swift et al. 1975; Bonan 1999a). All of these studies focus on one small area of constant LULC, however, and do not apply to real-world forecasting where LULC naturally changes over distances of varying scales. In addition, landscapes often exhibit LULC heterogeneity that is not well represented in previous studies.

Applying these ideas to the southeastern United States, this study will be conducted across portions of Mississippi, Tennessee, Arkansas, and Louisiana (Fig. 1.1), for the years 1994 to 2005, to see how the various LULC types differ with respect to diurnal temperature range (DTR). The main LULC types present in this area include urban, agriculture, deciduous forests, pine forests, and mixed forests. The most dominant LULC in the study area is agriculture, encompassing over 37% of the area. The agricultural areas used in this study are mainly located in an area referred to as "the Delta," located in the alluvial sediment of the Mississippi river (Fig. 1.2). The next most dominant LULC types are deciduous, evergreen, and mixed forests, which cover about 29%, 16%, and 12%, respectively. The final LULC category used in this study is urban, which accounts for almost 2% of the study region. Although past studies have shown the effects of these LULC categories on daily temperatures in different parts of the country, this study area provides a new outlook, since it is much larger and LULC varies realistically (Eaton 1956, Bonan 1999b).

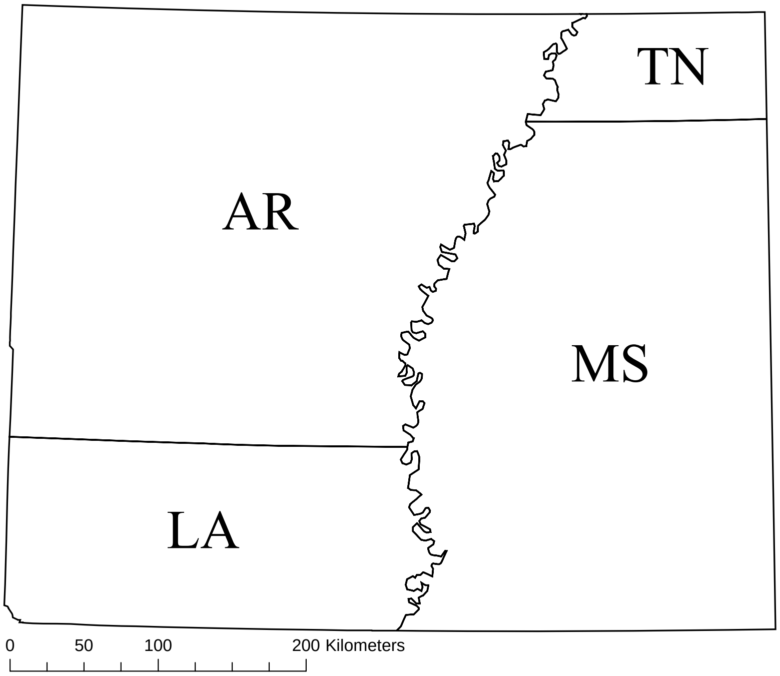


Fig. 1.1. The portion of the southeast United States being used in this study.

In order to isolate LULC as a variable, days with any synoptic forcing will not be used. For a day to be used in this study, both the 0000 UTC and 1200 UTC soundings must not report surface wind speeds over 10 kts or 800-mb wind speed over 15 kts. In addition, the entire study area must be under the same spatial synoptic classification (SSC), or air mass type. The DTR will also be evaluated separately for each air mass, as the presiding air mass provides large effects on an area's maximum and minimum temperatures. This step will not only help isolate DTR as a variable, but will allow for evaluation of the effects each air mass has on a particular LULC class.

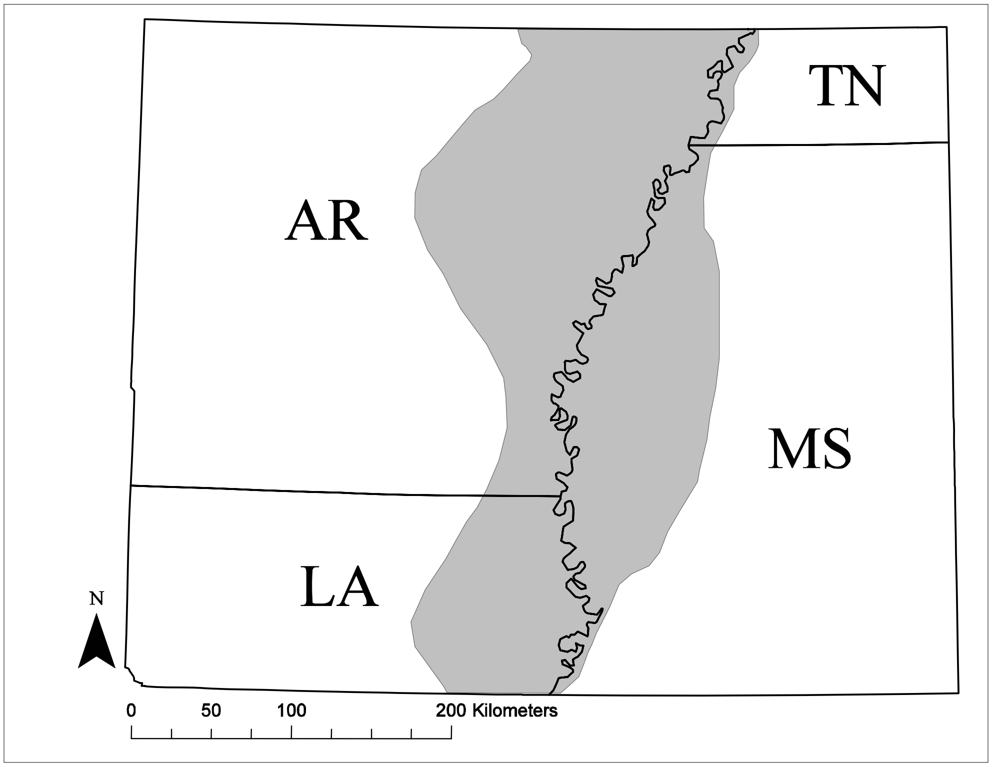


Fig. 1.2. The study area, with the shaded region representing "the Delta."

In addition to variations in the DTR due to presiding air mass, several of the LULC types vary according to season. The planting and harvesting of crops in agricultural areas may provide different effects on the temperature of the area due to seasonal variability of evapotranspiration. Also, the deciduous forests will experience loss of leaves in the fall and winter seasons, again creating a change in evapotranspiration rates. Therefore, the DTR will be evaluated separately for each season. This will aid in determining if the vegetation response to seasonal changes have a significant effect on the temperature of the area.

Objectives and Hypotheses

The primary objectives of this study are:

1) To discover any variations in DTR due to LULC.
2) To evaluate how each LULC reacts to each presiding air mass with respect to DTR.
3) To evaluate changes in the DTR of each LULC due to seasonality.

The following hypotheses will be tested in this study:

1) Urban areas experience a slightly smaller DTR than the other LULC categories all times of the year, however it is less extreme in the winter when the vegetated areas are more barren. Also, the urban areas will not differ as much as in previous studies, since the cities in this research area currently have less than 1,000,000 people.
2) Air masses will affect the LULC types differently, since a dry air mass will increase the potential for evapotranspiration in areas with plants, cooling the surrounding environment.
3) Agricultural areas, as well as deciduous and mixed forests, will have varying DTRs according to season. Since less evapotranspiration will occur in the fall and winter seasons, the DTR will be larger during these seasons.

CHAPTER II

LITERATURE REVIEW

Urban Heat Island

Urban heat islands are probably the most researched phenomena associated with LULC and temperature, characterized by a temperature difference between a city and surrounding areas (Duckworth and Sandberg 1954; Bornstein 1968; Oke 1973; Changnon 1981; Moreno-Garcia 1994; Morris et al. 2001). The first studies on urban heat islands date back to 1833 when Howard researched the climatology of London, England. Howard (1833) claimed that the urban heat island is a product of a man-made micro climate within a major city, and thus began the research on the relationship between LULC and temperature.

As a given area becomes more urbanized, deforestation and new urban surfaces radically modify the radiation budget of an area by altering albedo and surface geometry (Oke 1987). During urbanization, asphalt is added to the area, which has a typical albedo of 0.02, as opposed to vegetation, sand, and soil, which all have albedos near 0.25 (Black and Tarmy 1963). The lower albedo of the asphalt means that less incoming solar energy is reflected. This allows more energy to be absorbed and converted to terrestrial radiation resulting in higher sensible heat values. Eaton (1956) found that an asphalt road in

Riverside, Illinois was 49º C at 1400 LST; approximately 7º C higher than the grass field only 9 meters away. Moreover, Eaton (1956) demonstrated that the asphalt can sustain higher temperatures for 12 hours, between 1000 and 2200 LST. Black (1963) found that soil underneath asphalt in Arizona can also reach temperatures 7º C higher than the surrounding soil that is not coated by asphalt. Black and Tarmy (1963) argue that the excess heating is capable of producing enough convective circulation to result in rainfall.

The impervious materials often used during urbanization are also known to have a substantial effect on evapotranspiration rates (Oke 1987). Grimmond and Oke (1999) showed that although meteorological factors provide the strongest influence on evapotranspiration, urbanization also has a considerable effect. In 10 major cities, evapotranspiration rates were well below surrounding areas, mostly due to the utilization of impervious surface materials (Grimmond and Oke 1999). Variations in evapotranspiration also create large temperature differences since the process of evapotranspiration provides a cooling effect. Huang et al. (1987) showed that a 25% increase in urban tree cover can save 40% of the energy used to cool some major cities, mostly due to the increased evapotranspiration rates and shading.

In addition to these new surface materials, the tall buildings that are often erected during urbanization aid in affecting daytime temperature due to their geometric arrangement (Oke 1987). Buildings create additional surfaces to absorb solar radiation and assist in increasing the temperature. Additionally, if made from low-albedo materials, the buildings are capable of reaching more extreme temperatures.

Since urban areas also tend to retain heat longer at night, the overnight minimum temperature remains high compared to adjacent vegetated and rural areas. According to Oke (1982), the principal reason behind this phenomenon is that tall buildings in the city absorb longwave radiation from other buildings, thereby trapping in the heat. This is referred to as the sky view factor. If less of the sky is seen due to building obstruction, the sky view factor is lower, and more terrestrial radiation will be trapped at night (Oke 1987). Additionally, the alignment of the buildings can also have an effect, since the buildings often block the wind, not allowing the urban air and atmosphere to mix, which would potentially cool the area. Oke (1987) also suggests that building materials aid in keeping temperatures warmer at night, since the materials used in urban areas often possess higher specific heat values, so they can retain heat longer. Due to a combination of these factors, the heat island effect is usually stronger at night than during the day.

A study in Seoul, Korea, indicated that the average maximum urban heat island intensity occurred around 0300 LST, while the least amount of thermal differences between the city and surrounding rural areas happened around 1500 LST (Kim and Baik 2005). Sometimes the urban heat island effect will be completely non-existent during the day (Oke 1982). Therefore, the difference between the overnight temperatures of urban and rural areas is greater than that of the daytime temperatures, resulting in a smaller DTR in urban areas (Howard 1833; Roth et al. 1989; Kim and Baik 2005). Gallo (1996) found that weather stations in the United States in areas classified as urban (large city, small city, and airport) had the smallest DTR of all land uses 74% of the time.

The impact of LULC and climate change suggests that urbanization is responsible for half of the DTR decrease within the United States (Kalnay and Cai 2003). Vose et al. (2004) found that the average urban area DTR has decreased by 0.86º C within the past century, while the average rural area DTR only decreased by 0.41º C. Urbanization has also been credited with a 0.27º C surface temperature warming per century (Kalnay and Cai 2003) and at least two thirds of the warming over the past 40 years (Vose et al. 2004).

Season also affects the strength of the urban heat island. Oke (1982) found the strength of the heat island increases in the warm season. Jin et al. (2005) suggests this is partially due to albedo, since the albedo of urban areas is much closer to the winter albedo of forest and croplands, rather than the summer albedo when the vegetation is lush (Jin et al. 2005).

The strength of the urban heat island is a factor of city size. When a city's population grows, the urban heat island becomes more intense (Oke 1973). However, studies on the urban heat island of smaller cities are rare. Duckworth and Sandberg (1954) studied Palo Alto, California, Hutcheon et al. (1967) attempted to document the heat island of Corvallis, Oregon, and Kopec (1970) did a similar study in Chapel Hill, North Carolina. Each of the studies found evidence of a small urban heat island in their respective city, but they could not draw any significant conclusions due to a small number of observation dates. However, the need for research on the urban heat island of smaller cities has been established, as all of the authors encourage further research in the area.

Agriculture

Many studies have examined the effect of changing climate on agriculture. For example, Hubbard and Flores-Mendoza (1994) estimated how much land will be used for each crop type during certain growing seasons due to changing climate. Changes in crop yields and spatial movements of vegetation due to climate change have also been studied (Parry 1990; Easterling et al. 1993). Not as many people, however, have researched what agriculture's impact on the climate.

Similar to urbanization, a forest is often removed in order to create land for agriculture. The agricultural areas in this study are mostly located in the Mississippi River floodplain in northwest Mississippi and eastern Arkansas and Louisiana, commonly referred to as the Delta (Fig. 1.2). Deforestation of the lower Mississippi River Valley for agricultural land began with the arrival of European settlers in the 1700s, and by the early 1900s only half of the original forest remained (Stanturf et al. 2000). During the 1950s and 1970s, the forests were cleared at the rate of 300,000 acres per year (King and Keeland 1999). By 1982, only 6.9 million acres remained forested of the 24.7 million acres that once made up the hardwood forests of the lower Mississippi River valley (King and Keeland 1999). Though there is no major addition of urban surfaces, the removal of trees for agricultural purposes can still affect daily temperature.

As previously discussed, urbanization alters the albedo of an area and changes evapotranspiration rates, as does deforestation for agriculture. However, since most crops only cover agricultural land during the warm growing season, the albedo and evapotranspiration rates change seasonally (Bonan 1999a). The albedo of an agricultural area is often a factor of the crop height (Oke 1987). For most live crops less than one meter tall, the albedo is usually around 0.20. When crops are harvested, the dark humus layer at the surface is often reduced, exposing the lower horizons of the soil which are usually brighter, increasing the albedo (Charney et al. 1977). Dirmeyer and Shukla (1994) revealed that a large portion of climate change due to deforestation is dependent upon the change in surface albedo. Bonan (1999b) found that when forests are cleared for agricultural land there is about a 0.5º C decrease in the daily mean temperature in the summer and 2.5º C decrease in the winter. This decrease in temperature is mostly due to the difference in albedo changing the amount of solar radiation absorbed by the area (Bonan 1999b). The instability of the soil outside of the growing season also allows the wind to pick up more dust, and Charney et al. (1977) believe this dust scatters solar radiation, thus reducing the amount of radiation making it to the ground. In addition to seasonal variations, Bonan (1999b) noted that DTR seems to correlate with crop growth, however, his study was inconclusive in determining whether this is a causal relationship or a result of other seasonally changing variables.

Seasons aside, Bonan (1999b) discovered that deforestation for agriculture in the northern Mississippi River portion of the midwest United States had a net cooling effect on the region, attributing agriculture with a 0.6º C − 1.0º C decrease in the daily maximum temperature. This cooling effect was more of a factor during the day than at night, resulting in a 1º C decrease of DTR during summer and autumn (Bonan 1999b). Although crop types differ in the Southeast from the Midwest, Monteith (1959) suggests that net radiation does not differ greatly between crop types, as long as they have moisture available, since evaporative cooling should keep the temperatures fairly similar. Therefore, regardless of crop type, conclusions of this study should be similar to those of Bonan (1999b).

Feddema et al. (2005) discovered that the conversion of tropical forests in the Amazon region of South America into agricultural land had the opposite effect, causing a DTR increase of more than 2º C. After seeing the relatively large DTR change in the Amazon, Feddema et al. (2005) were surprised to later find that the change of forest to agriculture in China had the opposite result, similar to the cooling effect Bonan (1999b) had found in the midwest United States. Therefore, Feddema et al. (2005) concluded that the DTR of areas located in significantly different latitudes react differently after deforestation.

Evergreen and Deciduous Forests

Most research is done in order to show the climatic effects of deforestation, so it is more difficult to find studies focusing on climate's relationship to forested areas. As shown above, it is well documented that these changes to the LULC of a region also cause changes to the climate. Robinson et al.'s (1985) study in the northern United States shows that deforested portions of land have twice the amount of snow as the areas with their native vegetation. Bonan (1997) found that the climate changes due to deforestation are so significant that they are even evident through the 500-mb level of the atmosphere.

The DTR of a forested area should differ from that of various LULC types, and different forest types should also vary slightly in DTR. As the vegetation varies spatially from deciduous to evergreen, evapotranspiration rates can be expected to change, which, in turn, affect the DTR. Oke (1987) says the maximum daily temperatures and humidity of a forest occur at the level of maximum leaf area, allowing the most radiative absorption for heat, and transpiration for humidity, showing the importance of forest type in daily temperatures. A few studies have compared the evaporation rates of deciduous forests to that of pine forests (Foley et al. 1996; White et al. 1997). One study on modeling the evapotranspiration and draining rates of deciduous and pine forests found that both have the same evapotranspiration rates in the summer but the evergreen forests had greater rates in the winter and early spring (Swift et al. 1975). Therefore, based solely on evapotranspiration rates, the evergreen forests would most likely experience a smaller DTR than the deciduous forests in the winter and early spring.

Evergreen and deciduous forests also differ in albedo. The albedo of an evergreen forest being 0.05 − 0.15, depending on the season (Oke 1987). Stewart (1971) found the mean albedo for an evergreen forest to be 0.09 in June and 0.11 in December, attributing much of the seasonal variation to the difference in solar angle. The albedo of the average deciduous forest is 0.15 during the winter when the trees are bare, and 0.20 when the trees are leaved (Oke 1987). Thus, in disagreement with evapotranspiration, due to the lower albedo of the evergreen forests, they would experience a larger DTR than deciduous forests. The actual DTR of each forest should be a factor of evapotranspiration, albedo, air mass, sun angle, and season (Oke 1987).

Spatial Synoptic Classification

The Spatial Synoptic Classification (SSC) of air masses was developed in 1996, for use in climate impact studies, when the creators discovered that the four air masses of the conventional Bergeron method were too limited for use in environmental problems (Kalkstein et al. 1996). Seeing the errors in both manual and automated classification methods, the SSC is a hybrid of the two. The SSC classifies the daily weather at a number of stations across all 50 states and Canada. The weather is classified as one of six weather types (or air masses) based more on meteorological characteristics than geographical source (Sheridan 2002). In order to create a basis for classification, seed days were found for each location during each season. These are days when a location showed typical meteorological characteristics of a certain air mass, and were used to define typical temperature, vertical and horizontal wind, cloud cover, and sea-level pressure for a certain location under each air mass (Sheridan 2002). The same variables are evaluated daily in order to determine which air mass is a closest fit to the present weather. The air masses being used in this research are Dry Polar, Dry Tropical, Dry Moderate, Moist Polar, Moist Tropical and Moist Moderate, as classified by the SSC (Sheridan 2002). There is also a transition air mass, however it will not be used for this study.

The Dry Air Masses

The first of the dry air masses is Dry Polar (DP), which is equivalent to the typical Continental Polar (cP) air mass in the Bergeron classifications (Sheridan 2002).

This air mass is often associated with northerly winds, clear and dry conditions, and often generates the lowest temperatures a place will experience through the year. This cold air comes from regions of higher latitudes, such as Canada, and is usually brought down to the United States through a cold-core anticyclone (Sheridan 2002). The DP air mass is most prevalent in the study area during the winter, but usually dominates this area for only 15 to 20 days during the season. During the summer, the DP air mass is usually absent along the Gulf Coast and Florida (Kalkstein et. al 1998).

The next air mass, Dry Tropical (DT), is very similar to the Continental Tropical (cT) air mass in the Bergeron classifications. This air mass is associated with hot, dry and sunny weather, and often comes from the desert region (Sheridan 2002). The DT air mass generally affects only the western United States, even in the summer, when it is present in the eastern United States less than 2% of days (Kalkstein et al. 1998). For the study area, the DT air mass usually controls the weather 5 to 10 days each season.

The final dry air mass is one not found in typical air mass classifications, and is called Dry Moderate (DM). The addition of DM and Moist Moderate (MM) categories was to increase the precision of air mass classification (Sheridan 2002). The DM air mass has no specific source region and can be a result of an older, modified air mass. Somewhere between DP and DT in temperature, it is marked by mild temperatures and dry conditions, and is one of the most common air masses dominating the study area (Sheridan 2002). Generally, the DM air mass will prevail in the Southeast about 30% of the time, but slightly less in the summer (Kalkstein et al. 1998).

The Moist Air Masses

The first moist air mass is the Moist Polar (MP), which is comparable to the Maritime Polar air mass (mP) in the Bergeron classifications. This is a cool, humid air mass whose source region is in the high latitude oceans and often brings cloudy conditions and small amounts of precipitation (Sheridan 2002). The MP air mass is rarely seen along the Gulf Coast and the southwest United States (Kalkstein et al. 1998)

Next is the Moist Tropical air mass (MT), which is comparable to the Maritime Tropical (mT) air mass in the Bergeron Classifications. This air mass brings warm, humid air to the area, and oftentimes some cloud cover (Sheridan 2002). MT is very common in the study area, exceeding 20% of the days in the winter, and exceeding 50% of the days in the summer (Kalkstein et al. 1998).

The last of the moist air masses is MM, which is between MP and MT in temperature, and often associated with cloudy skies. MM only affects the eastern half of the United States, prevailing over the area 5 −15% of the time in the winter, and 12 − 25% of the time in the summer (Kalkstein et al. 1998).

Incidental Factors: Latitude, Elevation, and the Mississippi River

It is a basic climatic principle that temperature generally decreases from the equator to the North Pole. As previously mentioned, this study area is longer in longitude than latitude in order to try to minimize effects of latitude. Using the DTR will also contribute to minimizing latitude as a factor, since maximum and minimum temperatures themselves are not being compared between latitudes.

Climate is also highly dependent upon elevation, with temperatures typically decreasing about 6.5°C for each 1,000-m increase in elevation. The stations' elevations range from 5.5 to 176 meters above sea level, with 95% of the stations located less than 60 meters high. Once again, using the DTR should help minimize these effects.

Similar to latitude and elevation, water bodies are also documented to affect the temperature of an area, as they are known to cause a decrease in DTR. However, effects of a river are minimal, as suggested by Pilgrim et al. (1998), thus the Mississippi River should not be considered an underlying source of error for this study.

CHAPTER III

DATA AND METHODS

The purpose of this project is to discover any variations in DTR resulting from differences in LULC. In order to isolate LULC as a variable, the mean DTRs of each LULC are statistically compared for each air mass, as well as each month. Also, each LULC is studied to see if any notable DTR changes occur with a change of air mass or month. This allows comparisons of how each LULC reacts to each air mass and season.

Climate Data

The most accurate climate data are likely those of the United States Historical Climate Network (USHCN), however, not all the stations used in this study are available from the USHCN (Quayle et al. 1991). To avoid dissimilarities between data sets, all of the temperature data were gathered from the National Climatic Data Center (NCDC). The largest known problems with NCDC data arise from changes in instrumentation, observer or time of observation, and movement of the instruments or station. Since this study will use ten years worth of climate data, the large sample size should help minimize any false inferences due to random erroneous observations.

The study area includes 526 surface weather stations that report daily maximum and minimum temperatures to NCDC. Of these stations, only 145 have complete data records extending from 1994 through 2005. The daily maximum and minimum temperatures were acquired for each of the 145 stations from NCDC for all 10 years of the study period, and the DTR was then calculated from these values.

Air Mass Data

The spatial synoptic classification (SSC) air mass data were obtained from Kent State University (available online at http://sheridan.geog.kent.edu/ssc.html). The website currently provides air mass classifications for over 300 stations across the United States and Canada from 1948 through 2004. The data for the stations located in Jackson, Mississippi; Memphis, Tennessee; Little Rock, Arkansas; and Shreveport, Louisiana were acquired for this study, with each of the stations reporting one of the SSCs: dry polar (DP), dry moderate (DM), dry tropical (DT), moist polar (MP), moist temperate (MM), moist tropical (MT) or transitional (TR).

LULC Data

The LULC classifications are based on a LULC map of the area from the United States Geological Survey (USGS) National Land Cover Dataset (NLCD) based on 30 m Landsat Thematic Mapper data from the Multi-resolution Land Characterization Consortium (Fig. 3.1) (Vogelmann et al. 1998). In order to dissolve small LULC sections that do not have a great effect on the climate, a more simplified LULC map is made using ArcGIS 9.1 as the platform.

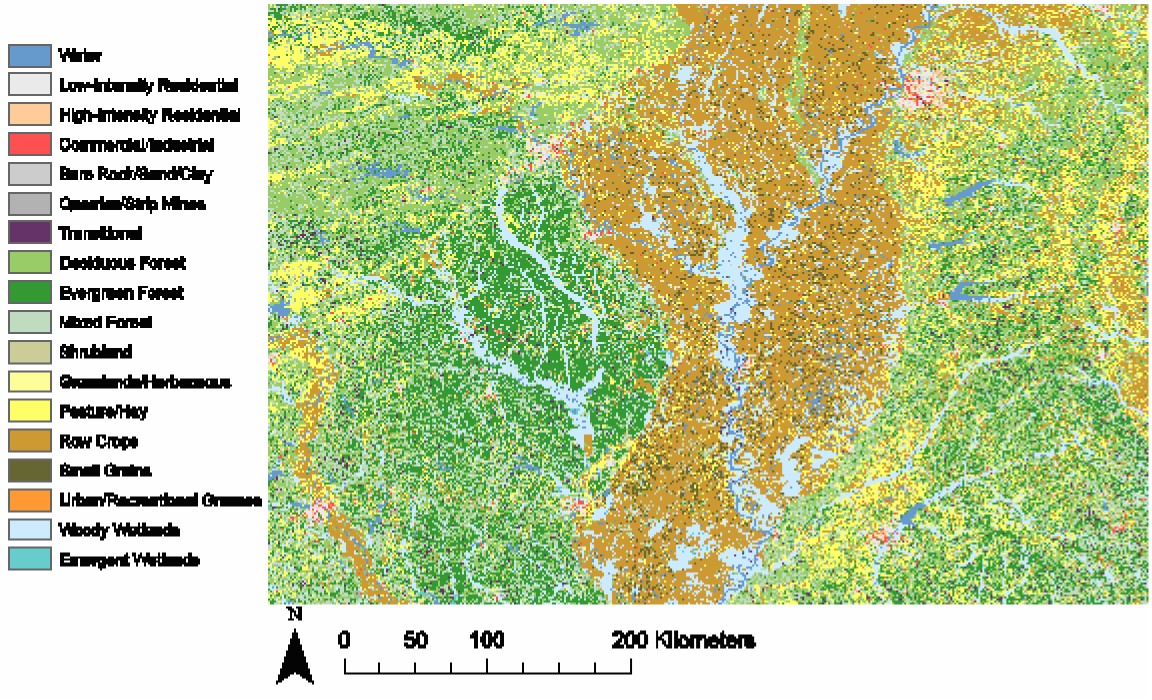


Fig. 3.1. LULC classifications as provided by USGS.

LULC Simplification/Aggregation and Station Classification

The NLCD classifies LULC into 9 categories with 21 sub-categories, 16 of which exist in the study area and are shown in Fig. 3.1. The entire NLCD Regional Land Cover Classification Key (summarized below) can be seen at http:/fisher.lib.virginia.edu/nlcd/virginia_info.html.

To begin the simplification process, the sub-categories used in the map provided by NLCD were reclassified into fewer, more general categories. The classes in the

“Developed” category of NLCD include areas that are comprised of at least 30% constructed materials. This includes low-intensity residential, high-intensity residential, and commercial/industrial land cover. For the purposes of this study, these categories are referred to as “urban” areas. The classes referred to as “Wetlands” by NLCD are areas where the soil is periodically or nearly always saturated or covered in water, including woody wetlands and emergent wetlands. Similarly, these two categories will be combined to make up the “wetland” category for this study. The “Planted/Cultivated” category of the NLCD represents areas with herbaceous vegetation accounting for 75−100% of the land cover. This category includes pasture/hay, row crops, and small grains, which are classified as “agriculture.” Urban/recreational grasses will be included in the “urban” class for this study. The “Barren” category of NLCD is made up of bare rock/sand/clay, quarries/strip mines, and transitional land cover where there is little green vegetation present. These three categories will be classified as “other”. The “Forested Upland” category of NLCD includes areas where 25−100% of the cover is tree canopy. This includes deciduous forests, evergreen forests, and mixed forests. These classes, as well as water, will all have their own category for this study.

After the LULC classifications was made, a HRAP (Hydrologic Rainfall Analysis Project) grid was placed on top of the LULC map in ArcGIS. The HRAP grid is commonly used by the National Weather Service, with grid cells approximately 4.8 km x 4.8 km, varying slightly with latitude (NOAA 2002). The pixels within the grid cells were counted using Hawth’s Analysis Tools for ArcGIS, which provided the number of pixels of each LULC type within each of the grid cells.

In order to determine which LULC should represent each grid cell, a calculation was made similar to that of Scott et al. (2005). Using the pixel count, the percentage of each LULC was calculated for all of the grid cells, as well as the entire study area (Table 3.1). Also, the percent of cells with more than 90 percent of a certain land use were calculated, and this was repeated in increments of 10 percent (Table 3.2).

When comparing tables 3.1 and 3.2, one can see that it is generally between the 30 and 40 percentile columns where the percentage of grid cells is most representative of the overall percent of each LULC in the entire study region. Therefore, 40 percent was chosen as the boundary between LULC classifications. If a grid cell has 40 percent, or more, of one LULC type and the next most prevalent LULC type represents less than half of the percentage of the most common type, the grid cell is classified as being the most common LULC category. Also, if a cell does not meet the above requirements but any combination of mixed forest, deciduous forest, and evergreen forest is greater than 60 percent, that respective grid cell is classified as mixed forest. If the grid cell does not satisfy either of the above percentages, then it is classified as a transitional cell. Most of the transitional cells for this study are along the border of agricultural areas and some type of forest.

Table 3.1. The percentage of each LULC type in the entire study area.

LAND USE	PERCENT
Agriculture	37.39
Deciduous	28.95
Evergreen	15.89
Mixed Forest	12.00
Urban	1.77
Water	2.74

Table 3.2. The percentage of total grid cells that display at least the categorical percentile (e.g. >90%, >80%, etc.) of each LULC type.

LULC	90%	80%	70%	60%	50%	40%	30%	20%	10%
Agriculture	8.1	16.2	22.7	28.7	34.3	40.5	47.9	57.3	70.7
Deciduous	0.7	1.7	3.4	6.6	13.4	25.1	43.4	63.9	83.0
Evergreen	0.1	0.3	1.2	3.4	7.0	12.6	20.7	32.9	48.1
Mixed Forest	0.0	0.0	0.0	0.0	0.2	1.2	5.9	22.2	53.3
Urban	0.1	0.3	0.5	0.6	0.7	1.0	1.4	2.3	4.0
Water	0.1	0.1	0.2	0.4	0.5	1.0	1.8	3.1	6.4

After the calculations were made for every grid cell, each cell was classified as the appropriate LULC, resulting in a simplified LULC map (Fig. 3.2). When comparing the new map to the original LULC map acquired from USGS, one can see the similarities in LULC patterns, while diminishing smaller LULC areas that should not have a significant effect on the climate.

Once the simplified LULC map was produced in ArcGIS, the stations layer was placed on top of the LULC layer in order to classify each of the stations with one LULC type (Fig. 3.3). An extraction of the raster value of the LULC layer beneath each station was performed using ArcGIS in order to classify each station with the new LULC value of the grid cell beneath it. This resulted in 1 station being classified as “water”, 6 as "urban", 11 as "deciduous", 7 as "evergreen", 39 as "mixed forest", 57 as "agriculture" and 24 as "transitional". Since there is only one station classified as water, that station is not used during the statistical analysis. It should also be noted that the stations labeled as transitional are largely a mix of agriculture and some type of forest, whether it is evergreen, deciduous or a mix of the two.

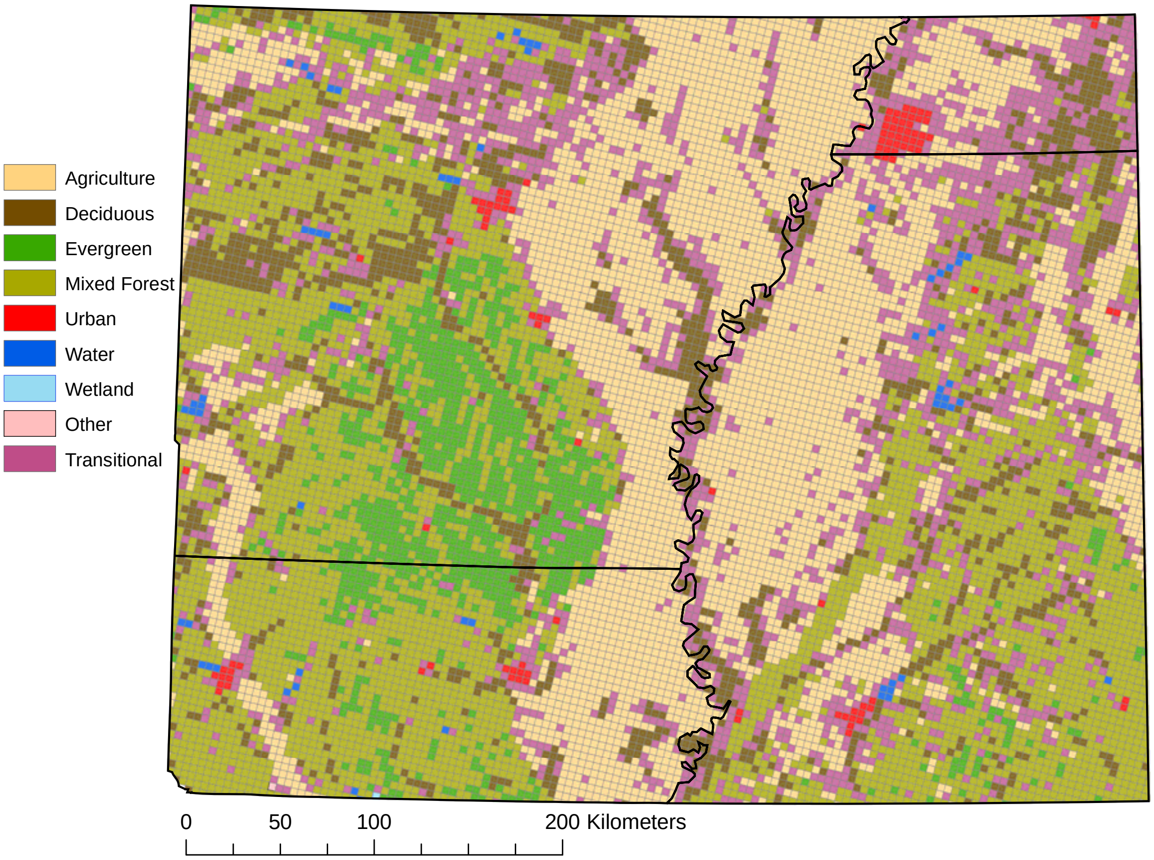


Fig 3.2. LULC classifications after simplification process.

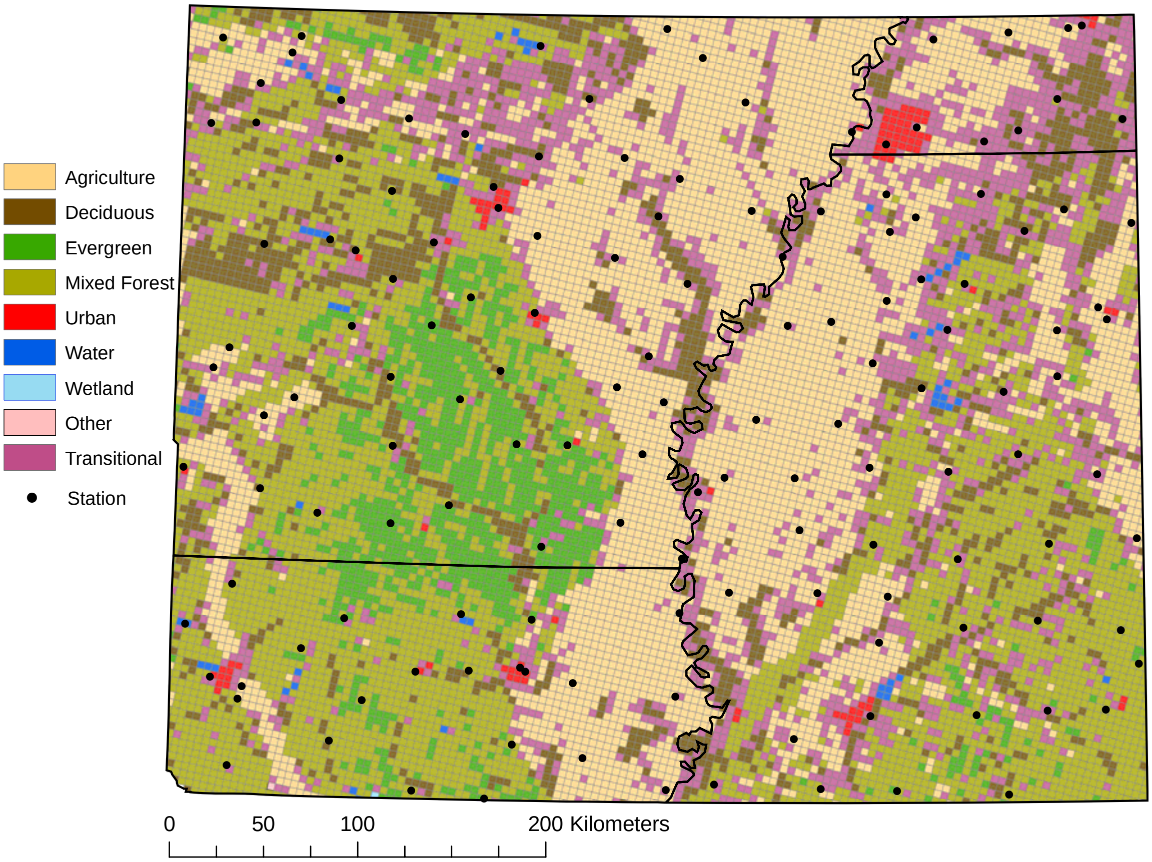


Fig 3.3. Simplified LULC with weather stations used in this study.

Selection of Appropriate Days

In order to accurately compare the DTR between the LULC types, DTR must be isolated as a variable. Therefore, synoptically strong days are not included in this study, since they tend to be influenced by frontal passages through the area or days with enhanced advection across multiple LULC types. Brown and Arnold (1998) defined weak synoptic flow as a day that experiences 500-mb wind speeds less than 15-kts, surface wind speeds less than 10-kts, and no synoptic-forcing mechanism (e.g. surface front, low pressure center) within 500 km. Since this study focuses on surface-atmosphere interactions and their influence on near-surface temperatures, the criteria are slightly modified. First, to be classified as synoptically weak for the purposes of this research, the SSC from all four sites within the study area (Little Rock, AK; Memphis, TN; Jackson, MS; and Shreveport, LA) must indicate the same air mass. This accounts for any synoptic forcing mechanism in the study area. Between the years 1995 and 2004, 903 days reported the same SSC at all four sites. Also, the 0000 UTC and 1200 UTC soundings from both locations within the study area (Little Rock, AK; and Jackson, MS) must indicate 850-mb winds less than 15 kts and surface wind speeds less than 10 kts. As a result, 236 of the remaining 903 days fit these criteria and are used for this research.

Statistical Analysis

LULC and Air Mass

For each SSC, an average DTR was calculated for every LULC category. Within each LULC type, independent samples t-tests were used to test for variations of DTR due to presiding air mass, noting the results in two separate tables; mean differences (dispersed within the next chapter) and probability values (located in the appendix). Also, t-tests will be utilized to test the significance of DTR differences between each of the LULC categories for every SSC. Once again, the results are in two separate tables; a mean difference table, which can be found dispersed throughout the following chapter, and a probability values table, which is located in the appendix.

LULC and Month (Season)

Similar to above, an average DTR will be calculated for each month, and for every LULC for each month. Independent samples t-tests will be used to test for differences between the DTR of each LULC for every month of the year and the probability values and mean differences were compiled in two separate tables (located in the appendix). In addition, for each LULC an independent samples t-test will be performed to compare the DTR of each month.

Seasonal differences are also important for this research, since deciduous forests and agriculture experience growing seasons. Therefore, seasonal inferences are based on the monthly data and discussed in the respective section in the results chapter.

CHAPTER IV

RESULTS

The goal of this study is to discover variations in DTR due to LULC type, DTR is used rather than maximum or minimum temperature in order to minimize any bias due to elevation or latitude. In order to discover any relationships between LULC and variations of DTR in a portion of the southeast United States, DTR had to be isolated as a variable. This study uses weather data from all synoptically-weak days in the study area between 1995−2004, leaving 236 valid days. In the research area, 144 weather stations reported continuous data for the entire time period. Using a simplified LULC map, the stations were classified by LULC type, resulting in 6 urban stations, 11 deciduous-forest stations, 7 evergreen-forest stations, 39 mixed-forest stations, 57 agricultural stations, and 24 transitional stations (Table 4.1). This resulted in 1300 different urban observations, 2549 deciduous observations, 1562 evergreen observations, 7823 mixed-forest observations, 12,160 agricultural observations, and 5187 transitional-LULC observations, for a grand total of 30,581 observations.

The mean DTR for the study area is 23.4° F (Table 4.1), with a standard deviation of 6.4° F. The minimum DTR of 1° F occurred on 10 December 1998 at the Dumas, AR station, which is classified as agriculture, while under a MP air mass, as well as on 15 March 2004 at the Saint Charles, AR station, also classified as agriculture, while under the MM air mass. The maximum DTR of 53° F occurred on 17 March 2001 at the Lexington, MS station, which is classified as mixed forest, while under a DM air mass. However, these are only extremes, and they certainly do not represent an average day.

Table 4.1. The mean DTR (°F) for each LULC type, and the number of stations (s) and total number of observations (n) for each.

LULC	DTR	s	n
Urban	22.86	6	1300
Decid. Forest	25.13	11	2549
Egreen. Forest	24.94	7	1562
Mixed Forest	24.36	39	7823
Ag.	22.80	57	12,160
Trans.	23.72	24	5187
Mean	**23.40**	-	-
Total	-	**144**	**30,581**

Three DTR means were calculated for each LULC type- a total-observations DTR, which is simply the mean of all of the observations for that LULC class; a mean-air mass DTR, which is the mean of the mean DTRs for each air mass for each LULC type; and the monthly mean DTR, which is the mean of the mean monthly DTRs for each LULC type. As shown in Table 4.1, the greatest total-observations mean DTR occurred in deciduous forests (25.1° F), followed by evergreen forests (24.9° F), mixed forests (24.4° F), transitional LULC (23.7° F), urban areas (22.9° F), and finally agriculture (22.8° F). Previous research suggests that agricultural areas have a smaller DTR than all of the forest types. Since deforestation for agriculture has been linked to a cooling effect, which is more of a factor during the day than at night, there is a resulting decrease in DTR (Bonan 1999b). Therefore, it was expected that agriculture has a relatively low DTR, especially compared to the forested LULC categories. However, According to Gallo (1996), weather stations classified as urban experience the smallest DTR of all land uses 74% of the time, so it is somewhat surprising that the mean agriculture DTR is lower than that of the urban areas. Variations within the forests should occur on a seasonal basis, therefore it is difficult to tell if the forest DTRs agree with previous research simply by looking at the total-observation means.

LULC and Air Mass

This section reports the descriptive statistics and results of the mean difference tests used to compare variations in the DTR for each LULC type due to presiding air mass type.

Descriptive Statistics

In order to discern variations in DTR for each LULC category as related to the presiding air mass, the means for each LULC type were calculated for each air mass, as well as the mean DTR for each air mass and the mean air-mass DTR for each LULC type

(Table 4.2, Fig. 4.1). The highest mean air-mass DTR occurred in deciduous forests while under a Dry Tropical (DT) air mass (31.8º F), while the lowest occurred in urban areas while under a Moist Polar (MP) air mass (8.6º F).

Urban areas experienced the lowest mean air-mass DTR (20.9º F), followed by agriculture (21.5º F), transitional LULC (22.4º F), mixed forest (23.2º F), evergreen forest (23.6º F), and deciduous forest (23.6º F). This differs from the total-observation DTRs, since agriculture has the lowest total-observation DTR, while urban areas have the lowest mean air-mass DTR. However, agriculture has the lower DTR for all three of the dry air masses, as well as Moist Temperate (MT). Urban areas have the lowest DTR only for the Moist Moderate (MM) and MP air masses. In spite of this, urban areas experienced a DTR lower than the mean air-mass DTR for all of the air masses, while agriculture (and transitional LULC) has a DTR below the mean for all air masses except for the MM and MP. All three of the forest types experienced a DTR greater than the mean for all of the air masses, except for evergreen while under the moist polar air mass. All of the LULC classes experienced their mean DTR for each air mass in the same order as the air mass means, with MP being the smallest, followed by MM, MT, Dry Polar (DP), Dry Moderate (DM), and DT.

Table 4.2. The mean DTR (°F) of each LULC type for every SSC, as well as the overall mean for each SSC and LULC type. The overall maximum and minimum DTR are in bold.

SSC	Urban	Decid. Forest	Egreen. Forest	Mixed Forest	Ag.	Trans.	Mean
DM	26.27	28.89	28.99	28.06	26.03	27.17	**27.57**
DP	25.81	26.68	28.70	26.45	23.33	24.00	**25.83**
DT	29.12	**31.75**	31.54	31.04	28.54	29.35	**30.22**
MM	14.57	17.36	16.87	17.35	16.95	17.81	**16.82**
MP	**8.63**	14.09	12.88	14.43	13.62	14.65	**13.05**
MT	21.10	22.78	22.38	21.83	20.69	21.45	**21.71**
Mean	**20.92**	**23.59**	**23.56**	**23.19**	**21.53**	**22.41**	**22.53**

Before making conclusions about these data, however, it is important to understand how many observations there are from each LULC for each air mass. Urban areas and evergreen forests have the fewest observations, with 1295 and 1555, respectively, while agriculture has the most with 12,109 (Table 4.3, Fig. 4.2). The total number of observations in Table 4.3 differs from that of Table 4.1 because the transitional air mass did not have its own statistics run, however is included within the LULC and monthly statistics. Although the transitional air mass varies too much to have any of its own conclusions, it represents a parallel day between LULC types where DTR can be accurately compared.

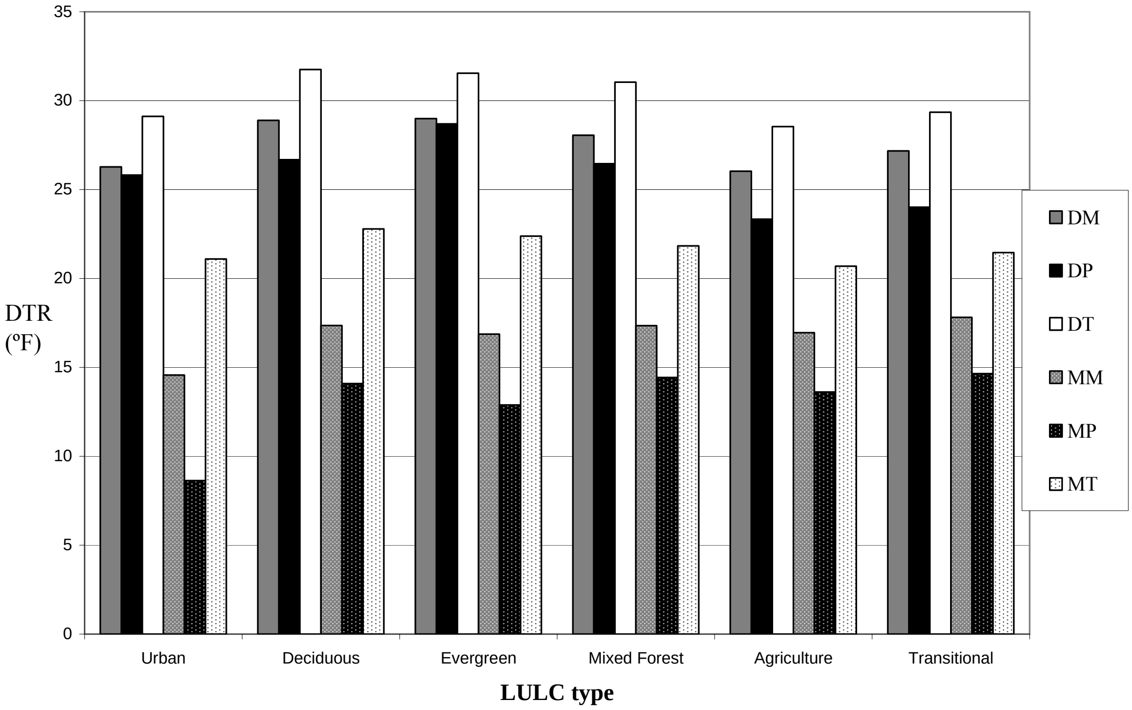


Fig. 4.1. The mean DTR (ºF) of each LULC category for every air mass type.

The effect of the uneven observations throughout the LULC and air mass types is evident in the difference between the total-observation and mean air-mass DTRs. All of the LULC types experienced a lower mean air-mass DTR than total-observation DTR, which can mostly be attributed to the "weight" of the MP air mass. In Table 4.1, the MP air mass is only responsible for approximately 3% of the days used to calculate the mean DTR. However, in Table 4.2, the MP air mass accounts for almost 17% (1/6) of the mean. Since all of the LULC classes experience their lowest DTR while under the effects of the MP air mass, this skews the mean air-mass DTR. This is most likely the reason for agriculture and urban areas switching places for the lowest DTR. Since urban areas experienced an extremely low DTR while under the MP air mass, the MP air mass had a larger effect on the mean air-mass DTR, thus making it lower than that of the agricultural areas.

Table 4.3. The number of observations for each LULC type for every SSC, as well as the total for each LULC type and SSC.

SSC	Urban	Decid. Forest	Egreen. Forest	Mixed Forest	Ag.	Trans.	Total
DM	501	993	611	3027	4682	2002	11,816
DP	16	31	20	95	153	67	382
DT	86	161	100	506	777	328	1958
MM	101	191	120	597	948	402	2359
MP	35	76	48	229	359	156	903
MT	556	1086	656	3334	5190	2211	13,033
Total	1295	2538	1555	7788	12,109	5166	30,451

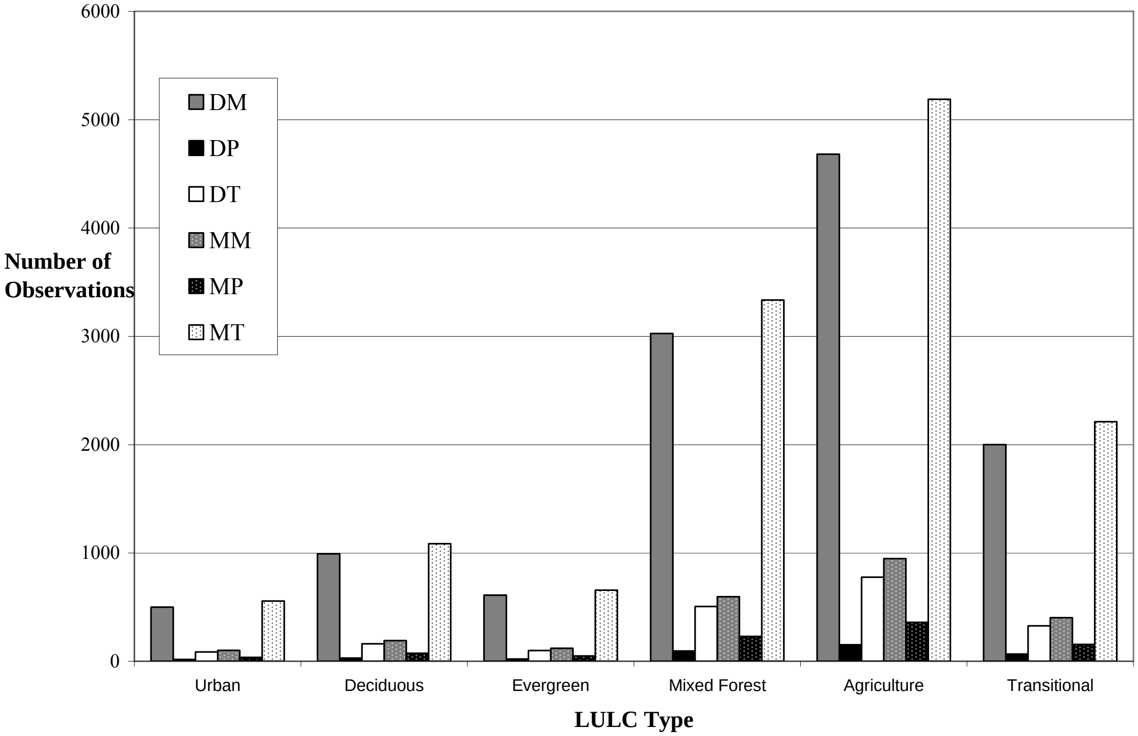


Fig. 4.2. The number of observations for each LULC type for every air mass.

Difference of Means Results

After the initial descriptive statistics were run, t-tests were performed between the DTR of each LULC type for each air mass to identify any significant differences in mean DTR between LULC categories while under the same presiding air mass. T-tests were also conducted between the DTR of each air mass type for every LULC category in order to determine any notable differences in DTR for each LULC type due to presiding air mass. The results of these t-tests are in two tables; one containing the mean difference that is dispersed throughout this chapter, and another containing the probability value (ρ), which can be found in the appendix. A negative value in the mean difference table indicates the LULC or air mass labeled in the corresponding column has a DTR less than that of the LULC or air mass labeled in the row against which it is being tested.

Variations in DTR between LULC Types

These results were found by testing for differences of means between the DTR of each LULC while under the same presiding air mass. The dry air masses all reported similar results, with agriculture having the lowest DTR for all three air masses. All of these differences proved significant (α=0.05) except for between agriculture and urban areas while under the DM and DT air masses, and agriculture and transitional while under the DP air mass (Tables 4.4−4.6). The only notable significant difference between the forest-type LULCs occurred under the DP air mass, with deciduous having a mean DTR 2.0º F less than that of the evergreen forests.

Table 4.4. The mean DTR difference (ºF) between each LULC type for the Dry Moderate air mass. A bolded number indicates that the difference is statistically significant (α=0.05). A negative number means that the LULC type labeled in the corresponding column has a DTR less than the LULC type in the row against which it is being tested.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-2.625**				
Evergreen	**-2.721**	-0.096			
Mixed Forest	**-1.795**	**0.830**	**0.926**		
Agriculture	0.235	**2.859**	**2.956**	**2.029**	
Transitional	**-0.899**	**1.725**	**1.822**	**0.895**	**-1.134**

Table 4.5. Same as table 4.4 for the Dry Polar air mass.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	-0.865				
Evergreen	**-2.888**	**-2.023**			
Mixed Forest	-0.640	0.225	2.247		
Agriculture	**2.479**	**3.344**	**5.367**	**3.119**	
Transitional	1.813	**2.677**	**4.700**	**2.453**	-0.667

Table 4.6. Same as table 4.4 for the Dry Tropical air mass.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-2.629**				
Evergreen	**-2.424**	0.205			
Mixed Forest	**-1.925**	0.704	0.498		
Agriculture	0.578	**3.207**	**3.002**	**2.504**	
Transitional	-0.234	**2.395**	**2.189**	**1.691**	**-0.813**

When looking at the results of the t-tests for the moist air masses, MP and MM show similar results with respect to significance (Tables 4.7 and 4.8). While under these two air masses, urban area DTRs are statistically significantly different (α=0.05) from all other LULC types, ranging from 2.3−6.0º F less than the DTR of the other LULC types. The only other significant difference for the MM t-tests is between agriculture and transitional, agriculture having a DTR 0.8º F less than transitional. The t-tests for the MT air mass, however, proved the LULC types to be statistically significantly different (α=0.05) (Table 4.9). Urban areas have a lower DTR than all of the other LULC types, except for agriculture, with a DTR ranging 0.4−2.1º F less than the other LULC types.

Table 4.7. Same as table 4.4 for the Moist Moderate air mass.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-2.782**				
Evergreen	**-2.292**	0.489			
Mixed Forest	**-2.771**	0.011	-0.478		
Agriculture	**-2.371**	0.411	-0.078	0.400	
Transitional	**-3.234**	-0.452	-0.942	-0.463	**-0.863**

Table 4.8. Same as table 4.4 for the Moist Polar air mass.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-5.464**				
Evergreen	**-4.246**	1.217			
Mixed Forest	**-5.804**	-0.340	-1.557		
Agriculture	**-4.987**	0.477	-0.741	0.817	
Transitional	**-6.025**	-0.562	-1.779	-0.222	-1.038

Table 4.9. Same as table 4.4 for the Moist Tropical air mass.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-1.675**				
Evergreen	**-1.271**	**0.404**			
Mixed Forest	**-0.729**	**0.946**	**0.542**		
Agriculture	**0.416**	**2.091**	**1.687**	**1.145**	
Transitional	**-0.344**	**1.330**	**0.926**	**0.384**	**-0.761**

Air Mass Effects on DTR for each LULC Type

The following results occurred when testing for significance in DTR variations due to presiding air mass type for each LULC type. Evident in Tables 4.10−4.15, deciduous forests, mixed forests, agricultural areas, and transitional areas each experienced statistically significantly different (α=0.05) DTRs between each air mass type. Both urban areas and evergreen forests show noteworthy variation in DTR due to air mass type, having significantly different DTRs between all of the air masses (except for when testing DM versus DP). Both MP and MM stand out as having very large mean differences from the other air masses for all of the LULC types, the largest differences occurring in urban areas (Table 4.10).

Table 4.10. Mean DTR (ºF) differences between each SSC in urban areas. A bolded number indicates that the difference is statistically significant (α=0.05). A negative number means that the SSC labeled in the corresponding column has a DTR lower than of the SSC in the row against which it is being tested.

SSC	DM	DP	DT	MM	MP
DP	0.455				
DT	**-2.849**	**-3.304**			
MM	**11.693**	**11.238**	**14.542**		
MP	**17.639**	**17.184**	**20.488**	**5.946**	
MT	**5.163**	**4.708**	**8.012**	**-6.530**	**-12.46**

Table 4.11. Same as table 4.10 for deciduous forests.

SSC	DM	DP	DT	MM	MP
DP	**2.215**				
DT	**-2.853**	**-5.068**			
MM	**11.536**	**9.321**	**14.389**		
MP	**14.800**	**12.585**	**17.653**	**3.264**	
MT	**6.113**	**3.898**	**8.966**	**-5.423**	**-8.687**

Table 4.12. Same as table 4.10 for evergreen forests.

SSC	**DM**	**DP**	**DT**	**MM**	**MP**
DP	0.289				
DT	**-2.551**	**-2.840**			
MM	**12.122**	**11.833**	**14.673**		
MP	**16.114**	**15.825**	**18.665**	**3.992**	
MT	**6.614**	**6.325**	**9.165**	**-5.508**	**-9.500**

Table 4.13. Same as table 4.10 for mixed forests.

SSC	**DM**	**DP**	**DT**	**MM**	**MP**
DP	**1.609**				
DT	**-2.979**	**-4.589**			
MM	**10.717**	**9.108**	**13.696**		
MP	**13.630**	**12.020**	**16.609**	**2.913**	
MT	**6.229**	**4.620**	**9.209**	**-4.488**	**-7.401**

Table 4.14. Same as table 4.10 for agricultural areas.

SSC	**DM**	**DP**	**DT**	**MM**	**MP**
DP	**2.700**				
DT	**-2.505**	**-5.205**			
MM	**9.088**	**6.388**	**11.593**		
MP	**12.417**	**9.718**	**14.922**	**3.330**	
MT	**5.345**	**2.645**	**7.850**	**-3.743**	**-7.072**

Table 4.15. Same as table 4.10 for transitional areas.

SSC	DM	DP	DT	MM	MP
DP	**3.167**				
DT	**-2.184**	**-5.351**			
MM	**9.358**	**6.192**	**11.542**		
MP	**12.513**	**9.346**	**14.697**	**3.155**	
MT	**5.718**	**2.551**	**7.902**	**-3.640**	**-6.795**

LULC and Month (Season)

This section reports the descriptive statistics and results of the mean difference tests used to measure variations in the DTR of each LULC type due to month.

Descriptive Statistics

In order to evaluate the relationship between DTR and month for each LULC type, the means for each LULC type were calculated for every month, as well as the mean DTR for each month, and the mean monthly DTR for each LULC type (Table 4.16). Agricultural areas experience the lowest mean monthly DTR (22.5º F), followed by urban areas (22.8 º F), transitional (23.7 º F), mixed forest (24.7 º F), deciduous forest (24.8 º F), and evergreen forest (25.1 º F). Agricultural areas experience below-mean DTRs every month, while evergreen and mixed forests experience DTR values greater than the mean for every month. Urban areas have a mean DTR greater than the monthly mean only for the month of January, and deciduous forests have a mean DTR less than the monthly mean only for January and December. All of the LULC types experienced their lowest monthly mean DTR in December, but vary after that. Consequently, December has the lowest monthly-mean DTR, followed by July, June, February, March, August, November, January, May, September, October, and April.

The monthly mean DTRs differ from the total-observation and mean air-mass DTRs, in that agricultural land replaces urban areas as the LULC type with the lowest DTR. However, both urban and agricultural areas experience the lowest DTR of all other LULC types six months of the year; agriculture having the lowest mean DTR in all of the winter (December−February) and summer (June−August) months, while urban areas have the lowest DTR in the spring (March−May) and fall (September−November) months. Additionally, evergreen forests replaced deciduous forests with the highest mean DTR.

The dispersal of monthly observations proves to be very uneven, December and January having only 258 and 376 data points, respectively (Fig. 4.3, Table 4.17). There is an obvious peak of observations from June to October, with all of the months having over 3400 data points. The lack of observations in December and January makes seasonal inferences difficult. However, data should prove affluent enough to make comparisons between “green” and “non-green” months for agricultural and forested LULC classifications.

Table 4.16. The mean DTR (°F) of each LULC type for every month, as well as the overall mean for each month and LULC type.

Month	**Urban**	**Decid. Forest**	**Egreen. Forest**	**Mixed Forest**	**Ag.**	**Trans.**	**Mean**
1	25.75	24.16	27.32	26.30	22.66	25.18	**25.23**
2	20.67	24.30	24.76	22.62	20.18	21.48	**22.34**
3	20.82	24.47	22.76	23.11	20.90	22.29	**22.39**
4	25.49	28.85	29.08	28.62	25.65	26.94	**27.44**
5	23.85	26.37	26.58	26.25	23.94	24.84	**25.31**
6	21.41	22.83	22.89	22.72	20.86	21.88	**22.10**
7	20.42	22.26	21.85	21.51	20.07	21.06	**21.20**
8	23.01	25.70	25.03	24.13	22.98	23.62	**24.08**
9	24.80	26.97	26.41	25.85	25.11	25.54	**25.78**
10	25.69	27.85	28.10	26.99	25.72	27.06	**26.90**
11	23.02	25.65	25.96	26.5	24.49	25.56	**25.20**
12	18.90	18.68	20.15	21.55	17.96	19.45	**19.45**
Mean	**22.82**	**24.84**	**25.07**	**24.68**	**22.54**	**23.74**	**23.95**

It is evident that, although there were not many urban observations, the urban areas follow the general trend of the other LULC categories (Fig. 4.4). Ignoring December and January, which do not have enough observations to draw any significant conclusions, all of the LULC types experience lower DTRs in February and March, followed by a peak in April. This peak is followed by another relative minimum in DTR during June and July, and another peak in October. Although all of the LULC types follow this same pattern, there are two different groups between the LULC classifications, with urban and agricultural areas having very similar DTRs, lower than that of the other LULC classes, while deciduous, evergreen, and mixed forests all act similarly with higher monthly DTRs. The two groups are very distinctive March−July, but look less organized and more spread out August−February.

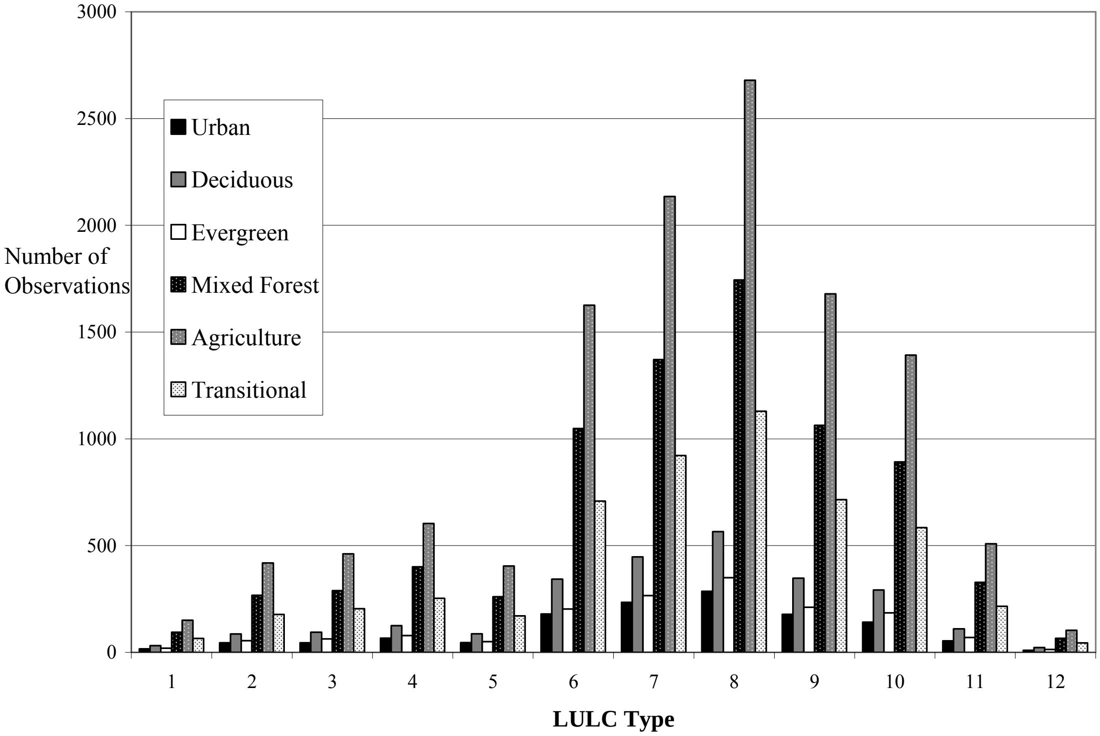


Figure 4.3. The number of monthly observations for each LULC classification.

Table 4.17. The number of observations for each LULC type for every month, as well as the total for each month and LULC type.

Month	**Urban**	**Decid. Forest**	**Egreen. Forest**	**Mixed Forest**	**Ag.**	**Trans.**	**Total**
1	16	31	19	94	151	65	**376**
2	45	86	54	267	418	177	**1047**
3	45	94	63	289	461	204	**1156**
4	67	125	78	400	603	253	**1526**
5	46	87	50	260	404	171	**1018**
6	179	343	203	1048	1626	708	**4107**
7	234	447	266	1371	2135	922	**5375**
8	286	565	350	1744	2680	1129	**6754**
9	178	347	211	1064	1679	715	**4194**
10	141	292	185	892	1392	584	**3486**
11	53	110	70	328	508	215	**1284**
12	10	22	13	66	103	44	**258**
Total	**1300**	**2549**	**1562**	**7823**	**12,160**	**5187**	**30,581**

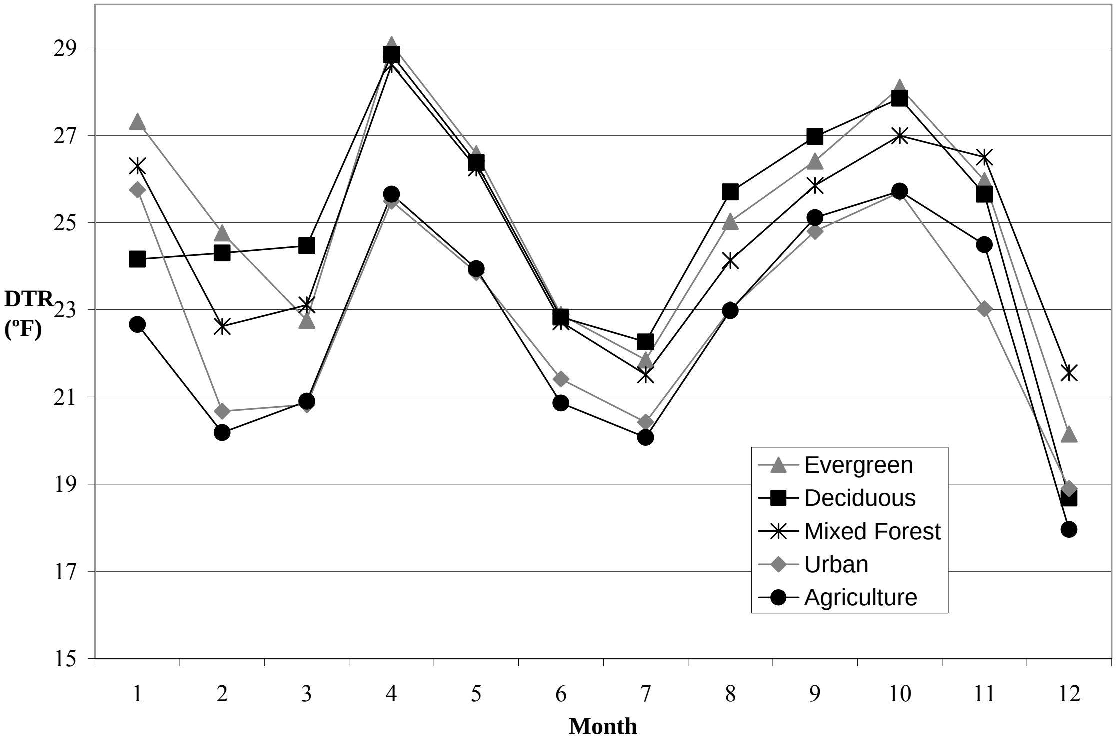


Fig. 4.4. The mean DTR (ºF) for each LULC by month.

Difference of Means Results

After the initial descriptive statistics were run, t-tests were performed in order to determine any statistical significance of monthly variations in DTR for each LULC, and then in order to determine any major differences in the DTR between each LULC category during the same month.

Variations in DTR due to LULC Type

The following results occurred when testing for significance in monthly DTR variations for each LULC. Similar to the previous section, the results of these t-tests are in two tables; one containing the mean difference and another containing the probability value (ρ), both of which can be found in the appendix. These results reinforce what is discussed above, that each of the LULC types follows a similar pattern. For every LULC type, the mean differences are statistically significantly different (α=0.05) when comparing both February and July (the observed relative minimums) to April and October (the observed relative maximums). Therefore, the notable trends shown in Figure 4.4 can be deemed statistically significant.

Inter-monthly DTR Variations between LULC Types

These results were found by testing the significance between the DTR of all the LULC types for each month, thus detecting any major inter-monthly differences in DTR between the LULC types. The results are in two tables; one containing the mean differences and another containing the probability value (ρ), both being located in the appendix. The months of January and December are not included except where specifically mentioned, because there are not many significant results due to lack of observations.

For every month, except November and March, the DTR of agriculture is significantly lower (α=0.05) than all three forest types, while urban areas and agriculture are not significantly different for a single month of the year. The DTRs of urban areas are significantly lower than all three forest types April through September. Deciduous forests have a DTR lower than that of the evergreen forests for every winter month, however, this difference is only significant in January when the mean difference is at its greatest at 3.1º F (Table A.26).

Summary

The statistical analyses for this study involved using the DTR of 144 weather stations on 236 synoptically-weak days. There are 6 urban stations, 11 deciduous-forest stations, 7 evergreen-forest stations, 39 mixed-forest stations, 57 agricultural stations, and 24 transitional stations, resulting in a total of 30,581 observations. The smallest mean DTR occurs in agricultural areas (22.8º F), followed by urban areas (22.9º F), transitional LULC (23.7º F), mixed forests (24.4º F), evergreen forests (24.9º F), and deciduous forests (25.1º F).

The descriptive statistics of LULC and air mass type show that all of the LULC types experience their mean DTR for each air mass in the same order as the overall air mass means. Therefore, while the smallest mean DTR is associated with the Moist Polar (MP) air mass, the smallest air-mass DTR for every LULC is also while under the MP air mass. This is followed by Moist Moderate (MM), Moist Temperate (MT), Dry Polar (DP), Dry Moderate (DM) and Dry Tropical (DT). Urban areas experience the lowest mean air-mass DTR of all the LULC types, followed by agriculture, transitional, mixed forest, evergreen forest, and deciduous forest. These results differ from the total-observation means because of the weight of the MP air mass, which only makes up approximately 3% of the total-observation means, but nearly 17% of the air mass means. Since all of the LULC types undergo their lowest DTR under the MP air mass, it dramatically decreases the DTR of the LULC types that previously reported a large DTR. Therefore, although it is beneficial to examine the differences due to air mass type, the total-observations DTR is a more accurate representation of the mean DTR for each respective LULC type.

The results of the independent samples t-tests show that there is much more DTR variability between the LULC types due to air mass than to month. Deciduous forests, mixed forests, agricultural areas, and transitional areas all experience statistically significant ($\alpha=0.05$) DTR differences between all air masses. The DTRs of MM and MP air masses stand out as having the largest mean differences from the DTRs of the other air masses for all of the LULC types. Also notable, agricultural land shows the lowest DTR for all of the dry air masses, with urban being the second lowest.

Inter-monthly DTR variations between the LULC types proved very consistent, with all of the LULC types following a very similar pattern, represented by two peaks in DTR in April and October and two lows in February and July. Although all LULC classes follow this pattern, there are two apparent groups: urban and agricultural areas with lower DTRs, and evergreen, deciduous, and mixed forests all acting similarly with higher DTRs. These groupings are more distinctive March−July. Agriculture and urban areas acted the most similar of all the LULC types, with none of the months reporting a statistically significant DTR difference between them. Additionally, both agricultural and urban areas both have the lowest mean DTR for six months of the year; agriculture having the lowest in the winter and summer months, while urban areas have the lowest in the spring and fall.

CHAPTER V

DISCUSSION

This chapter will discuss, and provide possible explanations for, the notable results mentioned in the previous chapter. Similar to the results chapter, after a brief mention of the total-observation DTRs for each LULC, the important results regarding LULC type and air mass will be discussed, followed by a discussion of the results involving the relationship between LULC type and monthly DTR.

Total-Observations DTRs

The ranking of LULC types by total-observations DTR is somewhat surprising; deciduous forests having the largest DTR, followed by evergreen forest, mixed forest, transitional LULC, urban areas, and agriculture (Table 4.1). The most widely-accepted idea regarding the topic of this study is most likely that urban areas experience the lowest DTR of all LULC types (Howard 1833; Roth et al. 1989; Kim and Baik 2005). This is not true for the total-observations DTRs in this study, as agriculture areas have a lower mean DTR than urban areas. This is most likely the result of two factors, the first of which being city size.

Table 5.1. The cities making up the urban stations for this study, and their respective 2000 population as reported by the U.S. Census Bureau.

Station (City)	**State**	**Population**
Memphis	TN	650,100
Shreveport	LA	200,145
Jackson	MS	184,256
Little Rock	AR	183,133
Monroe	LA	53,107
Texarkana	AR	26,448

As mentioned in Chapter II, the strength of the urban heat island is relative to a city's population (Oke 1973). Table 5.1 shows the six urban stations, and their respective city's population as reported by the 2000 census. Memphis, TN is by far the largest city included in this study with a 2000 population of over 650,000, while the rest of the cities are less than or just over 200,000 people. These smaller cities should have a less dramatic urban heat island effect than most of the larger cities commonly used for urban heat island studies, therefore they may not follow previous findings that urban areas have the smallest DTR of all LULC types. Nonetheless, in an urban heat island study, Gallo (1996) included smaller cities and still found that urban areas report the smallest DTR of all LULC types 74% of the time.

Although the small city size may be part of the reason why agriculture has a lower total-observation DTR than urban areas, it is also possible that it is an effect of the agricultural areas rather than the urban. Bonan (1999b) found that agricultural areas experience a smaller DTR than forested areas, most evident in the summer and autumn months when agriculture has a DTR 1º C (1.8º F) less than that of the forests. Conversely, the mean DTR of agriculture (as reported in Table 4.1) is 22.8º F; 1.6º F less than mixed forests, 2.1º F less than evergreen forests, and 2.3º F less than deciduous forests. This shows that the overall DTR difference between agricultural areas and forests in this study area are just near, or greater than, the maximum difference that Bonan (1999b) reported in the summer and fall months. It should be noted, however, that Bonan included synoptically strong days that most likely decreased the effect of the agricultural areas, lessening the DTR difference.

Also notable in Table 4.1 is the ranking of the DTRs of the forested-LULC types. As mentioned in the literature review, it has been shown that evapotranspiration (Swing et al. 1975) and albedo (Oke 1987) vary between forest types, both of which are factors of season, and affect the DTR of an area. Season aside, deciduous forests experience a slightly larger DTR than that of the evergreen forests, but the monthly-DTR section will provide a lot more detail regarding the relationship between DTR of the different forest types.

LULC and Air Mass

All of the LULC types experience the greatest DTRs in the following air mass order: DT, DM, DP, MT, MM, MP, showing that air mass type has a much larger and more consistent influence on the DTR of an area than the LULC type. Also, the order of the DTRs of the air mass types shows that moisture plays a larger role in DTR than temperature, since all of the dry air masses have larger DTRs than all of the moist air masses. After being separated by moisture content, it is evident that the warmer air masses have a larger DTR than the cooler air masses.

The LULC types rank very similarly in mean air-mass DTRs as they did for total-observation DTRs. All of the LULC types reported a smaller mean air-mass DTR, and as indicated in the results section, this is most likely due to the difference in the weight of the MP air mass. Similarly, the most notable difference in the ranking of the two mean DTRs is that urban and agricultural areas switched places. As explained in the results section, and most likely a misrepresentation due to the weight of the MP air mass, the total-observations DTR being much more representative of what actually occurs on a daily basis.

Variations in DTR between LULC Types

The t-tests between the DTR of the LULC types during the dry air masses begin to show a peculiar relationship between the urban and agricultural areas. Agriculture and urban areas only show a statistically significant difference ($\alpha=0.05$) while under the effects of the DP air mass, not during the DM or DT air masses. Although the mean difference for the DP air mass is somewhat large (2.5° F), the lack of observations of this air mass provides skepticism. Additionally, if the small number of observations does reflect what actually occurs, it is hard to make any conclusions simply off these data, since all of the DP air mass days occur in only three months of the year, and agriculture experiences seasonality (Table 5.2). This makes separating the effects of agriculture seasonality and the air mass itself rather difficult, since during all of these months, vegetation will not evapotranspire very productively, if the agriculture even exists to evapotranspire. Similarly, the only large significant difference between the forest-type LULCs occurred while under the DP air mass, providing the same seasonality dilemma. It will be more appropriate to use the monthly data in the next section to make these seasonal inferences.

Table 5.2. The total number of monthly observations for each air mass type.

Month	**DM**	**DP**	**DT**	**MM**	**MP**	**MT**
1	253	123	0	0	0	0
2	653	0	0	0	394	0
3	513	128	132	255	128	0
4	1267	0	127	132	0	0
5	631	0	128	119	0	134
6	1772	0	0	804	0	1535
7	792	0	0	128	0	4455
8	1028	0	1046	259	0	4423
9	1573	0	391	265	0	1965
10	2306	131	134	397	0	0
11	894	0	0	0	256	0
12	134	0	0	0	124	0
Total	**11,816**	**382**	**1958**	**2359**	**902**	**12,512**

The t-tests between LULC types for the moist air masses show urban areas having a statistically significant difference (α=0.05) from all of the other LULC types, agriculture included. In fact, these are the only notable differences among the MM and

MP air masses, and represent the largest and third-largest mean differences between agriculture and urban areas. Although urban areas have a significantly lower DTR than all other LULC types, and all of the vegetated LULC types experience no notable significant difference, these differences are not due to vegetation, since the MP air mass only occurs during colder months when deciduous forests and agriculture have minimal "active" vegetation. Since the MT air mass does not show such large mean differences, it is safe to assume that these effects are also not simply a result of moisture. Additionally, the MT and MM air mass occur at the same time of the year. This leads the author to the conclusion that during the MP and MM air masses, urban areas have a significantly lower DTR than surrounding areas because there is not enough energy available in order to allow evapotranspiration in an already moist environment. The lack of vegetation during the months of the MP air mass, as well as the already cold air in place, also prohibits evapotranspirational cooling to occur. However, during a MT air mass, there is enough energy available in the atmosphere to allow the vegetation to provide some evapotranspirational cooling, decreasing the DTR of the vegetated areas making them more similar to the urban areas.

Although it may seem contradictory, the MT air mass is the only air mass for which all of the t-tests between LULC types are significantly different. Most of the mean differences between the LULC types, however, are much less for the MT air mass than for all of the other air masses. This shows that the statistically significant differences are not due to large mean differences, but because the DTRs of all of the LULC types are consistently similar.

Air Mass Effects on DTR for each LULC Type

The mean differences of this section are, in general, much larger than those of the previous section. This shows that although differences can be seen between the LULC types while under the same air mass, air mass affects DTR much more than LULC classification. Once again, the MM and MP air masses stand out from the others, as all of the LULC types experience very large mean differences when comparing the MM and MP air masses to the other air mass types.

LULC and Month (Season)

The monthly DTRs rank the same as the total-observation DTRs except deciduous and evergreen forests switched places for the largest DTR. This is not an important change, since the two LULC types do not differ very much for either of the means. The switch most likely occurred because the winter accounts for much fewer days than the other months in the total-observations DTR. Since evergreen forests have a larger DTR in most of the fall and winter months, when these months are weighted heavier in the monthly mean, evergreen is able to surpass deciduous for the largest mean DTR. Agriculture has the lowest mean monthly DTR, however, agriculture and urban areas each have the lowest DTR for six months of the year. Unlike the DTR rankings by air mass, the DTRs of LULC types do not rank the exact same by month, but all of the LULC types follow a similar annual trend, which will be discussed soon in further detail.

Variations in Monthly DTR

Monthly variations for the DTR of each LULC type, and inter-monthly variations between LULC types prove somewhat difficult to separate when discussing possible reasons behind the results, and will be discussed together. Fig. 4.4 best represents the monthly DTR pattern found in Chapter IV. All of the LULC types followed a similar pattern, with relative minimum DTRs around February and July and DTR peaks around April and October. This graph plainly shows the connection between the DTRs of agricultural and urban areas, illustrating two distinctive groups between the LULC types, with urban and agriculture having very similar DTRs, lower than that of the forest types which also experience similar DTRs. Urban and agricultural areas have no statistically significantly different DTRs ($\alpha=0.05$) during the entire year, but the agricultural DTR is statistically significantly different than the forest types for 10 of the 12 months. This shows two definite monthly DTR groups, and further defines the connection between the agricultural and urban DTRs.

Within the two groups there was little DTR variability between March and July, and there were no notable statistically significant differences of DTR within the groups during these months. However, between August and February when the graph shows more variability between the groups, there are statistically significant differences between some of the forests for some of the months. Most notably, deciduous forests have a DTR smaller than the evergreen forests during the entire winter season, but a larger DTR in the late summer and early fall. This is not what was expected, since if the DTR was a factor of evapotranspiration, the deciduous forests would have a smaller DTR during the green season, and a larger DTR during the non-green season. Also, these results do not agree with previous ideas regarding the albedoes of the forests. Since deciduous forests have a lower DTR than the evergreen forests in the winter, it is expected that they would also have a higher DTR than the evergreen forests. These results may make more sense when looking at the seasonal variations of maximum and minimum temperatures, where the effects of albedo and evapotranspiration may be more easily identifiable. The deciduous forests were also expected to have a more dramatic annual DTR trend than the evergreen forests, as changes in evapotranspiration occur with loss of leaves in the winter, but once again, the relationship between deciduous and evergreen forests may be further explained by using maximum and minimum temperatures.

The overall annual trend of all of the LULC types (represented in Fig. 4.4) differs from results of a previous study by Gallo et al. (1996), that the DTR of all LULC types across the United States is greatest in the summer, but agrees with the findings of Durre and Wallace (2001), that in the eastern United States, there is a summer DTR minimum surrounded by two DTR peaks in the spring and fall. Durre and Wallace (2001) suggest the cause of this summertime minimum is the increased amount of evapotranspiration in the summer, overpowering the effects of the higher sun angle and longer days, which would actually increase the DTR during the warm season.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Research on the relationship between LULC and temperature began after the discovery of the urban heat island, often accredited to Howard (1833). Since then, it has been widely accepted that the urban heat island of a large city causes urban areas to have a smaller DTR than surrounding areas (Howard 1833; Roth et al. 1989; Kim and Baik 2005). Less attention, however, has focused on the effects of the small-city urban heat island.

After the discovery of the urban heat island, researchers began to investigate the effect of other LULC types on daily temperatures, including agriculture and forests. Bonan (1999b) attributed agriculture with a cooling effect and a DTR 1° C smaller than that of forested areas during the summer and autumn months. Additionally, different forest types should vary in DTR due to differences in evapotranspiration rates and albedo, although the exact relationship between these variables and seasonal changes in different forests has not been shown.

Although many of the relationships, discussed above, between LULC type and temperature are generally accepted, there are not many studies that look at multiple LULC types in the same temporal and spatial areas. This makes it difficult to make inferences between the multiple LULC types found in the “typical” landscape, which naturally changes over distances of varying scales. Furthermore, as mentioned above the relationship between the DTR of different forest types has not previously been clearly shown.

The main goal of this study was to test the known relationships between DTR and LULC type in a portion of the southeast United States, where the LULC types naturally vary at uneven intervals. Also, this study looked for seasonality of DTR due to changes in vegetation, creating a better understanding of the small-city urban heat island, and the differences in DTR among forests due to the many variables that differ between forest types. Ultimately, by testing all of these LULC types at the same time, this study provides a general understanding of how LULC can affect the DTR of an area.

The outcomes of this research include the following: an annual DTR trend for all LULC types; an understanding of the strength of the influence of air masses versus LULC types on DTR; an understanding of the importance temperature and moisture play in determining DTR; and information on the influences of each LULC on an area’s DTR.

Annual DTR Pattern

The annual DTR trend for all of the LULC types is represented by peaks in April and October, and minimums in February and July. Although some LULC types exhibit subtle variations, it is a very distinctive trend that has not been shown in many previous studies except for Durre and Wallace (2001), who first reported this bimodal pattern. Additionally, there are two separate groups, one consisting of urban and agricultural areas, while the other includes all of the forested-LULC types.

Urban Areas

As previously mentioned, it is generally accepted that urban areas cause a decrease in DTR. The urban areas in this study, however, are much smaller than cities used for most urban heat island studies. This is part of the reason why agricultural areas experience a smaller DTR in this study area, however, ignoring the agricultural areas, it is evident that the urban heat island does exist in this study area. It is also obvious that the heat island is at its peak during the warm season as Oke (1982) suggested. Although the urban areas lacked observations in this study compared to the other LULC types, this research further proves the existence of a small-city urban heat island, as Duckworth and Sandberg (1954) and Kopec (1970) suggested.

Agriculture

The behavior of the DTR of agricultural areas is most likely the most notable result of this research. Agriculture and urban areas acted very similarly, evident in both the air mass and monthly results. Although clearing of forests for agricultural purposes has been attributed with a cooling effect and DTR decrease, the intensity of the decrease shown in this study is much larger than expected. This leads the author to believe that it may not be the LULC of the agricultural areas that creates such a dramatic change in DTR, rather a characteristic of the area where the agriculture is located. This could be a number of things, including soil moisture and albedo. Since the agricultural portion of this study is mainly located in the area referred to as "the Delta," it would be possible in future research to test the differences between non-Delta and Delta DTRs in order to show that these results were in fact due to a property of the area where the agriculture is located.

Forested Areas

The forested areas of this study experience a larger DTR than the agriculture and urban areas. Generally, the DTR of the forested areas behave fairly similarly, which was not expected; however, using the DTR could mask seasonal influences that would be more easily identified by comparing maximum and minimum temperatures. Also, the natural mixing of the forests in this area, and the lack of evergreen and deciduous forest data, could have affected the results. It is the belief of the author that in an area so dominated by mixed forests, and lacking precise boundaries between deciduous and evergreen forests, the mixed forest characteristics are able to prevail, including the DTR. A different study area where deciduous and evergreen forests are more isolated would be of use to further determine the relationship between different forest types and DTR.

Strength of Influences on DTR

The results of this study suggest the following in terms of certain variables' influences on DTR:

- Although LULC type affects DTR, the presiding air mass provides a larger influence on the temperature of an area.
- The moisture content of the air mass is more important than the temperature in determining DTR.
- Annual trends of DTR for all LULC types depend on seasonal variations of evapotranspiration and albedo, as well as seasonal occurrences of air mass types.

Conclusions

Limitations

Aside from the limitations previously mentioned, there is also a lack of observations in general. For 10 years of data, only 236 days were considered valid for this study. The days that remained were uneven in terms of air-mass and monthly distributions. Increasing the time period would cause more problems due to the change of LULC types in a large period of time, and would add even more problems than it would help. In addition, the lack of observations for certain LULC types causes skepticism in the results, but increasing the size of the study area would only increase the likelihood of other variables, including latitude and greater elevation differences.

Implications

The results of this study cover a considerable amount of ideas, however, the main goal of this study was to analyze the variations in DTR due to LULC type, in an area and time frame allowing comparisons between multiple LULC types. By minimizing the influences of other variables, this research was able to show a definite annual pattern in DTR, and the relationship between different LULC types and DTR. As a result of this research, there are many opportunities for future studies, some of which are mentioned above, but the author takes particular interest in research that aims to explain the phenomena of the relatively low DTR in “the Delta.”

REFERENCES

Black, J. F., 1963: Weather control: Use of asphalt coatings to tap solar energy. *Science*, 139, 226-227.

Black, J. F., and B. L. Tarmy, 1963: The use of asphalt coatings to increase rainfall. *J. Appl. Meteor.,* 2, 557-564.

Bonan, G. B., 1997: Effects of land use on the climate of the United States. *Climatic Change* 37: 449–486.

Bonan, G. B., 1999a: Frost followed the plow: Impacts of deforestation on the Climate of the United States. *Ecological Applications*, 9, 1305-1315.

Bonan, G. B., 1999b: Observational evidence for reduction of daily maximum temperature by croplands in the Midwest United States. *J. Climate*, 14, 2430-2442.

Bornstein, R., 1968: Observations of the urban heat island effect in New York City. *J. Appl. Meteor*., 7, 575-582.

Brown, M. and D. Arnold, 1998: Land-surface-atmosphere interactions associated with deep convection in Illinois. *Int. J. Climatol.,* 18, 1637-1653.

Changnon, S.A., 1981: *METROMEX: A review and summary*, Amer. Meteor. Soc., 181 pp.

Charney, J., W. J. Quirk, S.-H. Chow, and J. Kornfield, 1977: A comparative study of the effects of albedo change on drought in semi-arid regions. *J. Atmos. Sciences*, 34, 1366-1386.

Dirmeyer, P. A., and J. Shukla, 1994: Albedo as a monitor of climate response to tropical deforestation. *J. Geophysical Research*, 99, 20,863-20,877.

Duckworth, F. A., and J.S. Sandberg, 1954: The effect of cities upon horizontal and vertical temperature gradients. *Bull. Amer. Meteor. Soc.*, 35, 198-207.

Durre, I. and J. M. Wallace, 2001: The warm season dip in diurnal temperature range over the eastern United States. *J. Climate*, 14, 354-360.

Easterling, W. E., P. R. Crosson, N. J. Rosenberg, M. S. McKenny, L. A. Kratz, and K.M. Lemond, 1993: Agricultural impacts of climate change in the Missouri-Iowa-Nebraska-Kansas (MINK) region. *Climatic Change*, 24, 23-61.

Eaton, G. S., 1956: High relative temperature of pavement surfaces. *Mon. Wea. Rev*., 47, 801-802.

Feddema, J. J., K. W. Oleson, G. B. Bonan, L. O. Mearns, L. E. Buja, G. A. Meehl, W. M. Washington, 2005: The importance of land-cover change in simulating future climates. *Science*, 310, 1674-1678.

Foley, J. A., I. C. Prentice, N. Ramankutty, S. Levis, D. Pollard, S. Sitch, A. Haxeltine, 1996. An integrated biosphere model of land surface processes, terrestrial carbon balance, and vegetation dynamics. *Global Biogeochemical Cycles,* 10, 603–628.

Gallo, K. P., 1996: The influence of land use/land cover on climatological values of the diurnal temperature range. *J. Climate*, 9, 2941-2944.

Grimmond, C. S. B., and T. R. Oke, 1999: Evapotranspiration rates in urban areas. *IAHS Publication*, 259, 235-243.

Howard, L., 1833: *Climate of London Deduced from Meteorological Observations*, Harvey and Darton, London

Huang, Y. J., H. Akbari, H. Taha, and A. H. Rosenfeld, 1987: The potential of vegetation in reducing summer cooling loads in residential buildings. *J. Appl. Meteor*., 26, 1103-1116.

Hubbard, K.G. and F.J. Flores-Mendoza, 1994: Relating United States land use to natural resources and climate change. *J. Climate*, 8, 329-335.

Hutcheon, R. J., R. H. Johnson, W. P. Lowry, C. H. Black, and D. Hadley, 1967: Observations of the urban heat island in a small city. *Bull. Amer. Meteor. Soc.*, 48, 7-9.

Jin, M., R. E. Dickinson and D. Zhang, 2005: The footprint of urban areas on global climate as characterized by MODIS. *J. Climate*, 18, 1551–1565.

Kalkstein, L. S., C. D. Barthel, M. C. Nichols, and J. S. Greene, 1996: A new spatial synoptic classification: Application to air mass analysis. *Int. J. Climatol*., 16, 983-1004.

Kalkstein, L. S., S. C. Sheridan, and D. Y. Graybeal, 1998. A determination of character and frequency changes in air masses using a spatial synoptic classification. *Int. J. Climatol.* 18: 1223-1236.

Kalnay, E. and M. Cai, 2003: Impact of urbanization and land-use change on climate. *Nature*, 423, 528-531.

Kim, Y. and J. Baik 2005: Spatial and temporal structure of the urban heat island in Seoul. *J. Appl. Meteor*., 44, 591-605.

King, S. L., and B. D. Keeland, 1999: Evaluation of reforestation in the Lower Mississippi Alluvial Valley. *Restoration Ecology*, 7, 348-359.

Kopec, R. J., 1970: Further observation of urban heat islands in a small city. *Bull. Am. Meteor. Soc*., 51, 602-606.

Monteith, J. L., 1959: The reflection of short-wave radiation by vegetation. *Quart. J. Roy. Meteor. Soc*., 85, 386-392.

Moreno-Garcia, M. C., 1994: Intensity and form of the urban heat island in Barcelona. *Int. J. Climatol.,* 14, 705-710.

Morris, C. J. G., I. Simmonds, and N. Plummer, 2001: Quantification of the influences of wind and cloud on the nocturnal urban heat island of a large city. *J. Appl. Meteor.,* 40, 169–182.

Oke, T. R., 1973: City size and urban heat island. *Atmos. Environ*., 7, 767-779.

Oke, T. R., 1982: The energetic basis of the urban heat island. *Quart. J. Roy. Met. Soc.*, 108, 1-24

Oke, T. R., 1987: Boundary Layer Climates 2nd Ed. *Routledge Publishing*, Cambridge University Press, 435 pp.

Parry, M., 1990: The potential impact of agriculture on the greenhouse effect. *Land Use Policy*, 7, 109-123.

Pilgrim, J. M., X. Fang, H. G. Stefan, 1998: Stream temperature correlations with air temperatures in Minnesota: Implications for climate warming. J. American Water Resources Association, 34, 1109-1121.

Quayle, R. G., D. R. Easterling, T.R. Karl, and P.Y. Hughes, 1991: Effects of recent thermometer changes in the cooperative station network, *Bull. Am. Meteor. Soc.*, 72, 1718-1724.

Robinson, D.A., E. Matthews and G. Kukla, 1985: Human-induced changes on winter surface albedo. *Meteor. Atmos. Phys.*, 34, 427-434.

Roth, M., Oke, T.R., and W.J. Emery, 1989: Satellite-derived urban heat islands from three coastal cities and the utilization of such data in urban climatology. *Int. J. Remote Sens.*, 10, 1699–1720.

Scott, C. T., W. A. Bechtold, G. A. Reams, W. D. Smith, J. A. Westfall, M. H. Hansen, and G. G. Moisen, 2005: Sample-based estimators used by the forest inventory and analysis national information management system. *The Enhanced Forest Inventory and Analysis Program- National Sampling Design and Estimation Procedures*, W. A. Bechtold and P. L. Patterson, Eds., U.S. Department of Agriculture, 50-51.

Sheridan, Scott C, 2002: The redevelopment of a weather-type classification scheme for North America. *Int. J. Climat.*, 22, 51-68.

Stanturf, J.A., E.S. Gardiner, P.B. Hamel, M.S. Devall, T.D. Leininger, and M.E. Warren Jr., 2000: Restoring bottomland hardwood ecosystems in the Lower Mississippi Alluvial Valley, *J. For.*, 98, 10-16.

Stewart, J. B., 1971: The albedo of a pine forest. *Quart. J. Roy. Meteor. Soc.*, 97, 561-564.

Swift, L.W., W.T. Swank and J.B. Mankin, 1975: Simulation of evapotranspiration and drainage from mature and clear-cut deciduous forests and young pine plantations. Water Resour. Res., 11, 667-673.

Vogelmann, J.E., T. Sohl, and S.M. Howard, 1998: Regional Characterization of Land Cover Using Multiple Sources of Data. *Photogrammetric Engineering & Remote Sensing*, 64, 45-47.

Vose, Russell S., Thomas R. Karl, David R. Easterling, Claude N. Williams and Matthew J. Menne, 2004: Climate (communication arising): Impact of land-use change on climate. *Nature*, 427, 213-214.

White, M. A., P. E. Thornton, S. W. Running, 1997: A continental phenology model for monitoring vegetation responses to interannual climatic variability. *Global Biogeochemical Cycles,* 11, 217–234.

APPENDIX

Table A.1. The probability values (ρ) for the independent samples t-tests comparing the DTR of urban areas for each SSC.

SSC	DM	DP	DT	MM	MP
DP	0.556				
DT	<0.000	<0.000			
MM	<0.000	<0.000	<0.000		
MP	<0.000	<0.000	<0.000	<0.000	
MT	0.001	<0.000	<0.000	<0.000	<0.000

Table A.2. Same as table A.1 for deciduous forests.

SSC	DM	DP	DT	MM	MP
DP	0.028				
DT	<0.000	<0.000			
MM	<0.000	<0.000	<0.000		
MP	<0.000	<0.000	<0.000	0.002	
MT	<0.000	<0.000	<0.000	<0.000	<0.000

Table A.3. Same as table A.1 for evergreen forests.

SSC	DM	DP	DT	MM	MP
DP	0.813				
DT	<0.000	0.037			
MM	<0.000	<0.000	<0.000		
MP	<0.000	<0.000	<0.000	<0.000	
MT	<0.000	<0.000	<0.000	<0.000	<0.000

Table A.4. Same as table A.1 for mixed forests.

SSC	DM	DP	DT	MM	MP
DP	0.005				
DT	<0.000	<0.000			
MM	<0.000	<0.000	<0.000		
MP	<0.000	<0.000	<0.000	<0.000	
MT	<0.000	<0.000	<0.000	<0.000	<0.000

Table A.5. Same as table A.1 for agricultural areas.

SSC	DM	DP	DT	MM	MP
DP	<0.000				
DT	<0.000	<0.000			
MM	<0.000	<0.000	<0.000		
MP	<0.000	<0.000	<0.000	<0.000	
MT	<0.000	<0.000	<0.000	<0.000	<0.000

Table A.6. Same as table A.1 for transitional areas.

SSC	DM	DP	DT	MM	MP
DP	<0.000				
DT	<0.000	<0.000			
MM	<0.000	<0.000	<0.000		
MP	<0.000	<0.000	<0.000	<0.000	
MT	<0.000	<0.000	<0.000	<0.000	<0.000

Table A.7. The probability values (ρ) for the independent samples t-tests comparing the DTR of each LULC for the Dry Moderate air mass.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	<0.000				
Evergreen	<0.000	0.728			
Mixed Forest	<0.000	<0.000	<0.000		
Agriculture	0.319	<0.000	<0.000	<0.000	
Transitional	<0.000	<0.000	<0.000	<0.000	<0.000

Table A.8. Same as table A.7 for the Dry Polar air mass.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	0.472				
Evergreen	0.046	0.190			
Mixed Forest	0.487	0.838	0.097		
Agriculture	0.006	0.002	<0.000	<0.000	
Transitional	0.054	0.018	0.001	0.002	0.328

Table A.9. Same as table A.7 for the Dry Tropical air mass

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	<0.000				
Evergreen	<0.000	0.762			
Mixed Forest	<0.000	0.155	0.381		
Agriculture	0.211	<0.000	<0.000	<0.000	
Transitional	0.635	<0.000	<0.000	<0.000	0.007

Table A.10. Same as table A.7 for the Moist Moderate air mass.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	<0.000				
Evergreen	0.002	0.504			
Mixed Forest	<0.000	0.984	0.426		
Agriculture	<0.000	0.428	0.894	0.189	
Transitional	<0.000	0.427	0.138	0.230	0.019

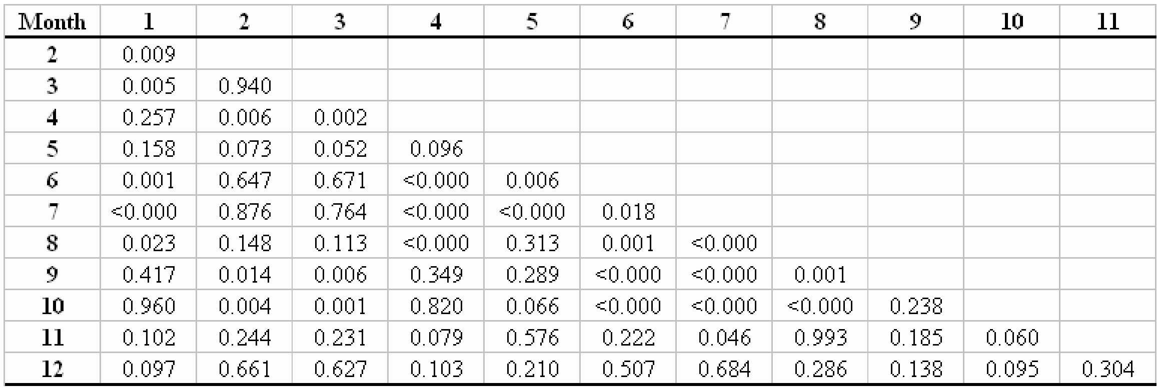
Table A.11. Same as table A.7 for the Moist Polar air mass.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	<0.000				
Evergreen	0.007	0.428			
Mixed Forest	<0.000	0.745	0.239		
Agriculture	<0.000	0.633	0.562	0.150	
Transitional	<0.000	0.603	0.188	0.752	0.098

Table A.12. Same as table A.7 for the Moist Tropical air mass.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	<0.000				
Evergreen	<0.000	0.035			
Mixed Forest	<0.000	<0.000	<0.000		
Agriculture	0.005	<0.000	<0.000	<0.000	
Transitional	0.031	<0.000	<0.000	<0.000	<0.000

Table A.13. The probability values (ρ) for the independent samples t-tests comparing the DTR of urban areas for each month.



Month	1	2	3	4	5	6	7	8	9	10	11
2	0.009										
3	0.005	0.940									
4	0.257	0.006	0.002								
5	0.158	0.073	0.052	0.096							
6	0.001	0.647	0.671	<0.000	0.006						
7	<0.000	0.876	0.764	<0.000	<0.000	0.018					
8	0.023	0.148	0.113	<0.000	0.313	0.001	<0.000				
9	0.417	0.014	0.006	0.349	0.289	<0.000	<0.000	0.001			
10	0.960	0.004	0.001	0.820	0.066	<0.000	<0.000	<0.000	0.238		
11	0.102	0.244	0.231	0.079	0.576	0.222	0.046	0.993	0.185	0.060	
12	0.097	0.661	0.627	0.103	0.210	0.507	0.684	0.286	0.138	0.095	0.304

Table A.14. The mean differences between the DTR of the urban areas for each month. A bolded number indicates that it is statistically significant (α=0.05). A negative number means that the month in the labeled in the corresponding column has a smaller DTR than that of the month labeled in the row that it is being compared.

Month	1	2	3	4	5	6	7	8	9	10	11
2	**5.083**										
3	**4.928**	-0.156									
4	0.257	**-4.826**	**-4.670**								
5	1.902	-3.181	-3.026	1.645							
6	**4.342**	-0.741	-0.586	**4.085**	**2.440**						
7	**5.331**	0.248	0.403	**5.074**	**3.429**	**0.989**					
8	**2.743**	-2.340	-2.185	**2.486**	0.841	**-1.599**	**-2.588**				
9	0.952	**-4.131**	**-3.976**	0.695	-0.950	**-3.390**	**-4.379**	**-1.791**			
10	0.062	**-5.021**	**-4.866**	-0.195	-1.840	**-4.280**	**-5.269**	**-2.681**	-0.890		
11	2.731	-2.352	-2.197	2.474	0.829	-1.611	**-2.600**	-0.012	1.779	2.668	
12	6.850	1.767	1.922	6.593	4.948	2.508	1.519	4.107	5.898	6.788	4.119

Table A.15. Same as table A.13 for deciduous forests.

Month	1	2	3	4	5	6	7	8	9	10	11
2	0.916										
3	0.818	0.905									
4	<0.000	<0.000	<0.000								
5	0.046	0.074	0.100	0.006							
6	0.170	0.153	0.112	<0.000	<0.000						
7	0.046	0.042	0.028	<0.000	<0.000	<0.000					
8	0.108	0.168	0.224	<0.000	<0.000	<0.000	<0.000				
9	0.006	0.011	0.017	0.011	0.382	<0.000	<0.000	0.002			
10	0.001	0.001	0.002	0.223	0.057	<0.000	<0.000	<0.000	0.134		
11	0.256	0.322	0.386	0.006	0.517	0.005	0.001	0.954	0.184	0.038	
12	0.005	0.005	0.004	<0.000	<0.000	0.018	0.038	<0.000	<0.000	0.000	0.001

Table A.16. Same as table A.14 for deciduous forests.

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
2	-0.141										
3	-0.307	-0.166									
4	**-4.687**	**-4.546**	**-4.380**								
5	**-2.207**	-2.065	-1.900	**2.480**							
6	1.327	1.469	1.634	**6.014**	**3.534**						
7	**1.906**	**2.047**	**2.213**	**6.593**	**4.113**	**0.579**					
8	-1.540	-1.399	-1.233	**3.147**	**0.667**	**-2.867**	**-3.446**				
9	**-2.807**	**-2.666**	**-2.500**	1.880	-0.600	**-4.134**	**-4.713**	**-1.267**			
10	**-3.688**	**-3.547**	**-3.381**	0.999	-1.481	**-5.015**	**-5.594**	**-2.148**	-0.881		
11	-1.484	-1.343	-1.177	**3.203**	0.722	**-2.812**	**-3.390**	0.055	1.323	**2.204**	
12	**5.479**	**5.621**	**5.786**	**10.166**	**7.686**	4.152	**3.573**	**7.019**	**8.286**	**9.167**	**6.964**

Table A.17. Same as table A.13 for evergreen forests.

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
2	0.149										
3	0.010	0.302									
4	0.170	0.006	<0.000								
5	0.595	0.269	0.019	0.024							
6	0.001	0.200	0.926	<0.000	<0.000						
7	<0.000	0.043	0.505	<0.000	<0.000	0.019					
8	0.050	0.850	0.102	<0.000	0.093	<0.000	<0.000				
9	0.438	0.259	0.011	0.001	0.863	<0.000	<0.000	0.006			
10	0.528	0.031	<0.000	0.276	0.155	<0.000	<0.000	<0.000	0.023		
11	0.395	0.511	0.075	0.023	0.671	0.015	0.001	0.443	0.716	0.108	
12	0.008	0.087	0.317	0.001	0.014	0.236	0.450	0.045	0.014	0.003	0.029

Table A.18. Same as table A.14 for evergreen forests.

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
2	2.557										
3	**4.554**	1.997									
4	-1.761	**-4.318**	**-6.315**								
5	0.736	-1.821	**-3.818**	**2.497**							
6	**4.424**	1.868	-0.130	**6.185**	**3.688**						
7	**5.462**	**2.906**	0.909	**7.224**	**4.727**	**1.038**					
8	**2.287**	-0.269	-2.267	**4.048**	1.551	**-2.137**	**-3.175**				
9	0.903	-1.653	**-3.650**	**2.665**	0.168	**-3.521**	**-4.559**	**-1.384**			
10	-0.782	**-3.338**	**-5.335**	0.980	-1.517	**-5.206**	**-6.244**	**-3.069**	**-1.685**		
11	1.359	-1.198	-3.195	3.120	0.623	**-3.066**	**-4.104**	-0.929	0.455	2.140	
12	**7.162**	4.605	2.608	**8.923**	**6.426**	2.738	1.700	**4.875**	**6.258**	**7.943**	**5.803**

Table A.19. Same as table A.13 for mixed forests.

Month	1	2	3	4	5	6	7	8	9	10	11
2	<0.000										
3	<0.000	0.544									
4	0.001	<0.000	<0.000								
5	0.950	<0.000	<0.000	<0.000							
6	<0.000	0.872	0.498	<0.000	<0.000						
7	<0.000	0.063	0.005	<0.000	<0.000	<0.000					
8	0.001	0.012	0.078	<0.000	<0.000	<0.000	<0.000				
9	0.473	<0.000	<0.000	<0.000	0.336	<0.000	<0.000	<0.000			
10	0.289	<0.000	<0.000	<0.000	0.110	<0.000	<0.000	<0.000	0.001		
11	0.796	<0.000	<0.000	<0.000	0.693	<0.000	<0.000	<0.000	0.217	0.375	
12	<0.000	0.269	0.103	<0.000	<0.000	0.141	0.969	0.001	<0.000	<0.000	<0.000

Table A.20. Same as table A.14 for mixed forests.

Month	1	2	3	4	5	6	7	8	9	10	11
2	**3.680**										
3	**3.187**	-0.493									
4	**-2.320**	**-6.000**	**-5.507**								
5	0.044	**-3.636**	**-3.143**	**2.364**	.						
6	**3.582**	-0.098	0.395	**5.902**	**3.538**						
7	**4.783**	1.103	**1.596**	**7.103**	**4.739**	**1.201**					
8	**2.171**	**-1.509**	-1.017	**4.490**	**2.127**	**-1.412**	**-2.612**				
9	0.449	**-3.231**	**-2.738**	**2.769**	0.405	**-3.133**	**-4.334**	**-1.721**			
10	-0.694	**-4.374**	**-3.881**	**1.625**	-0.738	**-4.277**	**-5.477**	**-2.865**	**-1.143**		
11	-0.199	**-3.879**	**-3.386**	**2.121**	-0.243	**-3.781**	**-4.982**	**-2.370**	-0.648	0.495	
12	**4.752**	1.073	1.565	**7.072**	**4.708**	1.170	-0.031	**2.582**	**4.303**	**5.447**	**4.951**

Table A.21. Same as table A.13 for agricultural areas.

Month	1	2	3	4	5	6	7	8	9	10	11
2	<0.000										
3	0.002	0.182									
4	<0.000	<0.000	<0.000								
5	<0.000	<0.000	<0.000	<0.000							
6	<0.000	0.092	0.904	<0.000	<0.000						
7	<0.000	0.773	0.032	<0.000	<0.000	<0.000					
8	0.431	<0.000	<0.000	<0.000	0.002	<0.000	<0.000				
9	<0.000	<0.000	<0.000	0.062	<0.000	<0.000	<0.000	<0.000			
10	<0.000	<0.000	<0.000	0.83	<0.000	<0.000	<0.000	<0.000	0.015		
11	<0.000	<0.000	<0.000	0.009	0.248	<0.000	<0.000	<0.000	0.113	0.004	
12	<0.000	0.002	<0.000	<0.000	<0.000	<0.000	0.001	<0.000	<0.000	<0.000	<0.000

Table A.22. Same as table A.14 for agricultural areas.

Month	1	2	3	4	5	6	7	8	9	10	11
2	**2.474**										
3	**1.751**	-0.723									
4	**-2.996**	**-5.470**	**-4.747**								
5	**-1.287**	**-3.761**	**-3.039**	**1.709**							
6	**1.799**	-0.675	0.048	**4.795**	**3.086**						
7	**2.586**	0.112	0.835	**5.582**	**3.874**	**0.787**					
8	-3.230	**-2.797**	**-2.074**	**2.673**	**0.965**	**-2.122**	**-2.909**				
9	**-2.459**	**-4.933**	**-4.210**	0.537	**-1.171**	**-4.258**	**-5.045**	**-2.136**			
10	**-3.066**	**-5.540**	**-4.817**	-0.070	**-1.779**	**-4.865**	**-5.653**	**-2.744**	**-0.608**		
11	**-1.831**	**-4.304**	**-3.582**	**1.166**	-0.543	**-3.630**	**-4.417**	**-1.508**	0.628	**1.236**	
12	**4.694**	**2.221**	**2.943**	**7.691**	**5.982**	**2.896**	**2.108**	**5.017**	**7.153**	**7.761**	**6.525**

Table A.23. Same as table A.13 for transitional areas.

Month	1	2	3	4	5	6	7	8	9	10	11
2	<0.000										
3	0.001	0.343									
4	0.028	<0.000	<0.000								
5	0.669	<0.000	0.001	0.001							
6	<0.000	0.537	0.506	<0.000	<0.000						
7	<0.000	0.505	0.042	<0.000	<0.000	<0.000					
8	0.024	<0.000	0.029	<0.000	0.014	<0.000	<0.000				
9	0.611	<0.000	<0.000	0.004	0.175	<0.000	<0.000	<0.000			
10	0.013	<0.000	<0.000	0.815	<0.000	<0.000	<0.000	<0.000	<0.000		
11	0.672	<0.000	<0.000	0.062	0.339	<0.000	<0.000	<0.000	0.973	0.028	
12	<0.000	0.060	0.008	<0.000	<0.000	0.009	0.072	<0.000	<0.000	<0.000	<0.000

Table A.24. Same as table A.14 for transitional areas.

Month	1	2	3	4	5	6	7	8	9	10	11
2	**3.704**										
3	**2.895**	-0.809									
4	**-1.752**	**-5.457**	**-4.648**								
5	0.348	**-3.356**	**-2.547**	**2.101**							
6	**3.306**	-0.398	0.411	**5.058**	**2.958**						
7	**4.124**	0.419	**1.228**	**5.876**	**3.776**	**0.818**					
8	**1.564**	**-2.141**	**-1.332**	**3.316**	**1.215**	**-1.742**	**-2.560**				
9	-0.357	**-4.061**	**-3.252**	**1.396**	-0.705	**-3.663**	**-4.481**	**-1.920**			
10	**-1.879**	**-5.583**	**-4.774**	-0.127	**-2.227**	**-5.185**	**-6.003**	**-3.442**	**-1.522**		
11	-0.378	**-4.083**	**-3.274**	1.374	-0.727	**-3.684**	**-4.502**	**-1.942**	-0.022	**1.501**	
12	**5.730**	2.026	**2.835**	**7.482**	**5.382**	**2.424**	1.606	**4.166**	**6.087**	**7.609**	**6.108**

Table A.25. The probability values (ρ) for the independent samples t-tests comparing the DTR of each LULC for the month of January.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	0.262				
Evergreen	0.306	0.029			
Mixed Forest	0.657	0.053	0.411		
Agriculture	0.013	0.134	<0.000	<0.000	
Transitional	0.655	0.364	0.099	0.213	0.001

Table A.26. The mean difference between the DTR of each LULC for the month of January. A bolded number indicates that it is statistically significant (α=0.05). A negative number means that the month in the labeled in the corresponding column has a smaller DTR than that of the month labeled in the row that it is being compared.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	1.589				
Evergreen	-1.566	**-3.154**			
Mixed Forest	-0.548	-2.137	1.018		
Agriculture	**3.094**	1.506	**4.660**	**3.642**	
Transitional	0.565	-1.023	2.131	1.113	**-2.529**

Table A.27. Same as table A.25 for the month of February.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	0.052				
Evergreen	0.053	0.788			
Mixed Forest	0.248	0.142	0.159		
Agriculture	0.765	<0.000	0.002	0.001	
Transitional	0.631	0.016	0.034	0.181	0.075

Table A.28. Same as table A.26 for the month of February.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	-3.636				
Evergreen	-4.093	-0.457			
Mixed Forest	-1.951	1.684	2.141		
Agriculture	0.485	**4.121**	**4.577**	**2.436**	
Transitional	-0.814	**2.822**	**3.279**	1.138	-1.298

Table A.29. Same as table A.25 for the month of March.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	0.029				
Evergreen	0.305	0.306			
Mixed Forest	0.116	0.231	0.811		
Agriculture	0.953	0.001	0.186	0.001	
Transitional	0.315	0.058	0.747	0.313	0.049

Table A.30. Same as table A.26 for the month of March.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	**-3.646**				
Evergreen	-1.940	1.706			
Mixed Forest	-2.289	1.357	-0.349		
Agriculture	-0.082	**3.564**	1.857	**2.206**	
Transitional	-1.467	2.179	0.473	0.822	**-1.385**

Table A.31. Same as table A.25 for the month of April.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	<0.000				
Evergreen	<0.000	0.806			
Mixed Forest	<0.000	0.754	0.536		
Agriculture	0.806	<0.000	<0.000	<0.000	
Transitional	0.051	0.015	0.007	0.002	0.010

Table A.32. Same as table A.26 for the month of April.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	**-3.355**				
Evergreen	**-3.584**	-0.229			
Mixed Forest	**-3.125**	0.231	0.459		
Agriculture	-0.159	**3.196**	**3.425**	**2.966**	
Transitional	-1.444	**1.911**	**2.140**	**1.681**	**-1.285**

Table A.33. Same as table A.25 for the month of May.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	0.012				
Evergreen	0.021	0.841			
Mixed Forest	0.007	0.872	0.731		
Agriculture	0.909	<0.000	0.005	<0.000	
Transitional	0.279	0.046	0.081	0.019	0.106

Table A.34. Same as table A.26 for the month of May.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-2.520**				
Evergreen	**-2.732**	-0.212			
Mixed Forest	**-2.406**	0.114	0.326		
Agriculture	-0.095	**2.425**	**2.637**	**2.311**	
Transitional	-0.988	**1.532**	1.744	**1.418**	-0.893

Table A.35. Same as table A.25 for the month of June.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	0.002				
Evergreen	0.006	0.905			
Mixed Forest	0.001	0.717	0.675		
Agriculture	0.150	<0.000	<0.000	<0.000	
Transitional	0.249	0.005	0.019	0.001	<0.000

Table A.36. Same as table A.26 for the month of June.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-1.426**				
Evergreen	**-1.484**	-0.058			
Mixed Forest	**-1.308**	0.118	0.176		
Agriculture	0.551	**1.977**	**2.035**	**1.859**	
Transitional	-0.471	**0.955**	**1.013**	**0.837**	**-1.022**

Table A.37. Same as table A.25 for the month of July.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	<0.000				
Evergreen	<0.000	0.138			
Mixed Forest	<0.000	<0.000	0.129		
Agriculture	0.101	<0.000	<0.000	<0.000	
Transitional	0.006	<0.000	0.001	0.002	<0.000

Table A.38. Same as table A.26 for the month of July.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-1.836**				
Evergreen	**-1.435**	0.402			
Mixed Forest	**-1.096**	**0.740**	0.338		
Agriculture	0.349	**2.186**	**1.784**	**1.446**	
Transitional	**-0.642**	**1.194**	**0.793**	**0.454**	**-0.991**

Table A.39. Same as table A.25 for the month of August.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	<0.000				
Evergreen	<0.000	0.060			
Mixed Forest	<0.000	<0.000	0.003		
Agriculture	0.923	<0.000	<0.000	<0.000	
Transitional	0.054	<0.000	<0.000	0.009	<0.000

Table A.40. Same as table A.26 for the month of August.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-2.694**				
Evergreen	**-2.022**	0.672			
Mixed Forest	**-1.120**	**1.574**	**0.901**		
Agriculture	0.029	**2.723**	**2.050**	**1.149**	
Transitional	-0.614	**2.080**	**1.408**	**0.506**	**-0.643**

Table A.41. Same as table A.25 for the month of September.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	<0.000				
Evergreen	0.008	0.299			
Mixed Forest	0.028	0.003	0.225		
Agriculture	0.490	<0.000	0.004	0.002	
Transitional	0.128	<0.000	0.068	0.289	0.099

Table A.42. Same as table A.26 for the month of September.

LULC	**Urban**	**Deciduous**	**Evergreen**	**Mixed Forest**	**Agriculture**
Deciduous	**-2.171**				
Evergreen	**-1.615**	0.556			
Mixed Forest	**-1.051**	**1.120**	0.564		
Agriculture	-0.317	**1.854**	**1.298**	**0.734**	
Transitional	**-0.744**	**1.427**	0.871	0.307	-0.427

Table A.43. Same as table A.25 for the month of October.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	0.006				
Evergreen	0.005	0.750			
Mixed Forest	0.053	0.124	0.096		
Agriculture	0.958	<0.000	<0.000	<0.000	
Transitional	0.049	0.182	0.134	0.867	0.001

Table A.44. Same as table A.26 for the month of October.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	**-2.161**				
Evergreen	**-2.409**	-0.248			
Mixed Forest	-1.304	0.857	1.105		
Agriculture	-0.034	**2.127**	**2.375**	**1.270**	
Transitional	-1.375	0.786	1.034	-0.071	**-1.341**

Table A.45. Same as table A.25 for the month of November.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	0.096				
Evergreen	0.090	0.836			
Mixed Forest	0.012	0.421	0.672		
Agriculture	0.267	0.251	0.236	0.001	
Transitional	0.071	0.941	0.765	0.226	0.126

Table A.46. Same as table A.26 for the month of November.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	-2.627				
Evergreen	-2.938	-0.312			
Mixed Forest	**-3.478**	-0.851	-0.540		
Agriculture	-1.467	1.159	1.471	**2.011**	
Transitional	-2.544	0.083	0.394	0.934	-1.077

Table A.47. Same as table A.25 for the month of December.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	0.957				
Evergreen	0.770	0.590			
Mixed Forest	0.490	0.118	0.554		
Agriculture	0.803	0.677	0.346	<0.000	
Transitional	0.884	0.674	0.768	0.074	0.160

Table A.48. Same as table A.26 for the month of December.

LULC	Urban	Deciduous	Evergreen	Mixed Forest	Agriculture
Deciduous	0.218				
Evergreen	-1.254	-1.472			
Mixed Forest	-2.645	-2.864	-1.392		
Agriculture	0.939	0.721	2.193	**3.584**	
Transitional	-0.555	-0.773	0.699	2.091	-1.493