The Effect of Urban Tree Canopy Cover and Vegetation Levels on Incidence of Stress-related Illnesses in Humans in Metropolitan Statistical Areas of Texas

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SUMMARY. One-third of Americans are reportedly living with extreme stress, with 75% to 90% of visits to primary care physicians being for stress-related problems. Past research found visiting green areas lowers blood pressure, reduces headache and fatigue, improves mood, and hastens recovery from stress. The main objective for this study was to determine if stress-related illness rates in regions of Texas were related to vegetation rates and tree canopy cover. Data on the stress-related illnesses of high blood pressure and heart attacks were collected from the Center for Health Statistics and the Texas Department of State Health Services for all 25 metropolitan statistical areas (MSAs) in Texas. MSAs are counties or group of counties with a central city or urbanized area of at least 50,000 people. Percent canopy cover was calculated for each MSA using the Multi-Resolution Land Characteristics National Land Cover Data canopy cover dataset. Vegetation rates for all the MSAs were examined and mapped for illustration using geographical information system (GIS) software. Visual relationships among the data were observed. Quantitative data were also analyzed. When mapping stress-related illness rate into MSA regions of Texas, no clear trend was observed with vegetation rates or percent tree canopy cover when compared with stress-related illness rates. Semipartial correlations were calculated to analyze the relationship between tree canopy cover and vegetation rate and stress-related illness rate variables after controlling the effect of external variables like income levels, age, population, and ethnicity. There was no significant positive or negative relationship found between stress-related illness data when compared with percent canopy and vegetation index for any the 25 MSAs of Texas.

Stress is a psychological state developing when an individual is confronted with situations exhausting or exceeding their internal and external resources. It is the body's way of rising to a challenge and preparing to meet a tough situation with focus,

strength, stamina, and heightened alertness (Mirela, 2009). The term "stress" was originally defined as "the non-specific response of the body to any demand for change" (Selye, 1936). Other research defined stress as a process in which environmental demands strain an organism's adaptive capacity, resulting in both psychological as well as biological changes placing a person at risk for illness (Cohen et al., 1995).

The situations and pressures causing stress are known as stressors (Richard and Folkman, 1984). Any change, positive or negative, can have a stressful impact on the human mind or body. Therefore, anything putting

high demands on a person or forcing a person to adjust can be stressful (Holmes and Masuda, 1974). Stress can be generated by external stressors such as relationship difficulties, major life changes, work, financial problems, children and family, illness, or by internal stressors such as the inability to accept uncertainty, pessimism, unrealistic expectations, perfectionism, or negative self-talk (Selye, 1983).

Many major illnesses may be due to or exacerbated by stress. These can include cardiovascular diseases, high blood pressure, negative effects on the immune system, digestive problems, angina or coronary heart diseases, depression, high blood cholesterol, insomnia, and hyperthyroidism (Griffin, 2014). Stress is recognized as a factor in headaches; people with either tension or vascular headaches named stress as one of the leading precipitating factors (Deniz et al., 2004; Spierings et al., 2001).

Research has indicated the higher the person's stress level, the more likely a person is to become ill (Cohen et al., 1991, 1993, 1998; Cohen and Pressman, 2005). Physical symptoms of stress include fatigue, headache, muscle tension, upset stomach, change in appetite, change in sex drive, and feeling dizzy. Psychological symptoms of stress include experiencing irritability or anger, feeling nervous, lacking energy, and feeling as though one could cry. In addition, almost half of Americans reported lying awake at night due to stress.

According to the American Psychological Association (APA, 2014), healthy behaviors used to manage stress include listening to music, reading, walking in green areas, spending time with family and friends, and praying. This research also found most of the people in the United States lack the motivation to make lifestyle and behavior changes after a diagnosis of stress, and only 35% reported they would modify their behavior following the diagnosis of a chronic condition.

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
1.6093	mile(s)	km	0.6214

Table 1. Compilation of results for high blood pressure (HBP) rates, ranked in order from highest to lowest, in the study of the effect of tree cover and vegetation on incidence of stress-related illness in metropolitan statistical areas (MSAs) of Texas.

Ranking	MSA	Population sample (no.)	HBP sample (no.) ^z	HBP patients (%) ^y
1—Highest	Beaumont-Port Arthur	97	37	38.4
2	Lubbock	67	22	33.5
3	Abilene	64	21	33.2
4	Waco	51	17	32.7
5	Longview	52	16	30.4
6	Brownsville-Harlingen	66	18	28.1
7	Bryan-College Station	56	16	28.0
8	Corpus Christi	71	18	25.9
9	Amarillo	71	17	24.1
10	Houston-Baytown-Sugarland	947	222	23.4
11	San Antonio	521	121	23.3
11	Dallas-Ft. Worth-Arlington	1,176	274	23.3
12	McAllen-Edinburg-Mission	115	22	19.5
13	El Paso	650	124	19.0
14	Killeen-Temple-Ft. Hood	76	14	18.8
15—Lowest	Austin-Round Rock	526	82	15.7
	Laredo	<50 ^y		
	Midland	<50 ^y		
	Odessa	<50 ^y		
	San Angelo	<50 ^y		
	Sherman-Denison	<50 ^y		
	Texarkana	<50 ^y		
	Tyler	<50 ^y		
	Victoria	<50 ^y		
	Wichita Falls	<50 ^y		

^zMSAs that had less 50 respondents who answered positively for HPB diagnosis.

^yData on percentage of HBP were obtained from the Center for Health Statistics, Texas Department of State Health Services for the years 2005–06 (Centers for Disease Control and Prevention, 2014). Data were rounded to the next highest or lowest raw number based on the normalized percentage of patients reported to HBP in the overall population.

Plants have a positive relationship with humans, community, and human culture. To be around plants can be beneficial to human beings (Relf, 1992). Visiting green areas in cities can counteract stress, renew vital energy, and speed healing processes (McPherson, 2000). People who live in a greener environment showed more signs of healthy living (DeVries et al., 2003). Furthermore, a study documented when college students under stress from an exam viewed plants, their positive feelings increased, while fear and anger decreased (Ulrich, 1979). Even brief visual contact with plants, such as urban tree plantings or office parks, might be valuable in restoration from mild daily stress. Views of nature had positive, physiological impacts on individuals whether they were consciously aware of them (Ulrich and Simons, 1986).

Horticulture has a long history as a treatment for individuals with a variety of diagnoses (Watson and Burlingame, 1960). Owen (1994) documented visiting a botanical garden lowered blood pressure and reduced the heart rate of

visitors. A similar study showed the presence of vegetation sped up recovery from stress (Kaplan, 1993; Ulrich et al., 1991). Views of nature or visual encounters with vegetation had the greatest impact for the mental health of individuals experiencing stress or anxiety (Ulrich, 1985). Leisure in green environments provided feelings of peace and made people open to activities providing for self-actualization (Waliczek et al., 1996).

In a study in New York, researchers found community gardening had a positive effect on enhancing physical activeness and also on reducing levels of stress and mental fatigue (Armstrong, 2000). People with access to nearby natural settings or parks were found to be healthier overall when compared with other individuals, and long-term, indirect impacts of “nearby nature” included increased levels of satisfaction with one’s home, job, and life in general (Kaplan and Kaplan, 1989).

The main objective of this research study was to determine if rates of stress-related illnesses in people

living in MSAs of Texas were related to the levels of tree canopy cover or amount of vegetation.

Materials and methods

MSAs OF TEXAS. The state of Texas has been divided into 25 different MSAs for the purposes of demographic and statistical analyses by various departments and organizations in Texas (Labor Market and Career Information Department of the Texas Workforce Commission, 2014). Each MSA was comprised of a county or group of counties with a population of at least 75,000 and contained a central city or urbanized area of at least 50,000 (Labor Market and Career Information Department of the Texas Workforce Commission, 2014). Metropolitan statistical areas included the following regions: Abilene, Amarillo, Austin-Round Rock, Beaumont-Port Arthur, Brownsville-Harlingen, Bryan-College Station, Corpus Christi, Dallas-Fort Worth-Arlington, El Paso, Houston-Baytown-Sugarland, Killeen-Temple-Fort Hood, Laredo, Longview, Lubbock, McAllen-Edinburg-Mission, Midland, Odessa,

Table 2. Compilation of results for heart attack rates, ranked in order from highest to lowest, in the study of the effect of tree cover and vegetation on incidence of stress-related illness in metropolitan statistical areas (MSAs) of Texas.

Ranking	MSA	Population sample (no.)	Heart attack (no.) ^z	Heart attack patients (%) ^z
1—Highest	Texarkana	58	7	11.5
2	Sherman-Denison	62	5	8.2
3	San Angelo	63	5	7.5
4	Tyler	278	19	6.9
5	Abilene	129	9	6.8
6	Longview	195	12	6.1
7	Beaumont-Port Arthur	207	12	5.7
8	Amarillo	160	9	5.6
9	Bryan-College Station	111	5	4.9
10	Wichita Falls	107	5	4.8
11	Lubbock	630	28	4.5
12	Houston-Baytown-Sugarland	1,480	62	4.2
13	Austin-Round Rock	1,042	40	3.9
14	Dallas-Ft. Worth-Arlington	2,173	83	3.8
15	Brownsville-Harlingen	147	5	3.4
16	Corpus Christi	174	6	3.3
17	McAllen-Edinburg-Mission	265	8	3.0
18—Tie	San Antonio	1,035	30	2.9
18—Tie	Odessa	56	2	2.9
19	El Paso	1,146	32	2.8
20	Midland	58	1	2.4
21	Waco	102	2	2.0
22	Victoria	69	1	1.9
23	Killeen-Temple-Ft. Hood	177	3	1.6
24—Lowest	Laredo	62	0	0.0

^zData on percentage of heart attacks were obtained from the Center for Health Statistics, Texas Department of State Health Services for the years 2005–06 (Centers for Disease Control and Prevention, 2014). Data were rounded to the next highest or lowest raw number based on the normalized percentage of patients reported to have heart attacks in the overall population.

San Angelo, San Antonio, Sherman-Denison, Texarkana, Tyler, Victoria, Waco, and Wichita Falls.

STRESS-RELATED ILLNESS DATA COLLECTION. Stress-related illness data were collected from the Center for Health Statistics, Texas Department of State Health Services for the year 2006 (A. Vincent, personal communication). Stress-related data were taken from the year 2006 to be consistent with the available data of urban tree canopy cover and vegetation levels. Major stress-related illnesses included in this study were high blood pressure and heart attack (Griffin, 2014). These were illnesses that had stress as one of the major causes (Griffin, 2014).

For this study, stress-related illness data were collected from all MSAs of Texas from the Behavior Risk Factor Surveillance System, which is a sub-agency under the Texas Department of State Health Services and the Center for Disease Control and Prevention (CDC). Behavior Risk Factor Surveillance System is a state-based system of health surveys generating information about health risk behaviors, clinical

preventive practices, and health care access and use primarily related to chronic diseases and injury. Stress-related illness data were collected through a cross-sectional telephone survey conducted by state health departments. Every year, states conduct monthly telephone surveillance using a standardized questionnaire to determine the distribution of risk behaviors and health practices among noninstitutionalized adults. The survey is conducted nationwide in conjunction with the American Heart Association, the National Institutes of Health, and other governmental agencies and is considered one of the most up-to-date and complete compilations of statistics on heart disease and other vascular diseases for the nation (American Heart Association, 2014).

Two questions considered for this study were: “Have you ever been diagnosed with high blood pressure?” and “Have you ever been diagnosed with heart attack?” (A. Vincent, personal communication). Respondents who answered “yes” to the above questions were placed in the stress-related

illness sample. Respondents who answered “no” to those same questions were placed in the control sample.

MAPPING OF TREE COVERAGE/VEGETATION RATES. Mapping of urban tree canopy cover and vegetation levels of MSAs of Texas was performed in collaboration with Texas A&M University using ArcView® (ESRI, Redlands, CA). To determine the percent urban canopy or vegetation levels for the MSAs in this study, a normalized difference vegetation index (NDVI) was calculated from satellite imagery (Landsat) for each MSA. Landsat 5 imagery was obtained from U.S. Geological Survey (USGS) Globvis site (U.S. Department of the Interior, 2014). Image “tiles” were downloaded to cover the extent of all MSAs included in the study. Each “tile” covered an area of 185 km wide. To obtain an accurate NDVI for each MSA, the imagery must be high quality and as cloud-free as possible. The images selected and used in the study were designated by USGS as having a cloud cover of 0% and an image quality of 9 out of 10 (Note 0% cloud cover may still include isolated clouds).

Fig. 1. High blood pressure (HBP) and heart attack (HA) data inserted into a general Texas state map and including corresponding metropolitan statistical areas (MSAs) of Texas with no data listed for MSAs having less than 50 respondents answering positively for high blood pressure diagnosis.

The downloaded image tiles were for the maximum foliage months of April to Sept. 2006 when possible. The year 2006 was chosen to coincide with the dates of the collected stress-related illness data. If data with the above criteria were not available, the next closest date (skipping dormant months) was acquired. Out of all MSAs used in this study, the following three used image tile data from either September or Oct. 2006: Dallas-Fort Worth-Arlington, Lubbock, and Killeen-Temple-Fort Hood.

The tiles were then “mosaicked” or pieced together to create one seamless image for each MSA. “Mosaicking” merged adjacent tiles into one image file removing overlapping values between tiles. The NDVI was calculated for each image using ENVI image-processing software (Exelis Visual Information Solutions, Redlands, CA). This process resulted in a grid with values ranging from -1 to 1. The NDVI grid was transferred to the GIS software, where statistics were calculated

for each MSA. Statistics generated included the minimum NDVI value, the maximum NDVI value, and mean NDVI value.

Landsat Satellite Imagery was performed with sensors which measured the amount of reflected energy for each 30 × 30-m area for each of the seven segments of the electromagnetic spectrum. There are total of seven bands of data for Landsat, each of which provides a record of the amount of energy reflected in a specific portion of electromagnetic spectrum.

For this study, out of seven bands, only two bands (near-infrared and red) were used, since these were the only ones required to calculate NDVI. This index was used as a simple numerical indicator to analyze remote sensing measurement to determine the amount of green vegetation in the observed target area. The resulting index range for this calculation was between -1 and 1 (barren/nonvegetation to dense green vegetation, respectively).

The calculation was as follows: $NDVI = (NIR - red) / (NIR + red)$, where NIR = near-infrared.

EXTERNAL VARIABLES. Data were collected on several external variables, which were known to precipitate symptoms of stress-related illness to control the impact in this study. Age, income levels, population, and ethnicity data for each MSA were obtained from the U.S. Census Bureau (2014). Age over 45 years and annual income level of \$15,000 to \$24,000 have been reported to increase the chance of high blood pressure and heart attack (CDC, 2014). African-Americans suffer more from high blood pressure problems, whereas Caucasians suffer more from heart attacks (CDC, 2014). Deaths from heart attacks are higher among lower income individuals (Moore, 2013), and people living in urban areas have been found to suffer more often from high blood pressure (American Thoracic Society, 2010).

DATA ANALYSIS. Stress-related illness data, NDVI, and canopy cover

data were analyzed using PASW Statistics 18 (IBM Corp., Armonk, NY). Descriptive statistics analyzed the vegetation cover levels for each MSA. A linear regression analysis was used to calculate the extent to which age, income levels, and ethnicity covaried with stress-related illnesses. Semipartial correlations were calculated to analyze the relationship between tree canopy cover/vegetation rate and stress-related illness rate variables while controlling for the effects of age, income levels, and ethnicity on stress-related illnesses.

Results

PUBLISHED DATA ON STRESS-RELATED ILLNESSES IN HUMANS LIVING IN MSAs OF TEXAS. A total of 19,793 adult respondents were interviewed by the Texas Department of State Health Services within the MSAs of interest, out of which 6495 adults were asked if they had high blood pressure and 13,298 adults were asked if they ever had a heart attack. In total, 1494 adults provided a valid response of “yes” for the question concerning high blood pressure and 532 adults provided a valid response of “yes” for the question concerning heart attack (A. Vincent, personal communication).

The stress-related illness data were compiled and compared within the 25 MSAs of Texas (A. Vincent, personal communication). Each MSA was analyzed and ranked in order from highest to lowest percentage of high blood pressure (Table 1) and heart attack (Table 2). Some MSAs did not have a total of at least 50 respondents answering the high blood pressure diagnosis questions positively. Therefore, for some MSAs, data were missing for high blood pressure (Table 1). Results indicated the highest level of high blood pressure occurred in Beaumont-Port Arthur and the lowest in Austin-Round Rock (Table 1).

The Texarkana MSA had the highest heart attack rate at 11.5% (Table 2). There was a 3.3% difference in heart attack rates between Texarkana MSA at 11.5% and the second highest rate of heart attacks, which was 8.2% for Sherman-Denison MSA. Afterward, the drop in heart attack rates across the different MSAs became much smaller, ranging from 0.1% to 0.7% points. The Laredo MSA had the

lowest heart attack rate at 0.0% (i.e., it had no heart attack patients in year 2006).

MAPPING RATES OF NUMBERS OF PATIENTS SUFFERING FROM STRESS-RELATED ILLNESSES IN DIFFERENT MSAs IN TEXAS. An overview map of Texas was used to map rates of high blood pressure and heart attacks to provide illustration of regions and illness. An overall map of stress-related illnesses as it related to specific MSA and location in Texas did not appear to reflect any clear pattern of stress-related illness rates in different vegetative regions of the state (Fig. 1).

MAPPING THE TREE CANOPY COVER FOR DIFFERENT MSAs OF TEXAS. Percent canopy of woody vegetation was calculated for each MSA to determine what proportion of each MSA was herbaceous low groundcover and small shrubby-vegetation vs. woody plant materials such as trees and taller shrubs. Statistics were calculated for each MSA using the Multi-Resolution Land Characteristics National Land

Cover Data canopy cover dataset (Table 3). The MSAs located in and around the Piney Woods natural region of East Texas had the highest rates of percent canopy cover. Longview had the highest total percent canopy cover with 45.31%; Texarkana MSA had 39.63% canopy cover and Tyler had 39.28% canopy cover (Table 3). The Piney Woods region of Texas vegetative composition is composed of pine (*Pinus* sp.)-hardwood forests, with tracts of farmlands and pasture throughout (Diamond et al., 1987; Lyndon B. Johnson School of Public Affairs, 1978). The major dominating vegetative type in this area is evergreen pine (Diamond et al., 1987; Lyndon B. Johnson School of Public Affairs, 1978).

The lowest percent canopy cover occurred in MSAs located in the furthest northwest region of Texas (Odessa and Midland) and the Texas Panhandle area (Lubbock) (Lyndon B. Johnson School of Public Affairs, 1978). Junipers (*Juniperus* sp.) are common to both the Rolling Plains

Table 3. Ranking of metropolitan statistical areas (MSAs) in order of highest to lowest total MSA acreage and percent canopy cover in the study of the effect of tree cover and vegetation on incidence of stress-related illnesses in MSAs of Texas.

Ranking	MSA	Area (acres) ^z	Canopy(%) ^y
1—Highest	Longview	1,159,916.6	45.31
2	Texarkana	592,751.23	39.63
3	Tyler	609,491.7	39.28
4	Beaumont-Port Arthur	1,457,562.6	34.83
5	Houston-Sugarland-Baytown	5,895,401.9	28.52
6	Bryan-College Station	1,366,481.36	24.39
7	Austin-Round Rock	2,739,283.9	23.51
8	San Antonio	4,722,912.8	20.43
9	Victoria	1,460,081.31	20.10
10	Killeen-Temple-Ft. Hood	1,828,212.9	17.47
11	Sherman-Denison	626,906.63	14.10
12	Waco	678,502.60	9.98
13	Dallas-Ft. Worth-Arlington	5,943,136.1	9.71
14	Abilene	1,763,723.93	9.03
15	Corpus Christi	1,142,613.3	6.67
16	San Angelo	1,658,729.26	3.83
17	Brownsville-Harlingen	602,397.6	3.66
18	Wichita Falls	1,710,745.89	2.69
19	McAllen-Edinburg-Mission	1,013,246.9	2.44
20	Amarillo	2,358,170.7	2.32
21	Laredo	2,158,763.50	1.31
22	El Paso	656,445.2	0.38
23	Lubbock	1,154,110.7	0.27
24	Midland	577,978.35	0.24
25—Lowest	Odessa	578,230.95	0.14

^z1 acre = 0.4047 ha.

^yPercent canopy was calculated using a normalized difference vegetation index calculated from satellite imagery [Landsat (U.S. Department of the Interior, 2014)] to determine what proportion of each MSA was groundcover vs. woody vegetation such as trees and shrubs.

and High plains natural regions of Texas (Diamond et al., 1987). Odessa had the lowest percent canopy cover at 0.14%; Midland had just 0.24% and Lubbock, the third lowest, had 0.27% canopy cover (Table 3). Odessa MSA in west Texas is composed of semiarid mesquite-mixed grasslands, subtropical steppe (a vast semiarid grass-covered plain) (Lyndon B. Johnson School of Public Affairs, 1978).

MAPPING VEGETATION LEVELS FOR DIFFERENT MSAs OF TREES. Tiles were “mosaicked” or pieced together to create one seamless image for each MSA. Brighter (white) pixels indicate vegetation and different shades of gray represent bare ground to vegetation, depending on the brightness of the pixel. The lighter grays are most likely vegetation, whereas the darker grays will be bare ground. Black pixels represent water or cloud coverage.

Descriptive statistics determined from tiles included minimum NDVI value, maximum NDVI value, and the average NDVI value for each MSA within the study (Table 4). The MSAs were listed in order from highest to

lowest average NDVI value. When comparing MSAs based on average NDVI, the top three locations for percent canopy were also the same top three for average NDVI. Longview MSA averaged 0.53 NDVI, while Tyler had a 0.51 average NDVI and the College Station-Bryan average NDVI value was 0.48 (Table 4). However, when looking at the MSAs with the lowest three average NDVI scores, there was some variation when compared with the percent canopy cover order. El Paso averaged the lowest rate of vegetation at 0.02, while Midland stood second lowest at 0.07. Previously, Odessa was the lowest with respect to percent canopy, while Midland was second lowest. Odessa had the third lowest average NDVI score at 0.08 (Table 4).

COMPARISONS OF DESCRIPTIVE STATISTICS. The calculated tree cover canopy data values for each MSA were compared with their corresponding percentage of stress-related illnesses (i.e., high blood pressure and heart attack) (Table 5). Lubbock had the second highest high blood pressure

rate and second lowest canopy cover ranking. This was similar to Abilene and Waco. However, Beaumont-Port Arthur had a high canopy cover and also a large percentage of high blood pressure sufferers (Table 5). Therefore, no clear trend was observed when high blood pressure rates (percent), heart attack rates (percentages), and average NDVI ranking from highest to lowest were compared.

DEMOGRAPHIC CONSIDERATIONS AND STRESS-RELATED ILLNESS RATES. An unstandardized residual of stress-related illness variables was calculated, which indicated the stress-related illness rates for each MSA controlling the extent to which age, income levels, population, and ethnicity covaried with heart attack and high blood pressure. No variables were found to be significantly related to high blood pressure. However, age over 45 years was statistically significant related to heart attack rates ($P = 0.03$) (Table 6), which was to be expected given medical literature stating those in this age range are more susceptible to heart attacks (Rosengren et al.,

Table 4. Minimum, maximum, and average normalized difference vegetation index (NDVI) for metropolitan statistical areas (MSAs), ranked in order highest to lowest average NDVI, in the study of the effect of tree cover and vegetation on incidence of stress-related illnesses in MSAs of Texas.

Ranking	MSA	Minimum NDVI ^a	Maximum NDVI ^a	Avg NDVI ^a
1—Highest	Longview	-0.49	0.78	0.53
2	Tyler	-0.49	0.79	0.51
3	Bryan-College Station	-0.49	0.88	0.48
4	Texarkana	-0.60	0.79	0.46
5	Beaumont-Port Arthur	-0.65	0.95	0.45
6	Houston-Sugarland-Baytown	-0.66	0.82	0.44
7	Victoria	-0.51	0.79	0.34
8	Austin-Round Rock	-0.54	0.72	0.30
9	Sherman-Denison	-0.66	0.77	0.29
10	Dallas-Ft. Worth-Arlington	-0.99	0.82	0.26
11	Lubbock	-0.54	0.79	0.25
12	San Antonio	-0.98	0.78	0.24
13—Tie	Abilene	-1.00	0.88	0.23
13—Tie	Wichita falls	-1.00	0.71	0.23
14	McAllen-Edinburg-Mission	-0.98	0.77	0.21
15	Killeen-Temple-Ft. Hood	-0.66	0.74	0.19
16	Corpus Christi	-0.72	0.75	0.19
17	Brownsville-Harlingen	-0.49	0.73	0.16
18	Waco	-0.60	0.71	0.14
19	San Angelo	-0.61	0.76	0.12
20—Tie	Amarillo	-0.53	0.79	0.11
20—Tie	Laredo	-1.00	0.70	0.11
21	Odessa	-0.33	0.71	0.08
22	Midland	-0.39	0.74	0.07
23—Lowest	El Paso	-0.56	0.76	0.02

^aNDVI was calculated from satellite imagery [Landsat (U.S. Department of the Interior, 2014)] for each MSA. Landsat imagery contains the two bands (near IR and red) required to calculate NDVI. This index is a simple numerical indicator used to analyze remote sensing measurements to determine the amount of green vegetation in the observed target. The resulting index range for this calculation is -1 to 1 (barren/non-vegetation to dense green vegetation, respectively).

2004), but would not skew results in this study.

PERCENT CANOPY COVER AND STRESS-RELATED ILLNESS. A Pearson's product-moment correlation between the percent canopy cover and the residual stress-related illness variables was calculated. This resulted in a semipartial correlation investigating the relationship between percent canopy cover and each stress-related illness controlling for the effect of external variables including population on each stress-related illness. No statistically

significant relationships were found. This suggested there was no positive or negative relationship between percent canopy cover and the prevalence of stress-related illness in humans when controlling for the external demographic variables previously identified in the study.

NDVI AND STRESS-RELATED ILLNESS. A Pearson's product-moment correlation between the minimum, maximum, and average NDVI and the residual stress-related illness variables was calculated. This resulted in

a semipartial correlation investigating the relationship between minimum, maximum, and average NDVI and each stress-related illness controlling for the effects of external variables including population on the stress-related illnesses. No statistically significant relationship was found. This finding indicated there was no positive or negative relationship between overall levels of vegetation calculated by the NDVI and stress-related illness in humans independent of the external demographic variables identified previously.

Table 5. Comparison of ranking of metropolitan statistical areas (MSAs) for highest to lowest stress-related illness, high blood pressure (HBP) rate and lowest to highest percent canopy in the study on the effects of tree cover and vegetation on HBP rates in regions of Texas.

HBP ranking ^z	MSA	Canopy ranking(%) ^y	MSA
1—Highest	Beaumont-Port Arthur	1—Lowest	Odessa
2	Lubbock	2	Midland
3	Abilene	3	Lubbock
4	Waco	4	El Paso
5	Longview	5	Laredo
5	Brownsville-Harlingen	6	Amarillo
6	College Station-Bryan	7	McAllen-Edinburg-Mission
7	Corpus Christi	8	Wichita Falls
8	Amarillo	9	Brownsville-Harlingen
9	Houston-Baytown-Sugarland	10	San Angelo
10	San Antonio	11	Corpus Christi
11	Dallas-Ft. Worth-Arlington	12	Abilene
12	McAllen-Edinburg-Mission	13	Dallas-Ft. Worth-Arlington
13	El Paso	14	Waco
14	Killeen-Temple-Ft. Hood	15	Sherman-Denison
15	Austin-Round Rock	16	Killeen-Temple-Ft. Hood
16	Laredo	17	Victoria
17—Lowest	Midland	18	San Antonio
	Odessa ^x	19	Austin-Round Rock
	El Paso ^x	20	Bryan-College Station
	San Angelo ^x	21	Houston-Sugarland-Baytown
	Sherman-Denison ^x	22	Beaumont-Port-Arthur
	Texarkana ^x	23	Tyler
	Tyler ^x	24	Texarkana
	Victoria ^x	25—Highest	Longview

^zData on percentage of HBP were obtained from the Center for Health Statistics, Texas Department of State Health Services for the years 2005–06 (Centers for Disease Control and Prevention, 2014). The data were rounded to the next highest or lowest raw number based on the normalized percentage of patients reported to have HBP in the overall population.

^yPercent canopy was calculated using a normalized difference vegetation index calculated from satellite imagery [Landsat (U.S. Department of the Interior, 2014)] to determine what proportion of each MSA was groundcover vs. woody vegetation such as trees and shrubs.

^xMSAs that had less 50 respondents who answered positively for high blood pressure diagnosis.

Table 6. Linear regression analysis to calculate the extent to which population, ethnicity, income levels, and age covaried with heart attack rates in the study of the effect of urban tree canopy cover and vegetation levels on the incidence of stress-related illnesses in metropolitan statistical areas (MSAs) of Texas.

Model	Unstandardized coefficients		Standardized coefficients		<i>t</i>	<i>P</i>
	<i>B</i>	<i>SE</i>	β			
Constant	–3.269	5.079			–0.644	0.527
Age group over 45 years ^z	0.350	0.105	0.616		3.330	0.003*
Income group \$15,000 to \$24,999 ^z	0.018	0.200	0.071		0.090	0.929
Caucasian ^z	–0.058	0.068	–0.171		–0.856	0.401

^zThese variables were selected to control for on the basis of a literature review indicated the impact of each of these on heart attack rates.

*Statistically significant at the 0.05 level.

Discussion

Findings indicated no statistical relationship between tree canopy cover/vegetation levels and rates of stress-related illness. Two major stress-related illnesses selected for this study were high blood pressure and heart attack. While several external variables were considered and controlled for, there were several other outside variables which were not able to be considered nor controlled for statistically. For example, Rosengren et al. (2004) identified a set of psychological stressors including workplace and home stress, financial problems, major life events in the past years, depression, and external locus of control, which were also significantly related to the risk of heart attack. Many events such as a disaster, life crisis, life changes, and daily hassles can be grouped as “stressors” (Rubin et al., 1993). Also, in this study, detailed information of respondents on their location or area where they reside (urban or rural) was not provided by the agency.

The study was limited to only two measures of stress-related illness: high blood pressure and incidence of heart attacks. These illnesses were selected based on the availability of data on the incidence of the diseases in the MSAs of interest. However, other illnesses are also triggered by stress and could offer more insight (Sapolsky, 2004). Additionally, while the data obtained were the most complete data known to be available on the variables of interest, it, too, had constraints. This study was conducted using self-reported stress-related illness rather than actual diagnoses from health professionals. Self-reported health statistics are known to have limitations especially among certain demographic groups (Quesnel-Vallee, 2007).

This study used an approach where quantity of vegetation was correlated to incidence of disease rather than the examining actual time spent in nature and stress reduction. People recuperate from stress when spending time viewing nature according to the Attention Restoration Theory (Kaplan and Kaplan, 1989). However, today, an urbanized lifestyle has led to people spending 80% or more of their time in indoor settings (Fjeld et al., 1998). Additional factors

that may be considered in future research may include the amount of interaction in nature of study participants and the proportion of built environment to natural environment within research settings.

This study was conducted using a large-scale approach of analyzing tree canopy across broad regions. The results of the study could have been impacted by the large variation of vegetation in each MSA, as well as the variety of vegetative types within the regions such as broadleaf vs. coniferous plants and grasslands vs. forests. As seen in the statistics calculated for each MSA (Table 4), a large range between the minimum NDVI and maximum NDVI exists within each MSA for a single time-period. This might indicate that MSAs are too large and too varied for this kind of research. Often, residents of a city are influenced instead on a neighborhood scale. While GIS and large-scale data by regions has been used in past studies to show the value of the urban forest on crime (Snelgrove et al., 2004) and childhood asthma (Pilat et al., 2012), future studies should perhaps focus on one individual MSA observing people’s relationship to tree cover on a street or neighborhood residence level integrating a smaller scale tree count and percent canopy cover approach (Nowak et al., 2001). Using smaller scale approaches were met with positive results when Kuo and Sullivan (1996) found domestic violence was reduced in Chicago’s urban housing surrounded by trees and vegetation when compared with those surrounded by asphalt. Smaller street-scale studies were also conducted of the benefits of trees to urban businesses in increasing retail traffic (Wolf, 2003).

It is also recommended when conducting future research that more detailed stress-related illness data sources be used if available. Past research has found people living in urban areas suffer more from stress-related illnesses than their rural counterparts (Rubin et al., 1993). Finally, it is recommended future research focus on comparing the relationship of stress-related illness and tree canopy cover/vegetative cover between geographical/vegetative regions of the entire United States to look at more extensive data with regards to sample sizes and vegetative data.

Literature cited

- American Heart Association. 2014. Heart and stroke statistics. 7 Sept. 2014. <http://www.heart.org/HEARTORG/General/Heart-and-Stroke-Association-Statistics_UCM_319064_SubHomePage.jsp>.
- American Psychological Association. 2014. Stress a major health problem in the U.S., warns APA. 23 June 2014. <<http://www.apa.org/news/press/releases/2007/10/stress.aspx>>.
- American Thoracic Society. 2010. Higher blood pressure found in people living in urban areas. 17 May 2010. <www.sciencedaily.com/releases/2010/05/100516195542.htm>.
- Armstrong, D. 2000. A survey of community gardens in upstate New York: Implication for health promotion and community development. *Health Place* 6:319–327.
- Centers for Disease Control and Prevention. 2014. Heart disease facts. 23 June 2014. <<http://www.cdc.gov/heartdisease/facts.htm>>.
- Cohen, S., E. Frank, W.J. Doyle, D.P. Skoner, B.S. Rabin, and J.M. Gwaltney. 1998. Types of stressors that increase susceptibility to the common cold in human adults. *Health Psychol.* 17:214–223.
- Cohen, S., R.C. Kessler, and L.U. Gordon. 1995. Strategies for measuring stress in studies of psychiatric and physical disorders. *Measuring stress: A guide for health and social scientists*. Oxford Univ. Press, New York, NY.
- Cohen, S. and S.D. Pressman. 2005. Positive effect and health. *Curr. Dir. Psychol. Sci.* 15:122–125.
- Cohen, S., D.A. Tyrrell, and A.P. Smith. 1991. Psychological stress and susceptibility to the common cold. *N. Engl. J. Med.* 325:606–612.
- Cohen, S., D.A. Tyrrell, and A.P. Smith. 1993. Negative life events, perceived stress, negative affect and susceptibility to the common cold. *J. Pers. Soc. Psychol.* 64:131–140.
- Deniz, O., R. Aygul, N. Kocak, A. Orhan, and M.D. Kaya. 2004. Precipitating factors of migraine attacks in patients with migraine with and without aura. *Pain Clinic Utrecht* 16:451–456.
- DeVries, S., R.A. Verheij, P.P. Groenewegen, and P. Spreeuwenberg. 2003. Natural environments: Healthy environments? An exploratory analysis of the relationship between green space and health. *Environ. Plan.* 35:1717–1731.

- Diamond, D., D. Riskind, D.H. Orzell, and L. Steve. 1987. A framework for plant community classification and conservation in Texas. *Tex. J. Sci.* 39:203–221.
- Fjeld, T., B. Veierstedb, L. Sandvike, G. Riisec, and F. Levyd. 1998. The effect of indoor foliage plants on health and discomfort symptoms among office workers. *Indoor Built Environ.* 7:204–209.
- Griffin, R.M. 2014. 10 health problems related to stress that you can fix. 7 Sept. 2014. <<http://www.webmd.com/balance/stress-management/features/10-fixable-stress-related-health-problems>>.
- Holmes, T.H. and M. Masuda. 1974. Life change and illness susceptibility, p. 45–71. In: B.S. Dohrenwend and B.P. Dohrenwend (eds.). *Stressful life events: Their nature and effects*. Wiley, New York, NY.
- Kaplan, R. 1993. The role of nature in the context of the workplace. *Landsc. Urban Plan.* 26:193–201.
- Kaplan, R. and S. Kaplan. 1989. *The experience of nature: A psychological perspective*. Cambridge Univ. Press, Cambridge, UK and New York, NY.
- Kuo, F. and W. Sullivan. 1996. Do trees strengthen urban communities, reduce domestic violence? U.S. Dept. Agr., Technol. Bul. No. 4, For. Rpt. R8-FR 55.
- Labor Market and Career Information Department of the Texas Workforce Commission. 2014. Metropolitan statistical area and composite counties: State of Texas. 23 June 2014. <<http://www.tracer2.com/default.asp?PAGEID=149>>.
- Lyndon B. Johnson School of Public Affairs. 1978. *Preserving Texas' natural heritage: A report*. LBJ School Policy Res. Project Rpt. 31. Univ. of Texas, Austin.
- McPherson, E.G. 2000. Urban forestry: The final frontier? *J. For.* 101:20–25.
- Mirela, B. 2009. Managing stress: The key to organizational wellness. *Ann. Univ. Oradea Econ. Sci. Ser.* 18:112–116.
- Moore, K. 2013. Income linked to heart attack survival. 7 Sept. 2014. <<http://www.thealmagest.com/income-linked-to-heart-attack-survival/871>>.
- Nowak, D., M. Noble, S. Sisinni, and J. Dwyer. 2001. People and trees: Assessing the US urban forest resource. *J. For.* 99:37–42.
- Owen, P.J. 1994. Influence of botanic garden experience on human health. Dept. For. Recreational Resources, Kansas State Univ., Manhattan, Master Thesis.
- Pilat, M., A. McFarland, A. Snelgrove, K. Collins, T.M. Waliczek, and J.M. Zajicek. 2012. The effect of tree cover and vegetation on incidence of childhood asthma in metropolitan statistical areas of Texas. *HortTechnology* 22:631–637.
- Quesnel-Vallee, A. 2007. Self-rated health: Caught in the crossfire of the quest for 'true' health? *Intl. J. Epidemiol.* 36:1161–1164.
- Relf, D. 1992. Human issues in horticulture. *HortTechnology* 2:159–171.
- Richard, S.L. and S. Folkman. 1984. *Stress, appraisal and coping*. Springer Publ., New York, NY.
- Rosengren, A., L. Wilhelmsen, and K. Orth-Gomer. 2004. Coronary disease in relation to social support and social class in Swedish men. A 15 year follow-up in the study of men born in 1933. *Eur. Heart J.* 25:56–63.
- Rubin, Z., L.A. Peplau, and P. Salovey. 1993. Psychology and health, p. 426–432. In: M. DeRocco, T. Mancuso, and S. Piland (eds.). *Psychology*. Houghton Mufflin, Boston, MA.
- Sapolsky, R. 2004. *Why zebras don't get ulcers*. 3rd ed. Holt Paperbacks, New York, NY.
- Selye, H. 1936. A syndrome produced by diverse nocuous agents. *Nature* 138:32–34.
- Selye, H. 1983. The stress concept: Past, present and future, p. 1–20. In: Cooper, C. (ed.). *Stress research: Issues for the eighties*. Wiley, Chichester, UK.
- Snelgrove, A.G., J.H. Michael, T.M. Waliczek, and J.M. Zajicek. 2004. Urban greening and criminal behavior: A geographic information system perspective. *HortTechnology* 14:48–51.
- Spierings, E.L., A.H. Ranke, and P.C. Honkoop. 2001. Precipitating and aggravating factors of migraine versus tension-type headache. *Headache* 41:554–558.
- Ulrich, R.S. 1979. Visual landscapes and psychological well-being. *Landscape Res.* 4:17–23.
- Ulrich, R.S. 1985. Human responses to vegetation and landscapes. Univ. Delaware, Newark.
- Ulrich, R.S. and R.F. Simons. 1986. Recovery from stress during exposure to everyday outdoor environments, p. 115–122. In: J. Wineman, R. Barnes, and C. Zimring (eds.). *The costs of not knowing: Proc. 17th Annu. Conf. Environ. Res. Design Assn.*, Washington, DC.
- Ulrich, R.S., R.F. Simons, and B.D. Losito. 1991. Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* 11:201–230.
- U.S. Census Bureau. 2014. Metropolitan statistical area (MSA) definition. 23 June 2014. <<http://www.census.gov/population/metro/>>.
- U.S. Department of the Interior. 2014. Landsat 5™ imagery. 23 June 2014. <<http://glovis.usgs.gov/>>.
- Waliczek, T.M., R.H. Mattson, and J.M. Zajicek. 1996. Psychological benefits of community gardening. *J. Environ. Hort.* 14:204–209.
- Watson, D.P. and A.W. Burlingame. 1960. *Therapy through horticulture*. Macmillan, New York, NY.
- Wolf, K.L. 2003. Public response to the urban forest in inner-city business districts. *J. Arboricult.* 29:117–126.