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RESEARCH ARTICLE

Examining the relationship between land-use cover change and sociodemographic characteristics: A case study of Madison County, Tennessee

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ABSTRACT

This study sought to holistically examine urbanization in Jackson, Madison County, TN. In order to accomplish this objective, a study of land-use and land cover (LULC) change in Madison County, TN from 1992–2011 was conducted. Once completed, noted changes in LULC were then compared to certain socio-demographic factors; these included, population, population density, point distance, central business district, and distance to roads. To determine if any significant relationships existed between socio-demographic factors and quantified LULC changes Spearman's Correlations were utilized. Relationships between socio-demographic factors and land-use indicators were established as urban areas grew, agricultural and forested areas declined, and population density near the city center decreased.

KEYWORDS

Land-use land cover change, Socio-demographic factors, urban sprawl

INTRODUCTION

The ability to accurately catalogue changes in the environment in a timely manner has become increasingly important (Yuan et al., 2005). Therefore, understanding what land-change science is and by noting the difference between land-use and land-cover is essential. These two terms are different, but are inexorably linked as one term describes the landscape or structures while the other describes activities that may occur on a land-cover (Fonji and Taff, 2014). For example, forested areas, agricultural lands, and urban areas all denote specific types of land-cover. Land-use might indicate that a specific forested area is part of a national park or state park or even how some urban areas can be separated between residential spaces and business or retail areas. The ability to map spatial and temporal changes in the land-use and land-cover (LULC) of an area is crucial to realizing the dynamics between subjects such as urban sprawl and environmental change (Banai and DePriest, 2014).

Changes over time in population growth, urban sprawl, and LULC in the Jackson-Madison County area will be derived and compared. Once completed, the objectives of this paper are: 1) quantify LULC changes and composition for Madison County, Tennessee between 1992–2011 and 2) to determine if any significant relationships exist between socio-demographic factors and the quantified LULC changes found in the study area.

LITERATURE REVIEW

The process of decentralization, or urban sprawl

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(Stone et al., 2010; Wassmer and Edwards, 2005) in the United States is said to follow a logical progression related to population, income, and the value of agricultural lands (Brueckner and Fansler, 1983). The authors state that urban sprawl is affected by the economic market process by which high yield in-demand agricultural land (agricultural rent) has a negative or limiting effect on urban growth. However, a case in which population increase followed the reduction of prime farmland can also be cited (Hasse and Lathrop, 2003). Part of Hasse and Lathrops's (2003) study describes a process in which an increase in population and the simultaneous widespread movement and relocation of inhabitants from a New Jersey city center to the outer suburbs both contributed to sprawl. Large tracts of land that were formerly either agricultural or forested in surrounding rural municipalities were lost to urban growth. In their report, the authors state that at the beginning of the 10-year study period over half of all land being used for growing crops was considered prime farmland, and by the end of the study period 60 percent of farmland lost to development was prime farmland. However, the largest land-cover lost to urban sprawl was forested lands with some 27,000 hectares lost to development.

Impacts of sprawl can be seen all throughout the country, especially the southeastern region of the United States. The Southeastern region experienced an increase in developed area of around 58 percent between 1982 and 1997; this was the highest increase in developed area within the U.S. (White et al., 2009). It is predicted that between 2003–2030, the southeast will experience a 51 percent increase in developed area; this means that the south is expected to develop at rates higher than the national average. Specifically, Tennessee is among southern states expected to develop at the some of the highest rates, over the 28-year time span, with an increase in developed land of some 90 percent. In general, the authors predict that the long term trend for the south is one of continued rise in population and development between 2003–2030 (White et al., 2009).

Urban growth in the southeast is being driven by a multitude of factors including availability of agricultural lands, current land use policies, and economic factors (Lopez and Hynes, 2003). According to Nagy and Lockaby (2011), there are many socioeconomic drivers influencing settlement in this particular region of the United States. For instance, the authors mention that more/better roads, increased accessibility, rising cost of land, and rising costs of maintaining undeveloped lands have contributed to sprawl in the southeast.

The case of increased population and the pervasiveness of urban sprawl has been made (Brueckner and Fansler, 1983; Hasse and Lathrop, 2003; Meyer and Turner, 1992) with the understanding that urban sprawl brings changes to LULC (Hamidi and Ewing, 2014). With the availability of population data from the United States Census Bureau, the technology available to map changes in LULC, and population over time, we may better understand the cause and effects of continued growth and anthropogenic changes (Banai and DePriest, 2014).

STUDY AREA

Madison County, Tennessee is located in Western Tennessee roughly half-way between Memphis and Nashville along Interstate 40 (Figure 1). The study area is approximately 1,443.14 km^2 (557.2 mi^2) with an estimated 2010 population of just over 98,000 (United States Census Bureau, 2017). The largest city in Madison County is Jackson, Tennessee, where nearly two-thirds of the county's population reside (Figure 2). Madison County has an elevation of nearly 120 m (400 ft) above sea level, is somewhat hilly but still has a significant agricultural presence (Bailey, 1993). Though agriculture played a much more important role in the area's past, the local economy is now more dependent upon businesses and industry (Madison County, TN, 2017).

METHODS AND DATA

This study makes use of National Land Cover Data (NLCD) sets from 1992 (retrofit), 2001, and 2011. NLCD maps are produced by the combined efforts of multiple federal agencies referred to as the Multi-Resolution Land Characteristics (MRLC) consortium (Multi-Resolution Land Characteristics Consortium (MRLC), 2017). The first land cover map produced in late 2000 was derived by Landsat Thematic Mapper™ satellite imagery at a 30-meter scale from the early 1990's. The LULC map developed for the conterminous United States made enquiry into many types of environmental investigations that required land-use data, such as wildlife biology, land management, and water quality possible (Vogelmann et al., 2001).

Due to advances in technology, the processes used in the development of the 2001 NLCD made comparisons between 1992 and 2001 not ideal (Fry et al., 2009; Graham and Congalton, 2017; Homer et al., 2007). Advanced

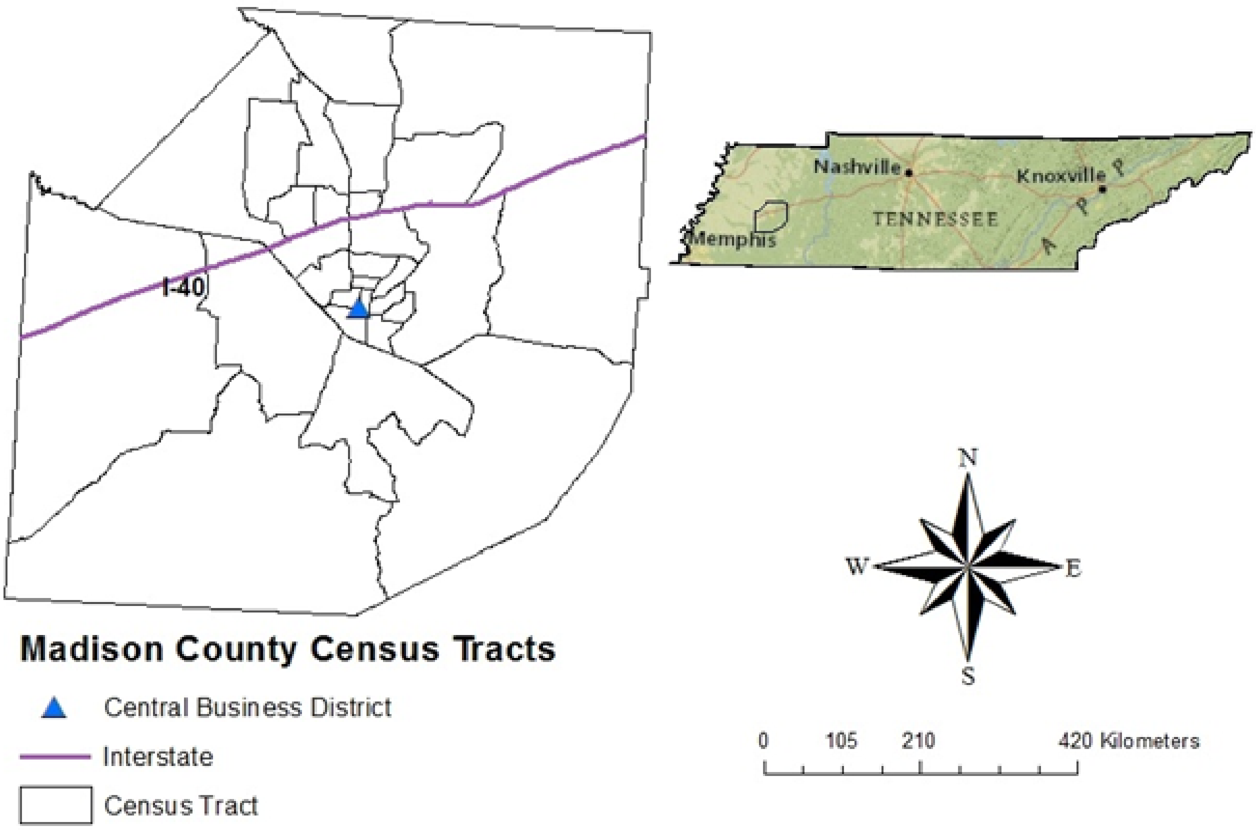

FIGURE 1: Location of Madison County, Tennessee; interstate and census tract boundaries (Map data from ESRI, Inc.).

techniques used in the classification process of the 2001 NLCD led to the production of two distinctly different data sets when comparing 2001 to 1992 NLCD maps. Because one of the ideas behind NLCD maps was to enable land change comparisons over time, the MRLC designed what Homer and others (2007) termed a "bridge product" that makes the comparison of 1992–2001 maps easier. The result was the completion of the NLCD 1992–2001 retrofit that makes use of a "hybrid" class I Anderson Classification technique (Anderson et al., 1976) developed from the more advanced 2001 NLCD map. Comparisons between the 2001 and 2011 NLCD maps are more straightforward because they both employ the same modified 16 class Anderson Land Cover Classification System (ALCCS). In addition, the specifications for the 2001–2011 maps also include 30 meter spatial resolution from Landsat 5 Thematic Mapper™ (Homer et al., 2007; 2015).

As previously mentioned, classification methods and coding of different land classes are not consistent between 1992–2001 NLCD maps. The addition of the 1992 retrofit map allows for a more direct comparison between 1992 and 2001 NLCD maps. The 1992 retrofit's classification is based on a Modified Anderson Level 1 class code in which similar classes are grouped together which reduced the overall number of class units when compared to 2001 or 2011 modified 16 class ALCCS. However, additional modifications to map classification were still needed. NLCD maps were loaded into GIS software ArcMap version 10.4 for the purpose of map reclassification.

Application of an "adapted" Anderson code to the 1992 retrofit map reduced the number of classes in the study area from seven to five class codes (TABLE 1). Specifically, "Open

TABLE 1: Reclassification of 1992 retro NLCD to "adapted" Anderson code.

Retrofit classification description	Modified Anderson level 1 class code	Adapted Anderson code
Open Water	1	1 Water
Urban	2	2 Urban
Barren	3	5 Agriculture
Forest	4	3 Forest
Grassland/Shrub	5	4 Grassland/Shrub
Agriculture	6	5 Agriculture
Wetlands	7	1 Water

Water" and "Wetlands" were combined and listed as "Water" and "Barren" was combined with "Agriculture" and listed as "Agriculture." The 2001 and 2011 NLCD classifications were also modified using the same "Adapted" Anderson classification code with the following results: "Open Water," "Woody Wetlands," and "Herbaceous Wetlands"

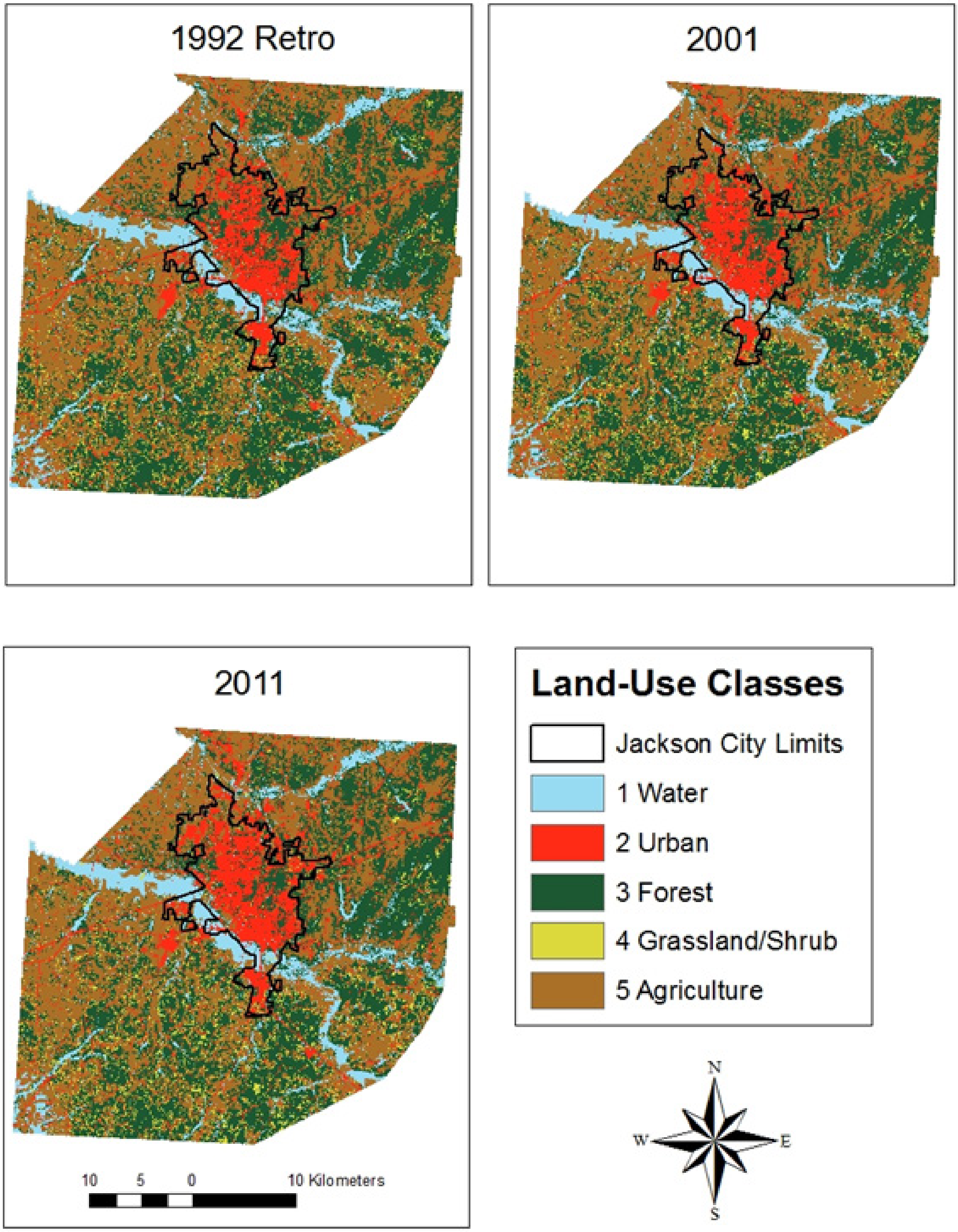

FIGURE 2: Reclassification land-use maps for 1992 retro, 2001, and 2011 (Multi-Resolution Land Charactertistics Consortium (MRLC), 2017).

were combined and listed as "Water;" "Developed Open Space," and "Low," "Medium," and "High Intensity" were combined and listed as "Urban;" "Barren Land," "Hay/Pasture," and "Cultivated Crops" were combined and listed as "Agriculture;" "Deciduous," "Evergreen," and "Mixed Forest" were combined and listed as "Forest;" and "Shrub/Scrub" and "Grassland/Herbaceous" were combined and listed as "Grassland/Shrub." The "collapsing" technique is utilized by previous land-use studies such as by (Antipova et al., 2011); when outside urban areas including low-density residential lands, agricultural and forested areas were consolidated into a single category of agricultural/rural due to sparse population and similar low-intense economic activity (Antipova et al., 2011). Results from recoding the 2001 and 2011 NLCD maps employing the "adapted" Anderson code are displayed in Table 2. In addition, percent changes in land use derived from the application of the "adapted" Anderson code to 1992 Retrofit, 2001, and 2011 NLCD maps are presented in Table 3.

Table 2: Reclassification of 2001 and 2002 NLCD to "adapted" Anderson code.

2001 and 2011 classification description	NLCD 2001 and 2011 class code	Adapted Anderson code
Open water	11	1 Water
Developed, open space	21	2 Urban
Developed, low intensity	22	2 Urban
Developed, medium intensity	23	2 Urban
Developed, high intensity	24	2 Urban
Barren land	31	5 Agriculture
Deciduous forest	41	3 Forest
Evergreen forest	42	3 Forest
Mixed forest	43	3 Forest
Shrub/Scrub	52	4 Grassland/Shrub
Grassland/Herbaceous	71	4 Grassland/Shrub
Hay/Pasture	81	5 Agriculture
Cultivated crops	82	5 Agriculture
Woody wetlands	90	1 Water
Emergent herbaceous wetlands	95	1 Water

Once reclassification of NLCD maps was completed (Figure 2), LULC changes for individual census tracts over the twenty-year study period were sought. To accomplish this, the tabulate area function in zonal statistics under the spatial analyst tools in ArcMap version 10.4 was employed. Each NLCD map (1992 retro, 2001, and 2011) was individually overlain with the 2010 census tract shapefile (TIGER/Line shapefiles) of Madison County. This procedure allowed for the calculation of all five of the "adapted" Anderson codes for each census tract for the 1992–2011 time of study. In addition to LULC changes over time, differences in population and population density during the same twenty-year time span were also sought. Because the dates of the LULC change maps coordinate well with the national census (1990–2010) the only consideration was the level of population data that could be reliably used throughout the study period.

For the purpose of data consistency, population and population density derived from the Longitudinal Tract Database (LTDB) were employed (Logan et al., 2014). In essence, the LTDB uses the 2010 census tract positions and employs techniques that allow population estimates to be tracked backwards and applied to census records back to 1970. Since the census tract boundaries are constant, researchers have the ability to make direct population comparisons over a 40-year time span (Logan et al., 2016). Census tracts generally have a population ranging between 1,200 and 8,000 inhabitants (1,000 to 3,000 housing units). Besides the ease of use, statistical comparisons from each decennial census to census enabled by constant tract boundaries mentioned above, we used this geographic hierarchy of the U.S. Census as an appropriate geographical unit representative of

Table 3: Statistical summary of land-use and population changes in Madison County from 1992-2011.

Land cover class and population change	1992 (retro) area (km²)	% of total	2001 area (km²)	% of total	2011 area (km²)	% of total	% Change 1992–2011
Water	114.14	7.89	119.12	8.23	118.61	8.20	3.92
Urban	141.50	9.78	156.07	10.79	167.80	11.60	18.58
Forest	552.49	38.19	530.56	36.67	526.07	36.36	−4.78
Grass/Shrub	69.12	4.78	77.09	5.33	81.69	5.65	18.18
Agriculture	568.45	39.29	562.86	38.90	551.53	38.12	−2.98
Population	77,982	NA	91,836.00	NA	98,294.00	NA	26.05

neighborhoods with relatively homogenous population attributes, as well as similar housing, and socio-economic characteristics (United States Census Bureau, 2017).

RESULTS AND DISCUSSION

As previously stated, classification maps of Madison County, Tennessee were produced from recoding of 1992 (retro), 2001, and 2011 NLCD maps using an "adapted" Anderson Code; statistical output derived from these maps are shown in Table 3. Land-use classes that increased in total area, over the study period, were Urban (18.5 percent) and Grass/Shrub (18.18 percent) while Forest and Agriculture both displayed decreases in total area (-4.78 percent and -2.98 percent respectively). Though Grass/Shrub class indicates a large percent increase from 1992–2011, it only accounts for a small portion of Madison County. In fact, the 81.69 km^2 (5.65 percent) was the smallest total area of all derived classes. Increases in the Urban class was more significant with an expansion of 26.3 km^2 over the study period; this accounted for 167.80 km^2 or 11.60 percent of the total study area. By far, the two largest land-use classes were Forest and Agriculture. These two classes accounted for nearly 75 percent of the total land make-up of Madison County in 2011. Between 1992–2011, Agriculture lost 16.92 km^2 (about 3 percent) and Forest lost 26.42 km^2 (5 percent) of land, while the Urban class had gained 19 percent by 2011, the largest growth among all land uses. The most insignificant change was observed for the water class which in absolute terms changed slightly over time with 4.5 km^2 of area; however, the class consistently accounted for about 8.00 percent of the total area. Changes in total water area could have been caused by fluctuations in actual area that was water, but were probably due to classification errors that will be further discussed in the limitations of study regarding this report.

Numerous variables for the study area were developed for the purpose of statistical assessment. Population and population density variables are straightforward and correspond to the total population amounts displayed in Table 3; however, procedures used to produce other variables within ArcMap 10.4 are given. For example, point distance (PT_DIST) was created by establishing a location to represent the central business district (CBD) of Madison County. This position was the historic downtown area of Jackson, Tennessee and represents places where the Madison County Courthouse and City Hall are located. Once established, ArcMap determined the distances from the CBD to the centroid of each census tract (Figure 3). In a similar fashion, the distance to roads (DIST_ROADS) was computed as the shortest distance between a census tract's centroid and a major or primary road (defined in the study as interstates, highways, or major four-lane roads).

As previously mentioned, each census tract's LULC was cataloged for 1992, 2001, and 2011. This information allowed us to determine the percent change in all land-use categories between 1992–2001, 2001–2011, and 1992–2011 in each census tract. Land-use data was then loaded into IBM's Statistical Package for the Social Sciences (SPSS) version 22. Due to the data not having a normal distribution, we employed nonparametric statistical analysis. Since the second objective of our study was to establish if any significant relationships between socio-demographic factors and LULC changes within Madison County exist, we employed Spearman's rho, a nonparametric correlation analysis (Helsel, 1987). For the purpose of data consistency and statistical analysis, LULC data was coded into SPSS to correspond with census data. LULC data from 1992 was entered as LULC data 1990; the same format was applied to LULC data from 2001 (entered as 2000) and 2011 (entered as 2010). All P values <0.05 are considered to be significant.

As explained above, the land data were matched with the closest Census data available for the time period. To illustrate, we used time series data including Census data for 1990, 2000, and 2010 while using 1992 LULC, 2001 LULC, and 2011 LULC, respectively, to examine changes in land-use and population as a function of distance to the city center between 1990 and 2010 in Jackson, Tennessee. Spearman's correlation coefficient was used to describe an association between the two variables and to test the hypothesis that no relationship exists between population density per square kilometer (PD) and distance to the city center (PT_DIST). Population decentralization manifests itself in the pattern represented by changes in the slope of the density gradient. In agreement with previous studies documenting decentralization of cities (Hasse and Lathrop, 2003; Luo et al., 2008; Nagy and Lockaby, 2011), we find this function downward sloping with distance and population density gradient flattening over a period of time. A steady decline in the steepness of the slope of the density gradient was observed and reflected in the correlation coefficient decreasing from –0.86 to –0.79 to –0.75 (each at the $p<0.01$ level of significance) indicating urban sprawl with low-density housing and fragmented residential development on semirural tracts (Table 4). In

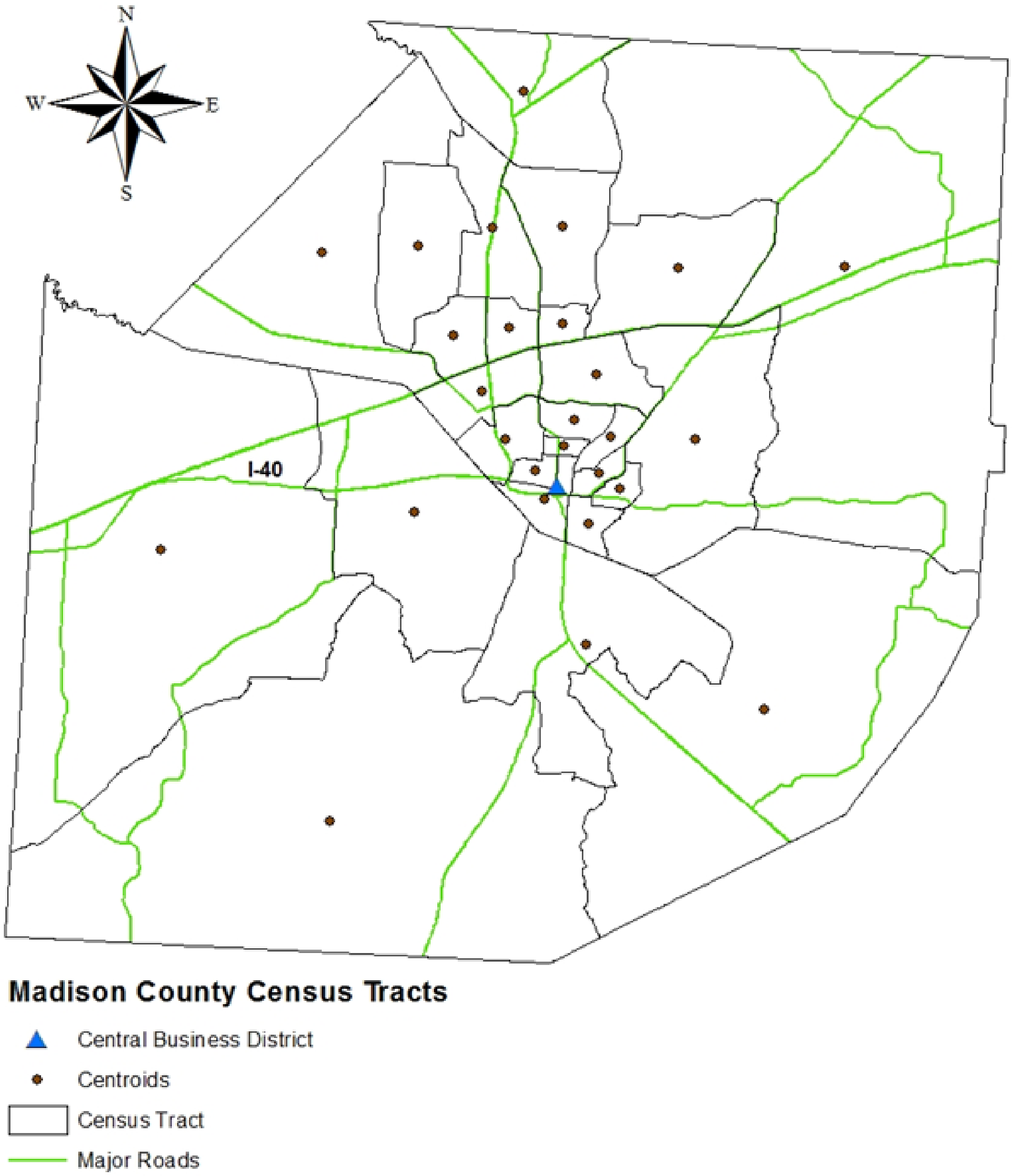

FIGURE 3: Census tract, centroid, central business district, and major roads in Madison County, Tennessee (Map data from ESRI, Inc.).

other words, this finding exemplifies the theory of urban sprawl in which land-use in less urbanized areas are more typically converted and developed into residential and/or urban areas (Luo et al., 2008).

Population density, in the study area, was less at the center as people are moving away from central areas to settle at the outskirts and in the suburban parts of urban areas. This process follows a pattern referred to as exurbanization, where low density housing in rurally located subdivisions allow people to live in the country (Brown et al., 2005; Hansen et al., 2005). Gated communities are a prime example of exurbanization and occur when the affluent locate outside of the city on large lots which enable separation or protection from the public (Le Goix, 2005). Madison County seems to be following the same pattern established by Brown and others (2005) who explain that exurbanization experienced rapid expansion in the U.S. from 1950–2000.

No relationship was found between distance to the city center (PT_DIST) and the percent change of land that was urban between 1990–2000, 2000–2010, and 1990–2010; nor did we observe that proximity to a major road (DIST_ROAD) was related to any land-use changes (TABLE 4). These findings disagree with Luo and others (2008) study in which a negative relationship between the distance to major roads and distance to urban centers and a change from non-urban to urban land was established. However, the relationship between population density (PD) and proximity to major roads (DIST_ROAD) was negative at –0.058 and significant (p<.01 level) indicating that people are deterred by the closeness of heavily trafficked roads. This association remained stable for each of the three-time periods in our study.

A minor increase in the relationship between the percent change of land that was forest (PC_Forest) and the distance to city center (PT_DIST) was detected. The coefficient from 1990–2000 (rho = 0.436) presented a slight increase to 0.446 during the study period (1990–2010). It seems that an increase in forest cover would be counter to expectations if sprawl is occurring outside of the city center. This situation might be explained by circumstances in which growth of extensive tree canopies may cause some urban areas to be incorrectly classified as forested (Yuan et al., 2005). A slight decrease in the percent change of land that was agricultural was also observed for the overall period 1990–2010 (PCAg): a modest but significant relationship between PCAg1990_2000 was observed with proximity to urban center (PT_DIST), rho = 0.40, p<0.05 indicating that more rural land is found farther away from urban areas. The coefficient decreased to 0.394 for the period of 1990–2010. This result is not surprising as Madison County has historically relied upon agriculture as a major economic driver. Though agriculture is not as prominent as it once was, in the study area, it is still an important factor in the local economy (Madison County, TN, 2017).

Table 4: Spearman's correlation output for LULC percent change, socio-demographic, point distance, and distance to major raods.

Socio demographic and LULC	Year(s)	Point distance	Road distance
Pop Density	1990	−0.862	−0.58
P-Values		**0.000**	**0.002**
Pop Density	2000	−0.794	−0.582
P-Values		**0.000**	**0.001**
Pop Density	2010	−0.748	−0.578
P-Values		**0.000**	**0.002**
PDPC	1990-2000	0.225	0.090
P-Values		0.259	0.654
PDPC	2000-2010	0.498	0.093
P-Values		**0.008**	0.645
PDPC	1990-2010	0.455	0.152
P-Values		**0.017**	0.449
PC Urban	1990-2000	0.314	−0.016
P-Values		0.110	0.935
PC Urban	2000-2010	0.272	0.068
P-Values		0.169	0.736
PC Urban	1990-2010	0.313	0.015
P-Values		0.112	0.940
PC Forest	1990-2000	0.436	0.331
P-Values		**0.023**	0.092
PC Forest	2000-2010	−0.013	−0.060
P-Values		0.948	0.767
PC Forest	1990-2010	0.446	0.297
P-Values		**0.020**	0.133
PC Grass	1990-2000	0.261	0.342
P-Values		0.188	0.081
PC Grass	2000-2010	0.293	0.258
P-Values		0.138	0.194
PC Grass	1990-2010	0.289	0.231
P-Values		0.143	0.246
PC Ag	1990-2000	0.399	0.224
P-Values		**0.039**	0.262
PC Ag	2000-2010	−0.135	0.095
P-Values		0.501	0.639
PC Ag	1990-2010	0.394	0.243
P-Values		**0.042**	0.222

Bold = p < 0.05 Significant

Finally, we investigated how population changes were reflected in percent change in population density over 10-year intervals across the urban area. Spearman's correlation values were used to describe population change trends. The population density percent change (PDPC) was correlated with distance to city center (PT_DIST) for 1990–2000, 2000–2010, and 1990–2010. Spearman's correlation index is positive indicating that more changes in population are occurring farther away from central high-density areas. The highly dynamic urban-rural fringe area has been described as a peri-metropolitan bow wave where the metropolitan growth occurs with the outward expansion of urban land increasing the value of the adjacent land and excessively decreasing the amount of high-quality agricultural land (Greene and Pick, 2012; Hart, 1991). The strongest correlation was percent change between 2000 and 2010 (0.498 at 0.01 level) supporting the previous finding that the fastest growing locations are places with relatively few people (Table 5). There was also a strong relationship between changes in urban land-use and population (increasing rho = 0.631, 0.652, 0.739) with more population changes taking place on land which is urban at 0.01 level of significance for each of the study periods of 1990–2000, 2000–2010, and 1990–2010, respectively (Table 5). Taken together, these last statements demonstrate that urban sprawl is occurring in the study area as more land is converted to urban and areas that previously had the fewest people are now being developed.

CONCLUSION

In this study we explored the relationship between urban sprawl and important drivers of urban change in the southeast US, which compared to other regions of the US, experienced high rates of urban development. For this purpose, we quantified land-use changes in Madison County, Tennessee over a twenty-year period. Additionally, we established relationships between socio-demographic factors and land-use indicators which suggests that sprawl is occurring in the study area. In general, population density near the city center is decreasing as the growing population (increase of 26 percent over the time of study) settles in areas that were once non-urban. The summation of land-use and population changes (Table 3) for Madison County indicates that population and urban areas are increasing as forested and agricultural areas are decreasing. Several studies are cited (Hasse and Lathrop 2003; Wolter et al., 2006; Yuan et al., 2005) in which a decrease in land that was forest or agriculture was accompanied by an increase in urbanized lands and is described as urban sprawl.

Table 5: Spearman's correlation output for population density percent change and LULC percent change.

LULC	1990-2010 PDPC	2000-2010 PDPC	1990-2010 PDPC
PC Urban	0.631	0.652	0.739
P-Value	0.000	**0.000**	**0.000**
PC Forest	−0.286	−0.357	−0.195
P-Value	0.148	0.067	0.329
PC Grass	−0.038	0.399	−0.111
P-Value	0.849	**0.039**	0.583
PC Ag	0.044	−0.268	-0.098
P-Value	0.828	0.177	0.626

Bold = p < 0.05 Significant

Alig and others (2004) explain the association of population growth and development in their study detailing urban expansion in different regions of the United States. The authors report that the south (southeast United States) had more land developed between 1982–1997 than any other area of the country. In addition, several southern states also had one-third of their development to occur during the same 1982–1997 time span. As a region, the south has typically experienced a large increase in population while its developed area per additional person is higher than average. Based on a 35 percent increase in population and considering historical data on urbanization and socio-economic changes, the authors derived 25-year projections for future urban development. Results from regression analysis for the next 25-years estimate the south will increase in population by about 20 percent but will experience an increase in development or urbanization at substantially higher rates (Alig et al., 2004).

Essentially, what is happening in the Jackson-Madison County focus area is a very close representation of what Alig and others (2004) reported in their study. Why is this important or what are the implications? A study by the U.S. Geological survey on the future of urban sprawl in the southeastern United States predict some of the negative ramifications and potential outcomes of sprawl (Terando et al., 2014). The authors state that some projections describe an increase in urbanization from 100 percent to nearly 200 percent over the next 50 years. If these projections are true, it would have a negative impact on water quality, air quality, and wildlife, just to name a few (Terando et al., 2014). These are examples of the same types of negative impacts that could affect the Jackson-Madison County area in the near future.

Limitations

The results of our study should be viewed with caution as there are limitations that must be considered. First, according to the MRLC, the NLCD maps were produced with the intentions of making regional comparisons. However, there are examples of land-use studies in which NLCD maps were used at a smaller than regional scale (Crowther, 2015). As previously stated, direct comparisons between 1992 data and 2001 NLCD data are not recommended (Fry et al., 2009; Homer et al., 2007) however, the MRLC does not declare that comparisons cannot be made (Crowther, 2015). In his thesis, Crowther (2015) uses 1992, 2001, and 2011 NLCD maps to quantify land-use changes in Pasadena and Inglewood, CA. Crowther stated that comparisons between the different NLCD maps were difficult and the reclassification of maps may have decreased the accuracy of the data. However, this study made use of the 1992 retrofit data and not the original 1992 NLCD data which should have increased the accuracy of derived analysis.

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