A scale-adjusted measure of “Urban sprawl” using nighttime satellite imagery

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Abstract

“Urban Sprawl” is a growing concern of citizens, environmental organizations, and governments. Negative impacts often attributed to urban sprawl are traffic congestion, loss of open space, and increased pollutant runoff into natural waterways. Definitions of “Urban Sprawl” range from local patterns of land use and development to aggregate measures of per capita land consumption for given contiguous urban areas (UA). This research creates a measure of per capita land use consumption as an aggregate index for the spatially contiguous urban areas of the conterminous United States with population of 50,000 or greater. Nighttime satellite imagery obtained by the Defense Meteorological Satellite Program’s Operational Linescan System (DMSP OLS) is used as a proxy measure of urban extent. The corresponding population of these urban areas is derived from a grid of the block group level data from the 1990 U.S. Census. These numbers are used to develop a regression equation between Ln(Urban Area) and Ln(Urban Population). The ‘scale-adjustment’ mentioned in the title characterizes the “Urban Sprawl” of each of the urban areas by how far above or below they are on the “Sprawl Line” determined by this regression. This “Sprawl Line” allows for a more fair comparison of “Urban Sprawl” between larger and smaller metropolitan areas because a simple measure of per capita land consumption or population density does not account for the natural increase in aggregate population density that occurs as cities grow in population. Cities that have more “Urban Sprawl” by this measure tended to be inland and Midwestern cities such as Minneapolis–St. Paul, Atlanta, Dallas–Ft. Worth, St. Louis, and Kansas City. Surprisingly, west coast cities including Los Angeles had some of the lowest levels of “Urban Sprawl” by this measure. There were many low light levels seen in the nighttime imagery around these major urban areas that were not included in either of the two definitions of urban extent used in this study. These areas may represent a growing commuter-shed of urban workers who do not live in the urban core but nonetheless contribute to many of the impacts typically attributed to “Urban Sprawl”.

Keywords: Urban sprawl; Sprawl Line; Nighttime satellite imagery

1. Introduction

The issue of what is commonly referred to as “Urban sprawl” is gaining increasing attention and concern from citizens, environmental organizations, and governments (http://www.sierraclub.org/sprawl/; http://www.vtsprawl.org/index3.htm; (Benfield et al., 2001)). Concerns are raised about the impact urban sprawl has on the loss of open space, traffic congestion, and energy consumption. Nonetheless, specific, measurable, and generally accepted definitions of urban sprawl are difficult to find. William Whyte’s 1958 definition of urban sprawl referred to patterns of urban development (“…the leapfrog nature of urban growth…”) (Whyte, 1958). Others have defined “Urban Sprawl” based simply on the aggregate population density of a given urban area (Fulton et al., 2001; Kolankiewicz & Beck, 2001). It is very likely that “Urban Sprawl” happens to some extent in specific areas of most cities. It could be argued that “Urban Sprawl” is similar to pornography in that it is difficult to define but ‘You know it when you see it’. It could be argued that “Urban Sprawl” is a multi-dimensional phenomenon

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that needs to be characterized with several variables. Nonetheless, this research focuses on providing a single, scale-adjusted (population corrected), aggregate indicator of “Urban Sprawl” for all urban areas of population greater than 50,000 in the conterminous United States.

Studies using aggregate population density as an indicator of “Urban Sprawl” have typically used ‘urban area’ designations of the U.S. Census along with corresponding population figures to determine an average population density for urbanized areas within the US (Fulton et al., 2001; Kolankiewicz & Beck, 2001). These aggregate measures of sprawl suffer from two problems: (1) problems associated with measurements of the areal extent of an urban area, and (2) the nonlinear variation of the aggregate population density of urban areas as a function of total population. Remotely sensed images of urban environments have great potential for delineating urban areas. GIS coverages of urban environments suffer from arbitrary administrative boundaries used in conjunction with housing unit density or population density thresholds. Nighttime imagery has some advantages over daytime imagery in that it is measuring emitted rather than reflected radiation, this avoids some classification problems in separating developed vs. non-developed land cover. This research utilizes a ‘scale-adjusted’ measure of “Urban Sprawl” that addresses the nonlinearity problem and uses two ‘thresholds’ of nighttime satellite imagery as a means of measuring the areal extent of urban areas in the United States.

The urban extent of cities varies as a nonlinear function of their total population (Nordbeck, 1965; Stewart & Warnzt, 1958; Tobler, 1969). This has also been demonstrated using nighttime satellite imagery as a proxy measure of urban areal extent both nationally and globally (Sutton et al., 1997, 2001). Typically, as cities grow their aggregate population density increases; consequently, the aggregate population density of large cities like Los Angeles and Chicago will be higher than the aggregate population density of smaller cities such as Portland and Kansas City. However, this does not imply that Los Angeles and Chicago suffer less from “Urban Sprawl” than Portland or Kansas City. Any aggregate measure of “Urban Sprawl” for an urban area should be scale-adjusted by the total population of that urban area.

The U.S. Census defines the urban area (UA) of a city each time a census takes place. A UA is designated for all central cities with a population in excess of 50,000. The urban areas designated by the census do not always correspond with land cover maps derived from satellite imagery (Vogelmann et al., 1998). This study uses nighttime satellite imagery provided by the Defense Meteorological Satellite Program’s Operational Linescan System (DMSP OLS) to measure the areal extent of the urban areas of the conterminous United States. Imhoff et al. (1997) have used the DMSP OLS imagery in similar ways. The DMSP OLS imagery is compared to a gridded population density dataset derived from the 1990 U.S. Census (Meij, 1995). This comparison results in measures of both the areal extent and the population of all the urban areas in the conterminous United States. These numbers are then used to calculate improved aggregate measures of urban sprawl.

2. Data and methods

The data required to develop a ‘scale-adjusted’ measure of urban sprawl are simply: (1) the areal extent of urban areas, (2) the corresponding population of those urban areas, and (3) a formula describing the relationship between the population and areal extent of these urban areas. The data used to obtain areal extent and population are: (1) a radiance calibrated DMSP OLS image of the United States (Elvidge et al., 1998), and (2) a grid of population density derived from the U.S. Census (Meij, 1995). Both of these images have a spatial resolution of 1 km² (Fig. 1). The numbers derived from these datasets are used in a population weighted regression of the Ln(Urban Area km²) vs. Ln(Urban Population) relationship. One problem associated with using the nighttime satellite imagery as a proxy measure of urban extent is the question of thresholding: (i.e. ‘What light intensity should be used to characterize an area as urban?’). The Denver metropolitan area illustrates this problem (Fig. 2). Fig. 2 shows the Denver Metropolitan area as represented by a 30-m resolution USGS National Land Cover Data (NLCD) image (Vogelmann et al., 2001). This image was used as a check on setting urban ‘thresholds’ on the DMSP OLS nighttime image. Defining ‘urban’ is a difficult problem unto itself. Many people contend that the corridor from Denver to Boulder is urban whereas the NLCD image classifies much of it as agricultural (The image derived by Vogelmann et al. is based in 1992 Landsat images.) The conurbation represented by Denver and Boulder is happening to lesser and greater extents throughout the United States. Because of this problem of conurbation and the more general problem of answering the “What is Urban?” question, two thresholds were used and analyzed separately. The blue line in Figs. 1 and 2 represent the lower threshold (900 μW/cm²/sr/μm) which measures larger urban extents. The red lines of Figs. 1 and 2 represent the higher threshold (2000 μW/cm²/sr/μm) for classifying the DMSP OLS image as ‘urban’. The high threshold separates Boulder from Denver and is a more accurate measure of strictly urban land cover. The lower threshold captures Boulder and Denver in one conurbation and is probably a better measure of urban areas as metropolitan areas. The 30-m resolution USGS NLCD dataset is probably one of the best measures of urban land cover available; however, the size of these datasets makes it very difficult to apply this analysis for an area the size of the conterminous United States. In addition, the spatial resolution of the NLCD data introduces a fuzzy ‘fractal’ boundary for urban areas that makes it difficult to define ‘urban’ systematically.

The lower threshold creates larger conurbations of cities which are consequently measured as one ‘urban cluster’.
(e.g. Philadelphia, PA; Newark, NJ; New York, NY; Hartford, CT; and Springfield, MA are all measured as one giant conurbation with the low threshold but are all distinct clusters with the higher threshold (Fig. 1)). That same distinction holds with the Denver–Boulder conurbation (e.g. the low threshold captures Boulder and Denver in the same ‘urban cluster’ where the high threshold identifies them as separate urban areas (Fig. 2)). The DMSP OLS image was classified into a ‘Low Threshold’ urban image and a ‘High Threshold’ urban image. These two urban images were compared with the population density image to create the paired (Area (km²), Population (total number of individuals)) points needed to derive the regression parameters for the following log–log relationship:

\[
\ln(\text{Population}) = B_0 + B_1 \ln(\text{Area})
\]

This relationship shows a strong correlation for the (Area, Population) data using both the ‘Low Threshold’ \((R^2 = 0.97, N=300)\) and ‘High Threshold’ \((R^2 = 0.96 \ N=244)\) urban areas with population greater than or equal to 50,000.

3. Results and analysis

The regression line on the scatterplots of the Ln(Area) vs. Ln(Population) relationship represents a scale-adjusted “Sprawl Line”. The line itself represents the average relationship between the areal extent and population of urban areas in the conterminous United States. It should be noted that the nature of this sprawl line is specific to the United States. A ‘Sprawl Line’ for other countries will generally have a higher intercept for countries with lower
GDP per capita (in general poorer countries have cities with higher population densities).

Each point in the scatterplot represents one of the urban areas of the US whose population is greater than 50,000. The points above the “Sprawl Line” represent urban areas with a higher than expected population, which implies lower land consumption per capita. These cities can be thought of as not suffering from “Urban Sprawl” as much as the urban areas that fall below the line. Points that fall below the “Sprawl Line” represent urban areas with lower than expected total populations and higher per capita land consumption. Scatterplots are provided for both the “High threshold” and “Low Threshold” definitions of urban (Figs. 3 and 4). The city name, state(s), areal extent, actual population, predicted population (‘Sprawl Line’ population), and percent difference are provided for both thresholds in Tables 1 and 2. The coding of the points in the scatter plots is based on the percent difference between the predicted population (i.e. on the ‘Sprawl Line’) and actual population of the urban areas in question. Images of the actual urban areas that the points in the scatterplots correspond to are provided for both the “Low Threshold” (Fig. 5) and the “High Threshold” (Fig. 6) data using the same coding.

Common patterns shown in Figs. 5 and 6 are the fact that the west coast urban areas such as the Los Angeles metropolitan area, the San Francisco Bay area, San Diego, Portland, and Seattle all fall above the “Sprawl Line”. In addition, several mid-western and inland urban areas such as Dallas–Ft. Worth, Oklahoma City, Saint Louis, Minneapolis–St. Paul, Atlanta, and Indianapolis fall below the “Sprawl Line”. Some interesting changes that resulted from different thresholds are the breakup of the Philadelphia–Newark–New York–Hartford–Springfield conurbation and the breakup of the Boston–Providence–Fall River conurbation. The Boston breakup resulted in a transition from below the “Sprawl Line” (red) to neutral (white) and above (sage) the “Sprawl Line”. The New York breakup resulted in a transition from neutral (White) to both above and below the “Sprawl Line” (New York, Hartford, Springfield went above (sage and green), Philadelphia went below
The overall variability of per capita land use as suggested by the distribution of percent error in Figs. 3 and 4 is also of interest.

Fig. 3. ‘The low threshold sprawl line’, a regression of the urban clusters identified by the DMSP imagery with population greater than 50,000. Urban areas below the line suffer from ‘sprawl’ more than points above the line. Color coding of points represents the percent difference between the actual population and the population predicted by this regression equation.

Figs. 3 and 4 show that the aggregate measures of urban sprawl for urban areas in the US have wide variability of per capita land use consumption. Large
Table 1  
Urban clusters of population greater than 50,000 identified using the low threshold (N = 300)

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<th>City name</th>
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<th>Urban area (km²)</th>
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<th>Estimated population</th>
<th>Percent difference</th>
<th>City name</th>
<th>State(s)</th>
<th>Urban area (km²)</th>
<th>Actual population</th>
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<th>Actual population</th>
<th>Estimated population</th>
<th>Percent difference</th>
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| CYPRESS LAKE (metro) | FL | 662              | 235,274          | 352,551             | – 50               | Marysville – Yuba City | CA     | 101              | 55,466           | 34,571            | 38
| DALLAS – FT WORTH (metro) | TX | 5316             | 3,467,946        | 4,620,166           | – 33               | Medford        | OR      | 150              | 63,537           | 56,346            | 11
| Danbury      | CT      | 247              | 108,759          | 104,327             | 4                  | Melbourne       | FL      | 283              | 128,557          | 123,418            | 4
| DAYTONA BEACH (metro) | FL | 210              | 136,524          | 85,379              | 37                 | MEMPHIS (TN) | TN/MS/AK | 1385             | 875,665          | 1,016,429          | – 18
| De Land – Deltona | FL | 198              | 76,117           | 79,394              | 4                  | Merced          | CA      | 111              | 64,216           | 38,847            | 40
| Decatur      | IL      | 297              | 94,048           | 131,002             | 39                 | MIAMI (metro)  | FL      | 3506             | 3,676,239        | 2,763,015          | 25
| Denison – Sherman | TX | 300              | 54,757           | 132,639             | 142                | Midland         | TX      | 151              | 89,118           | 56,811            | 36
| DENVER (metro) | CO | 2456             | 1,721,453        | 1,788,147           | – 5                | MINNEAPOLIS – ST. PAUL (metro) | MN        | 4195             | 2,193,189        | 3,448,442          | – 57
| Derby        | KS      | 656              | 351,952          | 348,609             | 1                  | Missoula        | MT      | 180              | 51,334           | 70,577            | – 37
| DES MOINES (metro) | IA | 738              | 314,031          | 403,197             | – 28               | MOBILE (metro) | AL      | 552              | 278,531          | 281,675            | – 1
| DETROIT (metro) | MI | 4551             | 4,002,492        | 3,772,066           | 4                  | Modesto – Ceres | CA      | 339              | 246,740          | 293,251            | 27
| Dothan        | AL      | 362              | 50,606           | 61,965              | – 22               | Monroe          | LA      | 209              | 94,746           | 84,877            | 11
| Dubuque      | IA      | 180              | 65,137           | 70,577              | – 8                | MONTEREY (metro) | CA      | 76               | 78,265           | 24,331            | 69
| Duluth – Superior | MN/WI | 354              | 111,452          | 162,724             | – 46               | Montgomery      | AL      | 360              | 182,291          | 166,137            | 9
| Durham – Chapel Hill – Raleigh | NC | 1152             | 517,449          | 698,847             | – 35               | Muncie          | IN      | 228              | 91,087           | 94,507            | – 4
| Eau Claire – Chippewa Falls | WI | 330              | 86,084           | 149,209             | – 73               | Muskegon – Grand Haven | MI      | 286              | 120,472          | 125,036            | – 4
| EL PASO (metro) | TX | 685              | 516,816          | 367,741             | 29                 | Myrtle Beach    | SC      | 397              | 79,716           | 187,476            | – 135
| Elmira        | NY      | 119              | 61,672           | 42,333              | 31                 | Napa            | CA      | 82               | 62,516           | 26,725            | 57
| Erie          | PA      | 212              | 173,743          | 86,384              | 50                 | NAPLES (metro)  | FL      | 409              | 116,202          | 194,499            | – 67

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<th>Estimated population</th>
<th>Percent difference</th>
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<th>Urban area (km²)</th>
<th>Actual population</th>
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<th>Percent difference</th>
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| Corpus Christi | TX     | 467              | 229,114          | 215                | 76,612            | 87,896       | – 15
| CYPRESS LAKE (metro) | FL | 662              | 352,551          | 101                | 55,466            | 34,571       | 38
| DALLAS – FT WORTH (metro) | TX | 5316             | 4,620,166        | 150                | 63,537            | 56,346       | 11
| Danbury      | CT      | 247              | 104,327          | 283                | 128,557          | 123,418      | 4
| DAYTONA BEACH (metro) | FL | 210              | 85,379           | 1585               | 875,665          | 1,016,429    | – 18
| De Land – Deltona | FL | 198              | 79,394           | 111                | 64,216           | 38,847       | 40
| Decatur      | IL      | 297              | 131,002          | 3506               | 3,676,239        | 2,763,015    | 25
| Denison – Sherman | TX | 300              | 132,639          | 151                | 89,118           | 56,811       | 36
| DENVER (metro) | CO | 2456             | 1,788,147        | 4195               | 2,193,189        | 3,448,442    | – 57
| Derby        | KS      | 656              | 348,609          | 180                | 51,334           | 70,577       | – 37
| DES MOINES (metro) | IA | 738              | 403,197          | 552                | 278,531          | 281,675      | – 1
| DETROIT (metro) | MI | 4551             | 3,772,066        | 339                | 246,740          | 293,251      | 27
| Dothan        | AL      | 362              | 61,965           | 209                | 94,746           | 84,877       | 11
| Dubuque      | IA      | 180              | 70,577           | 76                 | 78,265           | 24,331       | 69
| Duluth – Superior | MN/WI | 354              | 162,724          | 360                | 182,291          | 166,137      | 9
| Durham – Chapel Hill – Raleigh | NC | 1152             | 698,847          | 228                | 91,087           | 94,507       | 4
| Eau Claire – Chippewa Falls | WI | 330              | 149,209          | 286                | 120,472          | 125,036      | 4
| EL PASO (metro) | TX | 685              | 367,741          | 397                | 79,716           | 187,476      | – 135
| Elmira        | NY      | 119              | 42,333           | 82                 | 62,516           | 26,725       | 57

Table 1 (continued)
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<th>Estimated population</th>
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**Notes:**
- The table lists cities and their metropolitan areas, along with their populations and percentage changes.
- The data seems to be organized by city, state, and codes, with population and change percentages.
- The table includes columns for the city name, state abbreviation, population (in thousands), change, and percentage change.
urban areas such as the Los Angeles metropolitan area and the Dallas–Ft. Worth metropolitan area have dramatically different per capita land use consumption. This variability is the fundamental basis of many questions regarding “Urban Sprawl”.

4. Discussion

These aggregate indicators of “Urban Sprawl” for the urban areas of the United States do not suggest that there are

Fig. 5. Low threshold urban clusters with population greater than 50,000 classified based on Ln(Area) vs. Ln(Population) relationship. Cities with “sprawl” appear red and orange.

Fig. 6. High threshold urban clusters with population greater than 50,000 classified according to percent deviation from expected population based on Ln(Area) vs. Ln(Population) relationship. Cities with “sprawl” appear red and orange.
no areas of “Urban Sprawl” within urban areas above the “Sprawl Line”; however, these results are comparable yet different than previously determined aggregate numbers because they are scale-adjusted. It is very likely that the green urban areas in Figs. 5 and 6 that are well above the “Sprawl Line” contain smaller areas within them that most people would characterize as “Urban Sprawl”. In order to identify these areas, finer spatial resolution data would be needed in addition to other metrics that accounted for mixed use zoning, availability of green-space, residential-employment based commuter-sheds, etc. It is very likely that larger urban areas have ‘pockets of sprawl’ within or around them that are not captured by these aggregate measures. Despite the coarse resolution of the indicators presented here, the patterns displayed are interesting. The majority of coastal urban areas (with the notable exception of Houston) had lower per capita land consumption (i.e. fall below the “Sprawl Line”). This may result from the higher costs of coastal land and the pressures to utilize coastal lands more intensively. Similar reasoning may explain why so many of the inland cities have high per capita land consumption (i.e. fall above the “Sprawl Line”). This may result from the higher costs of coastal land and the pressures to utilize coastal lands more intensively. Similar reasoning may explain why so many of the inland cities have high per capita land consumption (i.e. fall below the “Sprawl Line” because inland real estate is not influenced by coastal effects). Other geographic influences such as mountain ranges, deserts, and swamps may also influence urban areal extent. Nonetheless, this regional variability of “Urban Sprawl” conflicts with conventional wisdom in many ways (Fulton et al., 2001).

Conventional wisdom suggests that ‘auto-oriented’ western cities will suffer from “Urban Sprawl” more than older Northeastern and Midwestern cities because their initial development occurred prior to widespread automobile use. The results of this research and the conclusions of Fulton et al. counter conventional wisdom. Western cities, despite their ‘automobile-oriented’ development have less per capita land consumption than most Midwestern and many Northeastern cities. Some of the temporal dynamics that explain this counter-intuitive truth are described in: “Who Sprawls Most? How Growth Patterns Differ Across the U.S.” (Fulton et al., 2001). As cities grow in population, urban sprawl questions often come down to questions of per capita land use consumption.

This study provides a snap-shot of urban land use consumption utilizing a ‘scale-adjustment’ and a systematic measure of urban area. As urban areas grow, a key question regarding urban sprawl is whether it is a result of population growth or land use planning decisions. The relative contributions of increasing population and land use planning decisions complicate public perception of “Urban Sprawl”. Per capita land use consumption as measured by scale-adjusted aggregate population density indicators show counter-intuitive results with respect to the issue of “Urban Sprawl”.

Most residents of Denver, CO would claim that Denver is experiencing “Urban Sprawl”. Yet these same people would be surprised to find that cities like Minneapolis–St. Paul have more “Urban Sprawl” than Denver. They would also claim that “Urban Sprawl” in Los Angeles is much worse than it is in Denver (despite evidence to the contrary). In many respects, the term “Urban Sprawl” may be a polite or ‘politically correct’ means of complaining about the negative consequences of population growth or the changing ‘scale’ of the total population of the city they live in. Future studies may show that absolute scale (i.e. total population of contiguous urban area) may have more influence on both public perception and practical assessments of the negative consequences of what is conventionally termed “Urban Sprawl”.

“Urban Sprawl” is often blamed as the cause of traffic congestion, loss of open space, and other general problems in the urban environment. Rational Land Use Planning is often touted as the means of avoiding the negative consequences of “Urban Sprawl”. In Denver, this rational planning has resulted in high-density developments on the urban fringe. The resulting high residential density on the urban periphery with traditional high-density employment in the core resulted in long commuting distances and traffic congestion. Subsequently, the following unplanned results were: (1) development of the “Tech Center” outside of the central business district (CBD) to the southeast, 2) ‘Pop-tops’ and ‘Scrape-offs’ resulting in increased housing density and cost just outside the CBD, and (3) an ever expanding ‘commuter-shed’ of people who work in Denver but live over 20 miles outside of the city in ‘rural’ or ‘ex-urban’ places like Conifer, Evergreen, Genesee, and Bailey.

The economics of real estate in many cities in the US is forcing the core ‘middle class’ citizens (e.g. Teachers, Police Officers, and Nurses) out of their midst because of the increasing cost of urban housing. Populations that live in the ‘commuter-shed’ but not in the ‘urban’ area represent a significant and growing fraction of the driving public of many urban areas in the United States. These populations raise significant questions about the meaning and legitimacy of measurements of urban sprawl based on contiguous urban areas (including this one). Important questions to ask are: (1) To what extent do ‘ex-urbas’ contribute to the negative consequences of “Urban Sprawl”, (2) Why do ‘ex-urbas’ choose to live outside the urban area (cheaper housing, better schools, commute with nature, they like to drive, etc.), and (3) What mechanisms can city planners use to influence the areal extent and population of their ‘ex-urban’ commuter-shed?

The low light levels seen the DMSP OLS imagery that do not fall in either the “High Threshold” or “Low Threshold” definition of urban used here often represent this commuter-shed of middle and high income people who work in the urban core. This phenomenon is perhaps an ironic counter example of the “Spatial Mismatch” of low-income inner-city potential employees and the suburban employment opportunities that exist for them (Kasarda, 1988). It is interesting to note that cities like Los Angeles (often noted for urban sprawl) do not suffer from high per capita levels of land use consumption. Does this fact imply that Los
Angeles does not suffer from “Urban Sprawl?” These low light intensity areas that are measured by the DMSP OLS imagery but fall outside of both of the thresholds used here may be usefully incorporated into new measures of urban extent for characterizing more complex definitions of regions such as commuter-sheds and ‘functional regions’ for urban areas.

Measuring “Urban Sprawl” may be a red herring in that it is too difficult to provide a single number that characterizes “Urban Sprawl” for any meaningful areal extent. Los Angeles is developing in all the right ways to avoid “Urban Sprawl” as far as the experts are concerned; nonetheless, Los Angeles continues to suffer from traffic congestion, lack of open space, and high per capita expenditures of energy (Egan, 2002). There are many reasons that potentially explain why Los Angeles and other cities in the US perform well by aggregate indicators of “Urban Sprawl”: (1) It may be due to the aforementioned reasons associated with coastal land and/or the local cost of real estate, (2) It may simply be a function of the absolute size of the city, or (3) It may be due to impacts that the forces of globalization have on ‘global’ cities like Los Angeles. Cities in less developed countries generally have much lower levels of per capita land consumption (Sutton et al., 2001). This is typically explained by the lower levels of economic development found in these cities and the implications that these levels of development imply with respect to fewer people driving cars (and the sprawl associated with a driving population).

Aggregate measures of “Urban Sprawl” as provided here do not provide much insight to planners for any given urban area. Intra-urban decisions about land-use planning and residence vs. employment intensive areas will have more impact on traffic congestion, green-space availability, and per capita energy consumption. In this respect, William Whyte’s focus on ‘patterns of development’ regarding “Urban Sprawl” is more useful (Whyte, 1958). Nonetheless, the aggregate measures of “Urban Sprawl” described here do raise interesting questions about the dynamics of urban development. “Urban Sprawl” can be measured by aggregate measures of per capita land consumption; however, the negative attributes associated with “Urban Sprawl” are really a complex interaction of the total size of the urban area in question (scale), the intra-urban land use planning (i.e spatial ‘match’ or ‘mis-match’ of jobs and housing), and culturally defined tolerances associated with urban life (globalization). Remotely sensed datasets at a range of spatial and temporal scales nonetheless have great potential for informing the planning process and monitoring and characterizing many urban patterns and processes.

The patterns shown in Figs. 5 and 6 raise interesting questions about the dynamics of “Urban Sprawl” in the United States. Coastal cities as far apart as Boston and Los Angeles show lower aggregate levels of “Urban Sprawl” than inland cities such as Atlanta and Minneapolis–St. Paul.

Conventional wisdom suggests that aggregate levels of “Urban Sprawl” would be more related to historical development than these measures indicate. Conventional wisdom may be ignoring the more recent ‘historical’ international migration to many of these cities with lower per capita land use consumption. This migration is differentially changing the demographics, social mores, and aggregate density of the cities of the United States. The spatial patterns shown in Figs. 5 and 6 suggest future research questions about the relative contributions of the impacts of globalization, land-use planning, and scale on “Urban Sprawl”.

5. Conclusion

Clearly, measuring “Urban Sprawl” is a daunting task. Many people decide “Urban Sprawl” is happening in their backyard based on perceived negative experiences such as traffic congestion, changing demographics, or overall population growth that is correctly or incorrectly attributed to “Urban Sprawl”. This investigation presents a measure of “Urban Sprawl” that is scale-adjusted to the total population of an urban area and uses nighttime satellite imagery as an objective and uniform measure of the areal extent of metropolitan areas with populations greater than 50,000. Aggregate measures of per capita land consumption using these methods show that western cities like Los Angeles and San Francisco have lower levels of “Urban Sprawl” than inland and Midwestern cities such as Atlanta, St. Louis, and Minneapolis. This total population or ‘scale-adjusted’ method of measuring sprawl produces an aggregate measure that allows for fair comparisons of the “Urban Sprawl” in large metropolitan areas to the “Urban Sprawl” in small metropolitan areas. Nonetheless, the nighttime imagery used to provide this measure of the areal extent of “urban” areas hints at problems with “Urban Sprawl” measures based on a single aggregate statistic derived solely from contiguous measures of areal extent. Most, if not all, of the low light levels not counted as “Urban” exist on the periphery of the areas that are counted as “Urban” (Fig. 1). These low light areas in the DMSP OLS imagery represent a growing population of ‘ex-urban’ citizens who drive to, and work in, urban environments and contribute to the negative consequences typically attributed to “Urban Sprawl.” Thorough understanding of the problems presently attributed to “Urban Sprawl” will require more in-depth studies that address the inter-related issues of globalization, intra-urban land use planning, and total spatio-demographic extent of the urban areas in question.

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References


