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Title: Spatial Characteristics of Exurban Settlement Pattern in the U.S.

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Abstract:

Despite pervasive exurban development in the United States over the last several decades, a lack of relatively precise data has hindered basic research, including classification of the types of emerging exurban settlement patterns. To address this gap, we make use of a spatially explicit population database to examine exurban pattern. A typology of exurban patches is developed revealing substantial heterogeneity in fine-scale pattern not reflected by aggregate measures of population density. Exurban pattern is found to be positively correlated with metropolitan characteristics commonly believed to influence urban decentralization, including size of the urbanized area, commuting, income, and agricultural profitability.

Key Words: exurban, peri-urban, landscape pattern

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Introduction

Urban decentralization has been the dominant trend in shaping land use patterns in United States (US) metropolitan regions over the last century. In addition to suburban growth, urban development is increasingly occurring in formerly agricultural or natural areas located outside suburban areas (Heimlich & Anderson, 2001; Irwin & Bockstael, 2006; Fulton, Pendall, Nguyen, & Harrison, 2001). Development in these exurban[1] regions is most often low density and scattered, resulting in a patchwork of residential development, roads and rural land punctuated by other urban land uses, including retail strips, mega-churches and industrial facilities.

While a few researchers sought to define and describe exurban regions as they evolved in the 1980s and 1990s (e.g., Audirac, 1999; Nelson, 1992), it has remained an understudied region. Only recently has it emerged as a distinct geographical, political and cultural force within modern America, spurred in part by the 2004 presidential elections. Lack of spatially explicit and consistent data on exurbanization nationwide is a major limitation in developing a better understanding of exurban regions and their basic characteristics. Analysis of population and housing trends in nonmetropolitan areas has provided some indication of the pervasiveness of exurban development (e.g., Heimlich & Anderson, 2001; Nelson, 1992). However, because exurbia transcends the traditional dichotomy of urban versus rural and metropolitan versus nonmetropolitan, standard census data are of limited value in analyzing these regions (Theobald, 2001). Previous attempts to measure exurban development have had problems with scope (misspecifying the exurban "field" as distinct from urban/suburban and rural) (Wolman, Galster, Hanson,

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[1] This region has been referred to by many different names including: exurbia, peri-urban area, rural-urban fringe, urban shadow, metropolitan orbit, extended urban area, and urban shadow.

Ratcliffe, Furdell, & Sarzynski, 2005) or scale problems as a result of relying on aggregate data, such as county-level statistics, that mask lower-level patterns (Longley & Mesev, 2002).

The lack of basic descriptive data on exurban areas has inhibited consistent comparison of exurban places across the country and therefore hindering meaningful public debate and policymaking (Galster, Hanson, Tratcliffe, Wolman, Coleman, & Freihage, 2001). As a result, many urban researchers are aware that development is taking place beyond urbanized boundaries, but do not have a precise measure of this phenomenon. While local planners and officials are aware of this growth and are forced to grapple with its consequences, they know only the specific manifestations of this growth in their local area. Thus, while some aggregate measures and anecdotal evidence of these trends exists, there is a dearth of consistent analysis on the extent and characterization of exurban patterns nationwide, let alone the relationship between these patterns and the geographic, economic and other characteristics of metropolitan areas.

The goal of this paper is to provide a national examination of exurbia, addressing previous problems of scope and scale by providing a straightforward method that provides a consistent, fine-scale measure of exurbia across the US. We construct a definition of exurbia that is conceptually accurate and spatially explicit. Using techniques from the field of landscape ecology, we are able to focus specifically on the *pattern* and *configuration* of exurbia. We use the term “exurbia” or the description of “low-density, urban-dependent development” in this paper to represent the phenomena of interest and the term “exurban field” to describe the geographical area in which exurban development can take place.

To the extent that pattern and process are related, such pattern analysis is the first step to identifying variation in the structure and function of exurban settlements across the US. Towards this end, we seek to answer the following questions: (1) Can we usefully operationalize a measure of exurbia across the United States? (2) Can we create an effective method for looking at finer scale exurban pattern? (3) Does analyzing cross-scale exurban patterns in this way suggest potential hypotheses regarding the underlying processes that lead to the variation in exurban pattern that we observe?

Defining the Exurban Field

Spectorsky (1955), who is commonly credited with coining the term "exurbia," first elucidated this new form and function of residential settlement emerging in the New York metropolitan area in his book, *The Exurbanites*. At that time exurbia was an oasis only accessible by the urban elite because of the high cost of automobiles and limited highway network. As incomes and automobile ownership increased and new roads were built, this oasis expanded to become the new frontier for those seeking larger houses for less money, better schools, a bit of country, and the like. Currently, there are several related approaches to defining the exurban field. Most commonly, exurbia is conceptualized as a place of transition between urban and rural, located somewhere between the suburbs and truly rural areas and within the commuting zone of a large, urbanized area (Patel, 1980; Lamb, 1983; Nelson, 1992; Morrill, 1992; Davis et al., 1994; Nelson & Sanchez, 1997; Audirac, 1999; Theobald, 2001; Wolman et al., 2005).[2]

In operationalizing these concepts, researchers have had to use a more aggregate delineation of exurban areas due to the limitations of available data. For example, Nelson

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[2] Audirac (1999) and Berube, Singer, Wilson, & Frey (forthcoming) provide an overview of this literature.

(1992) utilizes population density at the county level. Hoffine Wilson, Hurd, Civco, Prisloe, and Arnold (2003) also create a replicable model that and can analyze over various time periods, but they use LandSat imagery, which dramatically understates the amount of low-density development, the very phenomena of interest. More recently, Berube et al. (forthcoming) use fast growing census tracts within commuting distance of urban areas.

Measuring Exurban Patterns

Density is the most common description of urban land use pattern, including exurban patterns, but there is little agreement on how to operationalize this measure (Torrens & Alberti, 2000). As Bessusi and Chin (2003) point out, average density, often the average density over the entire study area, is the simplest measure, but is often too imprecise or incomplete. A density gradient, which measures the change in population density as distance from a central urban node increases, is a measure often used to describe population decentralization (e.g., Mieszkowski & Smith, 1991). However, this approach typically imposes functional form assumptions that often do not allow for the asymmetric "peaks" and "valleys" that characterize most urban-rural density patterns.

Moving beyond density, several authors have suggested a two-dimensional typology of urban and exurban growth patterns. Hoffine Wilson et al. (2003), for example, identify five classes of urban growth patterns: infill, expansion, isolated, linear branch and clustered branch. Camagni, Gibelli & Rigamonti (2002) provide an elegant framework to classify patches of exurban development, following five dimensions that are combined in a matrix to produce ten different types. These types vary by form (linear, clustered and unclustered) and location (infilling and scattered). According to Forman

(1995), these patterns are typical of exurban development, occurring along exurban transportation corridors (linear), spreading from towns and infilling near towns (contiguous clusters), some small built areas (isolated). See Figure 1 for an illustration of some of these types.

Landscape ecology principles have been useful in operationalizing spatially explicit measures of urban form and in particular, measures of urban sprawl (Bessusi & Chin, 2003; Malpezzi & Guo Wen-Kai, 2001; Galster et al., 2001; Torrens & Alberti, 2000). Galster et al. (2001), for example, develop measures that characterize eight different dimensions of urban form: density, contiguity, concentration, clustering, centrality, nuclearity, mixed uses, and proximity. Sprawl[3] is defined as a pattern of land use that exhibits low levels of some combination of these eight measures. They apply their approach using 1990 Census block data for a sample of thirteen urbanized areas in the U.S. and compute a composite sprawl index for each of these urbanized areas. Results show that cities tend to be ranked differently depending on the particular dimension of pattern considered. Burchfield, Overman, Puga and Turner (2006) measure sprawl utilizing a 30 X 30 meter grid to determine the amount of undeveloped land surrounding an average urban dwelling.

Several types of data have been used to measure urban form. These databases include the US Department of Agriculture (USDA) National Resource Inventory (an assessment of land use), different land cover imagery, and the US Bureau of the Census

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[3] It is important to distinguish exurbia from the notion of suburban sprawl. The word “sprawl,” despite its popular appeal, is an imprecise term used for different urban forms. “Sprawl” promotes the idea that the development is attached to or extending from something, with amoeba-like arms. In reality, exurbia merely needs to be only loosely within proximity of urban areas so that exurbanites can experience urban benefits when they want to. The pattern of exurban development typically occurs scattered and in traditionally rural areas, regardless, perhaps, of the suburbanization pattern.

population census. While the population census does provide disaggregated data at the block group level, block groups vary in size, becoming larger and larger in the very area of interest beyond the urban fringe. None of these databases represent changes beyond the fringe well because they are based on notions of “urbanization” rather than “exurbanization,” which occurs mostly at population densities below urban densities (Theobald, 2001). Thus, much of the explicit spatial analysis of urban form has focused on urbanized areas (e.g., Galster et al., 2001). Moreover, most of the studies suffer from overbounding and underbounding because of coarse spatial analytical units (Theobold, 2001). Available time-series satellite data, such as Landsat imagery, can be useful, but generally dramatically understates the amount of low-density development, the very phenomena of interest (Irwin & Bockstael, 2006).

Because of these data limitations, no study to date has provided a comprehensive description of exurbanization patterns across the U.S. We are aware of only two studies that have provided a comprehensive analysis of exurban areas across the U.S. at a more aggregate scale of analysis: Nelson (1992) and Berube et al. (forthcoming). This paper provides a first attempt at moving beyond aggregate descriptions of exurban areas by considering the spatial configuration of exurban settlement patterns at a finer scale of analysis.

Study Area

The extent of the study area for this analysis is the lower 48 United States (see Figure 2). Within this, we are interested in defining the US “exurban field”—the regions of the US in which exurban development takes place. We begin by defining the outer boundary of the exurban field using the US Bureau of the Census 2003 defined

Metropolitan Statistical Areas (MSA). There are 356 MSAs in the lower 48 states, comprised of 1,080 counties. MSAs are geographic areas that consist of the county or counties associated with at least one core urbanized area with a population of at least 50,000, plus adjacent counties having a high degree of social and economic integration with the core, as measured through commuting ties with the counties containing the core. Thus, the MSA delineation provides an approximate geographical extent of the commutershed that corresponds to large urbanized areas in the U.S.

To isolate the exurban field within MSAs, we omit the more densely populated areas. In the US, urbanized areas are densely settled areas (typically at least 1,000 people per square mile) with a population of at least 50,000 people. Using Geographic Information Systems (GIS), we remove the urbanized areas from the MSAs. In addition, we omit non-developable land by removing major water bodies and federal lands (including National Forests, Bureau of Land Management lands, National Wildlife Refuges, National Parks and Wilderness Areas).[4] The remainder area is the less densely populated area of MSAs, what we refer to as the U.S. exurban field. This method of identifying the exurban field satisfies three primary objectives: first, it delineates the exurban field based on the notion of a potential commutershed; second, it captures those areas that that are dependent on urbanized areas, but are not already urbanized; and third, it overcomes the problem of under-bounding and over-bounding discussed earlier.

Measuring Exurbia

With this definition in hand, data from the 2003 LandScan population distribution model, created by the US Department of Energy's Oak Ridge National Laboratory (UT

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[4] The spatial data for federal lands, major water bodies, and state, county and urbanized area boundaries were obtained from the National Atlas of the United States of America, US Department of the Interior: http://www.nationalatlas.gov/maplayers.html.

Battelle, LLC., 2005), are used to describe the spatial characteristics of exurban settlement patterns located within the exurban field. The LandScan model estimates worldwide ambient populations at a 30” by 30” resolution (approximately 0.69 square km in the lower 48 states), which is the finest-scale global population data produced to date (Bhaduri, Bright, Coleman & Dobson, 2002). The model spatially allocates population on this grid by assigning a probability coefficient to each cell which is then applied to census counts. The probability coefficients for each cell are based on factors that contribute to population density, e.g. transportation networks, land cover, slope, and nighttime lights. This dataset has been described as making a “foundational” contribution to future social economic and demographic study (Sutton, Elvidge, & Obremski, 2003). Nonetheless, it should be noted that these are population density estimates and not actual counts. Despite this weakness, the LandScan data provide a consistent, fine-scale representation of population density on a regular grid for the entire U.S. For this reason, we conclude that the advantage of using the LandScan data for national comparison of regional exurban patterns far outweighs the limitation.

To identify the pattern of exurban settlement using data on population density, a classification scheme is necessary. We assign a density class and settlement type for each cell according to the categorization found in Table 1. While any classification scheme is to some extent ad hoc, the definition for the medium density class used here to quantify exurban settlement patterns generally reflects lot sizes typified by the “hobby farms” that can support houses without sewer connections, in addition to reflecting densities suggested by other researchers (Daniels, 1999; Theobald, 2001; Wolman et al., 2005).[5] Figure 3 provides an illustration of these categories for selected metropolitan exurban regions.

Table 2 reports the basic characteristics of the exurban field and exurban settlement patterns within this field in the US and by major region. The total estimated size of the exurban field is 668,342 square miles (1,731,009 square kilometers). Of this, ten percent is comprised of exurban settlement areas. The total amount of exurban area within the exurban field is 66,908 square miles (173,291 square kilometers), which is approximately the same size as all the urbanized areas in the lower 48 states (about 71,815 square miles or 186,000 square kilometers). There is considerable variation among regions of the US and among MSAs themselves. For instance, the South has the most exurban areas, while the Northeast has the highest percentage of the total land in its exurban field in an exurban settlement type. It is estimated that the Flagstaff, Arizona MSA has the smallest amount of exurban settlement, 28 kilometers, and also the smallest percentage of the exurban field in exurban settlement at 0.1%. The Atlanta, Georgia MSA has the largest quantity of exurban areas, 1,875 square miles (4,857 square kilometers), and the Gainesville, Georgia MSA has the highest percentage of the exurban field in an exurban settlement type at 57.6%. Tables 3 and 4 list the bottom and top twenty MSAs according to the amount of exurban settlement areas in the exurban field.

Spatial Characteristics of Exurban Settlement Patterns

While the aggregate statistics provide some insight as to the magnitude of exurban settlement, they do not provide any information regarding the pattern of exurban

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[5] In certain locations, densities in the 40-100 persons per square mile range can be observed in limited parts of the Western United States, where large ranches are subdivided as 20 to 40 acre ‘ranchettes.” Adopting a standard exurban density class, in order to have an unbiased national comparison of metropolitan areas, can introduce some regional bias.

development. This requires explicit consideration of the spatial configuration of the cells categorized as exurban settlement. To consider this, we define a patch as two or more contiguous cells that are of the same settlement type. We then consider the distribution of these patches across the landscape and the particular spatial configuration of exurban patches to further describe exurban patterns.

To characterize the spatial distribution of exurban cells across the exurban field, we calculate the Shannon Evenness Index:[6]

$$(1) \qquad -\sum_{i=1}^{m} \frac{(P_i * \ln P_i)}{\ln m},$$

where P_i is the proportion of the landscape occupied by settlement type i and m, the total number of settlement types present in the landscape. This index is close to zero when the distribution of patches across classes is uneven and approaches one as the distribution becomes more uniform.

To consider the spatial configuration of individual exurban patches and their spatial relation with other patches, we identify the patch shape, size and contiguity as the three most important attributes of patches in the landscape (Farina, 2000). First, each exurban density patch is categorized as one of three possible shapes: single cell, linear or clumped. Second, each patch is categorized as either small or large relative to the regional median size, where region refers to one of the four US Bureau of the Census regions (East, South, Midwest and West). Third, contiguity of an exurban patch is measured by whether or not a more dense settlement type is within a two cell distance. This three by two by two classification scheme results in ten unique shape-size-contiguity

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[6] This was calculated using Patch Analyst (McGarigal and Marks, 1994) in conjunction with ESRI's ArcView Spatial Analyst.

combinations that describe the spatial configuration of exurban settlement patches.[7] Figure 4 illustrates the corresponding three by two by two matrix. This matrix also identifies a natural rural-urban continuum of the various combinations from most rural-like exurban development (1) to most suburban-like exurban development (10). This rank ordering is indicated by the arrow in Figure 4.

To summarize the variation in spatial exurban settlement patterns across metropolitan areas, we compute a spatial index variable for each metropolitan area that reflects this rank ordering. Each exurban patch in each metropolitan region is typed using the classification scheme in Figure 4. For each metropolitan region, the frequency of patches across each of these ten categories is then calculated and from this, an index is calculated. This spatial index is computed by multiplying the frequency of patches for each category by the rank order of that category and summing over all ten categories. Thus, the higher the spatial index measure, the more contiguous and concentrated a metropolitan area's exurban settlement pattern. Table 5 illustrates the bottom and top twenty metropolitan areas in terms of this measure of exurban development. Comparing this table to tables 3 and 4, which rank metropolitan areas in terms of the amount of exurban settlement areas, there appears to be no similarities between the bottom or top twenty.

We use this spatial index variable to examine the extent to which aggregate measures of exurban spatial pattern correspond with variations in fine-scale exurban development patterns. To do so, we compare the spatial patch index, which summarizes variations in finer scale exurban patterns, with three aggregate measures of exurban

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[7] Because a single cell cannot be considered "large" by regional standards, there are only ten unique combinations that result from this three by two by two categorization of patches.

pattern: exurban population density,[8] the proportion of the exurban field that is exurban settlement and the Shannon's Evenness Index. If these aggregate measures are strongly correlated with the spatial patch index, then the added information from the fine-scale pattern measures is limited. However, we hypothesize that that these fine scale measures capture important variations in the pattern that are not reflected by aggregate pattern measures and thus that the correlation between the aggregate measures and the fine-scale pattern index is not high. To test this hypothesis, we perform a simple correlation analysis of the spatial index variable and these aggregate exurban measures by metropolitan region. Table 6 reports the correlation coefficients and their significance levels. In each case, we find that the fine-scale pattern index captures substantial differences in the pattern of exurban development from the aggregate measures of exurban pattern.

Exurban Patterns and Metropolitan Characteristics

A number of geographical, demographic and economic characteristics of metropolitan areas have been found to be associated with urban decentralization. For example, some studies have found that higher density urbanized areas are associated with less suburban sprawl and that urbanized areas with more land area are correlated with more urban decentralization (Fulton et al., 2001; Mieszkowski & Mills, 1993; Lopez & Hynes, 2003; Ewing, Pendall & Chen, 2002). Geographic factors, such as physical access to exurban areas and longer commuting times (Ewing, 1997; Brueckner, 2000; Mieszkowski & Mills, 1993; Cervero & Landis, 1995; Davis, 1993) are associated with increased urban decentralization. In addition, urban decentralization is correlated with

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[8] Population density was computed for the exurban field using 2000 population census non urbanized population by metropolitan area.

higher rural natural amenities (McGranahan, 1999; Shumway & Otterstrom, 2001; Deller, Tsai, Marcouller, & English, 2001) and inferior central city services, including public schools (Bayoh, Irwin & Haab, 2006). Regional economic factors like increased income (Margo, 1992) and decentralization of employment centers (Thurston & Yezer, 1994; Glaeser, Kahn & Chu, 2001) are correlated with increased population suburbanization, whereas a healthy rural sector or a large prime farmland base is correlated with less urban decentralization (Fulton et al. 2001). Finally, local administrative conditions, such as the amount of local governmental fragmentation are linked to greater suburban sprawl (Carruthers & Ulfarsson, 2002).

None of the above studies have explicitly considered the association of these urban decentralization factors with measures of exurban patterns. Instead, they have focused on urban decentralization patterns at the scale of the entire metropolitan area, urbanized area or individual county. Here we explore the association of urban decentralization factors with the following explicit measures of exurbia: (1) population density of the exurban field; (2) the proportion of the exurban field that is classified as an exurban settlement type; (3) the spatial distribution of exurban settlement areas across the exurban field (using the Shannon Evenness Index) and (4) the spatial pattern of exurban patches (using the spatial patch index).

We first compute simple correlations of these four exurban measures and the following metropolitan characteristics: urbanized area size, average urbanized area population density, exurban road density, percent of workers commuting more than 30 minutes; natural amenity index; average household income; percent of employment within one mile of the central business district (CBD); average agricultural sales per acre;

and the density of local governments.[9] The direction of hypothesized correlation is summarized in Table 7 and Table 8 reports the results of the correlation analysis. The spatial patch index is significantly correlated all of the metropolitan characteristics. However, three are in the opposite direction than theorized: urban area population density, exurban field road density and agricultural sales per acres. The proportion of the exurban field that falls within an exurban density of 100-1,000 persons per square mile and the Shannon Evenness Index follow all expected relationships except for total agricultural sales per acre. They have the same directional relationship as the aggregate measure of population density of the exurban field, but the associations are stronger with the other two measures. The only factor that is significantly correlated with aggregate density and not with the other two measures is the density of the road network in the exurban field. Because the population density measure takes into account *all* settlement patterns within the exurban field, it is more likely to capture the variations reflected in road density. Also, road density is an input into the LandScan model, perhaps contributing to this correlation. In contrast, the exurban settlement measure is a more refined measure that takes into account only the exurban settlement pattern in the exurban field. The Shannon Evenness Index provides more information concerning distribution of the exurban settlement pattern in the exurban field. Overall, it appears that the spatial patch index, exurban settlement measure and the Shannon Evenness Index of the exurban

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[9] Data on the road mileage by county were obtained from US Department of Transportation (USDOT) (Office of Highway Policy Information, USDOT, 2005). Employment data for 2000 by zip code were acquired using the Economic Census “Zip Code Business Patterns” (Bureau of the Census, 2000). The central business districts (CBDs) used in this analysis are those that were delineated in the 1982 Economic Census Geographic Reference Manual (Glaeser, Kahn & Chu, 2001). Because this is the most recent data available, only those CBDs in metropolitan areas that existed in 1982 are identified in this study. The 1982 CBDs were attributed to the appropriate 2003 MSAs. To calculate the percent of metropolitan employment that is located within one mile of the central business district, an area-weighted assignment was made for zip codes that crossed the one-mile CBD buffer boundary.

settlement measure provide more information than simple population density for the exurban field, capturing more precisely the variations in exurban development patterns that are correlated with these characteristics. This suggests that these measures are capturing important variations in exurban development pattern that are possibly linked to these underlying geographical and socioeconomic processes.

Second, to further examine these relationships, we estimate four separate OLS regression models in which each of the four exurban measures is regressed on the same set of metropolitan characteristics listed in Table 7 using Ordinary Least Squares (OLS) regression.[10] Based on the correlation results reported in Table 8, it is expected that the metropolitan characteristics associated with urban decentralization will explain more variation in the explicit exurban density pattern measures than aggregate population density. Table 9 reports the results of this exercise. The R-square result from the model with the spatial patch index dependent variable is very low and only one metro characteristic is significant and in the anticipated direction. For all other dependent variables, the results are as expected (expect for the agricultural and amenity factors). The percent of the exurban field in exurban settlement behaves in the same direction, has higher R-squared and coefficients with larger magnitudes, indicating again that this exurban measure captures more of the variation in exurban development that is correlated with this set of metropolitan characteristics. The Shannon Evenness Index also has a higher R-squared than the aggregate population density model, which indicates that the spatial distribution of this exurban settlement patterns matter is more strongly associated with these factors as well. In addition, the standard errors are smaller with the Shannon

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[10] Given the simultaneity of many of these factors with our measures of exurbanization, such an analysis reveals a more refined indication of association, but not causation, between these urban decentralization factors and the various measures of exurban pattern.

Evenness Index than in either of the other two models, indicating a better model fit. These results suggest that the explicit amount and spatial distribution of exurban density patterns are capturing important variations in exurban development pattern that are related to the underlying geographical and socioeconomic processes represented by these metropolitan characteristics.

Finally, given the low R-square of the spatial pattern index regression, we further explore how different pattern types related to the metropolitan factors associated with urban deconcentration. The relative amount of each patch type that makes up the spatial patch index (Figure 4) is correlated with the metropolitan characteristics listed in Table 7. All variables that had skewed distributions were normalized using the box-cox transformation so that these methods could be carried out. It is expected that some or all patch types will be correlated with these characteristics, but overall, it is expected that the relationships will vary across patch types. Table 10 is the first of these tables, demonstrating relationships between the total amount (in km^2) of each pattern type in the exurban field. The significant relationships ($p < 0.05$) are noted and highlighted in gray if the results conform with expected direction.

The results indicate substantial variation by patch type. First, some types have stronger relationships than other types. In general, the contiguous patch types appear to have stronger relationships, except with urban area population density. Second, some patch types are significantly correlated to the factors while some are not. None of the patches are significantly correlated in the expected direction with the amenity index and only two patch types, single-contiguous, and linear-contiguous-small, are correlated with exurban field road density. None of the patches are correlated in the expected direction with agricultural sales per acre. Overall, the clumped-contiguous-large pattern had the strongest significant correlation with most factors when compared to other types.

Because there appears to be a distinction among the patch types in Table 10, particularly between isolated and contiguous patches, we generalize the groupings used to distinguish patch types. Table 11 reports the correlations between each of these more general groups and the metropolitan characteristics. The first grouping omits the size dimension and distinguishes the patch types by shape (single, linear and clumped) and contiguity (isolated and contiguous), yielding six patch types. Two interesting findings emerge. First, all the isolated shapes appear to behave like one another while the contiguous shapes do not; and, second, the isolated shapes generally behave opposite of the expected direction, while the clumped-contiguous shape has relationships with the factors in the expected direction. The second grouping reported in Table 9 is simply by contiguity. This grouping demonstrates the clear distinction between contiguity and the relationship with urban decentralization factors. In general, the contiguous patches behave in the expected direction while the isolated patches do not. This is interesting because isolated patches are still within the commuting zone of an urban area. Finally, the third grouping reported in Table 11 is by shape. Here it appears that single and linear patches are similar in their relationship to urban decentralization factors, while clumped patches are clearly different. The associations of single and linear patches with these factors are contrary to the expected direction whereas the associations with clumped patches conform to expectations.

Summary and Conclusions

Using consistent definitions and readily available data, this paper identifies and quantifies exurban pattern across 356 metropolitan areas in the U.S. Our concept of the exurban field, as defined by those areas that are outside urbanized areas, but still economically dependent on urban centers, creates a consistent and defensible definition for the region in which exurban settlements can occur. Within this field we are able to measure the amount and spatial distribution of exurban settlement using a population database this is finer than even census block group geography. We use correlation and simple regression analysis to examine associations among aggregate exurban measures, fine-scale measures of exurban pattern and a set of metropolitan characteristics commonly believed to be related with urban decentralization.

The analysis is limited in several ways, First, this study is merely a snap-shot in time and therefore does not capture the dynamics of these settlement patterns, Second, although we take a stab at linking pattern to process by examining the associations between pattern and urban decentralization factors, this study speaks more to form than to function. Lastly, because we seek a consistent approach for delineating and quantifying all exurban areas in the U.S., we impose constant criteria across all regions. However, regional variations are substantial and thus, any regional study would have to adjust the density levels used to determine exurban density and the determination of the exurban field for local conditions.

Despite these limitations, a number of interesting findings emerge. First, we estimate that the total amount of exurban settlement areas within the exurban field is 66,908 square miles, which is slightly less than the combined area of all the urbanized areas in the lower 48 states. Thus, the total land area in the U.S. associated with population density levels that correspond to urban and exurban settlement respectively is roughly equal. Second, we find that the most commonly used measure of urban pattern, population density, captures very little of the variation in the spatial pattern of exurban form. Two alternative aggregate measures of exurban pattern, the relative amount of exurban settlement areas (defined as the percent of the exurban field that is in exurban settlement) and the spatial distribution of exurban settlement across the exurban field (as defined by the Shannon Evenness Index), have a stronger association with the overall spatial variation in fine-scale pattern. These two alternative measures of exurban pattern are better explained by the variations in metropolitan characteristics contributing to decentralization than is the aggregate population density measure. These results suggest that both the composition and spatial distribution of exurban density patterns are more closely related to the underlying geographical and socioeconomic processes represented by these metropolitan characteristics.

At the patch level, we find substantial heterogeneity across exurban patterns of development, ranging from clumped-contiguous-large exurban settlements to small-isolated settlements. These differences in pattern are meaningful and are found to vary in ways that cannot be collapsed into a single measure of population density. In examining the relationships between these pattern measures and the aggregate measures of exurban settlement and pattern, we find that the amount of exurban settlement and the population density in the exurban field are positively correlated with the proportion of clumped-contiguous exurban patches and negatively correlated with isolated-dispersed exurban patches. This suggests that as exurban areas grow, the pattern of exurban settlement evolves away from a scattered, isolated patterns of exurban settlement to one of greater contiguity and concentration in the exurban field. Finally, in examining the correlations between each of the fine-scale pattern types and the metropolitan characteristics associated with urban decentralization, we find a substantial amount of variation across different pattern types. The direction of the correlations between clumped-contiguous patches and the set of metropolitan characteristics are very similar to those found between the aggregate measures of exurban settlement and these same metropolitan characteristics. Many of the same factors that are positively associated with higher amounts of exurban settlement—including the size of the urbanized area, the proportion of workers commuting over 30 minutes, average household income, the number of local governments and agricultural sales per acre—are the same factors that are positively associated with greater contiguity and concentration of the exurban settlement pattern. In contrast, the correlations between the isolated-dispersed patches and the metropolitan characteristics are opposite in almost all cases. These results suggest several hypotheses regarding underlying causal relationships that warrant further exploration. First, it appears that the factors that contribute to more exurbanization may also lead to greater contiguity and concentration of exurban settlement. This again suggests an evolution of exurban settlement in which exurban growth leads to the transformation of isolated, dispersed patches of exurban settlement into contiguous, clumped exurban patches. Second, the processes that lead to isolated and dispersed exurban settlement may be different in some ways from those that drive exurban growth and foster contiguous, concentrated exurban settlement. The latter appears to be much more related to the general process of urban decentralization whereas the former may be influenced more by other forces not captured here, such as those associated with rural changes. This suggests important aspects of heterogeneity in exurbanization processes that may correspond to some of the differences in exurban pattern that we observe.

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Professional Experience

The Ohio State University, Columbus, Ohio
Interim Director, The Center for Farmland Policy Innovation, 2006-current

- Manage all operations of the Ohio Center for Farmland Policy Innovation.
- Establish an advisory board
- Prepare proposals, budgets and reports.
- Create the Farmland Policy Partnership Program and select field experiments and begin development
- Seek continuation funding
- Hire and manage additional staff (including graduate research students), as needed.

The Ohio State University, Columbus, Ohio
Program Manger, Exurban Change Program, 2002-current

- Organize and maintain a database of socioeconomic, demographic and geographic data for Ohio communities
- Manage and contribute to ongoing exurbanization research
- Conduct program outreach on managing growth and change at the rural-urban interface
- Develop and maintain an interactive website for the program
- Serve as land use and farmland preservation planning and policy expert on appropriate boards and committees
- Provide technical assistance in regards to population growth and change and land use
- Manage the OSU Retail Market Analysis Program

American Farmland Trust, Columbus, Ohio

Ohio Field Manager, 1999-2002

- Responded to technical requests from state and local governments, landowner and service providers on legislation, planning and program development and implementation
- Developed local farmland preservation programs with county and township partners
- Conducted public education, including preparing and delivering workshops
- Researched and evaluated other state and county farmland protection programs for partners
- Carried out all media communications
- Developed and engaged membership
- Organized annual statewide conference
- Managed all office activities, including budgeting, reporting developing and executing field office work plans and managing interns

Wisconsin Land Use Research Program and Program on Agricultural Technology Studies, University of Wisconsin – Madison Policy and Planning/GIS Research Assistant, 1998-1999

- Collected and statistically analyzed town-level land use data
- Created land use data books for Wisconsin counties and towns
- Constructed a Wisconsin agricultural Geographic Information System (GIS) database
- Conducted cost of community services studies in three Wisconsin towns
- Conducted interviews with local, county, regional and state government officials concerning land use decision-making

Land Information and Computer Graphics Facility, University of Wisconsin – Madison GIS Research Assistant, 1997-1999

- Developed GIS coursework for "Hands-On Land Use Planning" class with a focus on farmland preservation
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- Developed a land use GIS for Dane County
- Created and managed a GIS for University of Wisconsin Agricultural Research Stations

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Rural Sociology Society - member
Association of American Geographers - member
Regional Science Association International - member
Ohio Agricultural Easement Purchase Program advisory board – member 2000-2002 and 2005

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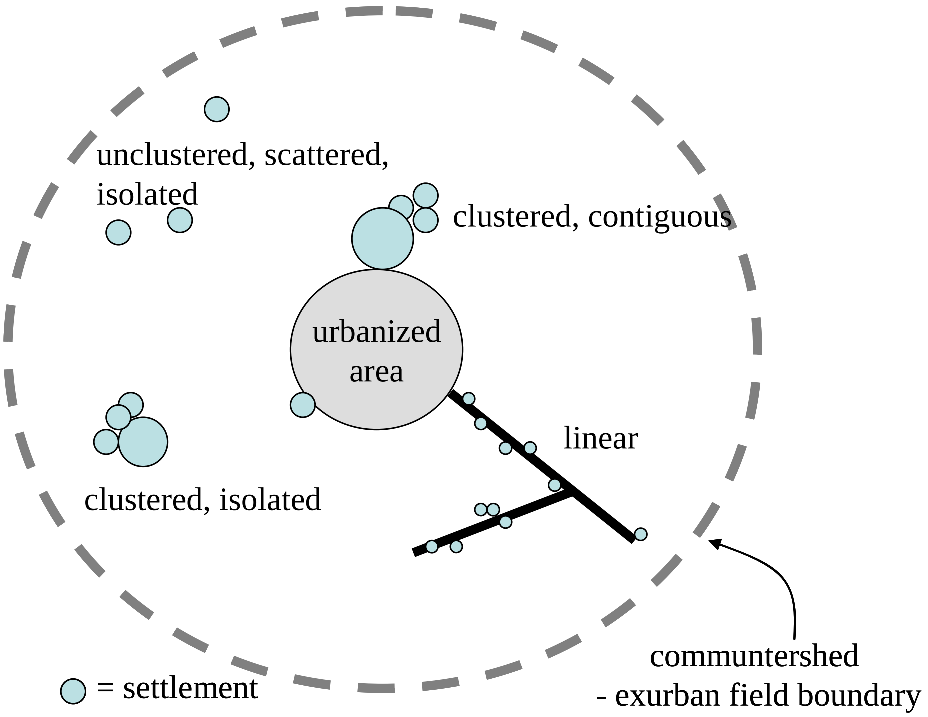

Figure 1. Exurban Settlement Patterns

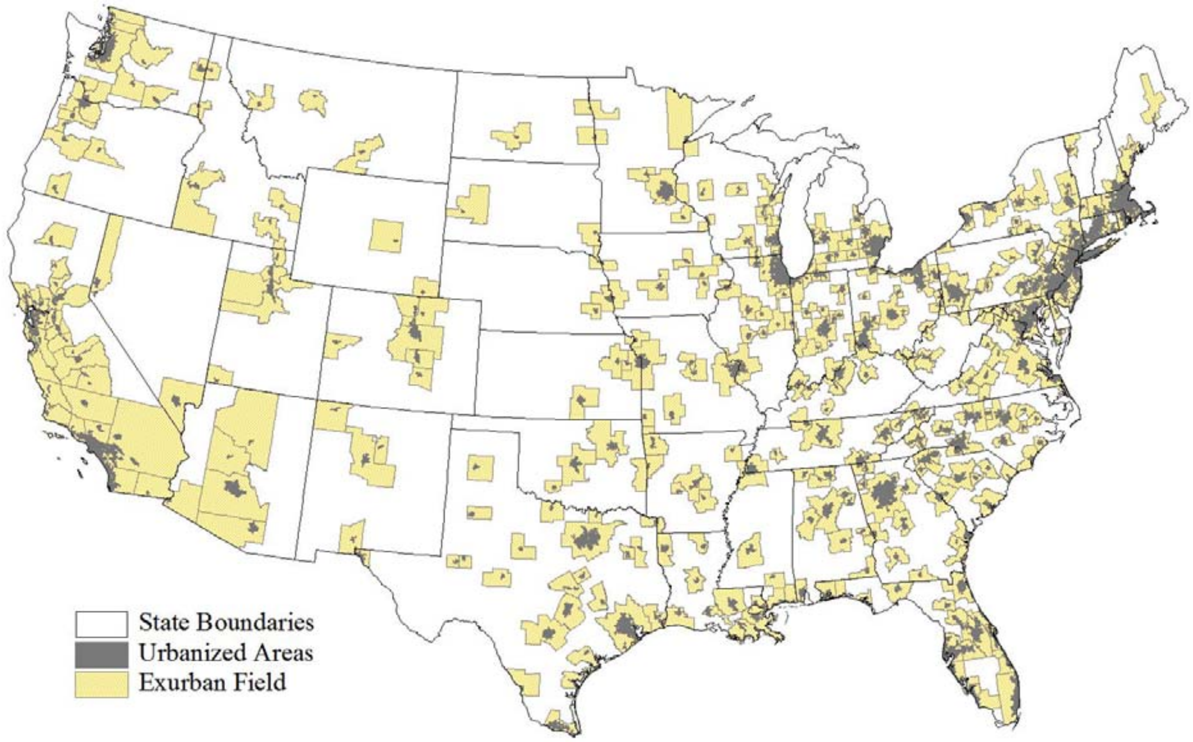

Figure 2: Map of Study Areas

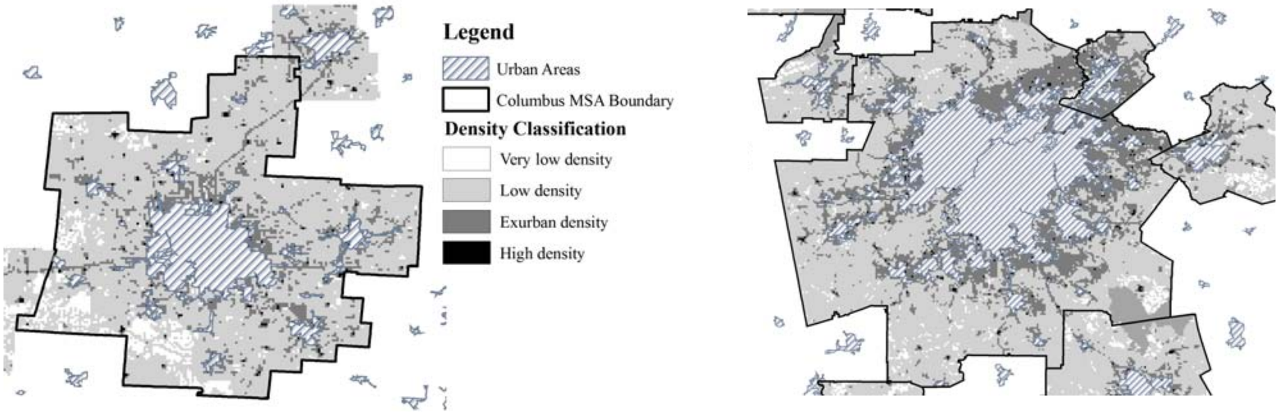

Figure 3. Density Patterns, Columbus, Ohio (left) and Atlanta, Georgia (right)

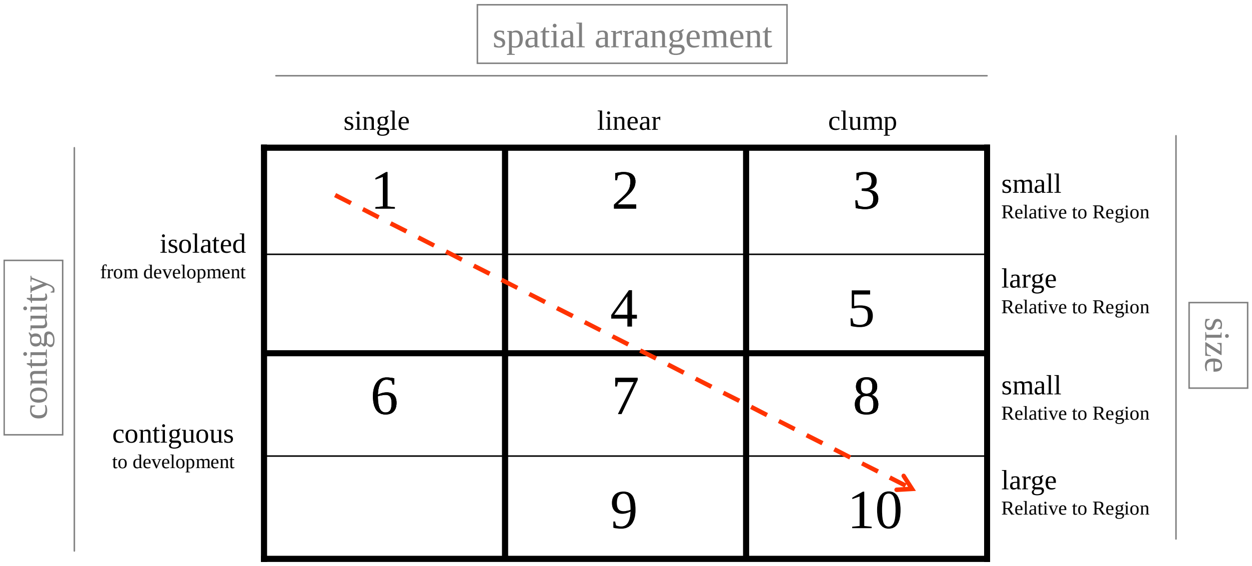

Figure 4. Matrix and Rank Ordering of Spatial Patch Types

Density class	**Settlement type**	**People per square mile**	**No. of acres per household**[a]
Very low	Rural/wilderness	0-10	165 or greater
Low	Rural	10-100	16.5-165
Medium	Exurban	100-1,000	1.6-16.5
High	Suburban/urban	1,000-100,000	1.6 or less

[a] Based on average household size in the U.S.

Table 1. Settlement Type Classification

Region	Entire MSA	MSA Exurban Field	Exurban Settlement Type	% Field in Exurban Density
Midwest	428,466	388,505	39,206	10.1%
Northeast	189,130	150,322	30,307	20.2%
West	5,224,922	489,259	23,337	4.8%
South	777,221	702,923	80,441	11.4%
Total	6,619,739	1,731,009	173,291	10.0%
	By MSA			
Minimum	591	259	28	0.1%
Maximum	35,737	33,343	4,857	57.6%
Average	5,386	4,862	487	12.6%
Standard Deviation	4,853	4,394	560	9.9%
				N=356

Table 2. Estimated LandScan Size (in kilometers) of the MSA, Exurban Field and Exurban Settlement Type by Region and by MSA

CBSA Name, State	Amt. Exurban Density (km)	UA Area (km)	Ratio Exurban/UA
Atlanta--Sandy Springs--Marietta, GA	4,857	5,317	91%
Minneapolis--St. Paul--Bloomington, M	3,843	2,316	166%
Washington--Arlington--Alexandria, VA	2,727	3,489	78%
Dallas--Fort Worth--Arlington, TX	2,726	4,029	68%
Houston--Baytown--Sugar Land, TX	2,561	3,733	69%
Pittsburgh, PA	2,541	2,549	100%
New York--Newark--Edison, NY-NJ-PA	2,444	10,208	24%
Philadelphia--Camden--Wilmington, PA-	2,183	6,215	35%
Nashville--Murfreesboro, TN	2,137	1,344	159%
Birmingham--Hoover, AL	2,085	1,016	205%
Boston--Cambridge--Quincy, MA-NH	2,027	7,521	27%
St. Louis, MO-IL	2,015	2,280	88%
Riverside--San Bernardino--Ontario, C	1,914	6,389	30%
Chicago--Naperville--Joliet, IL-IN-WI	1,828	5,998	30%
Detroit--Warren--Livonia, MI	1,797	4,589	39%
Cincinnati--Middletown, OH-KY-IN	1,793	2,702	66%
Baltimore--Towson, MD	1,704	5,167	33%
Charlotte--Gastonia--Concord, NC-SC	1,556	1,829	85%
Raleigh--Cary, NC	1,497	1,234	121%
Portland--Vancouver--Beaverton, OR-WA	1,444	1,297	111%

Table 3. Top 20 MSAs by Amount of Exurban Density Development (km)

CBSA Name, State	Amt. Exurban Density (km)	UA Area (km)	Ratio Exurban/UA
Flagstaff, AZ	28	84	34%
Lewiston, ID-WA	33	73	44%
Casper, WY	42	68	62%
Cheyenne, WY	50	88	57%
Laredo, TX	52	110	48%
Lawrence, KS	57	59	98%
Lawton, OK	64	143	45%
Great Falls, MT	67	74	90%
Pocatello, ID	67	78	87%
Bismarck, ND	74	88	84%
Billings, MT	75	119	63%
Corvallis, OR	76	75	101%
Victoria, TX	80	132	61%
Trenton--Ewing, NJ	82	8,999	1%
San Angelo, TX	85	118	72%
Vero Beach, FL	86	211	41%
Midland, TX	87	117	74%
Pueblo, CO	87	139	62%
Decatur, IL	88	130	67%
Danville, IL	88	80	110%

Table 4. Bottom 20 MSAs by Amount of Exurban Density Development (km)

CBSA Name, State	Rank - Patch	CBSA Name, State	Rank - Patch
Bowling Green, KY	2.83	Trenton--Ewing, NJ	6.32
Bangor, ME	2.90	Akron, OH	6.25
Owensboro, KY	2.93	Atlantic City, NJ	6.17
Gadsden, AL	2.94	Miami--Fort Lauderdale--Miami Beach,	6.16
Coeur d'Alene, ID	2.96	Lancaster, PA	6.14
Kennewick--Richland--Pasco, WA	2.98	Brownsville--Harlingen, TX	6.13
Burlington--South Burlington, VT	2.99	Laredo, TX	6.13
Charlottesville, VA	3.03	York--Hanover, PA	6.03
Florence, AL	3.18	Salem, OR	5.85
Portland--South Portland, ME	3.18	Bremerton--Silverdale, WA	5.85
Nashville--Murfreesboro, TN	3.26	Lebanon, PA	5.84
Erie, PA	3.26	Flagstaff, AZ	5.78
Jackson, TN	3.26	Las Vegas--Paradise, NV	5.75
Clarksville, TN-KY	3.29	Orlando, FL	5.72
Greensboro--High Point, NC	3.31	Tucson, AZ	5.71
Hinesville--Fort Stewart, GA	3.32	San Antonio, TX	5.71
Pittsfield, MA	3.33	Hanford--Corcoran, CA	5.67
Louisville, KY-IN	3.34	Lawrence, KS	5.65
Boise City--Nampa, ID	3.36	Philadelphia--Camden--Wilmington, PA-	5.62
Anderson, SC	3.37	Cheyenne, WY	5.62

(Note: Higher spatial index values correspond to more contiguous and concentrated exurban settlement)

Table 5. Bottom and Top Twenty MSAs According to the Spatial Patch Index

	spatial patch index	exurban field population density	% of exurban field in exurban settlement type
exurban field population density	-0.03		
% of exurban field in exurban settlement type	0.03	0.47[a]	
shannon evenness index	0.03	0.72[a]	0.55[a]

[a] Correlation is significant at the 0.01 level (2-tailed); n= 356

Table 6. Correlations

Characteristics	Direction
Ecological/Population	
Size of urbanized area associated with exurban field	+
Population density of urbanized areas	-
Geographic factors	
Physical access to exurban areas	+
Commuting time	+
Amenities	+
Regional economy	
Household income	+
Decentralization of employment centers[a]	+
Healthy agricultural sector	-
Local Administrative conditions	
Governmental fragmentation[b]	+

[a] from Glaeser, Kahn and Chu (2001)

[b] from Carruthers and Ulfarsson (2002)

Table 7. Metropolitan-level Characteristics Associated with Low-Density, Urban-Dependent Development

Metro Area Characteristics	spatial patch index	pop dens of exurban field from census	% of field in exurban density	shannon evenness index
urbanized area size (sq miles)	0.26[a]	0.29[a]	0.51[a]	0.52[a]
urbanized area population density	0.33[a]	-0.20[a]	-0.23[a]	-0.26[a]
exurban field road density	-0.20[a]	0.15[a]	0.06	0.04
percent works commuting > 30 min.	0.19[a]	0.34[a]	0.46[a]	0.41[a]
amenity index - January temp	0.14[a]	-0.04	0.01	-0.09
average household income	0.18[a]	0.16[a]	0.27[a]	0.28[a]
% employment within 1 mi of cbd	-0.25[a]	-0.20[a]	-0.32[a]	-0.28[a]
agricultural sales per acre	0.13[a]	0.42[a]	0.47[a]	0.42[a]
density of governments	0.24[a]	0.09	0.06	0.05

[a] = significant $p < 0.05$; cells highlighted gray are significant correlations in expected direction

Table 8. Correlations of Exurban Measures and Metro Characteristics and Other Factors Associated with Exurban Development

	Dependent Variables							
Independent Variables	spatial patch index		pop density in exurban field		% of field in exurban density		shannon evenness index	
Metro Area Characteristics	Beta	Std. Error	Beta	Std. Error	Beta	Std. Error	Beta	Std. Error
urbanized area size (sq miles)	0.24[a]	0.07	0.02	0.06	0.29[a]	0.42	0.10[a]	0.02
urbanized area pop. density	0.69[a]	0.15	-0.74[a]	0.15	-0.86[a]	-0.33	-0.26[a]	0.04
exurban field road density	0.02	0.18	0.44[a]	0.18	0.41[a]	0.12	0.07	0.04
% workers commuting > 30 min.	-0.02[a]	0.01	0.03[a]	0.01	0.03[a]	0.32	0.01[a]	0.00
amenity index - January temp	0.12[a]	0.05	-0.16[a]	0.05	-0.20[a]	-0.24	-0.08[a]	0.01
average household income	0.00	0.00	0.00	0.00	0.00[a]	-0.01	0.00	0.00
% employment within 1 mi	0.04	0.07	-0.10[a]	0.07	-0.09	-0.09	-0.01	0.02
agricultural sales per acre	0.04	0.04	0.12[a]	0.04	0.31[a]	0.37	0.07[a]	0.01
density of governments	0.01	0.06	-0.04	0.06	-0.22[a]	-0.24	-0.07[a]	0.01
R-square	0.22[a]		0.22[a]		0.81[a]		0.79[a]	
	0.19		0.38[a]		0.65[a]		0.62[a]	
	0.63		0.61[a]		0.51[a]		0.46[a]	

n = 356

* = significant $p < 0.05$; cells highlighted gray are significant correlations in expected direction

Table 9. Regression Models of Exurban Measures and Metro Characteristics and Other Factors Associated with Exurban Development

	Patch Type[a]									
Metro Area Characteristics	single isolated	linear isolated small	clumped isolated small	linear isolated large	clumped isolated large	single contiguous	linear contiguous small	clumped contiguous small	linear contiguous large	clumped contiguous large
urbanized area size (sq miles)	0.53[a]	0.38[a]	0.46[a]	0.41[a]	0.34[a]	0.57[a]	0.49[a]	0.53[a]	0.45[a]	0.66[a]
urbanized area population density	0.07	0.09	0.04	0.09	-0.01	0.35[a]	0.27[a]	0.25[a]	0.27[a]	0.05
exurban field road density	0.03	0.10	-0.03	-0.04	0.02	-0.13[a]	-0.12[a]	-0.03	-0.14[a]	0.01
% workers commuting > 30 min.	0.54[a]	0.42[a]	0.47[a]	0.41[a]	0.30[a]	0.51[a]	0.38[a]	0.42[a]	0.44[a]	0.63[a]
amenity index - January temp	0.09	0.03	0.13[a]	0.13[a]	0.10[a]	0.14[a]	-0.04	0.00	0.10	0.10
average household income	0.17[a]	0.11[a]	0.15[a]	0.10	0.10	0.26[a]	0.24[a]	0.23[a]	0.19[a]	0.27[a]
% employment within 1 mi of cbd	-0.53[a]	-0.43[a]	-0.47[a]	-0.46[a]	-0.31[a]	-0.56[a]	-0.49[a]	-0.55[a]	-0.47*	-0.56*
ag sales per acre	0.11[a]	0.06	0.05	0.03	0.05	0.13[a]	0.15[a]	0.13[a]	0.06	0.25[a]
number of goverments	0.51[a]	0.37[a]	0.41[a]	0.42[a]	0.27[a]	0.60[a]	0.52[a]	0.61[a]	0.48[a]	0.46[a]

[a] = significant $p < 0.05$; cells highlighted gray are significant correlations in expected direction

Table 10. Amount of Each Patch Type (km) Correlated with Characteristics Associated with Exurban Settlement

	Grouped by Shape and Contiguity						Grouped by Contiguity		Grouped by Shape		
Metro Area Characteristics	single isol.	linear isol.	clump isol.	single cont.	linear cont.	clump cont.	isolated	contiguous	single cell	linear	clumped
urbanized area size (sq miles)	-0.36[a]	-0.38[a]	-0.26[a]	-0.11[a]	-0.14[a]	0.43[a]	-0.11[a]	0.12[a]	-0.33[a]	-0.31[a]	0.33[a]
urbanized area population density	-0.03	-0.02	-0.11[a]	0.29[a]	0.23*	-0.01	-0.45[a]	0.43[a]	0.06	0.11[a]	-0.11[a]
exurban field road density	0.01	0.06	0.05	-0.18[a]	-0.17[a]	0.01	0.10	-0.09	-0.07	-0.07	0.07
% workers commuting > 30 min.	-0.27[a]	-0.27[a]	-0.27[a]	-0.13[a]	-0.10	0.41[a]	-0.39[a]	0.40[a]	-0.29[a]	-0.27[a]	0.29[a]
amenity index - January temp	0.00	0.02	-0.03	0.06	0.03	0.05	-0.04	0.05	0.00	-0.02	0.01
average household income	-0.21[a]	-0.23[a]	-0.16[a]	0.00	-0.07	0.22[a]	-0.25[a]	0.24[a]	-0.15[a]	-0.16[a]	0.17[a]
% employment within 1 mi of cbd	0.27[a]	0.25[a]	0.18[a]	0.00	0.02	-0.33[a]	0.32[a]	-0.36[a]	0.23[a]	0.20[a]	-0.22[a]
agricultural sales per acre	-0.20[a]	-0.20[a]	-0.11[a]	-0.08	-0.09	0.18[a]	-0.19[a]	0.17[a]	-0.16[a]	-0.15[a]	0.16[a]
density of governments	-0.15[a]	-0.19[a]	-0.20[a]	0.08	0.03	0.23[a]	-0.26[a]	0.29[a]	-0.10	-0.11[a]	0.12[a]

[a] = significant $p < 0.05$; cells highlighted gray are significant correlations in expected direction

Table 11. Proportion of Exurban Development by Patch Type, Grouped by (1) Shape and Contiguity (2) Contiguity and (3) Shape Correlated with Characteristics Associated with Exurban Development