Measuring the Amount and Pattern of Land Development in Non-Urban Areas

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Introduction

While urban decentralization is a well-established trend, the extent and spatial form of how this decentralization has influenced urban land patterns in outlying "exurban" regions located outside urban and suburban areas is not well known. For many years, researchers either ignored or dismissed development in these areas,[1] in part due to data limitations that hide the prevalence of development in these outer areas and in part because these areas contain relatively few people. In recent years, however, the "exurbs" have grown in stature and importance due to the recognition that, although they may not be home to proportionately many people, the proportion is rapidly growing and this has major implications for land use.

Recent analyses by Clark et al. (2006a, 2006b), Berube et al. (2006) and Brown et al. (2005) and earlier analysis by Heimlich and Anderson (2001) and others demonstrate that these areas are characterized by extensive low density development. Berube et al. (2006), for example, estimate that the typical exurban census tract has 14 acres of land per home, compared to 0.8 acres per home in the typical tract nationwide. Other than the low density nature of this development, however, there is little evidence or consensus on the spatial pattern of this development—e.g., the extent to which it is contiguous vs. scattered or clustered vs. dispersed.

The measurement of land use patterns depends critically on the data source, resolution, definitions, measurement and scale of analysis (Irwin, Bockstael and Cho, 2006). Due to the traditional difficulties in obtaining fine-scale data that are consistent across large regions, many analyses of urban land use patterns have relied on population density data at the census track or block group level. While this provides a small area geography, the approach is limited because of the mismatch between population density and land use and the lack of historical small area data for non-urban areas.

More recently, the National Land Cover Dataset (NLCD), derived from satellite imagery and corresponding to a very fine spatial scale of resolution, has been made available. However, important distinctions exist between land cover and land use. Land cover data records the location of built structures, including houses, commercial and industrial buildings and roads, and the vegetative cover of undeveloped land. Land use data will be very similar to land cover for highly developed areas, but can differ substantially as development densities diminish. For example, a one acre residential lot may be comprised of 80 percent grass or other natural vegetation, leading to a difference of 0.8 acres in the amount of developed land cover vs. land use. An additional limitation of the NLCD data is that these data systematically undercount the number of residential structures in exurban areas (Irwin, Bockstael and Cho, 2006).

Clearly conclusions regarding exurban development will depend on the type of data, e.g., whether land cover vs. land use data are used in the analysis. To explore these issues more systematically, we compare the amount and pattern of urban and other land uses as recorded circa 2001/2002 by several different datasets for exurban and rural regions in the state of Maryland. The differences in the basic amount and pattern of developed land are substantial. For example, 83 percent of low density development in 2002 occurred outside Census-defined urban areas and 82 percent of the land classified as low density residential by State of Maryland land use data is classified as undeveloped by the 2001 NLCD satellite-based land cover data. Our results demonstrate that the underrepresentation of exurban development by land cover data results in substantial differences in the observed location and pattern of exurban land uses and that conclusions regarding the extent of fragmented or scattered exurban development are highly dependent on the type of the data used.

Quantifying and Describing Exurban Development

The extent of exurbia is estimated to be sizeable, e.g., Clark et al. (2006a) estimate that U.S. exurban land totals approximately 69,000 square miles, which is roughly the same total area as Census-defined urban areas. Berube et al. (2006) estimate that six percent of the population lives in exurban areas, but that these residents consume far more than the average amount of land; they report that the typical exurban census tract has 14 acres of land per home, compared to 0.8 acres per home in the typical tract nationwide. Earlier analysis of American Housing Survey data by researchers at the U.S. Department of Agriculture's Economic Research shows that conversion of rural land into low density development is a substantive and growing trend. Heimlich and Anderson (2001) report that of the total acreage used for houses built between 1994 and 1997, approximately 80 percent (two million acres) occurred outside metropolitan areas. The vast majority of this development (94 percent) consisted of lots greater than one acre and a substantial portion (57 percent) occurred on lots10 acres or larger.

While researchers agree that low density development is the overwhelming type of development in exurban areas, there is far less consensus on other aspects of exurban patterns. In one of the few pattern analyses, Clark et al. (2006b) use 2004 raster-based data on population density defined by a 30" by 30" cell size (0.69 square kilometers approximately) to develop a typology of exurban settlement patterns across 356 U.S. metropolitan areas. They estimate that about 63 percent of the exurban settlement pattern can be classified as "clumped and contiguous." This suggests that, while the pattern of exurban development may be one of low density, it is not dominated by a high degree of scatteredness. In contrast, analyses of exurban development patterns using parcel data have found that fragmented development is a dominant feature of residential development and that it is persistent over time (e.g., Carrion-Flores and Irwin, 2004).

Data and Methods

Our study region is comprised of exurban, small urban and rural counties in central and eastern Maryland.[2] To perform the comparative analysis of land amount and pattern, we make use of several different datasets (for more detailed descriptions of the first two, see Irwin, Bockstael and Cho (2006)):

2002 Maryland Department of Planning (MDP) land use data: These are vector data derived from high altitude aerial photography and ancillary data with a minimum mapping unit of five acres with further refinement of urban parcels using land parcel data. Eight urban land use categories are distinguished: low, medium and high density residential, commercial, industrial, institutional and urban open space.

2001 National Land Cover Dataset (NLCD): These are raster data derived from remotely sensed Landsat satellite TM imagery with a spatial resolution of 30 x 30 square meters (circa 2001). Developed land is classified based on the relative mix of vegetative and impervious surfaces.

2000 U.S. Census Bureau Urban and Rural Population: Urban areas are delineated by Urbanized Areas (contain at least 50,000 people with a core density of at least 1000 per square mile) and Urban Cluster (contain 2,500 to 50,000 people with same core density requirement). Although not a direct measure of developed land, these data are one of the few sources of nationally consistent estimates of urban areas over time, making them the most commonly used data to track urban land change.

1997 National Resources Inventory (NRI) land cover/use data: These are estimates of land cover/use at a county level generated by the US Department of Agriculture based on aggregation of a stratified sample of land plots.

Using these data, we investigate how data on land cover vs. land use compare in terms of the total amount, location and spatial pattern of developed and undeveloped land uses. We use the MDP data as our primary land use dataset and compare the amount, location and pattern of these data with two of the most commonly used datasets used to measure urban pattern: Census urban areas and the NLCD land cover dataset.

Results

Table 1 reports aggregate land categories for our study region as recorded by the MDP (land use), NLCD (land cover), NRI (land cover/use) and U.S. Census (population density) datasets. Total developed land estimates range from a low of 2 percent (NLCD) to a high of 8 percent (MDP). Interestingly, the county-level NRI data correspond most closely with the land use totals according to the MDP data. Given the criticism that these data have come under for data accuracy, the fact that the NRI data provide a closer estimate of developed land than does the NLCD or the Census urban designation is noteworthy. In examining this distribution of land across exurban, small urban and rural counties of the study region, we find that the total developed land cover recorded by the NLCD land cover data is anywhere from 40 to 54 percent (for exurban and small urban counties respectively) of the total developed land use recorded by MDP. The NRI data provide closer estimates, recording 75 and 78 percent of the total MDP developed land use for exurban and small urban counties respectively.

Next, an explicitly spatial comparison of the MDP, NLCD and Census land cover/use designations is performed by transforming the MDP and Census vector data into grids with a 90 square meter cell size and aggregating the NLCD data to the same size. The transformed data have the same grid origin and thus can be overlaid to perform a cell-by-cell comparison of land type. In comparing the MDP and NLCD datasets, we find that 12 percent of the MDP low density residential land use is recorded by the NLCD data as a developed land cover (this includes developed open space) and that 82 percent is recorded as either agriculture or forest cover. The comparison between the MDP and Census data yields very similar results, e.g., 83 percent of the MDP low density residential land falls in Census-defined rural areas. In addition, 42 percent of other developed land uses are recorded as undeveloped land cover by the NLCD data and 44 percent of these other developed land uses are located outside of Census urban areas. On the other hand, 90 percent of land in agriculture or forest land uses are also recoded as agriculture or forest land cover by the NLCD data. Thus, while the datasets correspond well in identifying undeveloped (or rural) land, they diverge dramatically in their identification of developed land and in particular, of low density development.

Lastly, we compare the pattern of land use vs. land cover as recorded by the MDP and NLCD datasets respectively. A neighborhood metric is used that calculates, for each cell of a given land use, the proportion of neighboring undeveloped land: $p_{ik}(d)$ where i is the land use/cover of the "own" cell, k is the land use in the own cell's neighborhood and d is the size of the neighborhood. We set k = undeveloped land and consider three different land uses for *i*: (1) low/medium density development, (2) high density development and (3) undeveloped. The neighborhood is defined as a 5 km x 5 km square that is centered on each *i* cell. This is a relatively large neighborhood and thus allows us to consider a continuum of pattern: when *i* corresponds to developed land,[3] the statistic can be interpreted along a continuum from concentrated/clustered development (very small values) to fragmented development (intermediate values) to isolated development (very large values).

Figures 1a and b illustrate the frequency distribution of $p_{ik}(d)$ calculated with the MDP land use and NLCD land cover data for the whole study region for low density residential development and high density development respectively. We find that, not surprisingly, the low density residential pattern is more scattered and that the NLCD land cover plots lie almost everywhere below the MDP land use plots, indicating that NLCD records far less developed land. Differences in the qualitative aspects of pattern also emerge. Figures 1c and d illustrate the relative distribution of $p_{ik}(d)$ (normalized by the total number of cells of land type *i*) specifically for low density residential development for exurban and rural counties using the MDP land use and NLCD land cover datasets (we omit the plots for small urban counties, which are similar to the exurban plots). While the relative distribution of the MDP and NLCD $p_{ik}(d)$ statistic exhibit a close correspondence for rural areas, much more substantial differences in the qualitative pattern emerge for exurban counties. The NLCD land cover pattern in exurban counties is concentrated around very high values of $p_{ik}(d)$, suggesting that a substantial amount of the low density development is relatively isolated. On the other hand, the MDP plot for exurban low density residential land peaks at more intermediate values of $p_{ik}(d)$, suggesting a more fragmented pattern of development. This difference is reflected in the corresponding mean values of $p_{ik}(d)$: 74.5 (NLCD land cover) and 66.8 (MDP land use).

Conclusions

Our results demonstrate that the discrepancy in the amount and pattern of developed land as recorded by land use vs. land cover datasets is relatively small for rural areas, but is substantial for other non-urban regions, particularly exurban areas. Analysis of developed land in exurban areas based on NLCD land cover data underestimates the total amount of developed land use by 60 percent and underrepresents the degree of fragmentation of the land use pattern. Of course it is expected that land cover data will provide a much smaller estimate of developed land use than data on land use. However, we find that these differences in the amount and pattern of developed land in exurban areas are sufficiently large that they beg the question of the usefulness of using land cover data to measure developed land patterns in these areas. The large differences arise due to the prevalence of low density development in these areas, which is not recorded by land cover data. In comparing two other commonly used data sources with the Maryland Department of Planning land use data, we find that Census-defined urban areas provide a very poor representation of developed land, particularly of low density developed land, and that the NRI data provide more accurate aggregate estimates of developed land than either the NLCD or Census data.

Footnotes

[1] Important exceptions include Nelson (1992) and colleagues (e.g., Davis, Nelson and Dueker (1994)) and Audirac (1999) among others.

[2] Following Irwin, Bockstael and Cho (2006), we define ‘exurban’ as (a) counties located in large metro area (over 2 million) and with a population less than 150,000 or (b) counties located in a small metro area (100-250,000) and with population between 100,000-150,000; ‘small urban’ as (a) counties located in small metro area (100,000-250,000) and with a population of less than 100,000 or (b) counties located in a micropolitan area; and ‘rural’ as all other counties with lesser total population.

[3] This is the same metric used by Burchfield et al. (2006) with the exception that they use a one kilometer neighborhood.

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Table 1. Comparison of total land by aggregate land use categories circa 2000

Maryland Dept. of Planning (MDP) 2002

	Acres	*%*
low density residential*	243,683	5.4
medium density residential*	55,299	1.2
high density residential*	7,527	0.2
commercial/industrial*	38,662	0.9
urban open space	13,759	0.3
agriculture	1,255,590	28.0
forest	1,207,785	26.9
water/wetlands	1,628,978	36.3
other	34,358	0.8
total developed*	**345,171**	**7.7**

National Land Cover Dataset 2001

	Acres	*%*
developed open space	80,022	2.3
developed low intensity*	48,257	1.4
developed medium intensity*	17,624	0.5
developed high intensity*	5,967	0.2
agriculture	1,455,345	42.5
forest	1,056,332	30.9
water/wetlands	705,541	20.6
barren	51,625	1.5
total developed*	**71,849**	**2.1**
total developed* (including developed open space)	**151,871**	**4.4**

National Resources Inventory 1997

Land use	*Acres*	*%*
urban*	305,600	6.9
agriculture	1,179,800	26.6
forest	1,201,600	27.1
water	1,380,800	31.1
federal land	43,700	1.0
other	322,500	7.3
total developed*	**305,600**	**6.9**

U.S. Census Bureau (2000)

	Acres	*%*
rural	3,480,790	94.8
urban	**190,604**	**5.2**

Figure 1. Frequency distribution of $p_{ik}(d)$ pattern statistic for five square kilometer neighborhood

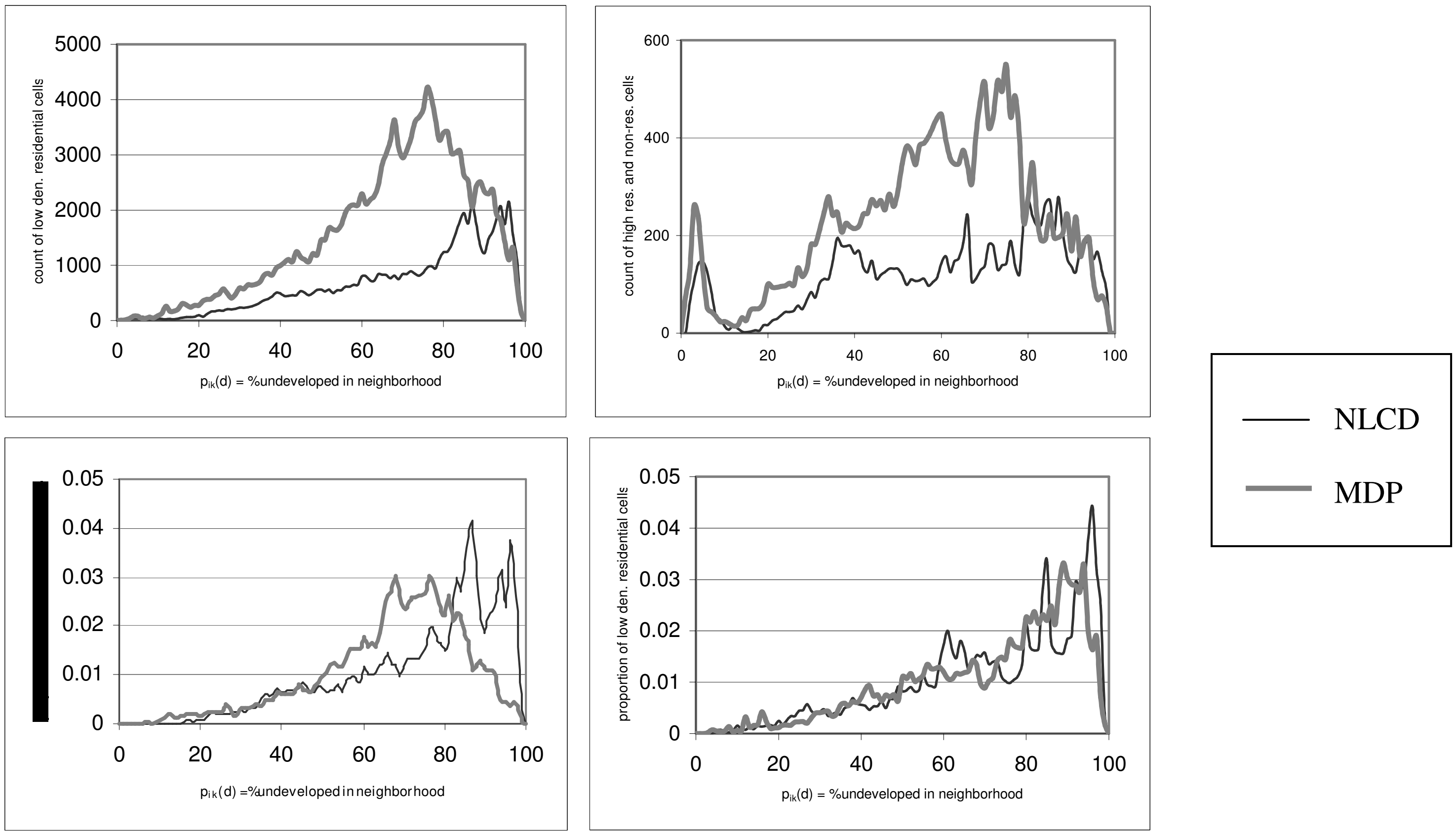

Figure 1a (top left): all counties, *i* = low density residential land use; figure 1b (top right): all counties, *i* = high density residential and non-residential development; figure 1c (bottom left): exurban counties, *i* = low density residential land use; figure 1d (bottom right): rural counties, *i* = low density residential land use.