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*Measuring the Amount and Pattern of Land Development in Nonurban Areas**

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Recent trends in the development of rural land have lead to renewed public concerns regarding decentralized development, fragmented land use patterns, and loss of farmland. These concerns are focused on exurban regions that may be largely rural, but fall within the shadow of urban and suburban areas and have experienced increasing transitions of land from rural to urban uses. For many years, researchers either ignored or dismissed exurban development,[1] because data limitations hid its prevalence and because these outer areas contained relatively few people. In recent years, though, the stature and importance of "exurbs" have grown due to the recognition that these rapidly expanding areas have major implications for land use.

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

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The measurement of land use patterns depends critically on the data source, resolution, definitions, measurement, and scale of analysis (Irwin, Bockstael, and Cho). Because it is difficult to obtain consistent fine-scale data 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 geographic area, the approach is limited because of the mismatch between population density and land use and the lack of historical small-area data for nonurban areas.

The National Land Cover Dataset (NLCD), which is derived from satellite imagery and corresponds to a very fine spatial scale of resolution, has been used recently to measure detailed residential land use patterns (Burchfield et al.). 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% grass or other natural vegetation, leading to a difference of 0.8 acres in the amount of developed land cover vs. land use. The NLCD data also systematically undercount the number of residential structures in exurban areas (Irwin, Bockstael, and Cho).

Clearly conclusions regarding exurban development will depend on the type of data used in the analysis. To explore these data 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. There are substantial differences in the basic amount and pattern of developed land. For example, 83% of low-density development in 2002 occurred outside Census-defined urban areas and 82% 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 use. As a result, 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. For example, Clark et al. estimate that U.S. exurban land totals approximately 69,000 square miles, which is roughly the same total area as Census-defined urban areas. Despite this sizeable area, only 6% of the total U.S. population is estimated to live in exurban areas (Berube et al.). Heimlich's and Anderson's analysis of American Housing Survey data shows a substantive and growing trend to convert rural land into low density development. They report that approximately 80% (2 million acres) of the total acreage used for houses built between 1994 and 1997, occurred outside metropolitan areas. The vast majority of this development (94%) consisted of lots greater than one acre and a substantial portion (57%) occurred on 10 acre or larger lots.

While researchers agree that exurban development is overwhelmingly low density, there is far less consensus on other aspects of exurban patterns. In one of the few pattern analyses, Clark, Munroe and Irwin use 2004 raster-based data on population density defined by a $30'' \times 30''$ 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% of the exurban settlement pattern can be classified as "clumped and contiguous." This suggests that, while exurban development may be low density, it is not dominated by a high degree of scatteredness. In contrast, analyses 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 (see Irwin, Bockstael, and Cho for more detailed descriptions of the first two):

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 5 acres. Urban parcels are further refined using land parcel data to yield eight urban land use categories: low-, medium-, and high-density residential, commercial, industrial, extractive, institutional, and urban open space.

2001 National Land Cover Dataset (*NLCD*): These are raster data derived from remotely sensed Landsat Thematic Mapper satellite imagery with a spatial resolution of 30×30 m^2 (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 (containing at least 50,000 people with a core density of at least 1,000 per square mile) and Urban Cluster (containing 2,500 to 50,000 people, with the 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 county-level estimates of land cover/use generated by the U.S. Department of Agriculture based on aggregation of a stratified sample of land plots.

Using these data, we investigate how land cover vs. land use data 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 NRI land use, Census urban areas and NLCD land cover datasets—three of the most commonly used datasets to measure urban land.

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 2% (NLCD) to 8% (MDP). Interestingly, the county-level NRI data correspond most closely with the MDP land use totals. The accuracy of the NRI data has been called into question (e.g., Burchfield et al.). However, it is noteworthy that the NRI data provide a closer estimate of developed land than the NLCD or the Census urban designation.

In examining the land distribution across the study's exurban, small urban and rural counties, we find that the total amount of developed land cover recorded by NLCD is 40 to 54% (for exurban and small urban counties, respectively) of the total developed land use recorded by MDP. The NRI data provide closer estimates of 75 and 78% of the total MDP developed land use for exurban and small urban counties, respectively.

Next, we transform the MDP and Census vector data into 90-m^2 cell size grids and aggregated the NLCD data to the same spatial resolution to conduct an explicitly spatial comparison of the MDP, NLCD and Census land cover/use designations. The transformed data are overlaid to perform a cell-by-cell comparison of land type. We find that the NLCD records 12% of the MDP low density residential land use as a developed land cover (this includes developed open space) and that 82% is either agriculture or forest cover. The comparison between the MDP and Census data yields very similar results: 83% of the MDP low density residential land falls in Census-defined rural areas. In addition, the NLCD data records 42% of other developed land uses as undeveloped land cover and 44% of these other developed land uses are located outside of Census urban areas. On the other hand, the NLCD also records 90% of land in agriculture or forest land uses as agricultural or forested land. Thus, while the datasets correspond well in identifying undeveloped (or rural) land, they diverge dramatically in identification of developed land and in particular, of low density development.

Last, we compare the pattern of land use vs. land cover recorded by the MDP and NLCD datasets, respectively. We used a neighborhood metric 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 $\times$ 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

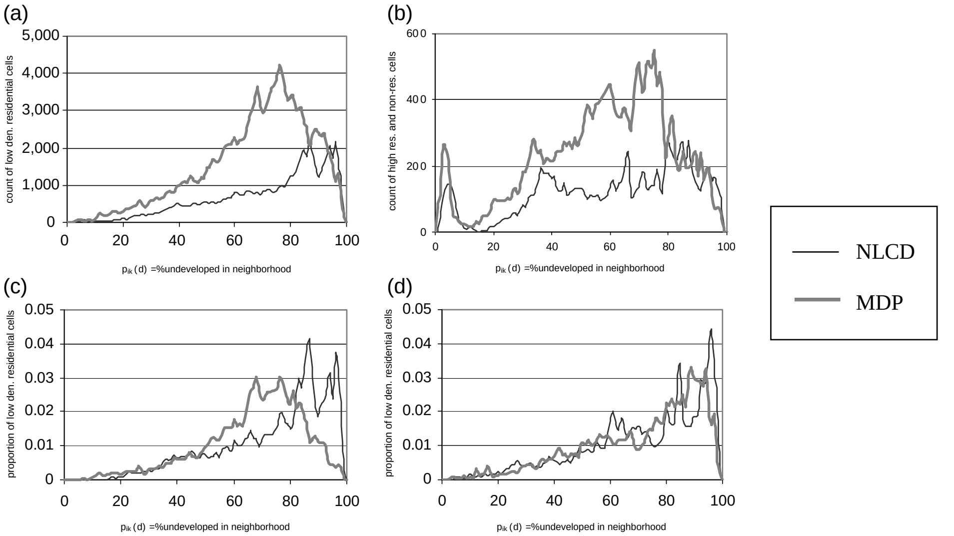
Table 1. Comparison of total land by aggregate land use categories, circa 2000

	Acres	%
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 (NLCD) 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 (NRI) 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

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

Figure 1. Frequency distribution of $p_{ik}(d)$ pattern statistic for 5 km^2 neighborhood: (a) all counties, i = low density residential land use; (b) all counties, i = high density residential and non-residential development; (c) exurban counties, i = low density residential land use; (d) rural counties, i = low density residential land use



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 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 nonurban 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% and underrepresents the degree of fragmentation of the land use pattern. 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. The NRI data provide more accurate aggregate estimates of developed land than either the NLCD or Census data.

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 the 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 exurban areas, which is not recorded by land cover data. The inability of these data to record such land use patterns is particularly troublesome as it is precisely this type of low density, fragmented growth in outlying areas that has prompted so many concerns regarding the impacts of such development on public service costs, environmental degradation, and rural economies.

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Endnotes

[1]Important exceptions include Nelson; Davis, Nelson, and Dueker; and Audirac, among others.

[2]Following Irwin, Bockstael, and Cho, 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" is defined as (*a*) counties located in small metro area (100,000–250,000) and with a population of less than 100,000 or (*b*) micropolitan-area counties located in (*a*). "Rural" is defined as all other counties with lesser total population.

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

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