SPATIAL ANALYSIS OF RESIDENTIAL DEVELOPMENT AND URBAN-RURAL ZONING IN BALTIMORE COUNTY, MARYLAND

A Thesis

by

ALEXANDER C. GRIFFIN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2011

Major Subject: Agricultural Economics

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Approved by:

Chair of Committee,	David A. Newburn
Committee Members,	Charles E. Gilliland
	J. Richard Conner
Head of Department,	John P. Nichols

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ABSTRACT

Spatial Analysis of Residential Development and Urban-Rural Zoning in Baltimore County, Maryland. (August 2011)

Alexander C. Griffin, B.A., Centre College

Chair of Advisory Committee: Dr. David A. Newburn

Over the past half-century, Baltimore County, Maryland has experienced various policy measures that have shaped development patterns. This thesis analyzes three spatially explicit parcel-level models of residential development in Baltimore County to examine the effects of land-use regulations on multiple density classes from 1996 to 2008. The first model analyzes the entire county, while the second analyzes areas outside the county urban growth boundary, while the third model studied areas inside the boundary. While this region has been previously analyzed, prior studies have generally ignored policy affects upon the density of new residential subdivisions. The use of a binary dependent variable, i.e. develop or not develop, represents a critical oversight as this assumes policy measures exert a uniform impact across all development types. This study addressed this issue with the literature by using a multinomial logit model to differentiate the effects of various development policies to better understand residential growth. The objective of this research is to determine what factors influence individual landowner's decision to convert an undeveloped property to residential use. The impacts of rural conservation (RC) zoning and urban growth boundaries (UGB) comprise the prominent land-use regulations analyzed in this study.

The empirical estimates provided significant evidence that maximum density zoning effectively limits the density of new residential development in almost every model. Other policy measures, mainly rural legacy areas and critical areas, were generally found to be ineffective at limiting growth. This research concludes that maximum density zoning comprises the strongest tool for limiting development to a density mandated by the county government. Finally, maps depicting the predicted probability of development at two densities are included and discussed to indicate the areas most likely to be subdivided for residential land use.

To Mom and Dad

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1. INTRODUCTION

1.1 General Overview

Even before the adoption of the Smart Growth Initiative in 1997, the State of Maryland had been a leader nationwide in land-use policies aimed at urban growth management and rural preservation. Baltimore County has experienced various policies that have shaped development patterns over the past 40 years. This research project analyses the growth patterns in the urban-rural fringe of Baltimore County, MD, using both spatial data and economic modeling to determine the effects of land-use regulation.

As cities continue to grow, the impacts on the surrounding regions become more pronounced. Between 1950 and 2000, Brown et al. (2005) estimated that the quantity of urban areas (land with densities greater than one house per acre) grew from nearly 1% to under 2% while exurban areas (between one and 40 acres per house) swelled from roughly 5% to 25% in the United States. This discrepancy between density classes epitomizes a fundamental shift in America's residential landscape that occurred during the latter half of the 20th century.

Exurban areas, defined as low-density development beyond city suburbs, uses a great deal more land than both urban and suburban development. Many of the adverse characteristics used to define urban and suburban sprawl, such as low-density,

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This thesis follows the style of the *Annual Review of Resource Economics.*

noncontiguous development, and complex infrastructure requirements are even more pronounced for exurban growth (Irwin et al. 2009). The reasons behind the pervasiveness of exurban growth are multifaceted; however, several key economic developments have facilitated the urban-rural transformation. Escalating real incomes, technological improvements, waning transportation costs, advancements in communications, increased desire for open space, and the general restructuring of the economy have precipitated rapid development of rural areas (Irwin et al. 2009). Another important factor was the abundance of credit in financial markets during the 1990's and early 2000's that spurred housing demand and allowed many borrowers to purchase exurban property that would have otherwise been unaffordable (Clark & Irwin 2009). Baltimore County also experienced moderate growth during the 1990's as the number of housing units increased by 11.4% during the decade (Baltimore County Site Planning Roundtable 2006).

Exurban development also causes various negative externalities for cities; for example, migration of middle and upper income households to exurban areas erodes the tax base of cities, causing urban services and infrastructure to atrophy (Clark & Irwin 2009). While exurban areas typically appear rural, they still remain highly dependent both socially and economically on adjacent urban and suburban areas. Furthermore, because sewer services are typically not extended to exurban development, septic systems are required, which can contaminate local watersheds. This non-point source pollution can also threaten urban residents; the 1.8 million residents of the Baltimore Metropolitan area rely on reservoirs in Baltimore County for drinking water. The threat of contamination has precipitated specific zoning legislation to limit development in key recharge areas (Pierce 2010).

The lack of effective public policy to curb exurban growth has left exurban development unchecked in many parts of the country. Some state and county governments have made planned growth a major priority over the past several decades; Baltimore County, MD stands as one of the earliest examples of a municipal government taking a firm approach to setting rules and guidelines for new development through policy initiatives. Before the 1997 state legislation, Smart Growth had already been pioneered by Baltimore County through the implementation of a framework including growth boundaries, strategic infrastructure placement, and natural resource preservation programs over the past 40 years. The impact of Smart Growth is evident in the demographics of the county; of the 809,000 residents, 87% live on one-third of the total land of Baltimore County (Outen 2007).

1.2 Objective

The purpose of this study is to develop a spatially explicit parcel-level model of residential development in Baltimore County, Maryland, in order to examine the effects of land-use regulations on suburban versus exurban development. The affects of rural conservation (RC) zoning and urban growth boundaries (UGB) comprise the prominent land-use regulations analyzed in this study. To investigate the individual landowner's decision to convert an undeveloped property to residential use, a multinomial logit model is used to determine the relative effects of various parcel attributes, with an emphasis on regulations related to zoning designations. This approach builds on similar work conducted by Newburn and Berck (2006 and unpublished manuscript) in Sonoma County, CA, a region with growth regulations fairly comparable to those in Baltimore County. Similarly to Newburn and Berck (2006), this analysis utilizes four stratified density classes for residential subdivisions with a fifth class signifying undeveloped parcels. The lower two density classes capture exurban development while the two higher classes contain suburban development.

The exurban and suburban classes are split at one unit per acre due to stipulations established by the Baltimore County Master Plan. The Master Plan distinguishes between 'urban' and 'rural' areas by using an urban growth boundary named the urban-rural demarcation line (URDL). The URDL limits city sewer and water utilities only to areas within the border while areas outside must rely on septic systems. In addition, areas outside the URDL are limited to densities less than one unit per acre while areas inside are allowed densities greater than one unit per acre. The differences in management of lands inside and outside the URDL remain the basis for the discrete break between urban and rural.

The main research objective is to determine the relative impacts of maximum density zoning on development at various residential density levels. Three models are featured in this research, each testing different portions of the county using alternative density classes. The first model tests the impacts of all zoning types on two general residential density classes, suburban and exurban, using data from across Baltimore County. This combined model allows for comparisons between the factors that influence the density of new subdivisions across a wide geographic area. The second model analyzes the impact of zoning and two other conservation policies on the proliferation of exurban growth in the area outside the URDL by using two lower density classes. This second model is of particular interest because it investigates the effectiveness of other policies at preserving rural agricultural areas and controlling exurban growth. The third model tests the impact of urban zoning on higher density development inside the URDL. These areas have been carefully zoned by Baltimore County to promote a greater variety of housing types; the third model also tests the effectiveness of these zoning types at determining subdivision density. Specifically, each zoning class is expected to affect alternative densities differently across the three models. By assessing the effectiveness of various growth management policies on suburban and exurban development, the results of this research will aid policy makers seeking to guide future development patterns.

To conduct these three models, parcel attributes comprise the explanatory variables and include zoned maximum density, distance to highways, soil quality, and land preservation programs. Among other uses, the findings of this research will offer recommendations for improving development regulations that support desired growth patterns and protect agricultural areas from sprawl. The remainder of the thesis is as follows. The next section contains a review of relevant literature concerning residential growth management policies. This analysis builds on the extensive literature examining the impact of growth policy on residential housing. Next, the background of growth regulations in Baltimore County is discussed to familiarize the reader with the geographic area of study. Following this synopsis, a description of the data, empirical model, and variables is used to describe the method of answering the primary research questions. This section includes a detailed explanation of the dependent and explanatory variables for the three models. Then, I discuss the estimation results and relate the findings to the research questions. Next, two maps depicting the predicted probability of development at exurban and suburban density classes are included to visualize the areas most susceptible to these levels of density. A brief discussion follows relating the results to previous literature. Finally, summary remarks and a conclusion are provided.

2. LITERATURE

2.1 Literature Review

Beginning in the 1960's, Maryland began controlling development using various regulations, later dubbed Smart Growth. The first major policy established an urban growth boundary (UGB) by limiting sewer and water services to specific areas designated for development. Many studies have already analyzed UGBs around the country to determine the effectiveness of various iterations of this policy. For example, when analyzing the impact of the UGB around Seattle, Washington, Cunningham (2007) found lower likelihood of residential development outside the boundary. However, this study also found that preventing future suburban development in areas outside the boundary reduced price uncertainty that partially undermined the effectiveness of the policy. Another study by Brueckner (2000) found UGBs to be an inferior growth management tool compared to congestion tolls, suggesting other policies are also needed. Newburn and Berck (2006) investigated how UGBs influence suburban versus rural-residential development by using multiple density classes. This study focused on the effect of limiting utility services (sewer and water) and zoning density constraints on residential development using data from Sonoma County, California. Using a random-parameter logit model to account for heterogeneity, the results of the study revealed that limiting sewer and water services was the most influential constraint in determining suburban development. However, these policies did not significantly affect exurban growth, which normally use septic systems and private wells (Newburn & Berck 2006).

While amenity-based growth restrictions successfully contain the bulk of the residential population, UGB's prove far less effective at limiting exurban development. A study conducted in Calvert County by Irwin, Bell, and Geoghegan (2003) using an empirical hazard model of residential land-use conversion patterns in Calvert County, Maryland, suggested that Smart Growth goals are best attained when combined with policy aimed to concentrate growth to preserve rural or open space. Combating exurban development requires subtler policy measures. Three prominent examples seen in Baltimore County include Priority Funding Areas (PFAs), maximum density zoning restrictions and the Rural Legacy Act.

Established by the Maryland 1997 Smart Growth Areas Act, PFAs restrict state infrastructure spending to areas determined by each county. Local county governments determine the most desirable areas for growth and the Smart Growth Areas Act concentrates state agency spending on development within PFAs. The goal of PFAs was to further smart growth by using the state budget as an incentive to bolster local development objectives. Because local discretion directs PFAs, the influence of legislation on zoning and planning differs across counties. In a comparison of parcels developed in new single-family units before and after PFAs for all 23 Maryland counties, Lewis, Knaap, and Sohn (2009) found this policy initiative to exert a limited impact. This statewide analysis listed lax compliance monitoring and ambiguous program guidelines as critical reasons for limited PFA success.

Intended to limit density in specific locations, zoning regulations are a widely used type of growth control. Residential zoning restrictions normally dictate minimum lot sizes, maximum subdivision density, or some combination of the two. While a wealth of literature examines the impact of zoning on population density, these studies tend to use aggregated census-level data to analyze macro trends across vast geographic areas. Fewer studies have utilized disaggregated parcel-level data on a smaller regional scale to analyze the impact of zoning on housing density. Examples of such studies include an investigation on the effects of land use and forest conservation regulation on open space in several Maryland counties by Lichtenberg, Tra, and Hardie (2007). When testing whether zoning requirements affect the number of lots in a subdivision, the authors found evidence that zoned minimum lot size constrains development. McConnell, Walls, and Kopits (2006) found subdivision density to be influenced by many factors other than zoning, using data from Calvert County, Maryland. The authors estimated an additional 10% of residential lots would have been developed without zoning regulations. Other empirical evidence provided by Fulton, Williamson, Mallory, and Jones (2001) found that subdivisions in Ventura County, California were built at densities much lower than zoned maximum capacity during the late 1990's. While arguing that factors other than zoning drive density decisions, this study emphasizes that regional differences may play an important role in determining the type of new residential development.

Zoned maximum-residential density is often stated as the minimum lot size restrictions in the literature to help explain the likelihood of residential development (i.e. Irwin, Bell, and Geoghegan 2003; Irwin and Bockstael 2004). While lot-size restrictions may limit development of higher densities, this policy does not restrict development at lower density. Observing this, Newburn and Berck (2006) demonstrated a differentiated effect of lot-size restrictions on different residential densities thus providing the basis for using the zoned maximum density for this project.

While the mechanics of rural legacy are discussed in the next section, a brief discussion of relevant literature appears below. Using propensity score matching, Lynch and Liu (2007) found higher rates of land preservation within designated rural legacy areas, yet the program had no significant effect on the likelihood of new developments in those areas. Similarly, Irwin et al. (2003) used a hazard model and found rural legacy to have no effect on the rate of land conversion in Calvert County, MD. However, Shen and Zhang (2007) analyzed the impact of multiple programs across several Maryland counties and found some evidence that rural legacy deters development, yet the authors admit their results varied across counties.

Using stratified density classes addresses a technical issue not addressed by other authors who use parcel-level residential models: by treating residential development as a binary outcome (i.e., subdivisions can be developed or undeveloped) the model assumes growth management policies affect all residential densities equally. In particular, Cunningham (2007), Irwin and Bockstael (2004), and Irwin et al. (2003), all utilize a binary hazard model. Furthermore, Shen and Zhang (2007) incorporate a binary logit model. Newburn and Berck (2006) provide evidence suggesting that multiple density classes allow for a broader understanding of residential development. Accordingly, this project takes a similar approach to address this issue with the literature by differentiating the impact of growth policy measures upon alternative density classes using a multinomial logit model. This thesis contributes to the body of literature by providing evidence that, in contrast to prior studies, suburban and exurban density classes react differently to various residential growth policies.

2.2 Smart Growth in Baltimore County

Stretching from the City of Baltimore to the border of Pennsylvania, Baltimore County covers roughly 607 square miles of land and today contains 805,000 residents (Figure 1). Both Baltimore County and Baltimore City experienced rapid population growth caused by arms and equipment manufacturing during World War II. After the conflict, the population of the City of Baltimore began a permanent decline that persists to this day. However, fueled by decentralizing factors such as the interstate highway system and public school desegregation, Baltimore County surged from 155,000 residents in 1940 to 621,000 by 1970 (Outen 2007).

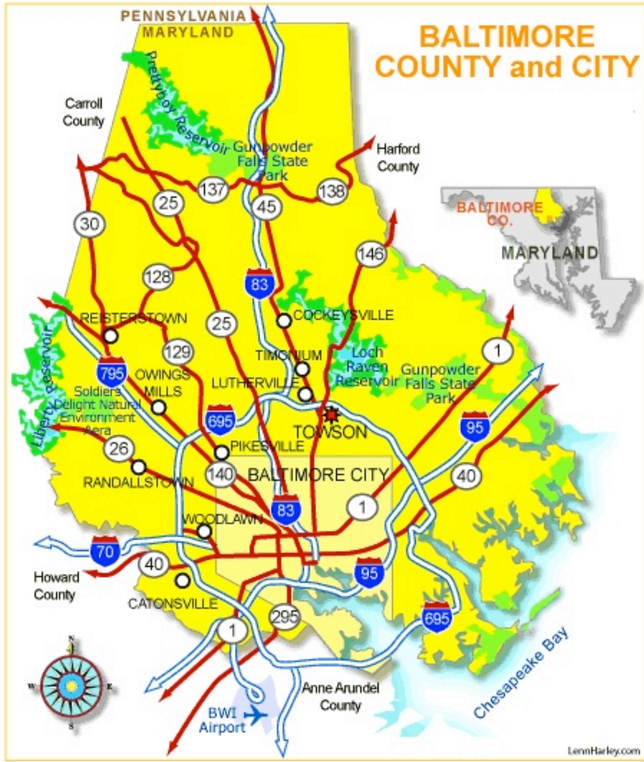

Figure 1

Map of Baltimore County with major roads (www.lennharley.com 2011)

Early attempts were made during the 1950's to adopt zoning regulations through various sector plans throughout the county, yet these proved ineffectual and the Baltimore County Office of Planning[1] realized comprehensive, county-wide policy was needed (Pierce 2010). Being one of the first of its kind in the nation, the urban-rural demarcation line (URDL) was established in 1967 and represents a milestone in land regulation by codifying two distinct land categories: urban area and rural area. As mentioned above, urban areas enjoy full water and sewer service while rural areas must rely on septic systems and private wells. This early example of a UGB was intended to

[1] The Office of Planning was named Office of Zoning and Planning until 2000.

protect agricultural and natural resources by limiting development and to minimize infrastructure costs through concentrated growth. However, the URDL alone lacked the ability to protect rural areas outside the growth boundary because rural zoning continued to allow one-acre minimum lot size for outside the boundary. Furthermore, the original URDL contained more land than the current boundary to accommodate expected suburban development over the next several decades (Baltimore County Office of Planning, 2000). Standing alone, the URDL was unable to curb exurban development resulting in continued loss of farmland.

With no incorporated municipalities with which to contend, the Baltimore County government can set regulation on land-use and zoning beyond the URDL unopposed by other local jurisdictions. To combat the continued exurban sprawl, the resource conservation (RC) zones appeared in the 1975 Comprehensive Plan, becoming policy in 1976 (Outen 2007). Originally, three zoning types comprised the rural classifications. The first, agricultural protection (RC2) covers the majority rural areas outside the URDL and had 25-acre minimum lot size, although it was increased to 50-acre minimum lot size in 1979. The second, watershed protection (RC4) was designated to protect the water supply of 1.8 million residents within the Baltimore metropolitan area who rely on three regional reservoirs (Liberty, Loch Raven, and Prettyboy). These reservoirs are visible in Figure 1. By limiting development to 5-acre minimum lot sizes, RC4 helps protect the watersheds associated with these reservoirs. The third zone, rural residential (RC5) provides the highest density rural residential development by allowing two-acre minimum lot size. Rural residential applies only to appropriate areas, normally around Interstate Highway 83 and in the vicinity outside the URDL. In short, the downzoning instilled by the 1976 RC zoning policy created a major push from rural areas that the URDL could not manage alone (Pierce 2010). Although both the URDL and RC zoning have undergone minor adjustments during successive years, these tools comprise key elements of the Baltimore County planned development strategy.

Three pieces of land preservation legislation were later enacted by the State of Maryland to address specific issues. The first, the 1984 Chesapeake Bay Critical Area Act, was intended to manage land use in coastal areas. This statewide legislation applies to all land and water within 1000 feet of the tidal waters' edge of the Chesapeake Bay. This enabled the state to exert greater influence in local development for these sensitive areas (Pierce 2010).

In 1997, the second legislative act provided for the designation of Rural Legacy Areas. This program seeks to preserve contiguous blocks of agricultural, natural resource, and scenic land through voluntary easement purchases. Functioning essentially as a state grant program, local government and land trusts (sponsors) apply to have desirable areas designated as rural legacy areas and then purchase land, easements, and transferable development rights from willing landowners. The third, PFAs, also came in 1997 and match almost exactly to land within the URDL in Baltimore County, thus strengthening the existing urban growth boundary. This close relationship prevents the analysis of PFAs in this study, however, the reader should keep in mind that areas within the URDL receive extra state infrastructure funding.

3. METHODOLOGY

3.1 Model

This model assumes individual landowners face a choice of how to best maximize the utility of an undeveloped parcel. Each landowner faces a set of *J* alternatives either to develop the parcel into one of the residential density classes or choose to leave the property undeveloped in the period of observation. The discrete choice made by landowners is assumed as a random utility model where U_{ij} for $j = 1,...,J$ represents landowner utility from being in alternative use *j* on parcel *i*. A function of observed variables, V_{ij}, comprises the systematic portion of the utility model that influences the net present value of alternative *j*. The model also includes, ε_{ij}, an unobservable random portion comprising the error term. In sum, parcel *i* has the probability of the landowner choosing alternative *k*

(1) $$P_{ik} = \Pr\left(V_{ik} + \varepsilon_{ik} > V_{ij} + \varepsilon_{ij} \quad \forall j \neq k\right)$$

Multinomial logit (MNL) models are used when all regressors do not vary over the alternatives and only case-specific variables exist in the dataset. MNL estimates are relative to the base alternative, here defined as the alternative to remain undeveloped. For example, a positive MNL parameter estimate for the low-density alternative means the regressor increases the probability of development at that density alternative relative to remaining undeveloped. The MNL model specifies that

(2) $$P_{ij} = \frac{\exp(x_i \beta_j)}{\sum_{l=1}^{m} \exp(x_i \beta_l)},$$

where $j = 1, \ldots, m$ and x_i are case-specific regressors that includes an intercept (Cameron & Trivedi 2009). This model sets β_j to zero for the baseline alternative to remain undeveloped.

To better understand the impact of each regressor, the odds ratios or relative-risk ratios are included. This technique transforms estimated $\hat{\beta}$ coefficients into $e^{\hat{\beta}}$ allowing an interpretation of estimates as Relative Risk Ratios. The ratio of choosing alternative j relative to the baseline alternative (j=1) is explained by

(3) $$\frac{\Pr(y_i = j)}{\Pr(y_i = 1)} = \exp(x_i \beta_j)$$

where $\exp(\beta_j)$ gives the proportionate change in the relative risk of selecting alternative j rather than the baseline alternative when x_i changes by one unit (StataCorp 2009).

3.2 Data

To conduct this analysis, the data must reconstruct existing development in the base year of study to ascertain the developable parcels. This model uses subdivisions from 1996 onward due to limitations of available data layers. Specifically, the Maryland Department of Planning has created a GIS zoning layer for 1996. This zoning layer provides the only reliable means of knowing which parcels were available for residential use at the beginning of the study. Incorporating additional data by using an earlier base year will bias the coefficient estimates due to periodic zoning adjustments. With this in mind, the 1996 zoning layer can still act as a relative proxy for the zoning classes for models using all data from 1980 onward; these results appear in appendix B, but do not comprise a significant part of this project.

The data for this analysis came from the 2008 version of MdProperty View, a GIS database built and updated yearly by the Maryland Department of Planning. This dataset contains parcel level information including land use type, name of owners, parcel size, and name of subdivision. The dependent variable for this analysis is based upon parcel-level data that must be manually edited within a Geographic Information System (GIS) from historic subdivision maps. These historic plat maps are available online from www.plats.net and this composes the core of the dataset.

The data were created with the reconstruction of subdivisions using GIS. Plat maps were collected and used to edit the appropriate parcel polygons containing the same subdivision name from MdProperty View within the parcel GIS layer. Subdivisions began from 1960 to present were combined and information on the year start was recorded. The year corresponds to when the plat map was filed and not when actual structures were built, thus capturing the time when the decision was made to convert an undeveloped parcel to residential use. Then, subdivision parcels were dissolved in GIS based on the unique identification number assigned during the preliminary work resulting in the parent parcel for each subdivision event. Finally, developed subdivisions were sorted into multiple density classes.

A meticulously planned set of pre-estimation screens was applied to the raw dataset to isolate parcels appropriate for this analysis. The first screen removed all commercial, industrial, and apartment developments due to this project focusing on single-family residential subdivisions. Next, parcels smaller than one acre were removed because of the rarity of subdivisions at this size. Then, parcels with a housing density greater then 0.05 units per acre (one house on twenty acres) in the base year were removed as these are considered developed. Finally, parcels protected by any state or local program that would limit development potential were removed. A full explanation of the screening process appears in section A of the appendix.

Patterned after Newburn and Berck (2006), a multinomial logit model (MNL) with multiple density classes was used. A key limitation of the MNL model is the requirement of observations in all classes. During this investigation, a lack of sufficient observations in each density class became apparent. While re-affirming the effectiveness of the URDL, this also prevents an analysis using four residential classes. The combined county model uses only two density classes, suburban and exurban, thus allowing for testing nearly all of the zoning types. The first, exurban, represents development at one to five acres per housing unit (0.2 to 1 unit per acre), while suburban encapsulates subdivisions greater than one unit per acre. Any subdivisions with a density less then one house on five acres (0.2 units per acre) are considered undeveloped in the county model. The number of buildable residential lots on each subdivision was recorded as a proxy for the sum of single-family residential housing because, in general, the Baltimore County Master Plan allows only one house per lot. The observed subdivision density was calculated as the total number of buildable single-family residential lots divided by the parent lot size, thus providing the average residential density in the subdivision.

As previously mentioned, the zoning types in Baltimore County restrict development by setting a maximum allowable residential density, as can be seen in Table 2 (appendix B). The parameters of the density classes were set to each include specific zoning classifications outlined in the Baltimore County Master Plan. For example, the exurban density class should allow RC5 but not RC2. This way, the model tests if zoning binds development to the stipulated density. Accordingly, the hypothesized effects of each zoning type are based on the maximum density allowed by the Master Plan. The lack of observations in each zoning type necessitated some data manipulation. Specifically, the combined model required the collapsing of the rarely used RC3 zone into the similar RC5 type and DR16 into the DR10.5 class. Table 3 provides the distribution of density observations across the 1996 zoning types while a similar table for 1980 data appears in the appendix (Table 6).

The combined county model seeks to answer several questions; the first of which is whether exurban development is deterred by the highly restrictive RC2 zoning, due to the maximum density of 50 acres per house allowed for this type. In addition, RC4 and RC5 zones are hypothesized to promote exurban growth because of the higher permitted density authorized in these types. Alternatively, because DR1 allows density up to one acre per home, this zone does not fall within the suburban class and is expected to restrict suburban density. However, DR2 and DR3.5 are expected to promote suburban density because each allows a maximum density within the suburban class parameters. Finally, the least restrictive DR10.5 zone is predictable to not restrict any density classes. The classes are all relative to DR5.5, which acts as the base. Figure 2 below visualizes the centroids of all subdivisions and undeveloped parcels in their respective zoning areas using the suburban and exurban density classes for the combined model. In sum, the effectiveness of zoning on controlling residential density can be determined using the results of this analysis.

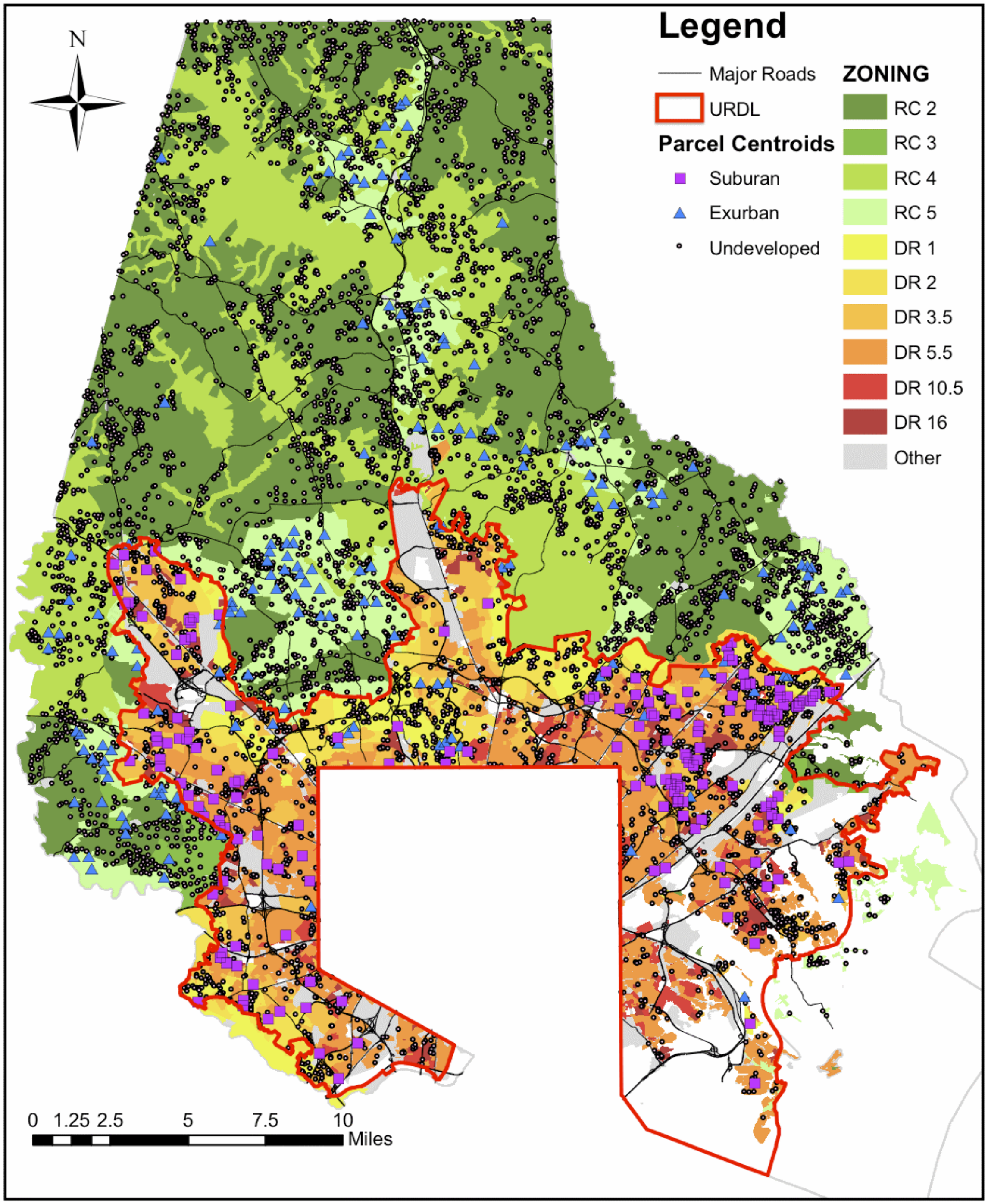

Figure 2

The 1996 zoning layer with developed and undeveloped parcel centroids

Physical land characteristics are used to represent the cost of converting an undeveloped parcel to residential development. Derived from Flood Insurance Rate Maps (FIRMs) and published by the Federal Emergency Management Agency (FEMA), a variable for the proportion of the parcel in a 100-year floodplain is included. This variable is expected to constrain residential development. Soil is based on an overlay with the National Soils Group of Maryland survey from 1973 provided by the Maryland Department of Planning. Soil runoff potential is sorted into four groups, A through D, denoting the rate of water infiltration when each type is completely saturated. The lower two permeability classes, C and D, are included as dummy variables and are based on the soil type at the centroid of each parcel. These soil dummy variables are expected to lower the likelihood of residential development across all density class. The soil data also contained information on the relative slope of each soil type. A dummy variable reflecting slopes greater than 15% is included which is expected to lower development potential across all density classes, particularly for suburban density because site construction costs increase with steep land gradient.

The natural log of total parcel acreage was incorporated in the model because the number of allowable subdivisions depends on the total parcel acreage. This variable is expected to positively influence the probability of development across all density classes. Finally, a dummy variable representing the existence of a house in 1996 was added to distinguish between completely vacant parcels and parcels with an existing house but with the ability to be further subdivided. This variable is predicted to be positive for exurban density classes because land with an existing house already had some desirable feature that caused the landowner to place a home on the parcel. The expected sign of this variable for suburban density classes is ambiguous because this may not occur very often in urban areas.

The Euclidean distance was calculated from the centroid of each parcel to the nearest major highway and geographical center of Baltimore City. The Euclidean distance is expressed in miles and represents accessibility to employment and shopping in major towns and cities. Parcels located farther from either Baltimore City or major highways are expected to exhibit a lower probability of residential development across all density classes.

Two policy variables are included to control for other land-use regulations. Both layers were created by the Maryland Department of Natural Resources. The first, critical areas, represents the percent of a parcel that falls within 1000 feet of the tidal waters' edge of the Chesapeake Bay. This variable is expected to have a negative impact on each density class, yet may be insignificant because it applies to specific coastal areas in the southeast portion of the county. The second, rural legacy, is a dummy variable expressing whether the parcel centroid resides in a rural legacy area. This variable indicates if the parcel is eligible for participation in the program while parcels already participating were screened out of the dataset. This variable is expected to negatively impact development for the exurban density class, but will be insignificant to suburban density.

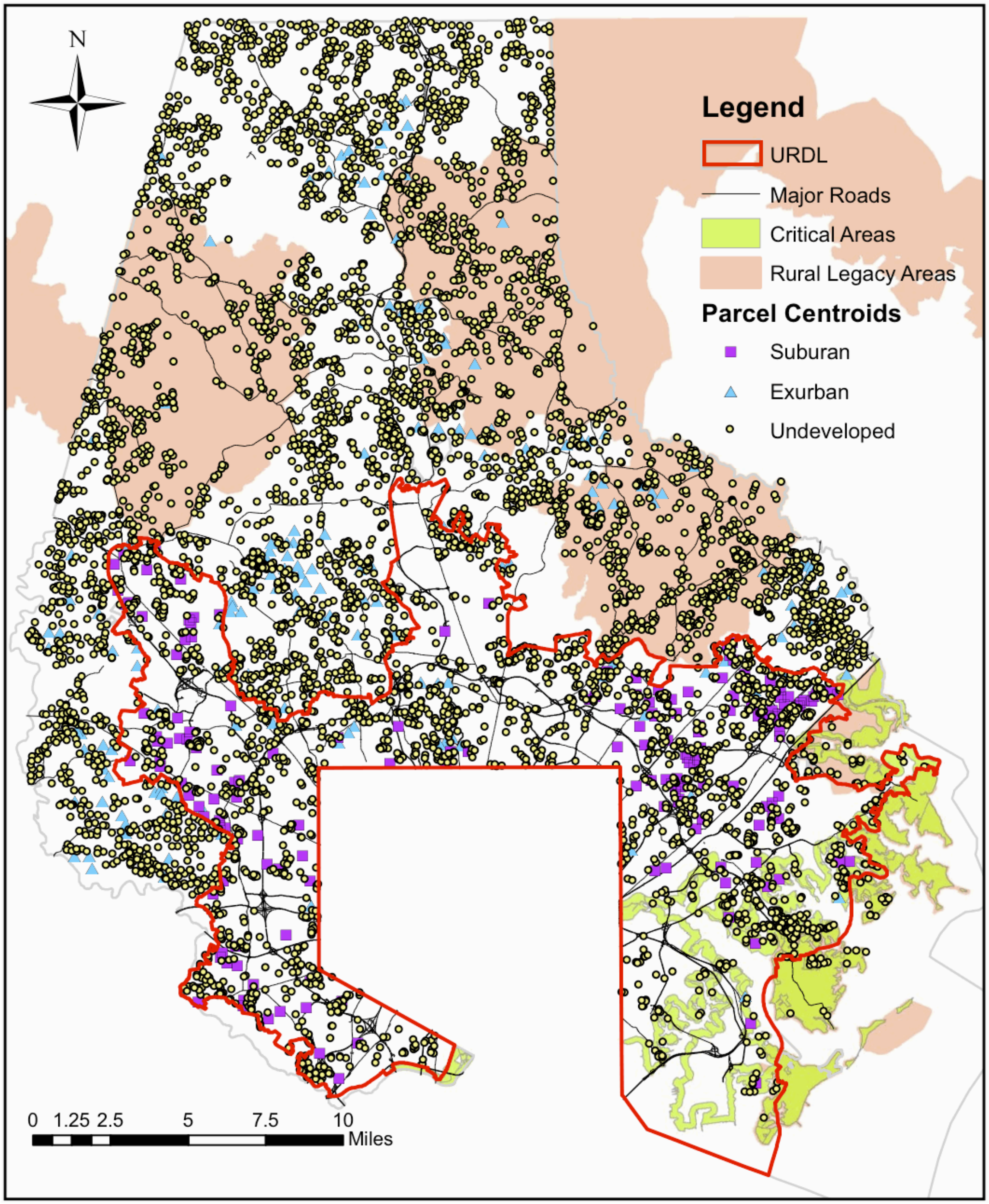

Figure 3

Coverage of critical areas and rural legacy

Figure 3 above demonstrates the limited coverage of both rural legacy areas and critical areas that may result in insignificant parameter estimates due to a lack of observations of these policy variables in each density class.

Due to the strong effect of the URDL, only simplified density classes can be applied to the county model. More specifically, outside the URDL almost no subdivisions contained a density in the high and very-high classes, while inside the URDL there were no very-low density observations (Table 4). Two additional models separately testing areas inside and outside the URDL are conducted to explore the different density levels in greater detail. For example, RC4 may affect very-low and low density in a different manner, a distinction indiscernible with the single exurban class used in the county model. In these additional models, the residential density was categorized into the following classes: very-high density (> 4 units per acre), high density (1 to 4 units per acre), low density (0.2 to 1 unit per acre), and very-low density (0.025 to 0.2 units per acre), while parcels that are vacant or less than 0.025 units per acre are considered undeveloped.

The model outside the URDL uses only the low and very-low density classes. Any high density observations were merged into the low density class (Table 4). The lack of observations in each category emphasizes how strongly enforced the URDL remains in Baltimore County as a growth regulation tool for restricting higher density suburban development. The seldom-used RC3 zone was merged into the similar RC5 classification. After the screening process, several thousand parcels under five acres remained in the dataset, while few subdivisions were of that size. Consequently, the final data for outside the URDL screened all parcels below five acres. The RC2 zone is expected to restrict development and to contain a negative coefficient for both low and very-low density because it restricts minimum lot sizes to fifty acres per house. Alternatively, the less restrictive RC4 is expected to reduce the probability of only low density. Again, these are both relative to the least restrictive RC5 zoning.

The third model analyzes data only inside the URDL. In this model, DR16 was aggregated into the DR10.5 class due to the lack of observations in this category (Table 4). All observations from 1980 onward appear in Table 5, located in appendix B. The model inside the URDL uses the low, high, and very-high density alternatives while any observations in the very-low class were merged into the low class. Similarly to the combined model, all parcels smaller then one acre were screened from this model. The DR1 zone is expected to restrict both high and very-high density due to this type not allowing subdivision density within either of these classes. Because DR2 limits density at two homes per acre, this variable will most likely restrict development for very high density. In addition, DR3.5 is expected to restrict only very-high as it allows density up to 3.5 units per acre. The least restrictive DR10.5 zone is expected to not restrict any density class. These zoning predictions are relative to DR5.5 zoning, which serves as the baseline zoning type.

4. RESULTS

4.1 County Model

The empirical results for the county model appear in Table 7 and the Relative Risk Ratio in Table 8, both in appendix B. All results are reported for robust standard error estimates. This method helps adjust for heteroskedasticity and facilitates randomly distributed error terms by providing robust variance-covariance estimations. As predicted, the RC2 zone significantly decreases the probability of exurban density, demonstrating that large minimum lot sizes can be a potent tool in preserving large tracks of rural land. While RC5 is positive and significant at the five percent level for exurban development, RC4 is insignificant and negative. This unexpected coefficient for RC4 may be due to the zone type allowing a maximum density of one house on five acres, which fits into the exurban class, yet in practice subdivisions may not always be conducted at the maximum allowed density. Despite RC4 being insignificant, the estimates for RC5 do suggest that future exurban growth is expected in areas with this zoning classification. In fact, the odds ratio reports that a parcel in the RC5 zone is 3.46 times as likely to be developed at exurban density while lots in RC2 are 0.075 times as likely compared to the base scenario. For the suburban density class, RC5, DR1, and DR2 were shown to be negative and highly significant at decreasing the probability of development compared to DR5.5 zoning. These robust estimates for these coefficients suggest that zoning policy acts as a strong tool for controlling suburban residential density in Baltimore County.

The empirical results for the physical parcel attributes mainly have the signs and significance as expected. The distance variables were positive and insignificant except for distance to the border of the City of Baltimore, which was negative and insignificant. The distance variables appear biased in all model possibly due to the timeframe is relatively recent where new subdivisions occur in the only remaining undeveloped parcels, mainly those far away from major roads and urban centers. While the natural log of acre size was positive and highly significant at both densities, the existence of a house before 1996 was positive and significant at the five percent level for exurban while negative and insignificant for suburban. This supports the hypothesis that rural parcels with an existing house are more likely to be subdivided as compared to vacant lots. The steep slope variable, while negative at both densities, is insignificant. The 100-year floodplain variable is negative and very significant for both alternatives, suggesting that policy measures aimed at protecting these areas and homeowner aversion to building in floodplains act as a potent deterrent to development. As expected, the soil variables are negative for exurban areas, although these results are insignificant. For suburban areas, very poor soil is negative and significant at the one percent level; however, poor soil is positive and insignificant.

4.2 Model for Outside the URDL

Table 9 shows the estimation results for the residential model for areas outside the URDL from 1996 to 2008 (see appendix B). The results for this model confirm the primary hypothesis regarding the impact of zoning on density. As expected, RC 2 deters development at the five percent level of significance for the very low category and at one percent for the low class. In addition, the RC 4 decreases the probability of development at the low class at the one percent level of significance. The relative odds ratio contextualize these findings; an undeveloped parcel in the RC 2 zone is 0.39 times as likely to be converted into the very low density meaning this zone type decreases the relative odds of development (Table 10). The impact of RC2 on low density is even more restrictive where vacant parcels are 0.0026 times as likely to be developed under this zoning type. Rural legacy was positive and insignificant for both density classes, thus supporting the findings by Irwin et al. (2003) that rural legacy has little effect on residential development. However, these results are biased because parcels already participating in the program were screened from the data, thus only leaving landowners uninterested in the program. The other policy variable, critical areas, was found to be positive for both density classes and significant at one percent for low density while insignificant for very low density. The positive signs for these variables suggest this policy does not protect the coastal areas of the Chesapeake Bay from exurban development.

The results for the physical land features generally contained the expected sign, yet were also insignificant. The one exception is the very poor soil class that was very significant and negative for both density classes. This suggests that low-density development is highly averse to poorly draining soil. This appears logical because areas outside the URDL rely on septic systems and poorly draining soils would cause serious issues.

4.3 Model for Inside the URDL

The results for the model inside the URDL can be seen in Table 11 (appendix B). As hypothesized, DR1 significantly restricts both high and very-high density. While DR2 is significant at the one percent level and negative for very-high density, it also restricts high density at the five prevent level of significance. The DR3.5 is shown to be negative and significant at the one percent level for the very high density, again demonstrating the ability of zoning regulations at limiting density. In fact, the odds ratio reports that a parcel zoned DR3.5 is 0.13 times as likely to be developed at a very high density (Table 12). The DR10.5 variable is negative and significant at the one percent level for both high and very high. While unexpected, these results may be due to selection bias in the dataset as apartments were removed during the screening process because these are not single-family homes. Devoid of the majority of the subdivision observations, this may explain the negative sign of DR10.5 for inside the URDL and for the combined model. As previously mentioned, these are all relative to DR5.5 zone. In general, these results demonstrate that zoned maximum density acts as a binding constraint on development. The other policy measure that applies to this model, critical areas, is negative and significant at the five percent level of significance for high density while it remains insignificant for the other two classes. While the negative impact was expected to stretch across all density classes, these limited results suggest a lack of observations in each class as discussed earlier.

For the physical land characteristics, the results do show some evidence that land characteristics are more important for higher density classes compared to lower density. For example, both soil variables were insignificant for low density while the very poor soil class was negative and significant at the one percent level for high density. The soil estimates for very-high density, while negative, both proved insignificant. The estimates for steep slope for very-high density were also shown to be very restrictive of development, while the coefficients for the other two classes proved negative but insignificant.

4.4 Predicted Probability of Future Development

The predicted probability for low density under the base scenario is provided in Figure 4 below. While this research does not test parcels within protected areas due to limited development potential, the probability figures do contain areas of the county subject to various protection programs (see appendix A for greater detail). Figure 4 visualizes what parcels in the dataset are most vulnerable to exurban development, based on the empirical estimates for the combined county model. The parcels most susceptible to exurban land fragmentation occur near the outer edge of the URDL or along the central highway stretching north through the center of the county. The areas least likely for development coincide with the highly restrictive RC2 zone that covers most of the remote areas in the county.

Figure 5 depicts the predicted probability of development at suburban density under the base scenario. While exurban density appears probable in some cases within the URDL (Figure 4), suburban density never appears likely outside the boundary. This map reaffirms the effectiveness of the URDL at restraining higher density subdivisions, thus supporting Cunningham's (2007) findings that urban growth boundaries remain an effective growth management tool. In addition, these findings reaffirm Newburn and Berck (2006); sewer and septic limitations provide the strongest policy for controlling the bulk of the population within a desired urban area.

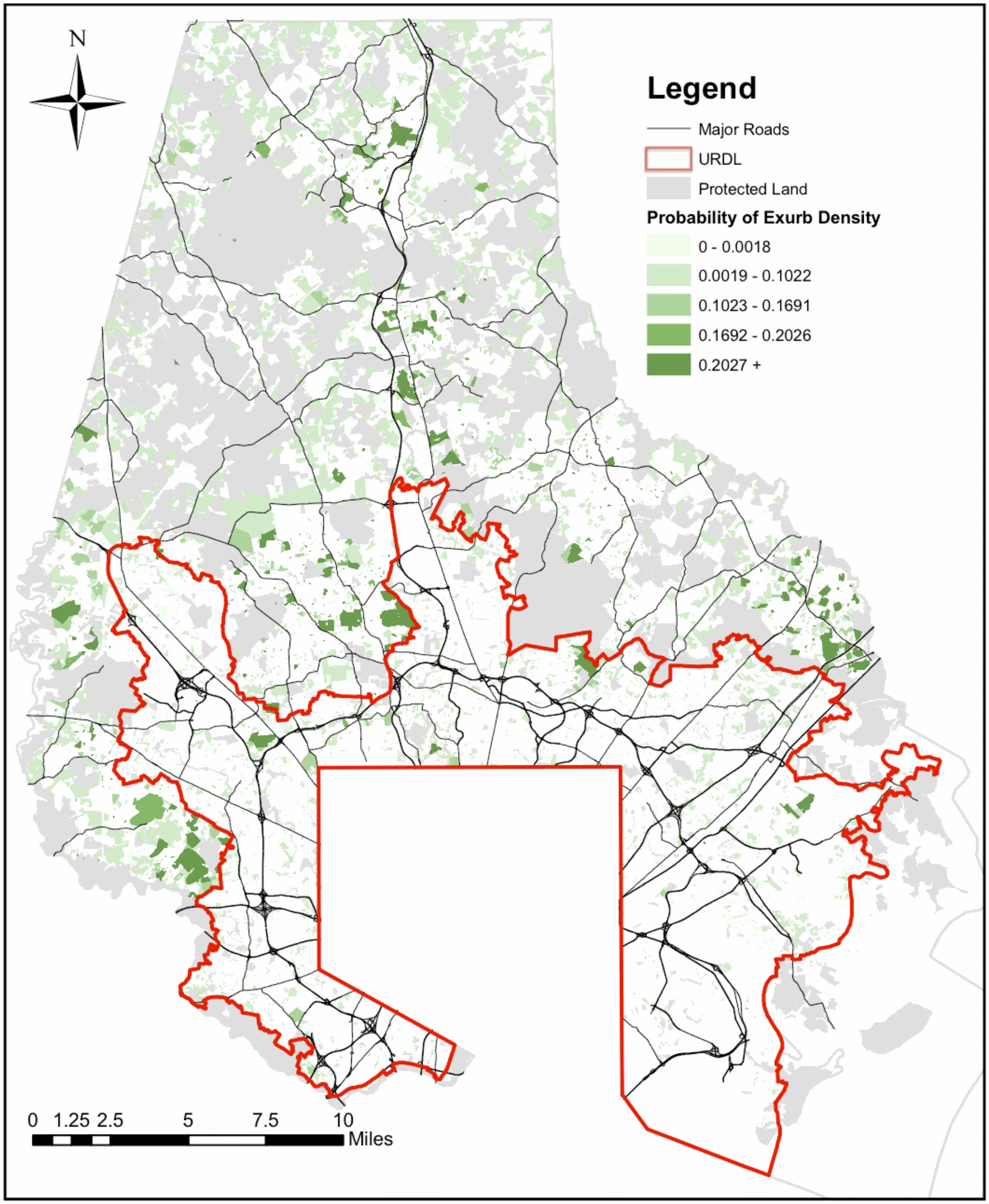

Figure 4
Predicted probability for exurban development, based on county model

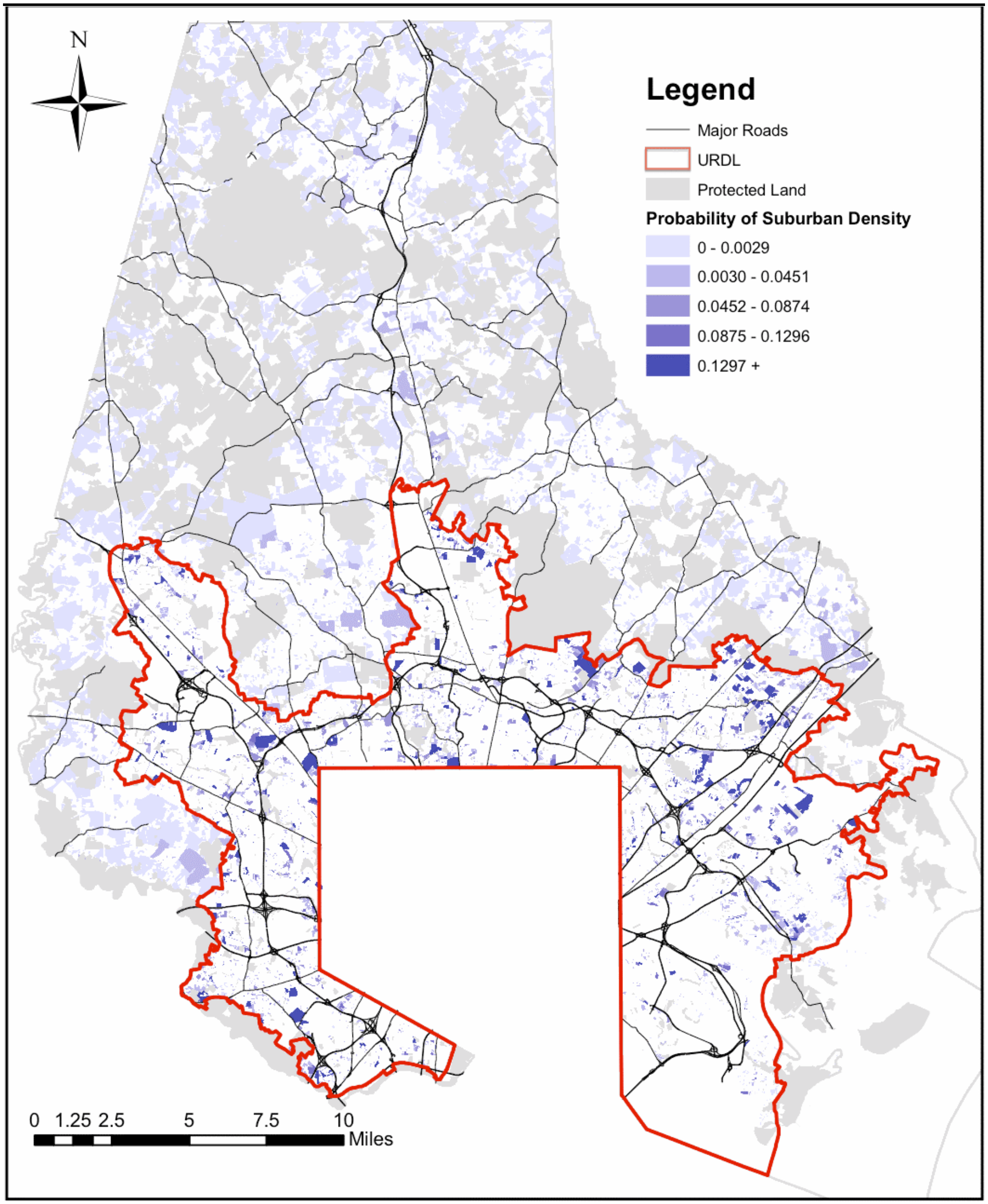

Figure 5

Predicted probability for suburban development, based on county model

4.5 Discussion

In general, all three models support the hypothesis that zoning comprises the pivotal factor in determining residential density in Baltimore County. The findings of this thesis support the evidence reported by Lichtenberg, Tra, and Hardie (2007) that zoned minimum lot sizes, in this case expressed as average density, constrain residential development. While other factors do influence density, the variables consistently determining density in nearly every model remains zoning, thus refuting the findings of McConnell, Walls, and Kopits (2006) that zoning is a minor factor in residential density. Furthermore, the results insinuate that lots are normally subdivided near the maximum allowed density, thus refuting the findings of Fulton, Williamson, Mallory, and Jones (2001). Furthermore, the diverse estimates across the multiple density classes provide strong evidence in support of the need for multiple density classes when analyzing residential development models. Finally, the maps for predicted probability visualize the effectiveness of the URDL at restricting high-density growth.

5. SUMMARY

This study develops a spatially explicit parcel-level model of residential development in Baltimore County, Maryland, to examine the effects of land-use regulations on suburban versus exurban development. This research differentiates the impact of alternative policy measures on residential development by applying four residential density classes using three separate models from 1996 to 2008. Although previous studies have been conducted on this region, never before has detailed residential subdivision data been utilized.

The empirical results demonstrate the importance of having a model that accounts for different effects across several alternative residential density classes. Otherwise, a model with a binary specification (i.e. develop or remain undeveloped) assumes that all residential density alternatives are affected the same by an explanatory variable. As hypothesized, maximum density zoned classes were also found to be binding for several density classes. For example, RC2 limits very-low and low (i.e. exurban) density, while RC4 deters low density outside the URDL and in the county model. For the model inside the URDL, DR2 was found to be restrictive at high density and DR3.5 proved binding for very high density. Given the estimates of three residential land-use models, this thesis argues that multiple density classes are needed when investigating residential development to better understand the complex impact of growth policies.

Given the results of this research, policy makers could protect farmland by applying stringent maximum zoning density regulations from exurban development. In addition, the predicted probability maps forecasting which parcels are most likely to be developed. Policymakers seeking to protect rural areas and open space should direct efforts towards protecting higher probability parcels these areas. In sum, further research on Baltimore County is needed to fully investigate the impact of factors influencing development. In particular, zoning layers for years before 1996 are needed to conduct this study over a longer timeframe.

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APPENDIX A

SCREENING PROCESS

To conduct this analysis, a series of filters was applied to screen out parcels already developed or protected prior to 1980. The goal of the screening process was to isolate the parcels likely to be developed from 1980 onward. The Baltimore County edition of MDProperty View contains roughly 330,000 separate polygons. Approximately 100,000 polygons were removed initially for being smaller than one tenth of an acre. Once exported from GIS into Microsoft Excel, any polygons less then 0.25 acres were removed.[2] Because this project focuses only on single family residential subdivisions, the 1996 zoning layer was used to screen out commercial, industrial, and apartment zoning types leaving approximately 56,000 parcels containing the DR and RC classes. Next, MDProperty View included a land use column, labeled LU_Code, providing the prominent use of the parcel based on tax records. From these, all codes other then the 100s (residential), 500s (environmental/recreational), 600s (rural), and 801 (undeveloped) were removed, cutting the number of remaining parcels by nearly half. The dissolved residential subdivisions were omitted from this screen because the LU_Code reflects the type at the centroid for the collected data, not the predominant use as in the undeveloped parcels.

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[2] The final county model and the model for inside the URDL only use parcels larger than one acre because of the rarity of residential subdivisions below the one-acre threshold; this final one-acre filter screened ten residential subdivisions while removing thousands of undeveloped polygons. The model outside the URDL used only parcels greater than five acres for the same reason.

After removing the non-residential polygons from the dataset, the next step was to eliminate parcels with existing development. After the subdivision data were dissolved, sets of columns were added to every parcel denoting the number of structures built. This included a pre1960 category while subsequent columns were separated in five-year intervals from 1960 onward providing a proxy for the development potential for parcels. Two density columns were added to the dataset, i.e. vacant in 1980 and 1996, by dividing parcel size by the number of buildings before 1980 and 1996 respectively. For the model outside the URDL, all parcels with an existing housing density greater then 0.05 units per acre (one house on twenty acres) in 1980 was considered developed and was not used, while for inside the URDL and combined models, this threshold was set at an existing density greater then 0.2 units per acre (one house one five acres) in 1980. Using these rules, a binary column denoting parcel vacancy before 1996 was also included to allow a simple method to differentiate between data for the 1980 and 1996 models.

Trimming inappropriate residential subdivision and remove undeveloped parcels in protected areas comprised the final steps in the screening process. First, any residential parcel subdivided before 1980 was removed. Then, using the landcode1c column, any subdivisions devoid of any residential parcels were removed. This insures all developed observations are residential, not commercial or industrial. Finally, two protected land layers based on polygon centroids were removed only for undeveloped parcels due to the decreased potential for residential conversion. The first, 'PresvDEPRM' comes from the Baltimore County Department of Environmental

Protection and Resource Management and represents conservation easements entered into voluntarily by landowners. The second, "ProtectLand" was created by the Maryland Department of Planning and conglomerates the various programs listed in Table 1. These two screens applied to the protected layers were not extended to the residential data because the dissolved subdivision centroids may not accurately reflect the development potential of the parcel. Figure 6 below provides visualizes the dispersal of subdivision and undeveloped parcel centroids compared to protected lands. The resulting 1980 data contains 14,444 total polygons, 8,498 parcels inside the URDL and 5,497 outside, while the 1996 model screens a further 3,085 polygons from the total dataset. When running the model, a final screen was applied removing all parcels smaller than five acres for the model outside the URDL. It was found that approximately ten subdivisions were below the five-acre threshold while several thousand undeveloped parcels were. This disproportion introduced bias into the model because these small parcels are very unlikely to be subdivided. Similarly, the model inside the URDL and the countywide combined analysis screened out any parcel smaller than one acre because of the rarity of subdivisions this size.

Table 1: Contents of the "ProtectLand" layer. Provided by Maryland Department of Planning, 2006

Definition	Last Update	Source
Maryland Agricultural Land Preservation Foundation Easements	6/30/06	MALPF
Maryland Agricultural Land Preservation Foundation District	7/2006	Maryland DNR / County
Rural Legacy Easement	3/2006	Rural Legacy/DNR
County Owned Property	1/2003	County
Department of Natural Resource's Property	1/2003	Maryland DNR
Federal Property	1/2003	Maryland DNR
Forest Legacy	1/2003	Maryland DNR
Greenprint	N/A	N/A
Maryland Environmental Trust	1/2003	Maryland DNR
Maryland Historical Trust	1/2003	Maryland DNR
Open Space from HOA or Local Open Space	1/2003	County
County Purchase of Development Rights	1/2003	County
Private Conservation Easements	1/2003	Maryland DNR / County
Military Property	1/2003	Maryland DNR

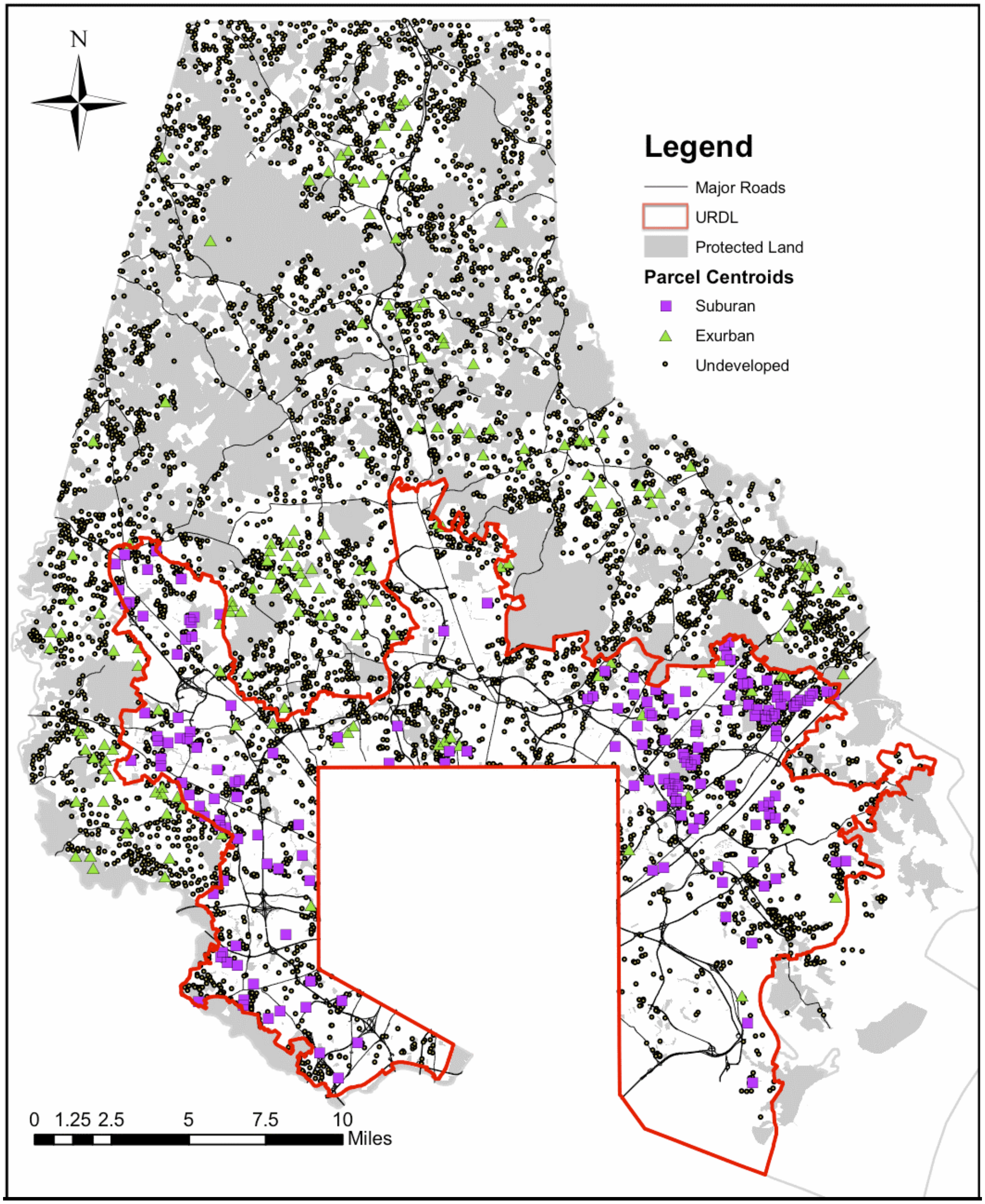

Figure 6
Observation centroid distribution compared to Protected Lands

APPENDIX B

TABLES

Table 2: Baltimore County residential zoning definitions (Baltimore County Master Plan 2000)

Zone	Name	Max Density (dwelling
RC 2	Agricultural Protection	0.02 du/ac (1 lot/50 ac.)
RC 3	Deferral of Planning and	0.3 du/ac (1 lot/3.3 ac.)
RC 4	Watershed Protection	0.2 du/ac (1 lot/5 ac.)
RC 5	Rural Residential	0.5 du/ac (1 lot/2 ac.)
DR 1		1 du/ac (1 lot on/1ac.)
DR 2		2 du/ac (2 lots on 1/ac.)
DR 3.5		3.5 du/ac (3.5 lots on 1/ac.)
DR 5.5		5.5 du/ac 5.5 lots on 1/ac.)
DR 10.5		10.5 du/ac (10.5 lots on 1/ac.)
DR 16		16 du/ac (16 lots on 1/ac.)

Table 3: Number of observations in each density class in 1996 for the combined model

Zone in 1996	Vacant	Exurban	Suburban	Total
RC 2	1790	7		1797
RC 4	1030	30		1060
RC 5	1106	101	1	1208
DR 1	500	13	6	519
DR 2	1033	4	19	1056
DR 3.5	1698	9	70	1777
DR 5.5	2796	4	69	2869
DR 10.5	953	1	15	969
Total	10906	169	180	11255

Table 4: Number of observations in each density category in the 1996 dataset with uniform density rules applied

Zone in 1996	Vacant	Very Low	Low	High	Very High	Total
RC 2	1611	27	3			1641
RC 3	76	1	3			80
RC 4	857	53	12			922
RC 5	968	12	78	1		1059
DR 1	498	2	13	6		519
DR 2	1031	2	4	19		1056
DR 3.5	1693	5	9	66	4	1777
DR 5.5	2790	6	4	42	27	2869
DR 10.5	206		1	4	3	214
DR 16	745			2	6	753
Total	10475	108	127	140	40	10890

Table 5: Number of observations in all density classes from 1980 dataset

Zone in 1996	Vacant	Very Low	Low	High	Very High	Total
RC 2	2102	47	31			2180
RC 4	1158	90	45			1293
RC 5	1693	22	203	1		1919
DR 1	605	2	22	16		645
DR 2	1256	2	13	60	2	1333
DR 3.5	2013	5	18	118	27	2181
DR 5.5	3547	7	7	81	108	3750
DR 10.5	987		2	12	36	1037
Total	13361	175	341	288	173	14340

Table 6: Number of observations in each density class in 1980 for the combined model

Zone in 1996	Vacant	Exurban	Suburban	Total
RC 2	2149	31		2180
RC 4	1248	45		1293
RC 5	1715	203	1	1919
DR 1	607	22	16	645
DR 2	1258	13	62	1333
DR 3.5	2018	18	145	2181
DR 5.5	3554	7	189	3750
DR 10.5	989	2	48	1039
Total	13538	341	461	14340

Table 7: County model for 1996 to 2008 in Baltimore County, Maryland

Multinomial logistic regression		Number of obs	=	6267
		Wald chi2(34)	=	24057.87
		Prob > chi2	=	0.0000
Log pseudolikelihood = -931.52178		Pseudo R2	=	0.4031

DensClassD~l	Coef.	Robust Std. Err.	z	P>|z|
Exurban				
RC2	-2.593845	.7535107	-3.44	0.001
RC4	-.4763498	.6407178	-0.74	0.457
RC5	1.240156	.5707667	2.17	0.030
DR1	.8469243	.6374177	1.33	0.184
DR2	-.0887471	.7509788	-0.12	0.906
DR3_5	.5667108	.631977	0.90	0.370
DR10_5	-1.655763	1.116797	-1.48	0.138
DistMjrRds	.0325867	.2508813	0.13	0.897
DstCityBdr	-.0368717	.0220515	-1.67	0.095
RuralLegacy	-.0360759	.2989	-0.12	0.904
CriticalArea	.301034	.920716	0.33	0.744
House96	.4971622	.2143184	2.32	0.020
lnParcelAcre	1.124121	.0793912	14.16	0.000
Slope15%	-.3466676	.3281908	-1.06	0.291
Floodplain	-3.897739	1.582575	-2.46	0.014
PoorSoil	-.2438405	.2790306	-0.87	0.382
VeryPoorSoil	-1.819576	1.107411	-1.64	0.100
_cons	-5.954538	.5642516	-10.55	0.000
Suburban				
RC2	-20.43471	.5561977	-36.74	0.000
RC4	-20.3142	.5500006	-36.93	0.000
RC5	-6.366789	1.059756	-6.01	0.000
DR1	-2.703867	.5115747	-5.29	0.000
DR2	-1.299243	.3476967	-3.74	0.000
DR3_5	-.2969527	.2293618	-1.29	0.195
DR10_5	-1.905268	.3190429	-5.97	0.000
DistMjrRds	.1734393	.3144437	0.55	0.581
DstCityBdr	.0019872	.0392126	0.05	0.960
RuralLegacy	-13.77193	.4345401	-31.69	0.000
CriticalArea	-1.003352	.5321391	-1.89	0.059
House96	-.0671083	.2484232	-0.27	0.787
lnParcelAcre	1.318106	.089576	14.71	0.000
Slope15%	-.6290608	.5383004	-1.17	0.243
Floodplain	-2.537232	.6983897	-3.63	0.000
PoorSoil	.2319266	.1959392	1.18	0.237
VeryPoorSoil	-1.518584	.4787817	-3.17	0.002
_cons	-3.752544	.2938407	-12.77	0.000

Table 8: Relative Risk Ratio estimates for county model

DensClassD~l	RRR	Robust Std. Err.	z	P>|z|
Exurban				
RC2	.0747322	.0563115	-3.44	0.001
RC4	.6210462	.3979153	-0.74	0.457
RC5	3.456151	1.972656	2.17	0.030
DR1	2.332462	1.486752	1.33	0.184
DR2	.915077	.6872034	-0.12	0.906
DR3_5	1.76246	1.113834	0.90	0.370
DR10_5	.1909462	.2132481	-1.48	0.138
DistMjrRds	1.033123	.2591914	0.13	0.897
DstCityBdr	.9637998	.0212532	-1.67	0.095
RuralLegacy	.9645671	.2883091	-0.12	0.904
CriticalArea	1.351255	1.244122	0.33	0.744
House96	1.644049	.3523499	2.32	0.020
lnParcelAcre	3.077511	.2443274	14.16	0.000
Slope15%	.7070403	.2320441	-1.06	0.291
Floodplain	.0202877	.0321069	-2.46	0.014
PoorSoil	.7836126	.2186519	-0.87	0.382
VeryPoorSoil	.1620944	.1795051	-1.64	0.100
Suburban				
RC2	1.33e-09	7.42e-10	-36.74	0.000
RC4	1.51e-09	8.28e-10	-36.93	0.000
RC5	.0017177	.0018203	-6.01	0.000
DR1	.0669461	.0342479	-5.29	0.000
DR2	.2727382	.0948302	-3.74	0.000
DR3_5	.7430792	.170434	-1.29	0.195
DR10_5	.1487828	.0474681	-5.97	0.000
DistMjrRds	1.189388	.3739957	0.55	0.581
DstCityBdr	1.001989	.0392906	0.05	0.960
RuralLegacy	1.04e-06	4.54e-07	-31.69	0.000
CriticalArea	.3666483	.1951079	-1.89	0.059
House96	.9350939	.232299	-0.27	0.787
lnParcelAcre	3.736338	.3346864	14.71	0.000
Slope15%	.5330923	.2869638	-1.17	0.243
Floodplain	.079085	.0552322	-3.63	0.000
PoorSoil	1.261027	.2470847	1.18	0.237
VeryPoorSoil	.2190218	.1048636	-3.17	0.002

Table 9: Model for outside the URDL from 1996 to 2008

Multinomial logistic regression	Number of obs	=	1693
	Wald chi2(24)	=	1852.87
	Prob > chi2	=	0.0000
Log pseudolikelihood = -469.96781	Pseudo R2	=	0.3402

DensClassC~e	Coef.	Robust Std. Err.	z	P>|z|
Very Low				
RC2	-.944923	.3996773	-2.36	0.018
RC4	.9417669	.3784455	2.49	0.013
RuralLegacy	.2706985	.2892468	0.94	0.349
CriticalArea	-41.69824	3.37335	-12.36	0.000
DistMjrRds	-.0813205	.3156165	-0.26	0.797
DstCityBdr	.0155378	.0216677	0.72	0.473
House96	.680023	.2580681	2.64	0.008
lnParcelAcre	1.387579	.1421722	9.76	0.000
Slope15%	-.2092688	.3700782	-0.57	0.572
Floodplain	-1.160063	1.246308	-0.93	0.352
PoorSoil	-.1933729	.4888383	-0.40	0.692
VeryPoorSoil	-14.16853	.5901759	-24.01	0.000
_cons	-8.03408	.6296121	-12.76	0.000
Low				
RC2	-5.954681	1.217909	-4.89	0.000
RC4	-2.071866	.3625342	-5.71	0.000
RuralLegacy	.1616063	.4114971	0.39	0.695
CriticalArea	5.925973	1.670222	3.55	0.000
DistMjrRds	-.2482387	.3300597	-0.75	0.452
DstCityBdr	-.0201419	.0253529	-0.79	0.427
House96	-.3548474	.3110731	-1.14	0.254
lnParcelAcre	1.198056	.1443264	8.30	0.000
Slope15%	-.6229235	.4704832	-1.32	0.186
Floodplain	-2.415766	2.216812	-1.09	0.276
PoorSoil	-.5643684	.4223634	-1.34	0.181
VeryPoorSoil	-16.19722	.4960021	-32.66	0.000
_cons	-4.47217	.5196319	-8.61	0.000

Table 10: Relative Risk Ratio estimates for the model outside the URDL

DensClassC~e	RRR	Robust Std. Err.	z	P>|z|
Very Low				
RC2	.3887095	.1553584	-2.36	0.018
RC4	2.564509	.9705267	2.49	0.013
RuralLegacy	1.31088	.3791679	0.94	0.349
CriticalArea	7.77e-19	2.62e-18	-12.36	0.000
DistMjrRds	.9218982	.2909663	-0.26	0.797
DstCityBdr	1.015659	.022007	0.72	0.473
House96	1.973923	.5094066	2.64	0.008
lnParcelAcre	4.005142	.56942	9.76	0.000
Slope15%	.8111772	.300199	-0.57	0.572
Floodplain	.3134663	.3906757	-0.93	0.352
PoorSoil	.8241746	.4028881	-0.40	0.692
VeryPoorSoil	7.03e-07	4.15e-07	-24.01	0.000
Low				
RC2	.0025937	.0031589	-4.89	0.000
RC4	.1259505	.0456614	-5.71	0.000
RuralLegacy	1.175397	.4836726	0.39	0.695
CriticalArea	374.6426	625.7364	3.55	0.000
DistMjrRds	.7801737	.2575039	-0.75	0.452
DstCityBdr	.9800596	.0248473	-0.79	0.427
House96	.7012805	.2181495	-1.14	0.254
lnParcelAcre	3.313668	.4782499	8.30	0.000
Slope15%	.536374	.252355	-1.32	0.186
Floodplain	.0892989	.197959	-1.09	0.276
PoorSoil	.5687192	.2402062	-1.34	0.181
VeryPoorSoil	9.24e-08	4.58e-08	-32.66	0.000

Table 11: Model for inside the URDL from 1996 to 2008

Multinomial logistic regression		Number of obs	=	2202
		Wald chi2(39)	=	8685.77
		Prob > chi2	=	0.0000
Log pseudolikelihood = -607.07362		Pseudo R2	=	0.2832

DensClassC~e	Coef.	Robust Std. Err.	z	P>|z|
Low				
DR1	.9503751	.6776234	1.40	0.161
DR2	-.1169786	.741953	-0.16	0.875
DR35	.5883014	.6529575	0.90	0.368
DR105	-1.540274	1.121803	-1.37	0.170
CriticalArea	.2898937	1.013948	0.29	0.775
DistMjrRds	.393378	.7331492	0.54	0.592
DstCityBdr	-.1272567	.1155778	-1.10	0.271
House96	1.038229	.4030469	2.58	0.010
lnParcelAcre	1.274255	.1581604	8.06	0.000
Slope15%	-1.703672	1.279109	-1.33	0.183
Floodplain	-6.499101	2.469592	-2.63	0.008
PoorSoil	.2167762	.4232032	0.51	0.608
VeryPoorSoil	-.9229707	1.14137	-0.81	0.419
_cons	-6.479819	.8176918	-7.92	0.000
High				
DR1	-2.249015	.543018	-4.14	0.000
DR2	-.7968829	.3712891	-2.15	0.032
DR35	.1451166	.2545262	0.57	0.569
DR105	-2.304614	.4417872	-5.22	0.000
CriticalArea	-1.207188	.5885075	-2.05	0.040
DistMjrRds	.2810383	.3388716	0.83	0.407
DstCityBdr	-.016695	.0480843	-0.35	0.728
House96	-.0471434	.2725241	-0.17	0.863
lnParcelAcre	1.400279	.1033431	13.55	0.000
Slope15%	-.7396287	.6008377	-1.23	0.218
Floodplain	-2.097617	.719944	-2.91	0.004
PoorSoil	.3348552	.2223059	1.51	0.132
VeryPoorSoil	-1.44296	.5149947	-2.80	0.005
_cons	-4.44427	.3608821	-12.32	0.000
Very High				
DR1	-18.23723	.3252738	-56.07	0.000
DR2	-17.92826	.3138153	-57.13	0.000
DR35	-2.0107	.5295438	-3.80	0.000
DR105	-1.388068	.4476755	-3.10	0.002
CriticalArea	-1.02546	1.095624	-0.94	0.349
DistMjrRds	-.2702217	.6610606	-0.41	0.683
DstCityBdr	.0090899	.067427	0.13	0.893
House96	.1180158	.5405272	0.22	0.827
lnParcelAcre	1.083852	.1643824	6.59	0.000
Slope15%	-15.43313	.3507496	-44.00	0.000
Floodplain	-5.675502	2.419028	-2.35	0.019
PoorSoil	-.1454543	.3689045	-0.39	0.693
VeryPoorSoil	-1.780049	1.092794	-1.63	0.103
_cons	-4.00703	.5033056	-7.96	0.000

Table 12: Relative Risk Ratio estimates for the model inside the URDL

DensClassC~e	RRR	Robust Std. Err.	z	P>|z|
Low				
DR1	2.58668	1.752795	1.40	0.161
DR2	.8896042	.6600445	-0.16	0.875
DR35	1.800927	1.175929	0.90	0.368
DR105	.2143223	.2404275	-1.37	0.170
CriticalArea	1.336285	1.354924	0.29	0.775
DistMjrRds	1.481978	1.086511	0.54	0.592
DstCityBdr	.8805076	.1017672	-1.10	0.271
House96	2.824212	1.13829	2.58	0.010
lnParcelAcre	3.576035	.565587	8.06	0.000
Slope15%	.1820139	.2328156	-1.33	0.183
Floodplain	.0015048	.0037162	-2.63	0.008
PoorSoil	1.242066	.5256463	0.51	0.608
VeryPoorSoil	.3973369	.4535084	-0.81	0.419
High				
DR1	.1055031	.0572901	-4.14	0.000
DR2	.4507317	.1673518	-2.15	0.032
DR35	1.156174	.2942766	0.57	0.569
DR105	.0997973	.0440892	-5.22	0.000
CriticalArea	.2990369	.1759854	-2.05	0.040
DistMjrRds	1.324504	.4488369	0.83	0.407
DstCityBdr	.9834436	.0472882	-0.35	0.728
House96	.9539506	.2599745	-0.17	0.863
lnParcelAcre	4.056331	.4191939	13.55	0.000
Slope15%	.4772911	.2867745	-1.23	0.218
Floodplain	.1227486	.0883722	-2.91	0.004
PoorSoil	1.397738	.3107255	1.51	0.132
VeryPoorSoil	.2362276	.121656	-2.80	0.005
Very High				
DR1	1.20e-08	3.91e-09	-56.07	0.000
DR2	1.64e-08	5.13e-09	-57.13	0.000
DR35	.133895	.0709032	-3.80	0.000
DR105	.2495569	.1117205	-3.10	0.002
CriticalArea	.3586315	.3929252	-0.94	0.349
DistMjrRds	.7632103	.5045282	-0.41	0.683
DstCityBdr	1.009131	.0680427	0.13	0.893
House96	1.125262	.6082347	0.22	0.827
lnParcelAcre	2.956044	.4859218	6.59	0.000
Slope15%	1.98e-07	6.96e-08	-44.00	0.000
Floodplain	.0034289	.0082947	-2.35	0.019
PoorSoil	.8646294	.3189657	-0.39	0.693
VeryPoorSoil	.1686298	.1842777	-1.63	0.103

Table 13: County model for 1980 to 2008 in Baltimore County, Maryland

```
Multinomial logistic regression       Number of obs   =       8095
                                      Wald chi2(34)   =   36402.30
                                      Prob > chi2     =     0.0000
Log pseudolikelihood = -1590.1017     Pseudo R2       =     0.4815
------------------------------------------------------------
             |               Robust
DensClassD~l |      Coef.   Std. Err.      z    P>|z|
-------------+----------------------------------------------
Exurban      |
         RC2 |  -1.912102   .5073163    -3.77   0.000
         RC4 |  -.9007281   .4827921    -1.87   0.062
         RC5 |   1.032123   .4236718     2.44   0.015
         DR1 |   .7229387   .4766937     1.52   0.129
         DR2 |   .4484969   .5006008     0.90   0.370
       DR3_5 |   .7394085   .4676163     1.58   0.114
      DR10_5 |  -1.196949   .8194394    -1.46   0.144
  DistMjrRds |  -.2576514    .205825    -1.25   0.211
  DstCityBdr |  -.0112526   .0148133    -0.76   0.447
 RuralLegacy |   .2114454   .2119295     1.00   0.318
CriticalArea |  -.3302741   .8761702    -0.38   0.706
     House80 |   1.457682   .1413776    10.31   0.000
lnParcelAcre |   1.045693    .051371    20.36   0.000
    Slope15% |  -.4019489   .2211987    -1.82   0.069
  Floodplain |   -3.33681   1.362778    -2.45   0.014
    PoorSoil |  -.1337332   .2191526    -0.61   0.542
VeryPoorSoil |  -1.668843    .796589    -2.09   0.036
       _cons |  -5.782816   .4288036   -13.49   0.000
-------------+----------------------------------------------
Suburban     |
         RC2 |  -22.75377   .4520129   -50.34   0.000
         RC4 |  -22.98413   .4157492   -55.28   0.000
         RC5 |  -7.838163   1.057357    -7.41   0.000
         DR1 |  -2.989887   .3289362    -9.09   0.000
         DR2 |  -1.407649   .2477383    -5.68   0.000
       DR3_5 |  -.5358478   .1856663    -2.89   0.004
      DR10_5 |   -1.23775   .2221574    -5.57   0.000
  DistMjrRds |   .0962129   .2325051     0.41   0.679
  DstCityBdr |  -.0020626   .0314787    -0.07   0.948
 RuralLegacy |  -15.93514   .5689975   -28.01   0.000
CriticalArea |  -1.014636   .4021352    -2.52   0.012
     House80 |    1.90295   .1528455    12.45   0.000
lnParcelAcre |   1.296892   .0720245    18.01   0.000
    Slope15% |  -1.029118    .407601    -2.52   0.012
  Floodplain |  -3.135894   .5824729    -5.38   0.000
    PoorSoil |   .0036131    .151894     0.02   0.981
VeryPoorSoil |  -1.652602   .3339554    -4.95   0.000
       _cons |  -3.537803   .2269884   -15.59   0.000
------------------------------------------------------------
```

Table 14: Residential model for outside the URDL from 1980 to 2008

Multinomial logistic regression	Number of obs	=	2170
	Wald chi2(24)	=	2208.55
	Prob > chi2	=	0.0000
Log pseudolikelihood = -919.95367	Pseudo R2	=	0.3019

DensClassC~e	Coef.	Robust Std. Err.	z	P>|z|
Very Low				
RC2	-.7716105	.3122683	-2.47	0.013
RC4	.9070792	.2933165	3.09	0.002
DistMjrRds	-.029407	.2235523	-0.13	0.895
DstCityBdr	.0291399	.0166703	1.75	0.080
RuralLegacy	.227451	.2237869	1.02	0.309
CriticalArea	-39.52907	3.178863	-12.43	0.000
House80	-.1352819	.2148475	-0.63	0.529
lnParcelAcre	1.378544	.1014311	13.59	0.000
Slope15%	-.2743878	.291097	-0.94	0.346
Floodplain	-1.446333	.9455756	-1.53	0.126
PoorSoil	-.295543	.4374435	-0.68	0.499
VeryPoorSoil	-13.17338	.4914647	-26.80	0.000
_cons	-7.285079	.4550724	-16.01	0.000
Low				
RC2	-3.531008	.2928766	-12.06	0.000
RC4	-1.750259	.2282746	-7.67	0.000
DistMjrRds	-.2697374	.2366991	-1.14	0.254
DstCityBdr	-.0172526	.0163709	-1.05	0.292
RuralLegacy	.1954915	.221847	0.88	0.378
CriticalArea	2.664342	1.301053	2.05	0.041
House80	-.5185408	.2007987	-2.58	0.010
lnParcelAcre	1.126726	.1026223	10.98	0.000
Slope15%	-.1617137	.2672136	-0.61	0.545
Floodplain	-3.422725	1.382386	-2.48	0.013
PoorSoil	-.8821261	.3309368	-2.67	0.008
VeryPoorSoil	-15.16294	.4092594	-37.05	0.000
_cons	-3.478485	.3517281	-9.89	0.000

Table 15: Residential model for inside the URDL from 1980 to 2008

```
Multinomial logistic regression          Number of obs   =       2703
                                         Wald chi2(39)   =   14596.93
                                         Prob > chi2     =     0.0000
Log pseudolikelihood = -1201.2558        Pseudo R2       =     0.309
```

DensClassC~e	Coef.	Robust Std. Err.	z	P>|z|
Low				
DR1	.9135067	.4707618	1.94	0.052
DR2	.7102435	.495629	1.43	0.152
DR35	.8429591	.4646849	1.81	0.070
DR105	-1.348546	.8393097	-1.61	0.108
CriticalArea	-.4417028	1.00017	-0.44	0.659
DistMjrRds	.1093512	.5073788	0.22	0.829
DstCityBdr	-.1015617	.0768714	-1.32	0.186
House80	.9487701	.3153912	3.01	0.003
lnParcelAcre	1.186773	.1302714	9.11	0.000
Slope15%	-1.064547	.6789746	-1.57	0.117
Floodplain	-4.064166	2.584478	-1.57	0.116
PoorSoil	.219819	.2869301	0.77	0.444
VeryPoorSoil	-1.053449	.8722424	-1.21	0.227
_cons	-5.731719	.5661456	-10.12	0.000
High				
DR1	-1.885348	.3512026	-5.37	0.000
DR2	-.1544766	.244892	-0.63	0.528
DR35	.2432839	.2010155	1.21	0.226
DR105	-2.161647	.3073993	-7.03	0.000
CriticalArea	-.6175186	.451764	-1.37	0.172
DistMjrRds	.2081392	.2388926	0.87	0.384
DstCityBdr	-.0470135	.0381026	-1.23	0.217
House80	-.0954199	.2084799	-0.46	0.647
lnParcelAcre	1.497818	.0859736	17.42	0.000
Slope15%	-1.24248	.4357548	-2.85	0.004
Floodplain	-2.583365	.6829932	-3.78	0.000
PoorSoil	.0536477	.1650043	0.33	0.745
VeryPoorSoil	-1.397418	.3719165	-3.76	0.000
_cons	-3.908644	.2618198	-14.93	0.000
Very High				
DR1	-18.42542	.2537457	-72.61	0.000
DR2	-3.966966	.7474771	-5.31	0.000
DR35	-1.643373	.2584087	-6.36	0.000
DR105	-1.417891	.2648134	-5.35	0.000
CriticalArea	-2.493492	.9429454	-2.64	0.008
DistMjrRds	-.0647257	.3424328	-0.19	0.850
DstCityBdr	.0235737	.0430278	0.55	0.584
House80	-.0193285	.269512	-0.07	0.943
lnParcelAcre	1.399128	.1019192	13.73	0.000
Slope15%	-1.426154	.6920977	-2.06	0.039
Floodplain	-5.444019	1.301621	-4.18	0.000
PoorSoil	-.1270514	.1943526	-0.65	0.513
VeryPoorSoil	-1.639762	.500467	-3.28	0.001
_cons	-3.339866	.2710957	-12.32	0.000

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