Consideration of Ecological Value and Development Pressure in Land Conservation Decisions

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Introduction. Throughout most of the Chesapeake Bay watershed, remaining large tracts of forests and farmlands are threatened with fragmentation and parcelization due to urban development pressure. "If recent trends continue, the area of developed land in the (Bay) watershed will increase by more than 60% by 2030" (Boesch and Greer, 2003). In light of these issues, the Chesapeake Bay Program Partnership has committed to permanently preserve 20% of the land area in the Bay watershed from development and to target the most valued and vulnerable lands for protection (Chesapeake Executive Council, 2000). This study focuses on assessing the vulnerability of large, contiguous forest tracts to development and proposes a method for combining measures of vulnerability and ecological value to prioritize areas for conservation.

Ideally, growth models such as SLEUTH (Clarke, et al., 1997) and the Western Futures Model (Theobald, 2001) would be employed to forecast development throughout the watershed, however, both models warrant customization to improve the accuracy of their long-term forecasts and to better understand their strengths and weaknesses (Claggett, et al., in press). Accuracy tests of the Western Futures Model revealed that areas within close proximity to recent growth hot spots are likely to be growth areas in the following decade (Ibid). Therefore, to forecast development pressure to the year 2010, proximity to recent growth hot spots was used as a surrogate measure for output from growth projection models. Growth hotspots were identified on the basis of recent changes in impervious surfaces and housing units.

Identifying developable lands. Forest lands were considered to be "vulnerable" if they were both susceptible to impairment and exposed to stressors. Eastern forests are affected by a variety of stressors in addition to development such as invasive species, diseases, acidic deposition, fire, and resource extraction. For the purposes of this study, however, "vulnerability" was defined as a function of suitability for development and proximity to growth hot spots. Areas of the Bay watershed considered unsuitable for development include emergent wetlands, open water, major roads, surface mines, steep slopes, and unpopulated census blocks (Figure 1). Forests within the remaining landscape were considered to be suitable for development and therefore susceptible to impairment (Figure 2).

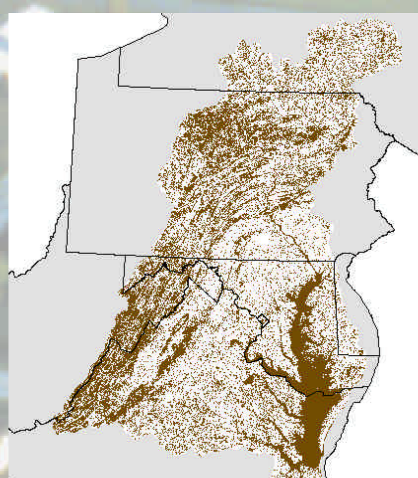

Figure 1. Unsuitable lands for development (brown). Including emergent wetlands, open water, major roads, surface mines, steep slopes, and unpopulated census blocks.

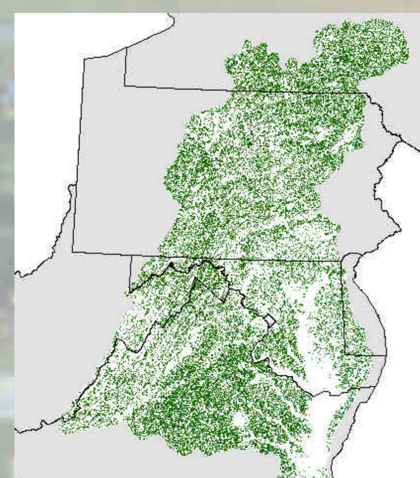

Figure 2. Forests on developable lands in the Chesapeake Bay watershed.

Mapping housing unit data. An overlay grid of 1-square-mile-cells was used to integrate impervious surface and housing unit data. Prior to aggregating the 1990 and 2000 census data to the overlay grid, the total number of housing units and single-detached housing units within each block group were distributed to a 30-m road density grid (derived from Tiger Line Files using a 1-km focalsum filter) on the basis of the relative proportion of road density values within each block group (Figure 3).

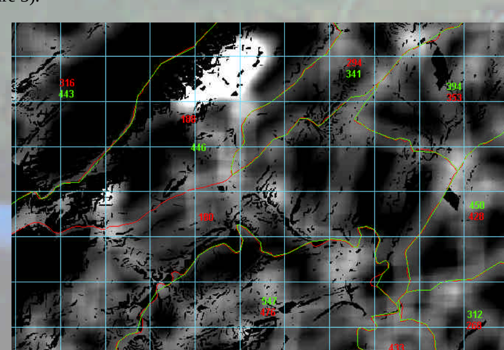

Figure 3. One-square-mile-cell overlay grid (blue lines) overlaying census block group polygons attributed with the total number of single-family-detached housing units in 1990 (red) and 2000 (green) overlaying a 1-km filtered road density grid (white depicts areas with relatively high road densities). Areas unsuitable for development and/or further than 1-km from an existing road are shown in black.

Estimating residential land consumption. To capture the differential impact of large lot residential development on the fragmentation and parcelization of forest lands, a linear regression model for determining lot size based on road density was developed (Figure 4). Mean lot size values for cells within the 1-square-mile-cell overlay grid were estimated from parcel center points (attributed with lot size) for eight counties in Maryland representing rural, suburban, and urban counties. Within these same cells, mean road density values were summarized from the 30-m road density grid (Figure 5).

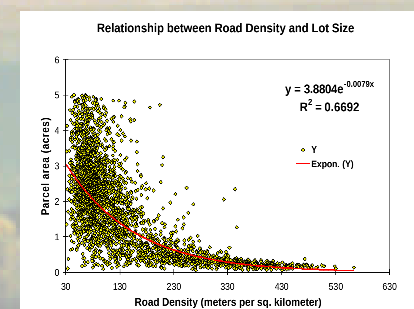

Figure 4. Linear regression model showing the relationship between mean road density and mean parcel area within eight counties in Maryland.

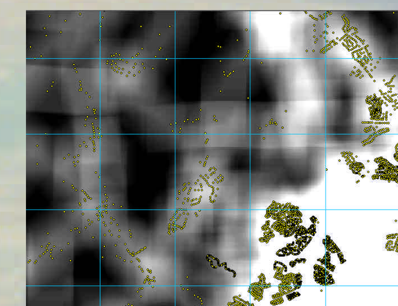

Figure 5. The 1-square-mile-cell grid (blue) overlaying the parcel point data (yellow) and 30-m road density grid (grey scale).

Identifying residential growth hot spots. Hot spots of significant residential development were identified using a stratified classification of changes in single-detached housing units between 1990 and 2000. Significant changes were defined as changes greater or equal to 0.5 standard deviations from the mean. Substituting single-detached housing units for the total number of housing units focused attention on moderate and low density residential development (Figure 6). Classifying changes in single-detached housing units separately within three categories of Rural-Urban Commuting Areas (RUCA) served to better detect relative hot spots of change in suburban and rural areas and to avoid biasing the analysis towards growth in urban centers (Figure 7). Multiplying the changes in single-detached housing units by the estimates of mean lot size focused attention on large lot suburban and rural development (Figure 8).

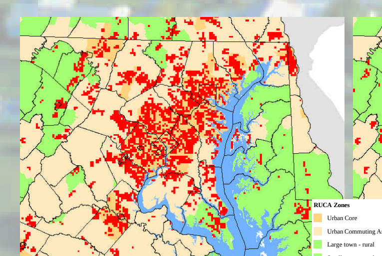

Figure 6. Significant changes in single-detached housing units in the Baltimore-Washington, D.C. region using a uniform classification.

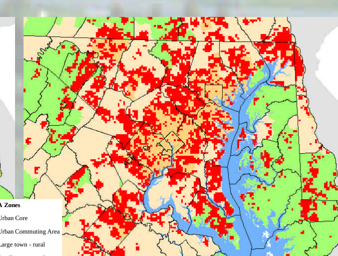

Figure 7. Significant changes in single-detached housing units in the Baltimore-Washington, D.C. region using a stratified classification based on three aggregate classes of Rural-Urban Commuting Areas.

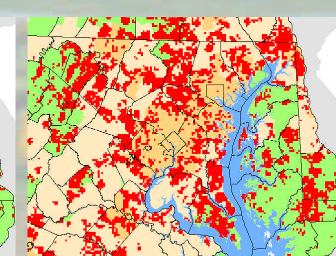

Figure 8. Significant changes in residential land consumption in the Baltimore-Washington, D.C. region derived by multiplying the stratified changes in single-detached housing units by estimates of mean lot size.

Identifying impervious surface growth hot spots. Smith et al. (in press) have produced 30-m grids of impervious surfaces for 1990 and 2000 covering the entire Bay watershed using a subpixel mapping algorithm. Mean impervious surface values from both years were summarized for cells in the 1-square-mile-cell overlay grid. Significant increases in impervious surfaces were estimated using a classification stratified on the basis of Rural-Urban Commuting Areas, similar to the method used to map the housing unit data. Change within an overlay grid cell was considered significant if it was within the highest three of five classes based on Jenks' optimization algorithm. This method resulted in assigning significance to all cells with increases in impervious surfaces greater than 15.6 acres. Generally, significant increases in impervious surface corresponded to significant increases in residential land consumption (Figure 9). Areas of difference may result from commercial, industrial, or multi-family housing unit development.

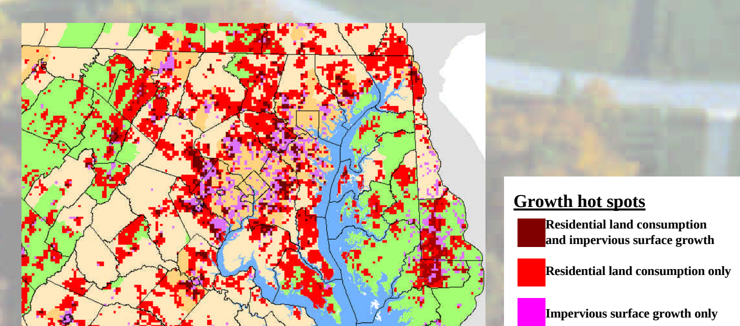

Figure 9. Growth hot spots. Overlay grid cells exhibiting significant increases in impervious surfaces and/or residential land consumption between 1990 and 2000.

Measuring development pressure. Development pressure in areas surrounding growth hot spots was determined on the basis of the mean travel time along the existing road network to all growth hot spots (Figure 10).

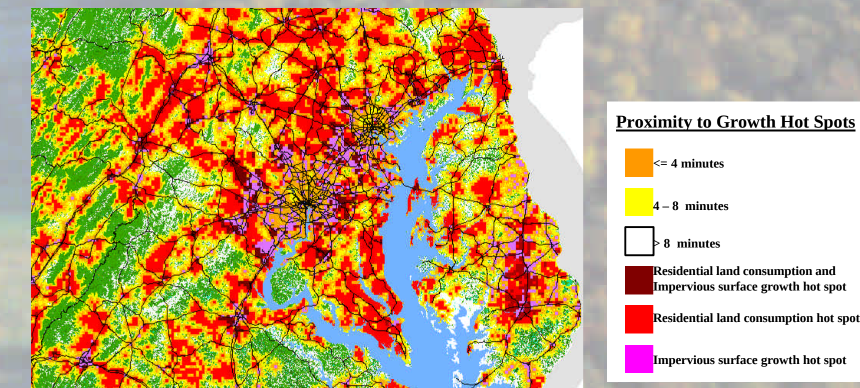

Figure 10. Development pressure ranging from very high (dark red, red, purple) to high (orange), moderate (yellow), and low (transparent) overlaying forest cover on developable lands. Major roads are shown as black lines.

Prioritizing conservation activities. To better prioritize conservation activities, all developable forest tracts were ranked based on a combination of their mean level of development pressure and ecological value. The Maryland Department of Natural Resources evaluated the relative ecological value all large, contiguous forest tracts in the Chesapeake Bay watershed, excluding those in New York. The ecological value represents a composite score of a variety of factors including native, rare, and neotropical migratory species richness, topographical relief, and distance from major roads (Weber, 2001). To combine the ecological values with development pressure, the value ranges of both were normalized to a categorical scale ranging from 1 (low) to 4 (very high). Ecological values were given precedence in the ranking scheme such that all levels of "4" indicate areas of very high ecological value with varying levels of development pressure (e.g., 4.4 indicates very high ecological value and very high development pressure).

Most the tracts in northern Virginia and southern Maryland exhibit very high ecological values (Figure 11). Integrating development pressure into the analysis, however, provides a means to better prioritize conservation activities by discriminating between areas of equal ecological value (Figure 12).

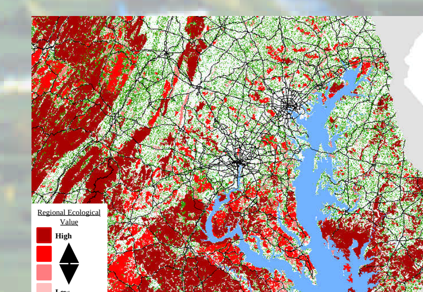

Figure 11. Ecological value of large, contiguous forest tracts on developable lands ranked separately within each Omernik ecoregion

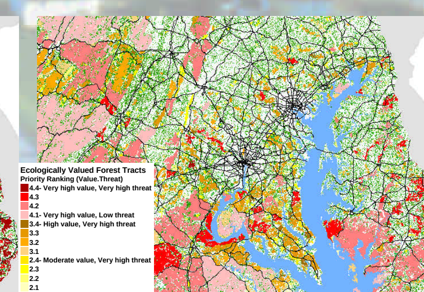

Figure 12. Conservation priority ranking of large, contiguous forest tracts. Priority scores represent a categorical ranking that combines ecological value with development pressure.

Conclusion. Measures of vulnerability can be useful for prioritizing areas for conservation. The identification of growth hot spots, however, is highly influenced by the choice of metric and classification scheme. Using single-detached housing units as a metric, stratifying the classification scheme according to Rural-Urban Commuting Areas, and incorporating a function for lot size proved useful, however, for identifying hot spots of land conversion associated with residential development outside of urban centers. Locating growth hot spots outside of urban centers is particularly challenging because even the smallest census boundaries may cover over 30-km² in rural areas. Redistributing the housing unit data on the basis of road density helped to address this challenge.

The linear regression model for estimating lot size functioned reasonably well in areas with relatively moderate to high road densities but the variance increased significantly in rural areas with low road densities. Further investigation into methods to forecast lot size based on regionally available data are needed.

Impervious surface data derived from satellite imagery has great potential for tracking development patterns and intensities. This potential could be enhanced with further comparisons between changes in impervious surface with changes in housing and economic variables.

The factors that influence land development vary by scale, political jurisdiction, and the degree of urban development among other things. Therefore, what can be learned about development trends and patterns on the basis of regional data alone is limited.

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