Spatial Predictive Modeling and Remote Sensing of Land Use Change in the Chesapeake Bay Watershed

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Introduction - Land use change in developed countries largely takes the form of conversion of land from agriculture and forests to residential use. In the U.S. the spatial pattern of this conversion has tended to be one of increasingly fragmented, low density development, popularly called "exurban sprawl". Sprawl is characterized by land conversion at a rate of 2 to 3 times the rate of population growth and by increases in vehicle miles traveled of 4 to 5 times the population growth rate. Because it generally occurs in areas well outside urban centers, low density sprawl will generally be serviced by septic fields rather than sewage treatment plants, increasing per capita nutrient loadings and fecal coliform discharges into the aquatic environment. In addition, this spatial pattern can be expected to have consequences for carbon sequestration as vegetative cover is lost and for carbon emissions because of the higher level of vehicle miles traveled as a result of a dispersed population.

The impact of development on the environment will be dependent on both the spatial form development takes and on the type of land use it replaces. Determining what policies might be adopted that could be effective in altering future outcomes requires understanding the underlying process that causes the changes. Our project will model and predict spatial patterns of land use change in the central Maryland portion of the Chesapeake Bay Watershed. The study area provides an excellent opportunity to model the spatial patterns of sprawl, because it is representative of a set of conditions generally prevalent in much of the U.S. and has clear links to water quality in the Chesapeake Bay itself. The model requires understanding the underlying economic decision process, affected by changing socio-demographics and constrained by a regulatory environment. We intend to augment the modeling approach by incorporating information available with satellite remote sensing.

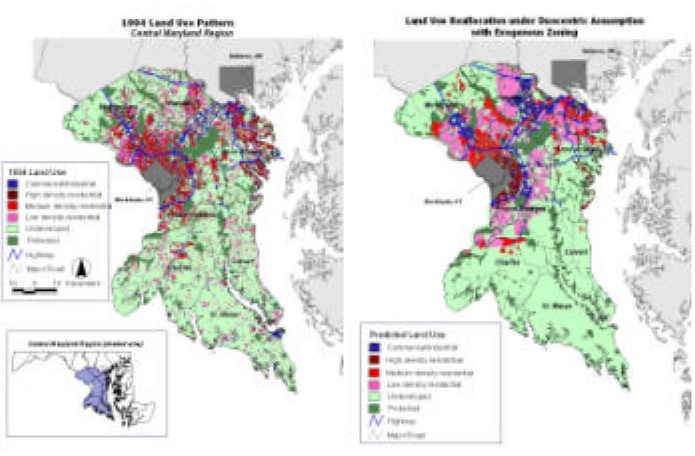

Figure 1 Traditional economic theories, in this case assuming duocentric exogenous zoning, predict spatial land use in which dispersed, low density residential land use patterns in the rural-urban fringe are not well explained.

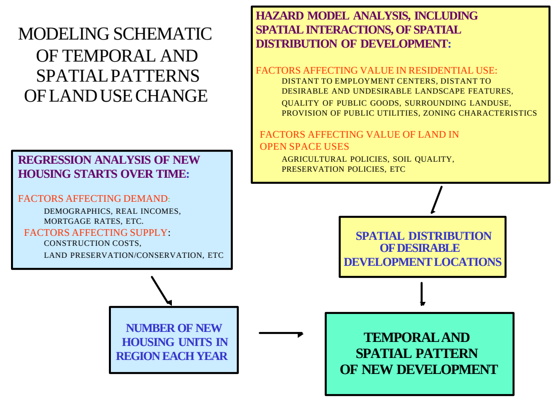

Figure 2 Increased fragmentation of land uses and growth in low density residential uses requires improved methods of predicting spatial patterns of change. Our work takes advantage of parcel level geocoded data, specifically recognizes heterogeneity in space, and incorporates spatial interactions of land use change. In this project we develop and apply this spatially explicit modeling approach, and link it with more conventional models that explain the amount of new development.

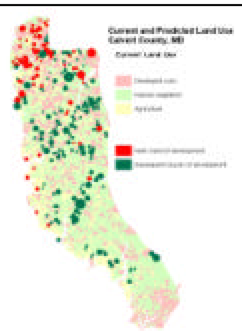

Figure 3 Predictions of the location of new development, in this case for Calvert county Maryland, from an "agent-based" microeconomic decision model that incorporates parcel level information (listed in Figure 2).

The availability of unique parcel-level data sets in Maryland permit us to develop and test techniques to extend the modeling approach to other, less data rich areas. Some of the limitations in data sets required to accurately predict the spatial pattern of future land use can be overcome by land surface maps provided by remote sensing.

Development of land cover/use change maps, including changes in subpixel impervious surface area and residential land use density, allow us to augment information at the parcel level with that from the pixel.

For example, the spatial and temporal information provided by impervious surface and residential density maps can be used to capture the specific land use properties of parcels before they are converted to a developed land use. The inclusion of endogenous interactions in the model, that is, including the land use surrounding a parcel at each decision point in time, provides the historical framework needed to develop and predict future patterns of change. This approach also permits linkages between the opportunity and conversion costs of development, which is important for predicting alternative future scenarios.

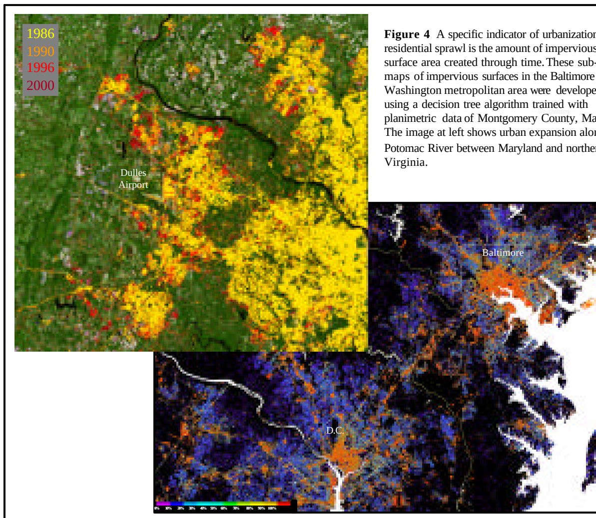

Figure 4 A specific indicator of urbanization and residential sprawl is the amount of impervious surface area created through time. These sub-pixel maps of impervious surfaces in the Baltimore – Washington metropolitan area were developed using a decision tree algorithm trained with planimetric data of Montgomery County, Maryland. The image at left shows urban expansion along the Potomac River between Maryland and northern Virginia.