Hotspots for Growth: Land Use Change and Priority Funding Area Policy in a Transitional County in the U.S.

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ABSTRACT

This paper uses a logit model to estimate whether and to what extent Maryland's Priority Funding Area (PFA) program steers urban growth to locations inside targeted growth area boundaries of an ex-urban county in the outer suburbs of the Washington, D.C. region. The results of our model indicate that the size of an agricultural parcel, its distance from urban parcels, its proximity to highways, the quality of the land for agriculture, and the location in or outside of PFAs influence the probability an agricultural parcel will remain in agriculture or be converted to urban use. We find that some of the areas experiencing the greatest market pressure for development are located outside PFAs and, although Maryland's incentive-based strategy reduces the likelihood a parcel outside a PFA will transition to urban use, this policy is not one hundred percent effective.

Keywords: *Smart growth, Maryland, land use change, growth management*

Introduction

In 1997, Maryland passed a package of legislation called the *Neighborhood Conservation and Smart Growth* initiative, one of the goals of which is to limit low-density residential development and sprawl outside existing cities, towns, and neighborhoods in the state. A major component of Maryland's Smart Growth program is the Priority Funding Areas (PFA) element. With this element the state requires county and municipal governments to identify areas designated for growth. The state then targets state spending for infrastructure such as public sewer, water, schools, and housing to these designated growth areas, known as Priority Funding Areas (PFAs). The provision of state assistance is intended to act as an incentive for local governments in Maryland to develop *within* rather than *outside* PFA boundaries (Cohen, 2002).

In this paper, we present a spatially explicit land conversion model that estimates the degree to which Maryland's PFA policy adequately directs urban development to designated growth areas in a rapidly urbanizing county of the state. We test our model and the success of the PFA policy on Frederick County, a largely agricultural but fast-growing county on the exurban fringe of the Washington DC—Baltimore metropolitan area. This county has grown tremendously in recent decades with the population increasing from about 85,000 residents in 1970 to more than 194,000 in 2000. Predictions are that the county will continue to grow, reaching a population of more than 325,000 by 2030 (Frederick County Department of Planning, 1998).

This paper has three major goals. One is to identify locations within Frederick County where there is the greatest market pressure for growth, measured as agricultural land conversion to urban use. Second, holding constant the conditions that influence market pressures for urban development, we examine the extent to which the current PFA policy directs development inside PFA boundaries. We measure this by identifying the probability that agricultural land both inside and outside the PFA boundaries will remain in agriculture over a specific time period. Third, we use an empirical model developed with 2000 to 2004 data to determine the extent to which our model accurately predicted land use change over the 2004 to 2008 period. We examine the more recent data to verify our predictions.

The overarching goal of this paper is to determine the success of Maryland's PFA policy, and identify where policy needs to be strengthened to prevent agricultural land conversion in the county. The loss of agricultural land is one of Frederick County government's key land use policy concerns. Given the importance of agriculture to the local economy and landscape, the loss of agricultural land is seen by policy makers as a real threat to the county's way of life (Blaser, 2004).

Background on Land Use Change Models

There are many comprehensive reviews of the various techniques and approaches that predict the likelihood undeveloped land will become developed. These reviews focus on land use change in the context of urban and regional planning (U.S. EPA, 2000), economic-based simulations (Plantinga, 1999), agent-based and multi-agent systems models (Parker, Manson, Janssen, Hoffmann and Deadman, 2004), and more theoretical-based considerations (Braissoulis, 2007). These studies reflect the recent emergence of a large number of spatially explicit models of urban growth. In this context, a number of researchers have, for instance, utilized cellular automata models (e.g. Jantz, Goetz, and Shelley, 2003); GIS-based logit models (Landis, 1994, 1995; Landis and Zhang, 1998a, 1998b; Shen and Zhang, 2007); duration models including propensity score matching (Lynch and Lui, 2007); and hazards ratios (Irwin, Bell and Geoghegan, 2003) to explain and predict land use change in different locations, under different policy scenarios and across different types of land uses.

Some of these and other studies model the impacts of policy on land use change in Maryland specifically. For instance, Shen and Zhang (2007) examined rural to urban land use transition in Maryland before and after the PFA policy was established in 1997. Like Landis and Zhang (1998a, 1998b), Shen and Zhang use 100 X 100 meter grid cells as their dependent variable. They included independent variables such as distance from the nearest highway exit, distance from the nearest urbanized area, and proximity to other developed areas to determine growth patterns in eight different counties in Maryland. They found that Maryland's Smart Growth program was generally successful at concentrating growth within PFA boundaries and protecting valuable farmland and open space in other areas. They studied eight Maryland counties. Frederick County was not one of them.

Using parcel data rather than data by grid cells, Irwin, Bell and Geoghegan (2003) developed a hazard ratio model of residential development for Calvert County, Maryland. The explanatory variables they included in their model relate to the costs of developing a parcel, the location of the parcel, the availability of public services, and a number of growth management policies. Included among the growth management policies was the PFA strategy. Focusing on the rate of conversion, they found that the hazard rate for parcels located within the PFA boundaries of Calvert County were four times larger than for parcels outside these designated growth areas. In other words, they found that parcels within the PFA were much more likely to be developed that those outside. Similar to Shen and Zhang (2007), this study of Calvert County suggests that the PFA strategy is an effective policy tool for concentrating residential development.

In contrast to both these studies, Lewis, Knaap, and Sohn (2009) tracked the ratio of development outside PFAs to total development, from 1990 to 2004 across Maryland counties, and found the PFA policy had little impact on development patterns. Their data tracks the period prior to and after the passage of the 1997 Smart Growth legislation that is responsible for the PFA policy.

As part of its overall strategy, Maryland initiated what has been referred to as the "inside/outside" approach to smart growth (Knapp and Frece, 2007). The PFA component of the smart growth package sets out to encourage growth and revitalization *inside* existing communities. Other components, notably the Rural Legacy program, focus on preserving agricultural land on the outer fringes. This state level initiative aims to preserve areas of natural, cultural, forestry and agricultural resources in prioritized areas of the state.

In the case of Frederick County, properties located west and south of Thurmont in the Catoctin Creek, and east of South Mountain are preservation areas where easements are purchased based on development potential, tract size, contiguousness to existing easements, soils, and natural and cultural resources. Other land preservation policies for Frederick County include the county's Critical Farms Program and the Installment Purchase Program. These policies are designed to supplement statewide agricultural land preservation efforts by purchasing a farm property's development rights and creating a perpetual easement so that no development for non-agricultural uses can occur. At the state level, the Maryland Agricultural Land Preservation Program is similar to that of the county, as the state purchases or donates a perpetual agricultural easement with a 25-year buy-back option available if profitable farming is no longer deemed feasible. Through the various land preservation programs, Frederick County has so far preserved 26,100 acres of agricultural land. The PFA boundaries as well as the agricultural preservation areas in Frederick County are noted in Figure 6.

Scholars have examined land preservation programs in Maryland with mixed results. Studies related to Maryland and beyond, (Daniels and Nelson, 1986; Daniels, 1991; Nelson, 1992; McConnell, V. Kopits, E., and Walls, M, 2006) argue that successful agricultural preservation requires a package of techniques that may include; comprehensive planning, zoning, purchase of development rights, tax preference for agriculture, transfer development rights, and urban growth boundaries. In other words, smart growth policies alone cannot contain urban sprawl and should be part of a package of programs.

For the purposes of this paper, we focus on examining the effectiveness of the PFA policy rather than that of the various land preservation policies in Frederick County. This study grounds land use conversion modeling in economic theory, tests a logit model on 2000 to 2004 data, and then tests the accuracy of model prediction with actual parcel level, land use change data in Frederick County for the years 2004 to 2008.

Theoretical framework

Micro-economic theory underlies many spatial land use change models (e.g. Landis, 1994; Landis and Zhang, 1998a, 1998b; Irwin and Geoghegan, 2001; Shen and Zhang, 2007). In this vein, Chomitz and Gray (1996) developed a model of deforestation where they assume landowners maximize expected profits, so that the optimal use is determined by the use with the highest rents. In developing our model, we too focus on fundamental economic processes that impact the conversion of agricultural parcels to urban use. Underlying the model is the economic theory that, in a market economy, land transitions into its highest and most profitable use. At the ex-urban fringe, agricultural and urban uses compete for land. Our model predicts the locations on the urban fringe where the economic returns to urban use rise above the returns to agricultural use, leading to a transition from agricultural to urban land use.

As William Alonso (1968) suggested in his renowned bid-rent function model, urban land rents decrease with distance from the city center until the returns to urban land fall below returns to land in agriculture use. In Figure 1, at the point A-D and beyond, economic theory suggests land remains in agricultural use. Increasing population size and improvements in transportation lead to an outward shift of the bid rent curve from “A” to “B.” When the bid rent curve shifts to “B” the new urban fringe boundary moves to B-D. Theoretically, the returns to land for urban development, particularly for residential use, are positively influenced by proximity to jobs and retail. Land is more accessible to jobs and shopping when employment and shopping centers are proximate and transportation networks are well developed (Moon, 1987; Haughwout and Boarnet, 2000; Heavner, 2000).

A number of land use models have demonstrated the relevance of closeness and accessibility to towns and urban centers to land use change. For instance, Sanchez (2004), in his analysis of land use change between 1970 and 1990 for 15 Oregon cities, found that highway investments and proximity to the center of town influenced the location of new residential, commercial, and industrial development. Variables that influence the location and slope of the bid rent curve ("A" and "B" in Figure 1) include the distance of a property from urban centers and access to the nearest highway entrance or exit.

In the context of this particular study, Frederick County’s growth is greatly influenced by its location near both Washington, D.C. and Baltimore. An extensive transportation network links Frederick City, the major urban center in the county, to other employment centers in the greater Washington-Baltimore region. This network —Interstate 270 linking Frederick City to Washington, D.C. and Interstate 70 linking Frederick City to Baltimore City— supports urban growth. According to 2000 census data, about a third of the workers that resided in Frederick County commuted daily to the Washington D.C. region. In 2000, 42,046 workers out-commuted from the Frederick County. Almost 55 percent of all out-commuters and 22 percent of all Frederick County workers traveled to Montgomery County, home to many high-tech firms off the I-270 highway. Frederick County is also an important exporter of workers to nearby urbanizing counties of Loudon and Fairfax in the Virginia side of the Washington D.C. region, with over 4,000 workers commuting to these counties daily in 2000. Clearly, the highway network is an important element of urban growth.

<< Figure 1 about here>>

In our theoretical framework, we go beyond the traditional bid-rent model's emphasis on distance to the urban center and include other variables. Another important determinant of agricultural land use conversion is the productivity of the land (Lee, 1979; Hart 1991; Plantinga and Irwin, 2006). Where land is highly productive for farming and the returns to agriculture are high, the probability a parcel will transition from agriculture to an urban use falls (see line "D" compared to line "C" in Figure 1). When land is more productive for agriculture, the urban fringe ends at B-D rather than B-C. Thus the poorer the quality of the land for agriculture ("C"), the greater the probability a parcel will transition to urban use.

In various land use models, land quality has been included as an important predictor of land use change (Veldkamp and Fresco, 1996), mostly measured by soil quality and slope (Chomitz and Gray, 1996). Low and decreasing farm productivity, combined with rising land values for urban use, provide incentives for farmers to sell their properties for urban development (Berry, 1978; Chicoine, 1981; Lopez, Adelaja, and Andrews, 1988; Hardie, Narayan, and Gardner 2001).

In addition, the incentive for farmers to sell is more intense the closer the agricultural property is to urban encroachment. Sinclair (1967) has shown that any anticipation of urban expansion is important in determining the value of agricultural land values. He suggests that as land is encroached by urban development it becomes less valuable for farming purposes because of use conflicts with neighbors. Distance of an agricultural parcel to non-agricultural or urban parcels is therefore important. We assume that farms chopped into small units and fragmented by urbanization are more vulnerable to development. Large consolidated parcels lead to economies of scale and greater profitability in agriculture, and therefore are more likely to stay in agriculture.

In Frederick County, the estimated market value of all agricultural property has grown tremendously in recent decades from about $3,900 per acre in 1974 to approximately $5,500 per acre in 2002. Statewide, agricultural land values went from $3,800 per acre in 1974 to about $4,000 per acre in 2002[1]. The market value of the products sold on the average farm in Frederick was more than $140,000 in 1978 compared to $76,000 in 2002. The percentage of farms that sold products totaling less than $2,500 increased from 20 percent to over 40

[1] All of the land prices per acre as well as the value of products sold are in 2002 dollars.

percent from 1978 to 2002, although the percentage of farms with the value of products sold totaling more than $100,000 has remained fairly constant since the late 1970s. The rise in agricultural property values and drop in value of sales in Frederick County provides an incentive for farmers to sell to speculators and developers. On land where the farming is profitable, the incentive to sell is lessened and clearly some farms in the county are still productive.

Much of what we have discussed so far relates to unconstrained markets. However, land use conversion is affected by land use policies and local zoning regulations that influence the pattern, type and extent of development (Landis 1994, Landis 1995). Growth management policies and zoning regulations affect land values, the amount of developable land, and land uses. The speculative value of agricultural land outside a growth boundary decreases with the implementation of agricultural protection policies (Boal, 1970), In the case of Frederick County, a property zoned for agricultural use must be 25 acres or more. In 1976, the county adopted an agricultural zoning policy that reduced the number of residential units per farm parcel from 49 to three. This has protected agricultural land from being converted to tract development. However, an unintended consequence of agricultural zoning regulations in Frederick County is the development of large-lot residential estates on 25 acre parcels of agricultural land. Residents of these estates are often not full-time farmers, and they engage in minimal agricultural activities (Blaser, 2004). In this case, agricultural land is preserved as open space rather than as an asset for farming.

Empirical model

Based on our theoretical assumptions, we test a logistic model that measures the impact of market and policy conditions on the probability an agricultural parcel remained in agricultural use over the 2000 to 2004 period. Based on an analysis of Landsat imagery, we calculated that Frederick County lost about six percent of its agricultural land (a total of 14,744 acres) to urban development from 1986 to 2001. Frederick County is the largest county in the state and one of the most agricultural.

The equation for our logistic model is as follows:

$$P_i = \frac{1}{1 + e^{-(B_0 + B_1X_1 + B_2X_2 + \ldots\ldots B_kX_k)}}$$

Where X_1, X_2 and X_k are independent variables influencing the probability of land conversion from agricultural to urban land use. Based on our theoretical assumptions, we hypothesize and test the extent to which the following factors influence whether or not an agricultural parcel in Frederick County remains in agricultural use: (1) distance of agricultural parcel to towns and urban centers; (2) distance of agricultural parcel to a highway entrance or exit; (3) distance of agricultural parcel to a non-agricultural use; (4) size of parcel; (5) quality of land for agricultural and (6) whether the agricultural parcel is located inside a PFA.

Table 1 provides a description of the variables we use in our model and the data sources.

<<Insert Table 1 about here>>

The data for the dependent and independent variables is at the land parcel level, identified as the centroid of a single parcel. There are advantages to using parcel level data. With this scale of analysis, the model captures land use change at the level of the individual property-owner, the actual decision making unit of land use change (Briassoulis, 2007; Bockstael, 1996). Grid cells, like those used in Shen and Zhang (2007), the California urban futures (CUF) model (Landis, 1994, 1995; Landis and Zhang, 1998a, 1998b) and elsewhere, oftentimes combine or cut across parcels and possible land uses. In this particular study, we use tax assessment data at the parcel scale. Matching land uses between 2000 and 2004, we were able to identify parcels that changed from agricultural to urban land uses over that period. We also identified parcels that remained in agriculture. There were a total of 4,504 parcels in Frederick County captured in our data set. We dropped 88 parcels because of incomplete or missing data.

The distance variables are measured in meters as straight-line distance, rather than distance by road. We measured the distances of each parcel from the city of Frederick and the nearest towns. We also calculated the distances between each parcel and the nearest major highway exit. We used ESRI street map data to identify the location of the major highways connecting Frederick County to other parts of the Washington, D.C.-Baltimore region.

We measured and calculated parcel size from the tax assessment data. The quality of the land we measured as the quality of soil for dairy farming. The values range from 0 to 13.5, and the higher value indicates more productive land. We obtained these data from The Natural Resources Conservation Service (2002) soil quality survey. In this survey, quality of land was available for various agricultural uses, such as corn production, but we utilized soil quality for forage for cattle since the primary form of agricultural production in Frederick County is dairy farming. We also identified whether or not a parcel was inside the PFA boundaries or not. We tested several other variables, but they were found not to be significant and uncorrelated with the other independent variables, and therefore dropped from the final model. Dropped variables include the value of improvements on agricultural parcels and distance from the closest county boundary.

Before providing the results of our statistical model, let us first describe a little of what exactly happened to the agricultural parcels in our dataset between 2000 and 2004. We found that a total of 202 out of the 4,504 agricultural parcels were developed over this period. Superficially, it would seem that few agricultural parcels converted to urban use. However, probing deeper into the numbers, we found instances where agricultural parcels were subdivided and developed into a rather large number of residential parcels. In many cases, there was not a one-to-one match where one agricultural parcel became one urban parcel. In fact, using tax maps, we found that the 202 agricultural parcels that were converted from 2000 to 2004 became a total of 1,659 urban parcels (residential and commercial), the overwhelming majority of which were residential developments. To simplify the statistical process, we created a dummy variable for each agricultural parcel as developed or not, and we did not include whether or how these parcels were subdivided.

Model results and policy implications

The statistical results of the model are reported in Table 2. The statistically significant variables, at least the 5 percent level of significance, are shown in bold text. The two variables which were not statistically significant are the distance from the nearest town and the distance from the City of Frederick. On the basis of testing various combinations of variables, we know that the distance from the City of Frederick turns up non-significant because the importance of this distance is captured in the highway variable. Frederick City is at the intersection of highways I-270 and I-70. We believe that the distance from the nearest town is insignificant because many captured towns are small agricultural centers which do not encourage surrounding urbanization. Similar to our results, Shen and Zhang (2007) found that land use conversion was influenced by proximity to already developed land and highways. In contrast, they found proximity to a town or municipality significant, whereas we did not. One explanation is that the towns in Frederick are small and they are not employment centers and therefore do not raise the value of a parcel for urban use.

<< Table 2 about here>>

The coefficients in Table 2 indicate that the size of parcel, distance from the closest non-agricultural parcel, the distance from the nearest I-70, I-270, or MD Route 15 exit, and the quality of land in agricultural production will influence the probability a parcel will remain in agriculture. The results of the logit model provided us with probability scores for each agricultural parcel which we also analyzed.

Table 2 reports the PFA independent variable is also significant at the .01 level. Examining the probability scores when all other variables are at their mean value, we find that, on average, the probability an agricultural parcel outside a PFA remains in agriculture is about 89 percent. For parcels inside the PFA, the probability that agricultural land remains agricultural is, on average, 82 percent. Thus we conclude that the PFA policy increases the probability of a land use conversion by an average of seven percent. Opinions may differ on whether or not a seven percent difference is pathetically small and a disappointment or impressive for a policy that relies on a carrot rather than a stick.

A shortcoming of this analysis is the correlation between variables. For example, parcels inside of PFA boundaries are more likely to be situated near towns, near developed parcels, and within proximity of the highway entrances and exits. Consistent with the results of Shen and Zhang (2007), Irwin, Bell and Geoghegan (2003) and Howland and Sohn (2007) however, we find evidence that Maryland's PFA policy has a positive impact on preserving agricultural land and directing urban development into the PFA boundaries.

Figure 2 reports the probability a parcel remains in agriculture by size, for parcels inside and outside PFA boundaries, when all other variables are at their mean value. Holding all other variables in the model constant at the mean values (Table 3), the probability a parcel stays in agriculture reached one hundred percent when the parcel is larger than 400 acres. When a one acre parcel is inside a PFA, the probability the land remains in agriculture is, on average, 70 percent and when the parcel is outside the PFA boundary the probability the parcel remains in agriculture is, on average, 81 percent[2].

Figure 3 shows the probability a parcel remains agricultural with distance from the nearest developed parcel. When all other variables are at their mean value, the probability is 73 percent that a parcel adjacent to a developed parcel and inside a PFA remains agricultural, while a parcel outside of a PFA, but adjacent to a developed parcel has an 82 percent probability of remaining in agriculture.

[2] Method taken from Greene (2003), pp 674-678.

Infill development is more likely to occur inside rather than outside the PFA. Irwin and Bockstael (1999) found that, along the rural-urban fringe, surrounding development may depress future development. Our results are slightly different but we did find that adjacent development is less likely to produce more development in fringe areas (i.e. outside PFA) than areas closer to urban core areas (inside PFA). Looking at surrounding development, when an agricultural parcel is 1,800 meters from a developed parcel (1.2 miles) the probability reaches nearly one hundred percent it will remain agricultural for parcels both inside and outside PFA.

Examining the distance variables (see Figure 4), we found that when a parcel is 1,333 meters (.83 miles) from the interstate entrance or exit and inside a PFA, the probability is nearly 78 percent it will remain agricultural over the next four years. If the parcel is outside a PFA, the probability rises to 86 percent. This clearly demonstrates that deciding the location of various highway exits and entrances is important for land preservation and growth management, and again, the location of a parcel inside the PFA matters.

When a parcel reaches 13.3, the highest in land quality and productivity, the probability a parcel will remain in agriculture equals 93 percent if it is in- or out-side a PFA (see Figure 5). For the lowest quality land at 0.41 (this measure relates to the amount of units of forage yielded by the soil for the average cow), the PFA boundary increases the probability of remaining in agriculture by one percent, 84 percent if inside the PFA and 85 percent if outside. Unproductive agricultural parcels, particularly inside the PFA, are only slightly more likely to be developed than productive agricultural parcels.

<< Insert Figures 2, 3, 4 and 5 about here>>

Mapping the Models Results

Our model suggests that the probability that an agricultural parcel remains in agriculture decreases if the parcel is small, fragmented, unproductive, near a highway exit and inside rather than outside the PFA. We found that, in general, the likelihood that agricultural parcels remain in agriculture is fairly high, and a little higher for parcels outside compared to inside PFAs. We interpolated and mapped the probability scores for the parcels in our dataset (see Figure 6). Areas that are already urban are not included in the map. Parks and protected areas are outlined as are PFAs. In Figure 6, the blackest color indicates where were predict agriculture to remain strong; the whitest color indicates where we predict that the shift to urban use is most likely to occur over the four years from 2004 to 2008. This is assuming all external conditions remain constant. The external conditions which would have to remain constant are such situations as no new investments in road infrastructure, a similar demand for agricultural output and constant oil prices. For example, if oil prices continue to rise, as they probably will, urban uses are less likely to spread into rural areas, since the cost of commuting increases. Figure 6 indicates that the area most likely to stay in agricultural production is in the northeastern and southwestern portions of the county.

<<Insert Figure 6 about here>>

The value of this map for land use policy is threefold. First, where white areas fall into PFAs, market forces will encourage the outcomes desired by county officials. Where white areas are outside the PFAs, county officials will have to be especially vigilant to constrain development because market forces will push development into areas currently not designated for growth. Second, when whiter-colored parcels fall in areas deemed environmentally sensitive, the county government should pay attention to be sure the appropriate land use controls are in place to keep these areas from turning to urban development. Left to market forces, we predict that the light colored areas will transition from agriculture to urban use. Third, where whiter areas expand the rural village boundaries, urban expansion is likely and again to keep these areas in agriculture will require government attention and intervention. Alternatively, the PFA boundaries could be expanded. In short, the map suggests that there are areas outside PFAs where development is likely, and the current PFA policy is not one hundred percent effective at discouraging the development of some agricultural land.

How Well Did our Model Predict the 2004 to 2008 Development Pattern?

Our logistic model measures the probability an agricultural parcel stayed agricultural based on data on land use conversion from 2000 to 2004. Based on the 2000 to 2004 results, parcels with the lowest probability scores of staying in agriculture —< 0.10— ought to have developed over the four year period from 2004 until 2008. So, what really happened? How accurate are our model predictions? How many of the parcels we predicted were highly likely to become urban actually became urban by 2008? We have model results for a total of 4,290[3] agricultural parcels for the year 2004. According to the 2008 data, 4,072 or 95 percent of these parcels were still agricultural in 2008. The remaining five percent or 218 parcels became urban. Fifty-two of these parcels that changed to urban use, or 24 percent of all the parcels that changed, were located inside PFAs and 166 or 76 percent were outside PFAs.

There were more parcels outside than inside PFA that developed. However, there were more parcels in total outside than inside the PFA. In total, in 2004 there were 4,290 agricultural parcels, and only 312 agricultural parcels, or seven percent, were inside PFAs. Therefore, we found about 17 percent of agricultural parcels inside the PFA boundary changed from 2004 to 2008 compared to about four percent of agricultural parcels outside the PFA.

[3] There were 4,504 agricultural parcels in 2000, 215 changed to urban over the 2000 to 2004 period. Thus 2004 started with 4,290 agricultural parcels.

Using the 2000 to 2004 probabilities, we took the value of those parcels with a ten percent probability or less of staying in agriculture and assumed they would change to urban in the years 2004 to 2008 period. A probability of ten percent or less was the mean probability of the 2000 to 2004 parcels that actually changed use. The comparison of our predicted and actual results is shown in Table 4. We predicted that 700 parcels would change use, while only 58 of our predicted parcels actually changed use. Our model predicted that 3,590 parcels would stay in agriculture, and 3,430 of those parcels actually remained in agriculture. Our model predicted 58+3,430=3,488 parcels correctly and 642+160=802 parcels incorrectly.

Comparing the parcels that changed use inside and outside PFA boundaries, the parcels outside the PFA boundaries that changed use tended to be larger in size (42 acres versus 36 acres), further from the interstate and from the nearest towns, and on lower quality, non-productive land (5.1 versus 6.4 inside PFAs). We also found that the converted agricultural parcels with the highest probability scores from our model results were also most likely to convert into large scale residential developments rather than one or two houses. Converted parcels with high probability scores became large subdivisions with, in some cases, up to 70 residential properties by 2008. The parcels with low probability scores tended to split into only one or two residences on the existing farm. In short, we found that our model was better at predicting intense residential development rather than a limited conversion to a couple of new urban properties.

Conclusion

In this paper, we developed a land use change model for Frederick County, Maryland. The results of this statistical analysis indicate that the size of an agricultural parcel, its distance from urban parcels, its proximity to highways, the quality of the land for agriculture, and the location of a parcel within a PFA influence the probability this parcel will shift from agriculture to urban use. According to our model results, the PFA policy has an effect on reducing urban sprawl as measured by the lower probability that agricultural parcels inside versus outside PFA boundaries will remain in agriculture. However, the PFA policy is not strong enough to completely preserve agricultural land in Frederick County and avoid sprawl in the face of continued development pressure. Market pressures will continue to result in non-agricultural uses outside of the PFAs. Mapping the results of the model demonstrate several locations where agricultural parcels are most threatened by development within Frederick County. Some of these areas are located outside the PFAs and policymakers need additional regulations or incentives to keep those areas in agriculture.

The results of our model demonstrate several policies that influence urban sprawl. Careful design of the location of entrances and exits on and off highways, limiting parcel fragmentation, and vigilant control of land use change in agricultural areas are all policies that can limit sprawl. Our model highlights the importance of communication between transportation and land use planners. The placement of highway exits and entrances should be carefully planned and placed in the areas where agricultural land preservation is of low priority.

Our results suggest that current policies are not strong enough to preserve agricultural land in many parts of the county. Market driven urban development pressures are occurring outside the PFA's and the incentive based PFA policy is not strong enough to keep land in agriculture where pressures for urban development are strong. Using the logit results from the Table 2 and the mean values reported in Figures 2, 3, 4, and 5, the current PFA policy reduces the probability of development outside of a PFA by about seven percent. While Frederick County has had some success preserving land in agriculture, it will need stronger growth controls to preserve agricultural land in the future. A final caveat is that agricultural land preservation does not necessarily lead to a healthy agricultural industrial sector. In a study comparing Oregon and Washington State, Daniels and Nelson (1986) conclude that Oregon's farmland preservation effectively kept the state's farmland from transferring to urban development, but that the proliferation of "hobby farms" occurred at the expense of commercial farming. Aggregate data and interviews with County officials (Blaser, 2004) suggest the same phenomenon is happening in Frederick County.

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Table 1

Indicators for determinants of land use change

Determinants of Land Use Change	Measurement of Variable	Variable Name	Data Source
Accessibility to employment and shopping	Parcels distance in meters to the historic urban core (Frederick City) Parcels distance in meters from the nearest town Historic Urban Cores and Towns Parcel's distance from the highway exit/entrance ramps in meters	Dist_Fred Dist_Town Dist_Inter State	Property View ESRI Street Map
Agricultural markets and productivity	Land use of adjacent parcels Size of parcel Quality of the land for agricultural use	Dist_Nonag Land Area NonIrryiel	Property View, 2000 and 2004 Natural Resources Conservation Service (2002)
Land Policies	Location of Priority Funding Area	PFA	Maryland Department of Natural Resources Frederick County Division of Planning

Table 2

Logistic model results: The probability a parcel remains in agriculture

Variables	Estimate	Standard Error	Wald Chi-Square	Pr>Chi Square
Intercept	**1.35**	**.285**	**22.55**	**<.0001**
Land Area	**.011**	**.0024**	**20.76**	**<.0001**
Dist_Nonag	**.002**	**.0006**	**12.74**	**<.0001**
Dist_Inter State	**.00006**	**.00002**	**7.30**	**.0069**
Dist_Town	-.00001	.00001	.76	.3811
Dist_Fred	.00004	.00001	1.53	.21
NonIrryiel	**.065**	**.020**	**10.64**	**.0011**
PFA	**-.55**	**.217**	**6.49**	**.010**
N = 4504				

Table 3

Mean value for variables

Variable	Mean Value	Minimum Value	Maximum Value
Land Area	57.71 acres	~.00 acres	16,117 acres
Dist_Nonag	.27 kilometers	~0 k.	1.22 k.
Dist_Interstate	5.88 kilometers	.14 k.	20.33 k.
Dist_Town	8.39 kilometers	.51 k.	21.12 k.
Dist_Fred	18.09 kilometers	7.00 k.	37.43 k.
NonIrryiel	5.48	0	13.30
Land in PFA	.07	0	1
N = 4897			

Table 4

Actual Change by Predicted Change in Land Use

Totals Predicted by Logit Model*

Actual

	1	0	Total
1	58	160	218
0	642	3430	4,072
Total	700	3590	4,290

1 = Change in land use
0 = Parcel stayed in agriculture
* = assuming that the 2000 to 2004 probabilities of P< .90 changed use and P > .90 change stay in agricultural use.

Figure 1

Theoretical model of land use change

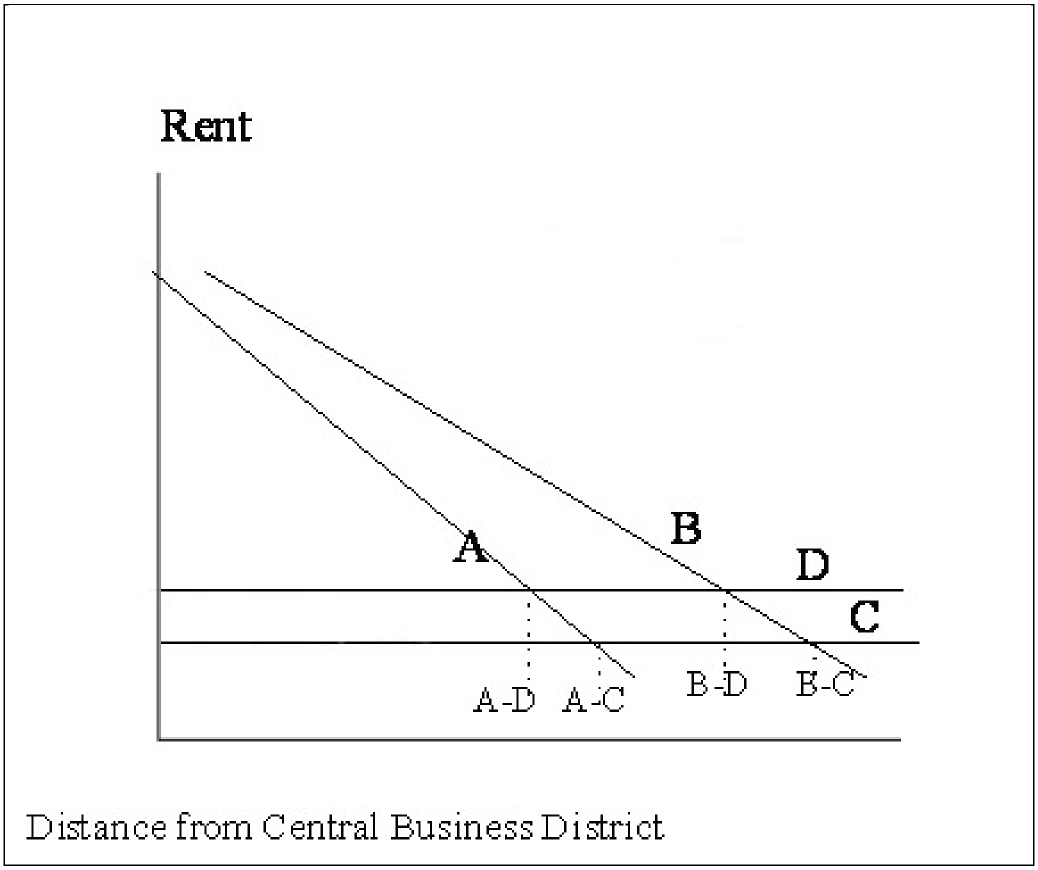

Figure 2

Probability of Agricultural Land Parcel Staying in Agriculture Use, by Parcel Size

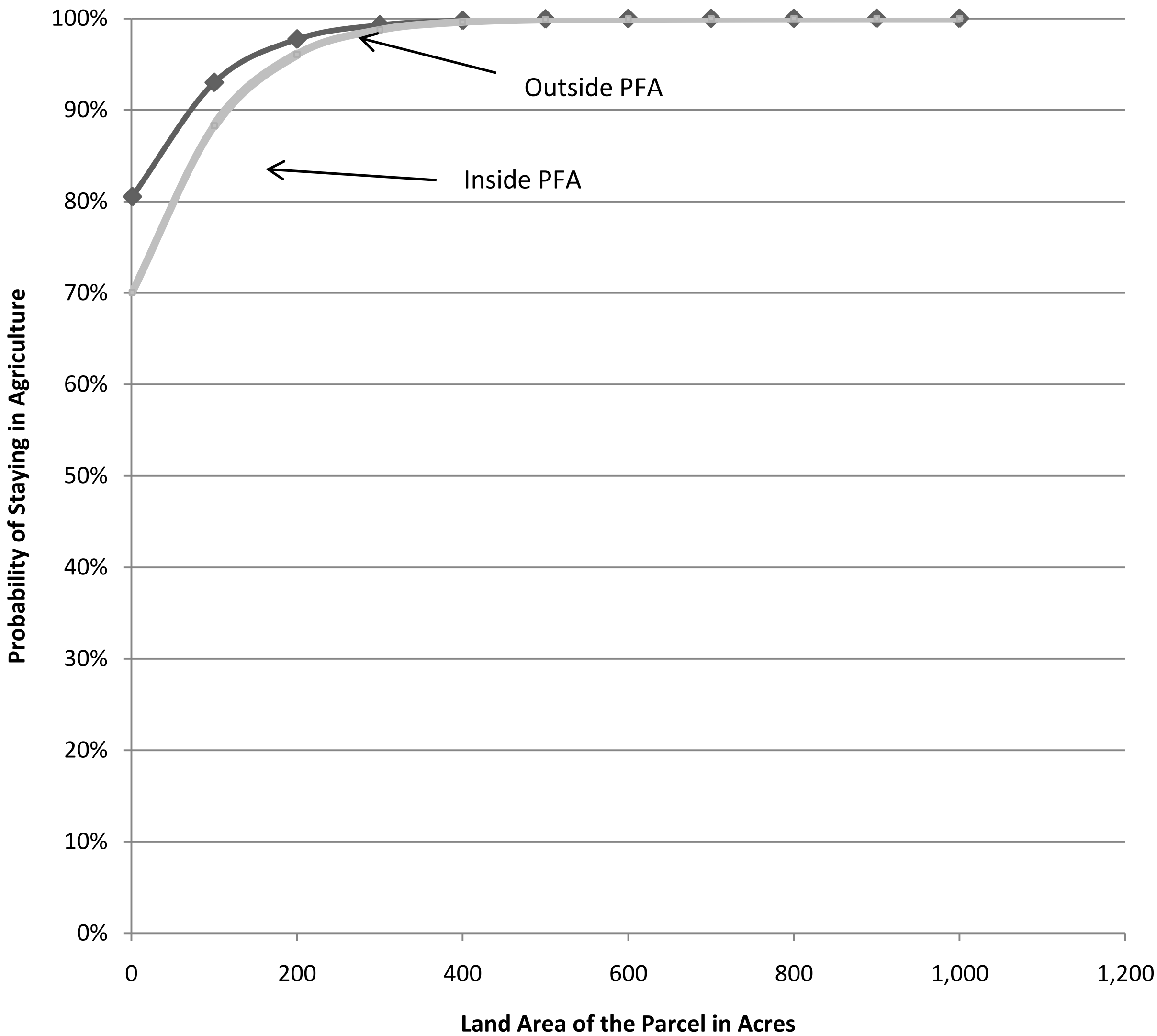

Figure 3

Probability of Agricultural Land Remaining in Agricultural Use, Distance from Nearest Urban Parcel

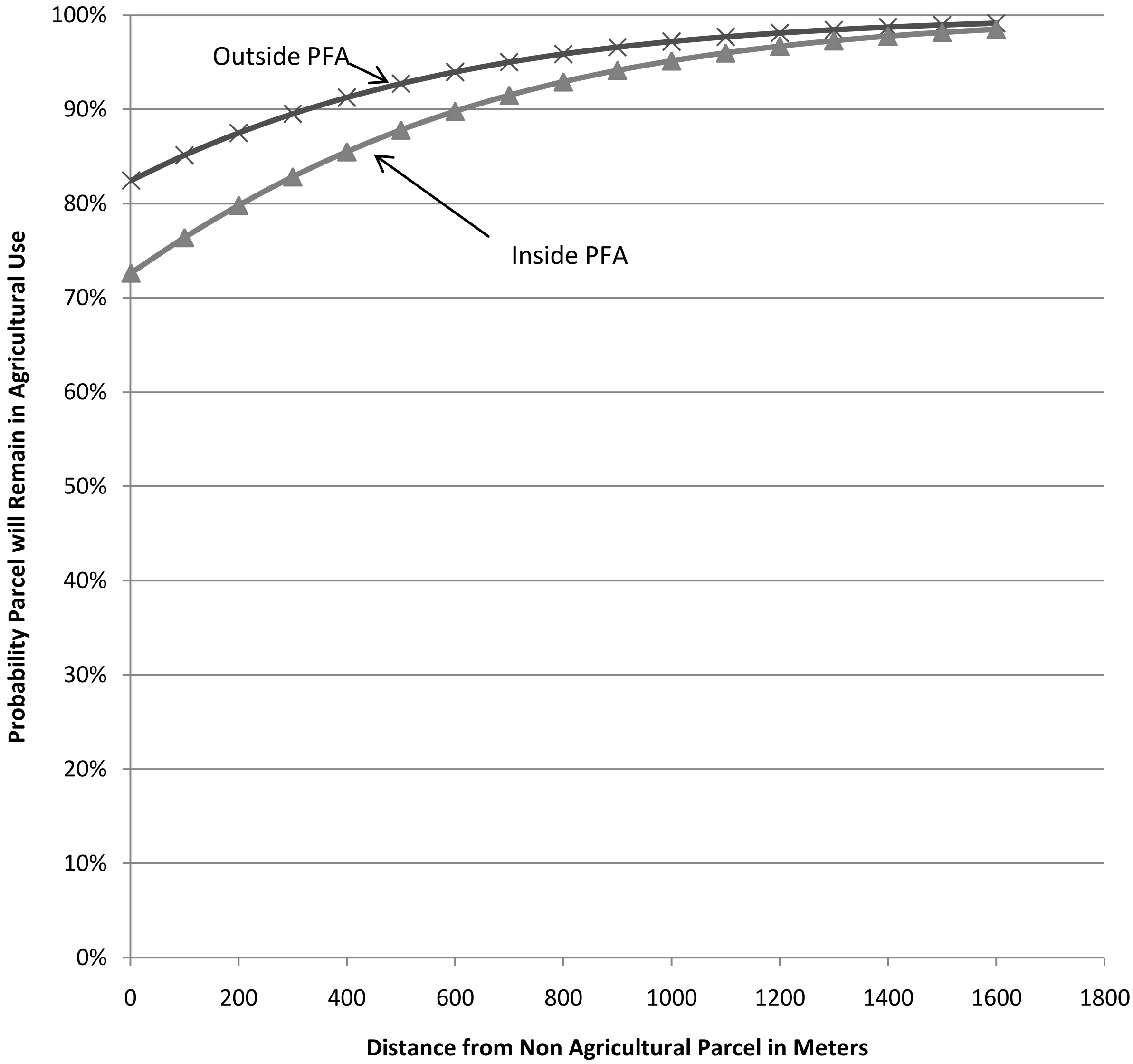

Figure 4

Probability Agricultural Land Remains in Agricultural Use, Distance from Nearest Interstate Exit or Entrance.

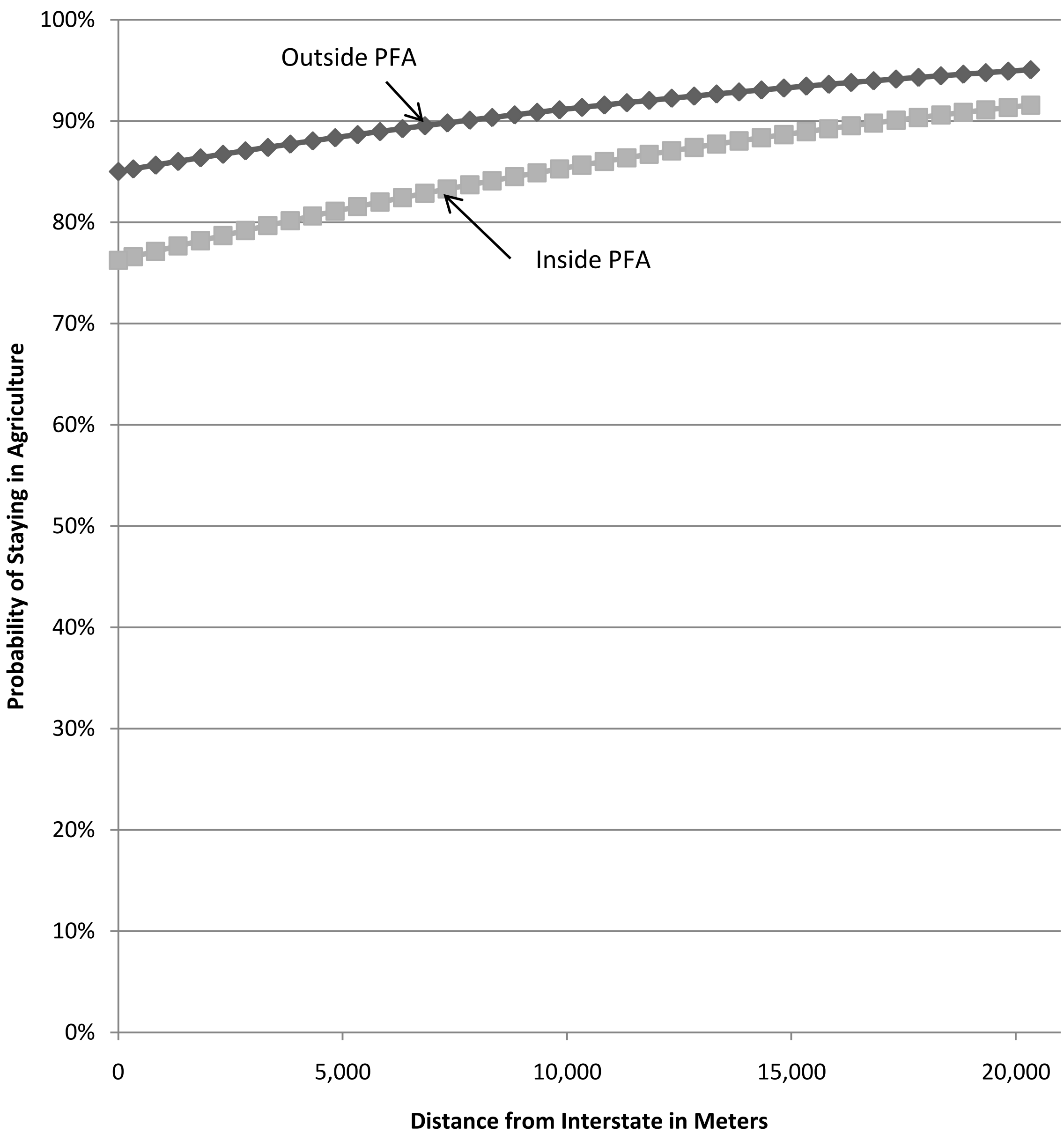

Figure 5

Probability of Agricultural Land Remaining in Agricultural Use, Quality of Land in Agricultural Production

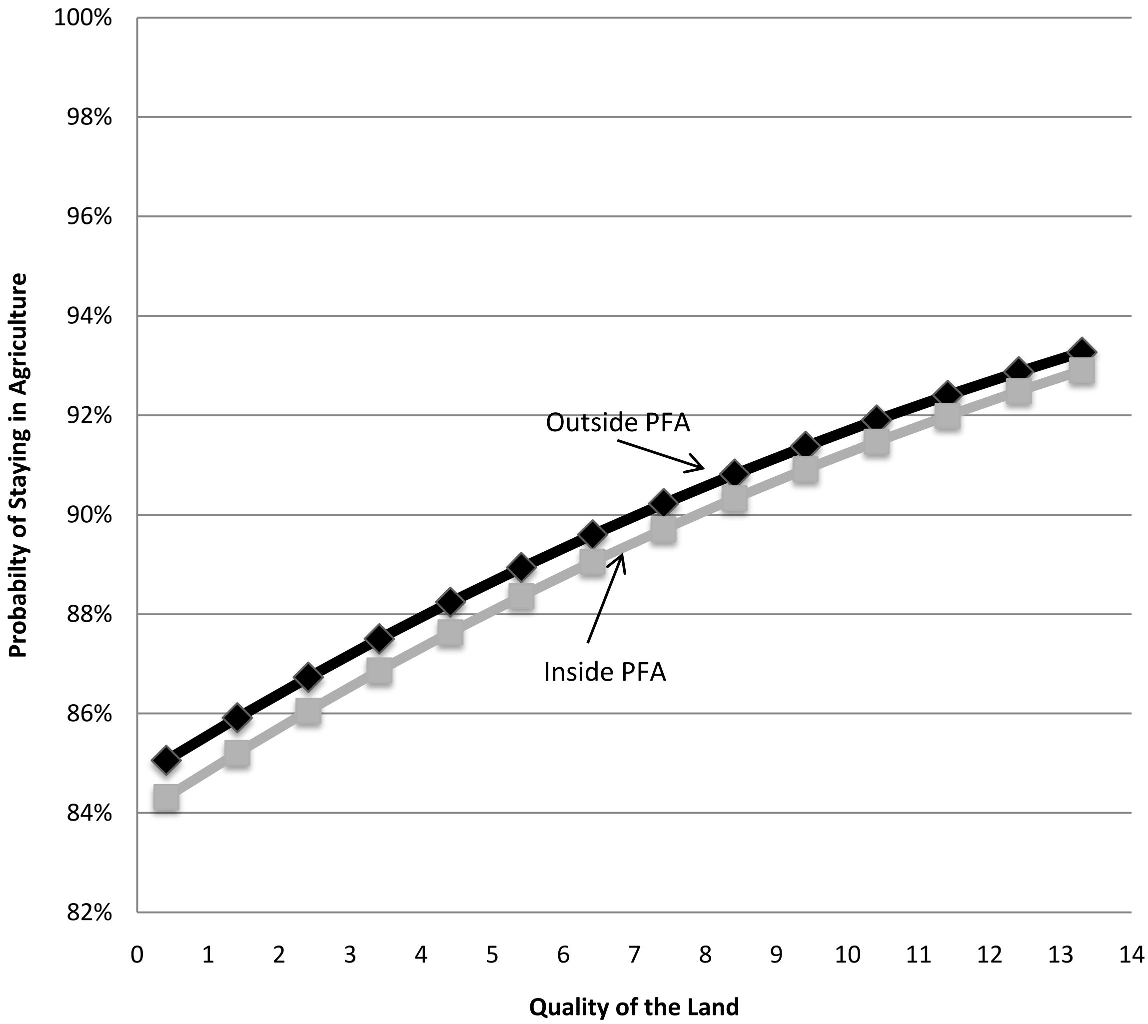

Figure 6

Map of Probability that Agricultural Land will Remain Agricultural, Frederick County