Critical Mass: Does the Number of Productive Farmland Acres or Farms Affect Farmland Loss?

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As farmland and the number of farms has decreased over the last 50 years, some have questioned whether there is a "critical mass" of agricultural land needed to sustain a viable agricultural sector. The total amount of farmland decreased by 20 percent in the United States between 1949 and 1997. In the Mid-Atlantic region, 50 percent of the farmland left the industry during this same period. The number of farms in the United States as a whole declined by 65 percent between 1949 and 1997, while the Mid-Atlantic lost farms at a rate of 71 percent. In metropolitan areas, agricultural land has been converted to alternative uses even faster than these averages (Lockeretz 1989; Gardner 1994). Given these patterns, one might question whether the continuing conversion of farmland to other uses will result in too few acres or too little farm activity to sustain an agricultural economy in certain areas.[2]

Many reasons exist for retaining farmland. Metropolitan residents have expressed concern about the loss of the amenities that farmland provides. Rural economies that are highly dependent on agricultural industries may suffer negative consequences when agricultural land is converted. Society as a whole may wish to retain an agricultural sector in order to maximize its welfare, or economic well-being. Given such motives, many counties are trying to determine how much agricultural land must be retained to ensure a viable agricultural economy and the long-term preservation of amenities associated with farms and farmland. Government officials need to determine how much agricultural land is enough, to ensure this retention. Therefore, it is important to establish whether the rate of farmland loss is affected by the level of agricultural activity within an area.

The idea that a critical mass of agricultural activity must be sustained in order for an area's agricultural economy to remain viable has a certain logic. The critical mass concept is based on the idea that economies of scale exist in both input and output businesses and services that are essential to agriculture. As production levels decline below a given threshold, costs will rise and support businesses will close or relocate. If input and output firms exit the county, the closest input supplier not only may be farther away for a farmer, but also may charge higher prices for inputs, veterinarian services, and equipment repairs because of reduced competition and the need to cover fixed costs. Similarly, if the nearest processor goes out of business because it cannot cover its fixed costs with a shrinking farm production, the nearest outlet for the product might involve additional transportation costs or a lower purchase price, either raising farmers' production costs or decreasing their revenue.[3] Changes in farmers' comparative advantage and their net revenues alter the relative returns of exiting farming. A decline in agriculture profits and thus a higher relative return for conversion to residential, recreational, or forestry uses may increase the rate of loss of farms and farmland in the area.

One may view research regarding a critical mass in agriculture as extending the urban economics literature on agglomeration externalities. In this vein of literature, people investigate whether synergies, innovativeness, and cost savings exist for like industries when they locate close to one another (localization economies such as Silicon Valley, California) and for different industries when they are located in a large city, despite higher rent and usually higher wage labor (urbanization economies). Agriculture might experience similar impacts on innovativeness and cost savings when operating in areas with other nearby agricultural enterprises. Most urban economics work in this area has focused on the location decisions of firms, but the related critical mass argument investigates decisions of farms to exit the agricultural economy and, often, to sell land to those who would convert it to residential, commercial, or other developed use.

Researchers and policymakers articulated the concept of critical mass and recognized its complexities as early as the 1970s. Lapping (1979) hypothesized that the critical mass level would vary from crop to crop, and that local growing conditions, traditions, and existing infrastructure would affect the profitability and sustainability of agriculture and thus the level of a critical mass threshold in any particular geographic area. Further, technological changes may change the threshold level over time. For example, the transition of suppliers from traditional farm-supply stores to Internet sales using delivery services might overcome some of the negative consequences of a local input supplier leaving the area.

Despite the recognition that a critical mass might exist, extensive research has not been conducted to prove the existence, or exact level, of such a threshold. A few studies have attempted to determine a critical mass. In 1974, for example, Dhillon and Derr estimated the critical size necessary to operate at or close to the minimum per-unit production cost. Focusing on agricultural commodities grown in the Philadelphia–New York–Boston corridor, they determined critical production levels for dairy, poultry, and fresh market vegetable production. In 2001, Daniels and Lapping used an either-or formulation, hypothesizing that at least 100,000 acres, $50 million in agricultural sales, or 20,000 acres of preserved farmland were needed to ensure a critical mass. Some programs have set goals for minimum continuous acres of preserved farmland (e.g., blocks of 1,000 contiguous acres) to slow the incursion of development (Anon. 2001), and some counties have set a minimum level of aggregate farmland acres they wish to retain. The methodologies for defining these levels, in all except the Dhillon and Derr study, appear somewhat ad hoc.

Defining a critical mass would provide information for policymakers engaged in activities that impact land use decisions and the preservation of farms and farmland. To increase efficiency, farmland preservation programs may need to target areas where a critical mass of agricultural activity exists (Daniels and Lapping 2001), rather than spread their resources to those areas where agriculture is less likely to survive because they have already dipped below the critical mass. Given the limited funds available, prioritizing where and how to protect farmland ensures the highest level of open-space preservation and agricultural activity. Programs that target contiguous agricultural areas rather than random, noncontiguous farms may also achieve more success by reducing conflicts between farmers and residential or commercial neighbors.

Economic theory suggests that agricultural landowners will farm the land until the value in an alternative use exceeds the agricultural value. The net market value in many developed uses (commercial, residential, and industrial) is often greater than in agricultural use. Thus, at least in theory, the market will allocate the land to this privately optimal developed use. This use may not always be socially optimal, however, as the loss of farmland affects the general public and the value of remaining agricultural land, and not just the individuals engaged in land purchases or sales. Maintaining land in agriculture can provide open space, improved quality of rural life, landscape vistas, and groundwater recharge areas, and it contributes to the local economy, all of which impact society as a whole. Agricultural land is also associated with less positive attributes that affect its neighbors, such as odors from livestock operations, drift from chemical pesticide, water-quality concerns from fertilizer use, insects, dust, noise, and slow-moving equipment on the roads. If the negative externalities outweigh the positive, the private market would retain too much land in agriculture.

The conversion of farmland can impact the value of the land remaining in agricultural use. Adjacent land use can affect agricultural land use in several ways. Population growth or suburbanization near farming areas can create problems for farmers. Nonfarm neighbors may object to nuisances related to traditional farming practices, such as those listed above, and may advocate limitations to these practices. Even in rural areas, incompatible activities in the surrounding landscape may affect the profitability of farms. For example, farmers may earn more profit operating within a thriving agricultural community than in a locale dominated by other land uses, be it a city, forest, or recreational area.

This chapter describes research conducted to establish whether a critical mass threshold exists for agricultural land. We analyze whether counties lose farmland at a faster rate if the number of acres or farms falls below a threshold level of acres. The study area includes six Mid-Atlantic states from 1949 to 1997. Because farmland loss can be affected by a variety of factors besides a critical mass, we also examine the effects of factors such as agricultural net returns and development pressure on the rate of farmland loss. The model both estimates the impacts of these factors and conducts an associated sensitivity analysis. Finally, we explore whether the effects of critical mass and other variables on agricultural land conversion appear to have changed over time.

Economic and Econometric Models

To investigate whether a critical mass threshold exists in the Mid-Atlantic agricultural sector, we analyze the difference in the rate of farmland loss for counties with varying levels of farmland acreage over time, holding constant all other variables.[4] The county's rate of farmland loss is modeled as a function of the number of productive agricultural acres, the net return in an agricultural use, the net value in a residential use, the existence of agricultural preservation policies, and the availability of off-farm income opportunities. When a county has a high number of productive acres, the farm sector can sustain a viable support sector, and local agriculture may remain competitive. Thus farmland and farm loss rates are hypothesized to be a function of the number of productive farmland acres, again holding all other variables constant.

Farmland might be converted for various reasons unrelated to the concept of critical mass. For example, theory states that it will be converted to nonfarm uses when the net value of an alternative use is higher than an agricultural use. This would increase the rate of farmland loss. If agricultural land is converted to housing because returns for agricultural use are lower than in a residential use, this is not evidence of critical mass. If, however, a county's farmland decreases below a certain critical level—only after which returns in agriculture fall below those of residential development—then this would provide some evidence of a critical mass. The farmland loss rate may also be high if the area has low or negative agricultural net return, even if residential, commercial, and industrial uses have low net values. In such cases, the farmland would be idled or possibly converted to forestland. It is important to recognize that this analysis does not assume that farmland is converted to housing rather than another nonagricultural land use; farms can also leave agriculture to become businesses or forests. Rather, the model attempts to isolate the effect of a critical mass from other reasons that farmland or farms might be lost.

Among factors hypothesized to influence farmland conversion, agricultural preservation programs purchase development rights on agricultural parcels, and preferential taxation programs decrease a farmer's property tax. Thus these programs can increase the relative return of retaining land in an agricultural use. Consequently, they can contribute to the retention of farmland acres and slow the rate of farmland and farm loss.

Off-farm employment may also increase or decrease the rate of farmland and farm loss. When off-farm income opportunities are high, farmers might choose to leave farming and enter other professions. This will tend to increase the rate of farmland and farm loss, unless this land is sold to another farmer. Alternatively, off-farm employment opportunities may decrease the farmland and farm loss rate if farmers supplement their farm income with off-farm income. Off-farm income may also be an important diversification strategy for farmers.

In addition to potentially confounding effects related to such factors as farmland preservation policies and off-farm income, the critical mass threshold itself may evolve over time. Improved communications and transportation infrastructure may reduce the costs of purchasing inputs and facilitate marketing. Growers may adapt when suppliers and processors exit the area. Adaptations could include switching to crops or animal products that are less reliant on these support industries. Farmers could shift to direct marketing rather than wholesaling. In addition, farming has experienced technological and structural changes over the last 50 years. The United States lost almost half of its farms between 1950 and 1970, partly because of mechanization and the consolidation of farms (Gardner 2002). U.S. average farm size and output per farm grew rapidly through the 1970s but have grown more slowly since then. Labor costs have decreased as a portion of total input costs beginning in the 1980s.

To account for such changes, a general model (Model 1) using farmland loss as the dependent variable is estimated for the entire time period 1949–1997, and then the sample is split into two periods with two additional models: 1949–1978 (Model 2a) and 1978–1997 (Model 2b). This allows the determination of a critical mass threshold and importance of other factors to vary by time period. We repeat the exercise using farm loss (number of farms rather than farm acres) as the dependent variable. Details of the econometric model are provided in the Appendix to this chapter.

Data and Study Area

Data were compiled from the agricultural and the population and housing censuses at the county level for the years 1949 through 1997, including the Mid-Atlantic states of Delaware, Maryland, New Jersey, New York, Pennsylvania, and Virginia (United States Department of Agriculture, 1999, 2001; United States Department of Commerce). In 1997, these six Mid-Atlantic states accounted for more than 26 million acres of farmland, representing 3 percent of U.S. total farmland and $12 billion (6 percent) of U.S. total sales. The analysis incorporates data on 269 counties[5] and 10 time periods of 4 to 5 years each. These time periods correspond to the years the agricultural censuses were taken. The data set was constructed as a panel by crop reporting district and by time period. A county's data were included in the crop reporting district to which it belonged. The USDA National Agricultural Statistics Service defines these crop reporting districts to reflect similar geography, soil types, and cropping patterns (Figure 6-1).

[<Insert figure 6-1 here>]

Because the two censuses were conducted on different schedules, we adjusted the population and housing census data to coincide with the years of the agricultural census data. The population and housing census is collected every 10 years, and the agricultural census every 4 to 5 years. We interpolated the population and housing census data by calculating a constant change in the variables between the census years, then using this change to adjust the population and housing census data to the year the agricultural census was collected. Thus, for example, if the population change were 25 percent for the 10-year period, it was assumed that population grew 2.5 percent each year. Data from the 2000 census were not yet available. Therefore, extrapolations of the 1990 population and housing census data were conducted for 1992 and

1997, with the values calculated based on the change in the variables between 1980 and 1990. The rates of change were assumed to remain constant during the 1990s.

Counties with limited agricultural activity (fewer than five farms) in 1949 were excluded from the analysis: Bronx, Queens, Richmond, Kings, and New York, in New York State, and Arlington in Virginia. If the sales-per-acre data were not available for a county for confidentiality reasons, the county was deleted for that particular time period, but not from the entire analysis.

[<Insert table 6-1 here>]

Table 6-1 provides the names, definitions, and descriptive statistics for the variables included in the analysis. The dependent variable is the rate of farmland and farm loss for time period *t*. It is calculated as $\frac{A_{t+1} - A_t}{A_t}$, where A_t is the number of acres in the initial period. Farmland is defined by the agricultural census as consisting of land used for crops, pasture, or grazing. Woodland and wasteland acres are included if they are part of the farm operator's total operation. Conservation Reserve and Wetlands Reserve Program acreage is also included in this count. The rate of farmland loss averaged 7.58 percent and of farm loss 11.76 percent over the study period. Changes for individual counties can be much higher or lower than these averages, however. For example, some counties lost 100 percent of their farmland in a time period. One county gained 77.65 percent more farmland in *t* (many counties gained in the period between the 1974 and 1978 censuses).

Independent model variables illustrating the percentage change in specific factors use the initial year of the time period as the ending year of the calculation. For example, the percent change in housing units for time period *t* was calculated as $\frac{HU_t - HU_{t-1}}{HU_{t-1}}$, where HU_t is the total housing units at time *t*.

County-level harvested cropland acres in *t* proxy the acres that contribute to the critical mass threshold. Harvested cropland includes land from which crops were harvested or hay was cut, as well as that in orchards, citrus groves, Christmas trees, vineyards, nurseries, and greenhouses. These acres are better indicators of the level of agricultural activity. Idled farmland or acreage that is enrolled in the Conservation Reserve Program, for example, requires the purchase of few inputs, produces no output, and may not contribute in the same manner to maintaining a viable agricultural sector. We hypothesized that the county's rate of farmland and farm loss will increase if the level of harvested cropland falls below the threshold needed to sustain a viable agricultural support sector. Harvested cropland acreage is also included as a squared term. By including it in this manner, we can compute an acreage threshold required to ensure a critical mass. Harvested cropland averaged 54,372 acres per county, and the highest acreage in any one county was 334,294.

Because farmland and farm loss are affected by changes in agricultural returns per acre, demand for land for nonagricultural purposes, farmers' alternative employment opportunities, and preservation policies, we include variables to control for these factors. The percentage of the county population in agricultural, forestry, fishing, or mining activities in *t* is also included to indicate the dominance of these resource-based activities in the county. Employment in this type of work varied among counties from almost none to 70 percent, with an average of 9.99 percent.

Agricultural net returns are proxied by county-level agricultural sales per acre and expenses per acre in *t*. Farmers are more likely to remain in agriculture if sales increase more than expenses. Sales per acre averaged $549.07 in 1997 dollars, and expenses per acre averaged

$331.51. Despite the almost 50 percent decrease in land devoted to agriculture in the Mid-Atlantic, total revenue has decreased by only 1 percent in real terms between 1949 and 1997. Per-acre sales have nearly doubled during this period. Price and technology changes are reflected in these expense and sales numbers. In addition, these numbers reflect shifts to alternative crops. By 1997, 42 percent of the study's counties derived the largest share of their income from a different commodity or animal source than in 1949 (Figure 6-2).

[<Insert figure 6-2 here>]

Decreases in agricultural net returns may also help explain the farmland loss that occurred in areas where the population decreased. Figure 6-3 depicts the areas where farmland decreased when the population decreased, and vice versa, for one decade of the study period—between 1987 and 1997.

[<Insert figure 6-3 here>]

Several variables represent demand for land for nonfarm uses: the population level scaled by the number of acres in the county, whether the county is in a metropolitan area, the percent change in total housing units, the percent change in median family income, and the percent change in median housing value. As population increases, demand for land in residential and commercial uses also increases. Thus population growth is hypothesized to increase the rate of farmland and farm loss. Total population in the six states has increased by 43 percent since 1950, climbing from 35 million to 50 million people. Given that the number of individuals per housing unit has decreased, we also include a direct indicator of the rate of growth in the housing stock. As the growth rate of housing units increases, the rate of farmland and farm loss is expected to increase. The percent change in total housing units averaged 8.09 percent, with some counties losing housing units at a rate of as much as 19 percent while others had a growth rate of 60 percent. As family income increases, people may demand larger homes, which usually sit on larger parcels. Thus we expect that an increase in income could increase the demand for farmland and accelerate the farmland and farm loss rate. Similarly, an increase in the median housing value may indicate an increase in the demand for land (Hardie et al. 2001) and accelerate the rate of farmland and farm loss.

An increasing proportion of farmers supplement their farm income with off-farm employment. Only 33 percent of Mid-Atlantic farmers reported working more than 100 days off the farm in 1949, but 44 percent did so in 1997. Their off-farm income opportunities will be greater if they are better educated and the unemployment rate in the county is low. An increase in off-farm opportunities, however, will increase the relative benefit of selling the land and shifting full-time to alternative employment. Off-farm opportunities are proxied by both the percentage of the county population that has at least a high school education and the percentage of unemployment. These opportunities could have either a positive or negative effect on the rate of farmland and farm loss. Education attainment increased over the time period, with an average of 48.41 percent of residents having a high school education. The unemployment rate averaged 5.49 percent, with a range of 0.07 to 14.5 percent. Increases in median family income might also signal a strong local economy and possibly more off-farm employment opportunities.

Policy variables are included to indicate whether the county has a preferential property tax program for agricultural land or some type of farmland preservation program. Preservation and taxation programs are hypothesized to slow the rate of farmland and farm loss. We consider four different types—state preferential property tax programs, state purchase of agricultural conservation easement programs, local purchase of agricultural conservation easement programs, and local transfer of development rights programs—and collected information on the existence of these programs by county (AFT 1997, 2001a, 2001b, 2001c). A binary (has/has not) variable indicates whether the state had established a preferential property tax program by *t*. Another binary (has/has not) variable indicates whether the county had one or more local- or state-level preservation programs in place by *t*. Counties were credited with having a program if any locality within the county had a program that had preserved at least 1 acre. By 1982, all the states had established preferential property tax programs. By 1997, 44 percent of the counties had a local or state preservation program in place.

Results

Results of Farmland Loss Model 1

As the number of harvested cropland acres increased in a county, the rate of farmland loss decreased in the period 1949 to 1997 (Table 6-2). Counties with fewer acres of harvested cropland had higher rates of farmland loss. In terms of a critical mass, we found that counties below 189,240 harvested cropland acres had a higher rate of farmland loss. The identified threshold, however, is nearly out of the data range. Only 2 to 7 out of 269 counties exceed 189,240 acres of harvested cropland in any time period. Therefore, the interpretation of this number as a threshold should be made cautiously.

[<Insert table 6-2 here>]

The rate of farmland loss is also explained by sales per acre, expenses per acre, population per acre, unemployment rate, percent change in median family income, and percent change in housing units. The rate of farmland loss decreases as harvested cropland acres, sales, and percent change in income increase. The rate of farmland loss increases, however, as expenses, population, percent change in total housing units, and percentage of unemployment increase. As expected, counties with preferential taxation programs had a lower rate of farmland loss than counties without such a program. Holding all else constant, metropolitan counties lost farmland at a higher rate than nonmetropolitan ones.

We compute the predicted rate of farmland loss at the average value of the continuous variables and at zero (has not) for the binary variables. The predicted rate of farmland loss is 7.9 percent. We then estimate how much the predicted rate will change for a 10 percent increase in each variable we found to affect farmland loss. For binary variables, we compute the rate of farmland loss if they were equal to one (has a program). Table 6-3 contains the predicted rate and the new rate given the 10 percent increase.

[<Insert table 6-3 here>]

The model predicts a baseline average rate of farmland loss of 7.9 percent. The rate decreases to 7.67 percent if the harvested cropland acres are increased 10 percent (Table 6-3). Sales and expenses per acre also affect the farmland loss rate. A 10 percent change in sales per acre has a greater effect than an equal percentage change in expenses. A 10 percent increase in sales per acre would decrease the rate of farmland loss to 7.83 percent (a change of –0.07), whereas a 10 percent increase in expenses per acre would increase the rate of farmland loss to 7.92 percent (a change of 0.02).

Development pressure also impacts the rate of farmland loss in Model 1. A 10 percent increase in population per acre increases the rate of farmland loss to 8.01 percent. Similarly, if the growth of housing stock increases 10 percent, the rate of farmland loss increases to 8.02 percent. Metropolitan counties lost farmland at a rate of 8.94 percent, and nonmetropolitan counties at a rate of 7.9 percent. Higher income growth levels and employment opportunities decrease the rates of farmland loss. A 10 percent increase in median family income growth lowers the rate of farmland loss to 7.73 percent. If the unemployment rate increases by 10 percent, the rate of farmland loss increases to 8.09 percent. Education has no impact on the rate of farmland loss.[6]

Preferential taxation programs were found to have a significant effect on the rate of farmland loss. Counties with preferential taxation programs had a farmland loss rate of 4.06 percent; counties without one had a rate of 7.9 percent. The presence of other agricultural preservation programs (purchase of development rights, transfer of development rights, or purchase of agricultural conservation easements) did not impact the rate of farmland loss.

[b-head]*Results of Farmland Loss Models 2a and 2b*

Models 2a and 2b demonstrate that the effect of independent variables on farmland loss changed over time. Moreover, the rate of farmland loss slowed about halfway through the study period. The actual average 5-year rate of farmland loss in 1949–1978 was 9.2 percent, and for 1978–1997, 5.1 percent. Both agriculture and the pattern of city and housing development changed during this time. We found that the variables' impacts were not consistent over the two time periods, 1949–1978 (Model 2a, early) and 1978–1997 (Model 2b, late).[7] The early model's results were similar to those reported above for Model 1, but those of the late model differed. Estimated coefficients are reported in Table 6-2.

Counties with more harvested cropland have a lower rate of farmland loss in the early model, but the number of cropland acres in the late model had no effect on the farmland loss. The critical mass level in the early model was estimated to be 180,795 harvested cropland acres—similar to the threshold of 189,240 harvested acres in Model 1. But as before, few counties actually had more than 180,000 acres of harvested cropland acres. The early period appears to drive the threshold result of Model 1.

The predicted rate of farmland loss in the early model was 10.12 percent, and in the late model 5.01 percent. In the early model, a 10 percent increase in harvested cropland acreage resulted in a lower farmland loss rate of 9.82 percent, a change of 0.30 (Table 6-3); in the late model, the harvested cropland had no effect.

Similar to the results of Model 1, a higher net revenue decreased the rate of farmland loss in the early model. Expenses per acre had a bigger impact than sales per acre, however. A 10 percent increase in sales per acre decreased the rate of farmland loss to 10.08 percent (a change of –0.04). If expenses increased by 10 percent, the rate of farmland loss increased to 10.25 percent (a change of 0.13). In the late model, surprisingly, the opposite relationship is observed. A 10 percent increase in sales per acre increased the rate of farmland loss from the predicted 5.01 percent to 5.10 percent. A 10 percent increase in per-acre expenses decreased the rate of farmland loss to 4.91 percent.

Effects of other variables in the early model were similar to those reported above for Model 1. The resulting farmland loss rate following a 10 percent increase in these variables for the early model can be found in Table 6-3 and graphically in Figure 6-4. In the late model, except for population per acre, none of the other variables had an impact on the rate of farmland loss. A 10 percent increase in population per acre increased the rate of farmland loss from 5.01 to 5.08 percent. The overall explanatory power of the early model, though not high, was greater than that of the late model. The R^2 for the early model equaled 0.23; in other words, 23 percent of the variation of the rate of farmland loss was explained by the included variables. The R^2 for the late model was only 0.06; thus the late model did not explain 94 percent of the variation in farmland loss rates for these counties between 1978 and 1997. Obviously, many other variables are affecting the rate of farmland loss during this later period, but they are not well captured by the county-level census data and the proposed model. County-level variables may mask spatial changes that have occurred in the farmland as well as other organizational adjustments. For example, many counties altered the crop and livestock mix, and the aggregate variables in the model may not capture these changes. Further research on individual sectors such as dairy or cattle may provide additional insights into the concept of a critical mass that a county-level analysis could not.

[<Insert figure 6-4 here>]

[b-head]*Results of Farm Loss Model 1*

We find many of the same results for the rate of farm loss as for farmland loss, but differences in the effect of certain variables do exist. The rate of decrease in the number of farms shows no critical mass of harvested cropland acres (Table 6-4). Although no threshold exists, the higher the number of farmland acres, the lower the loss of farm numbers will be. During the time period, average farm size throughout the region increased from 106 to 185 acres. Therefore, the rate of farm loss was greater than the rate of farmland loss.

[<Insert table 6-4 here>]

Factors that explain the rate of farm loss include harvested cropland, resource-based employment, sales per acre, expenses per acre, population per acre, percentage of unemployment, percentage of the county population with a high school education, percent change in median family income, and percent change in housing units. As harvested cropland, sales, resource-based employment, education, and income increase, the rate of farm loss falls. Similarly, as expenses, population density, total housing, and percentage of unemployment increase, the rate of farmland loss accelerates. A county with a preferential taxation program has a lower farm loss, as does one with a preservation program. Metropolitan counties, in contrast, had a higher farm loss rate.

The predicted 5-year farm loss rate from the model was 12.07 percent. We use this to determine the effects on the farm loss rate of a 10 percent change in the significant variables (Figure 6-5) or a change in the binary variables from has not to has (Figure 6-6). For example, if a county has 10 percent more harvested cropland acres, the 5-year rate of farm loss decreases from the predicted rate of 12.07 percent to 11.89 percent. If the average resource-based employment increased by 10 percent, the rate of farm loss decreased from the predicted 12.07 percent to 12.00 percent.

[<Insert figure 6-5 here>]

[<Insert figure 6-6 here>]

As with farmland, we found that as sales per acre increase, the rate of farm loss will decrease, and as the expenses per acre increase, the rate of farm loss will increase. Thus as the net returns to agriculture decrease in a county, it will lose farms at a quicker rate. If sales increased by 10 percent, the rate of farm loss decreased from the predicted rate of 12.07 percent to 12.04 percent. If expenses increased by 10 percent, the rate of farm loss increased from 12.07 to 12.09 percent. The effect of sales and expenses on farm numbers is smaller than on farmland loss. Also unlike patterns found in the farmland loss model, a change in sales per acre appears to have the same impact on farm numbers as expenses per acre. One may view this from two distinct perspectives: lower net returns will not accelerate farm loss dramatically, or alternatively, even if net returns increase, the impact on the rate of farm loss will be small.

An increase in population per acre also increases the rate of farm loss, just as it increases farmland loss. If population per acre increases by 10 percent, the rate of farm loss increases from 12.07 to 12.12 percent. Similarly, the percent change in housing units in the county impacts the farm loss rate. As the percentage of housing units increases by 10 percent, the rate of farm loss increases from 12.07 to 12.16 percent. We found that being in a metropolitan area also increased the rate of change, but with a slightly lower impact on farm loss than on farmland loss. The rate of farm loss was 12.76 percent in metropolitan areas, compared with the predicted rate of 12.07 percent for nonmetropolitan counties.

Similarly to the farmland loss model, here an increase in median family income is found to decrease farm loss. The effect of income is even larger on farm loss than on farmland loss.

This could be a function of better off-farm employment opportunities or households with higher incomes choosing to purchase farms and keep them in production. A 10 percent increase in the median family income decreases the rate of farm loss from 12.07 to 11.86 percent. In contrast, farms were lost at a higher rate if the unemployment rate in the county was high. If unemployment rate increases by 10 percent, the rate of farm loss increases from 12.07 to 12.21 percent. In such cases, farmers may have had fewer off-farm opportunities to supplement farm income and hence were more likely to sell their farms. Unlike in the farmland loss models, education affected the rate of farm loss. If the percentage of the county's population with a high school education increases by 10 percent, the rate of farm loss decreases from 12.07 to 11.47 percent.

The model also shows that having a preferential property tax assessment for agricultural landowners reduces the rate of farm loss—the same result as was found for farmland. Counties where preferential taxation existed had a farm loss rate of 9.08 percent, compared with the predicted rate of 12.07 percent. Similarly, having a preservation program (purchase of development rights, transfer of development rights, or purchase of agricultural conservation easements) resulted in a lower percentage of farms lost. Counties with these programs had a rate of farm loss of 9.76 percent. Thus we find that preservation programs are saving farms, although the results for farmland acres are mixed.

[b-head]*Results of Farm Loss Models 2a and 2b*

We also estimated the models for the two time periods—1949–1978 (Model 2a, early) and 1978–1997 (Model 2b, late)—to determine if the impacts of variables were consistent over time. We found that although the results were remarkably similar to those reported above for Model 1, for the earlier time period, they diverged in the later years like those for farmland loss (Table 6-4).

In the early period, no critical mass threshold for farm numbers was found, although a decrease in the number of harvested crop acres did increase the rate of farm loss. A decrease in the percentage of the county population that worked in resource-based sectors also increased farm loss. Sales and expenses per acre had slightly larger impacts in the early model. If sales increased by 10 percent, the rate of farm loss decreased from the predicted rate in the early model of 16.23 to 16.18 percent. If expenses increased by 10 percent, the rate of farm loss increased from 16.23 to 16.27 percent. In the early model, being in a metropolitan area had a bigger impact than in Model 1, increasing the rate of farm loss from 16.23 to 18.30 percent. Similarly, as the percentage of unemployment increased by 10 percent, the percentage of farms lost increased to 16.47 percent, a higher loss rate than in the more general Model 1. Interestingly, the existence of a preferential tax program had no effect on the farm loss rate in this early period, although many of the programs had begun by the end of this period. Many of the other variables estimated in this early period had the same magnitude of impact as in Model 1.

We do not find a critical mass threshold in the late model. In fact, contrary to expectations, the late model finds that as harvested cropland decreases, the rate of farm loss decreases as well. Changes in agriculture and development patterns may have altered the impact of many variables on the number of farms lost. As a whole, the late model did not explain a particularly large proportion of the observed loss of farms—the same result as was found in the farmland model. We do find that in this late period, an increase in population density per acre continues to increase the rate of farm loss. We also find that counties with agricultural preservation programs lose farms at a slower pace. The predicted farm loss rate during this late period was 6.13 percent. Counties with preservation programs lost farms at a rate of 2.32

percent. Given that all counties had a preferential taxation program by this time, we could not assess the existence of a differential rate for this type of program in the later years.

The Impact of Changes over Time on Farm and Farmland Loss

Model results suggest that patterns influencing farm and farmland loss are complex and likely have changed over time. Some evidence of a critical mass existed for the study area during the early period for farmland loss, although not for farm loss. The scale of agricultural activity in the latter half of the study period did not impact the rate of farmland loss, however, and actually had the reverse effect on farm loss. This raises some interesting questions with implications for the retention of agriculture.

First, to what extent have farmers adapted to the difficulties associated with shrinking input and output markets by shifting to alternative crops or marketing mechanisms? The data show that for 42 percent of the counties, the agricultural activity earning the highest gross income in 1997 was different from the activity that had generated the most income in 1949 (Figure 6-2). The implications of a county-level change from dairy to vegetables or from row crops to livestock require further investigation. Second, had the major technological changes in agriculture, in terms of improved mechanization and per-acre yields, occurred by the mid-1970s? Moreover, did these changes impact farm and farmland loss rate differently? Third, how did land development patterns change, as a result of changes either in housing consumers' preferences or in land use or development policies? How did these changes impact the rate of farmland and farm loss? Fourth, how have counties responded to the high rate of farmland loss between 1949 and the early 1970s? Counties implemented preferential taxation programs and agricultural preservation programs, which we consider. Other responses, however, not incorporated in the model, might have been equally or more important.

The impact of sales and expenses per acre changed for the latter part of the study period. In the early period, the expected result was found: increased sales or decreased expenses resulted in a lower rate of farmland loss. But from 1978 to 1997, an opposite—and somewhat puzzling—result was found. The reason for this shift is unclear. It may be, however, that farmers with the most marginal agricultural land were the first to exit agriculture, leaving only the most productive land under cultivation. County average per-acre sales therefore would increase. Also, farmers could have switched crops. If they shifted to higher-value, smaller-acreage crops, such as berries or vegetables, farmland loss would occur simultaneously with higher per-acre sales. This begs the question of why they had not shifted to higher-value crops at an earlier time period.

The health of the local economy also was found to impact the rate of farmland conversion. Counties with higher median family incomes and lower unemployment had lower rates of farmland loss. This could be a function of better off-farm employment opportunities or people with higher incomes choosing to purchase farms and keeping them in production. Farmers in counties with high unemployment may have had fewer off-farm opportunities for themselves or family members and may have chosen to sell their farms and relocate. Policies that focus attention on local or regional economic performance could promote farmland retention. Examining farmland prices, Hardie et al. (2001, *131*) conclude that "policies developed for broader purposes may have as much or more effect on farmland prices as policies targeted directly at improving agricultural returns."

Population growth also resulted in higher rates of farm and farmland loss in every model. In the early period, the growth rate of the total number of housing units was positively related to the rate of farmland and farm loss as well. This is expected, as population growth and housing development tend to cause the conversion of agricultural land. Local communities can exercise control over the extent and pattern of new development through thoughtful planning. Given the Chesapeake Bay Foundation's (2000a, 2000b) finding that the rate at which land is being consumed exceeds the population growth rate by almost 2.5 times, policies could focus on reducing land consumption per house or per person to limit the impacts of both population growth and housing development on agriculture.

As expected, metropolitan counties had higher rates of farmland and farm loss over and above losses related to population and changes in housing stock. This implies that metropolitan counties that wish to maintain agriculture may need to be even more active in implementing policies and programs to encourage farmland retention and strengthen the agricultural economy. Alternatively, states might decide to target regions far from metropolitan areas for preservation and retention programs, while deemphasizing farmland preservation in metropolitan areas. This approach could retain agriculture on a statewide basis and allow states to use their limited resources efficiently.

Preferential property taxation programs were found to slow the rate of farmland and farm loss. All six states in this study had enacted such programs by 1982. Additional evaluation of these programs may be warranted, as well as an examination of who participates and who does not. A further property tax reduction might slow the rate of farmland loss even more. Such a reduction potentially could be financed through a higher conversion tax rate. The state or counties thus could recapture some of the benefits the farmers accrue from the preferential tax program. This conversion tax could be collected when landowners choose to convert the land from agriculture to a nonfarm use. Chapter 8 in this book highlights the various aspects of differential taxation programs that may lead to greater landowner participation and perhaps a higher rate of farmland retention.

Other agricultural preservation programs—purchase of development rights, transfer of development rights, or purchase of agricultural conservation easements—did not impact the rate of farmland loss, but did slow the loss of farms. Apparently, when some farmers are offered another option to selling out, they are willing to take it. Few of these programs existed before the 1980s. Moreover, some programs have not had sufficient resources to preserve large numbers of acres. Farmland preservation programs may have more impact in the future if they are able to obtain increased resources and hence can enroll a greater number of acres.

Conclusions

The results do not provide clear evidence of a critical mass in agricultural economies in the Mid-Atlantic. They suggest that counties with fewer farmland acres lost farmland and farms at higher rates. An acreage threshold level was computed for farmland loss. Yet these calculated critical mass levels (189,240 acres per county in Model 1 and 180,795 per county in Model 2a) exceed the harvested cropland acres of most counties (97 percent) in the Mid-Atlantic region. Hence, even if a critical mass is applicable to farmland loss, our models suggest that it may entail a greater acreage of farmland than exists in the vast majority of the Mid-Atlantic counties. In addition, a critical mass of agricultural acreage was not found in the analysis of the 1978 to 1997 period. Counties with fewer harvested cropland acres did not have a higher rate of farmland loss and did have a lower rate of farm loss in the later period. Thus even if the computed levels were convincingly strong, the critical mass may have altered in the latter part of the study period, given the many changes over time.

Additional research is needed to more fully identify factors that affect the rate of farmland and farm loss and determine whether a critical mass exists. Farmers may have adapted to more limited support sectors in their regions by shifting to alternative crops or products that are less reliant on nearby suppliers or buyers. Specific sectors or commodities might be doomed once an area loses a certain number of acres, when the farmers cannot continue to produce these commodities profitably. Adaptation, however, could ensure the viability of the farm sector as a whole. A model incorporating all U.S. agricultural economies might further demonstrate whether and how much the level of a critical mass depends on cropping patterns and geography. In contrast, a more micro-level analysis could reveal information obscured by the present county-level analysis. A case study approach could provide insights about specific industries or agricultural sectors in specific regions during specific time periods. Alternatively, further analysis might consider individual farming sectors in different areas and how they have evolved over time.

Although this analysis does not provide a clear prognosis for the economic viability of the Mid-Atlantic's agricultural sector, it does suggest that the farm community has been resilient to large losses of farmland over time; that the health of the local economy in the county matters; and that controlling population growth and housing development is very important to slowing farmland and farm loss. The analysis also suggests that the recent emphasis on preserving a critical mass of agricultural land may be insufficient to ensure the long-term viability of an agricultural sector. As a result, decisionmakers may need to examine other policy objectives to sustain the sector.

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Table 1. Descriptive Statistics for the Entire Sample*

Variable name	Variable definition	Entire Sample	
		Mean	Std.Dev.
PCFLAND	Percent reduction in farmland	7.58%	0.1256
HCLAND	Harvested cropland (1,000 acres)	54.372	47.097
HCLAND-SQUARED	Harvested cropland squared (1,000,000,000)	5.1724	9.710
PAGFFM	Percent of adults employed in agriculture, forestry, fisheries and mining	9.99%	0.1056
SALESPER	Sales per acre ($/acre)	$549.07	2394.1100
EXPPERA	Expenses per acre ($/acre)	$331.51	2227.9300
POPPERA	Population per acre	0.5773	1.8430
MADUMMY	=1 if county in metropolitan area	33.72%	0.4728
PCTOTHU	Percent change in total housing units	8.09%	0.0689
PCMFINC	Percent change in median family income	11.92%	0.0838
PCMHVAL	Percent change in median housing value	11.66%	0.1017
PHIGHSCH	Percent of adults with at least a high school education	48.41%	0.0185
PUNEMP	Unemployment rate	5.49%	0.0223
STAX	= 1 if state has preferential taxation program for agricultural land	56.63%	0.4957
PRESPROG	= 1 if state and/or county has purchase or transfer of agricultural conservation easement program	8.47%	0.2785

* The percentage change variables use the initial year of the time period as the ending year of the percent change calculation. Thus the percent change in housing units for time period t was calculated as $\frac{HU_t - HU_{t-1}}{HU_{t-1}}$, where HU_t is the total housing units at time t

Table 2. Results of Model 1, 2a-b for Farmland Loss, Including All Observations Using Harvested Cropland as the Critical Mass Indicator

	Model 1 (1949-1997)	Model 2a (1949 to 1978)	Model 2b (1978 to 1997)
	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)
HCLANDD Harvested cropland	-0.00058994 *** (0.0001)	-0.00969508 *** (0.0002)	-0.00004426 (0.0002)
HCLAND-SQUARED	0.0015587 *** (0.0006)	0.00268124 *** (0.0007)	-0.00015372 (0.0010)
PAGFFM % resource employment	0.0415 (0.0334)	0.0477 (0.0381)	0.0500 (0.0972)
SALESPER Sales per acre	-0.00001 *** (0.0000)	-0.00002 *** (0.000002)	0.00002 *** (0.000005)
EXPPERA Costs per acre	0.000005 *** (0.0000)	0.00001 *** (0.000002)	-0.00003 *** (0.00001)
POPPERA People per acre	0.0187 *** (0.0017)	0.0175 *** (0.0019)	0.0148 *** (0.0053)
MADUMMY Metropolitan area	0.0103 * (0.0059)	0.0193 ** (0.0082)	0.0078 (0.0088)
PCTOTHU %Δ housing units	0.1587 *** (0.0401)	0.1780 *** (0.0498)	0.0823 (0.0861)
PCMFINC %Δ income	-0.1321 ** (0.0540)	-0.1416 ** (0.0608)	-0.0588 (0.1311)
PCMHVAL %Δ housing value	0.0236 (0.0307)	-0.0025 (0.0448)	0.0462 (0.0651)
PHIGHSCH % high school	0.0141 (0.0318)	0.0251 (0.0462)	-0.0032 (0.0584)
PUNEMP % unemployment	0.3207 * (0.1255)	0.3313 ** (0.1643)	0.2931 (0.2201)
STAX Preferential tax	-0.0404 *** (0.0105)	-0.0358 *** (0.0112)	
PRESPROG Preservation program	-0.0047 (0.0095)		-0.0082 (0.0111)
CONSTANT	0.0875 ** (0.0387)	0.1162 *** (0.0415)	0.0172 (0.0514)
R2	.1647	.2344	.0623
N	2604	1574	1030

Note: Three asterisks (***) indicates that based on an asymptotic t-test, the H_0: B=0 is rejected using a 0.001 criterion. Two asterisks (**) and one asterisk (*) reject using a 0.05 criterion and 0.10 criterion respectively.

Table 3. Effects of a 10% Increase in Significant Continuous Variables and Binary Variables Equaling 1 on Rate of Farmland Loss for Each of the Estimated Models

	Model 1 1949-1997	Model 2a 1949-78	Model 2b 1978-1997
Predicted Probability	7.90%	10.12%	5.01%
Probability after 10% Increase in Continuous Variables			
HCLAND Harvested cropland	7.67%	9.82%	
PCMFINC %Δ income	7.73%	9.99%	
SALESPER Sales per acre	7.83%	10.08%	5.10%
EXPPERA Costs per acre	7.92%	10.25%	4.91%
POPPERA People per acre	8.01%	10.30%	5.08%
PCTOTHU %Δ housing units	8.02%	10.36%	
PUNEMP % unemployment	8.09%	10.37%	
Binary Variables			
STAX Preferential tax	4.06%	6.62%	
MADUMMY Metropolitan area	8.94%	12.13%	

Table 4. Results of Model 1, 2a-b for Farm Loss, Including All Observations Using Harvested Cropland as the Critical Mass Indicator

	Model 1 (1949-1997)	Model 2a (1949 to 1978)	Model 2b (1978 to 1997)
	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)
HCLANDD Harvested cropland	-0.0002 * (0.0001)	-0.0006 *** (0.0002)	0.0004 *** (0.0002)
HCLAND-SQUARED	0.0001 (0.0005)	0.0011 (0.0007)	-0.0014 ** (0.0007)
PAGFFM % resource employment	-0.0660 ** (0.0294)	-0.0797 ** (0.0375)	0.0826 (0.0673)
SALESPER Sales per acre	-0.000007 *** (0.000002)	-0.00001 *** (0.000002)	0.000004 (0.000004)
EXPPERA Costs per acre	0.000007 *** (0.000002)	0.00001 *** (0.000002)	-0.000004 (0.000007)
POPPERA People per acre	0.0108 *** (0.0015)	0.0090 *** (0.0019)	0.0204 *** (0.0037)
MADUMMY Metropolitan area	0.0089 * (0.0052)	0.0207 *** (0.0083)	0.0058 (0.0061)
PCTOTHU %Δ housing units	0.1229 *** (0.0361)	0.1387 *** (0.0506)	0.0668 (0.0643)
PCMFINC %Δ income	-0.1740 *** (0.0474)	-0.1538 *** (0.0593)	-0.0484 (0.0929)
PCMHVAL %Δ housing value	0.0432 (0.0269)	0.0692 (0.0440)	-0.0258 (0.0516)
PHIGHSCH % high school	-0.1328 *** (0.0307)	-0.1388 *** (0.0499)	-0.1105 ** (0.0479)
PUNEMP % unemployment	0.3000 *** (0.1151)	0.4618 *** (0.1717)	0.0349 (0.1620)
STAX Preferential tax	-0.0265 *** (0.0095)	-0.0086 (0.0116)	
PRESPROG Preservation program	-0.0173 ** (0.0086)		-0.0380 *** (0.0089)
CONSTANT	0.1990 *** (0.0533)	0.2241 *** (0.0276)	0.1079 * (0.0585)
R2	.3458	.4772	.0841
N	2604	1574	1030

Figure 1. Distribution of Counties Among Crop Reporting Districts

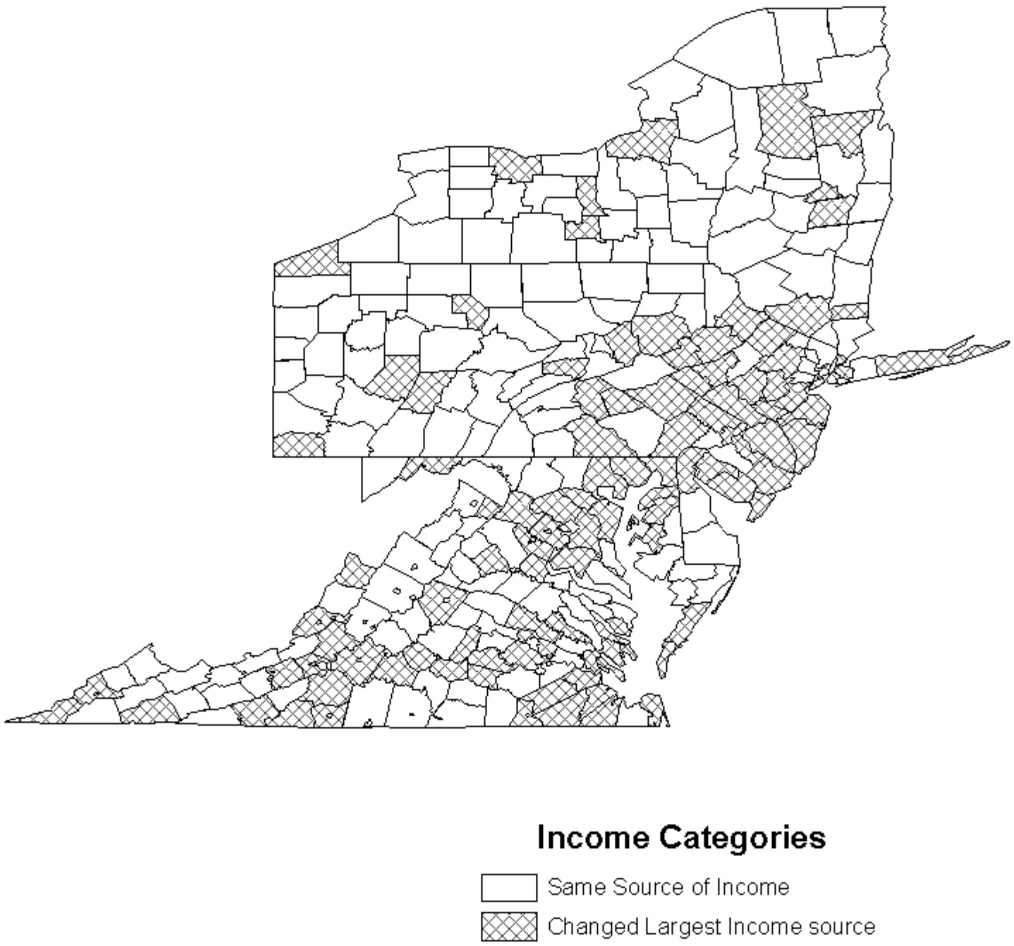

Figure 2. Counties That Changed Crop or Livestock Commodity From Which They Received Their Largest Share of Gross Income Between 1949 and 1997

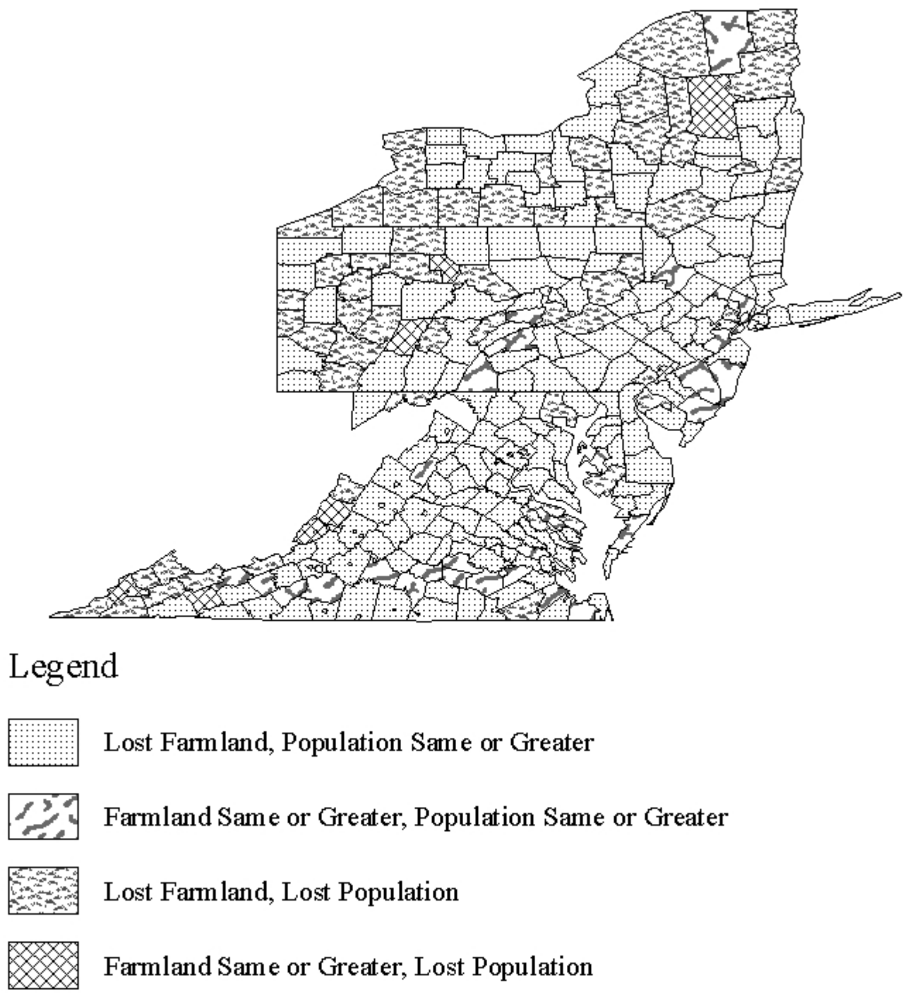

Figure 3. Changes in Farmland and Population Between 1987 and 1997

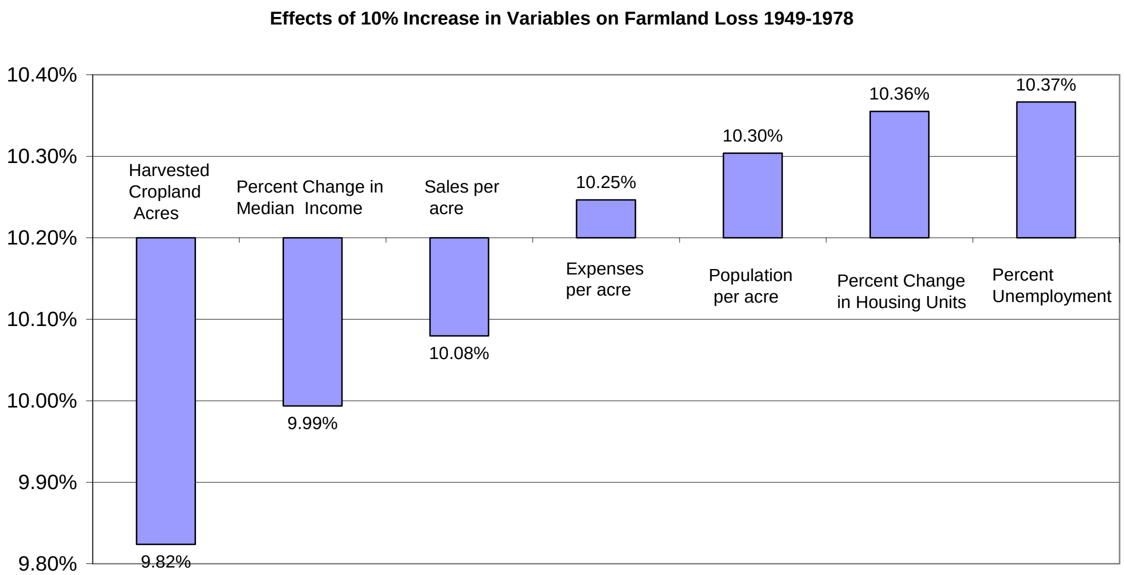

Figure 4. Effect of a 10% Increase in Significant Variable on the Rate of Farmland Loss (1949-1968)

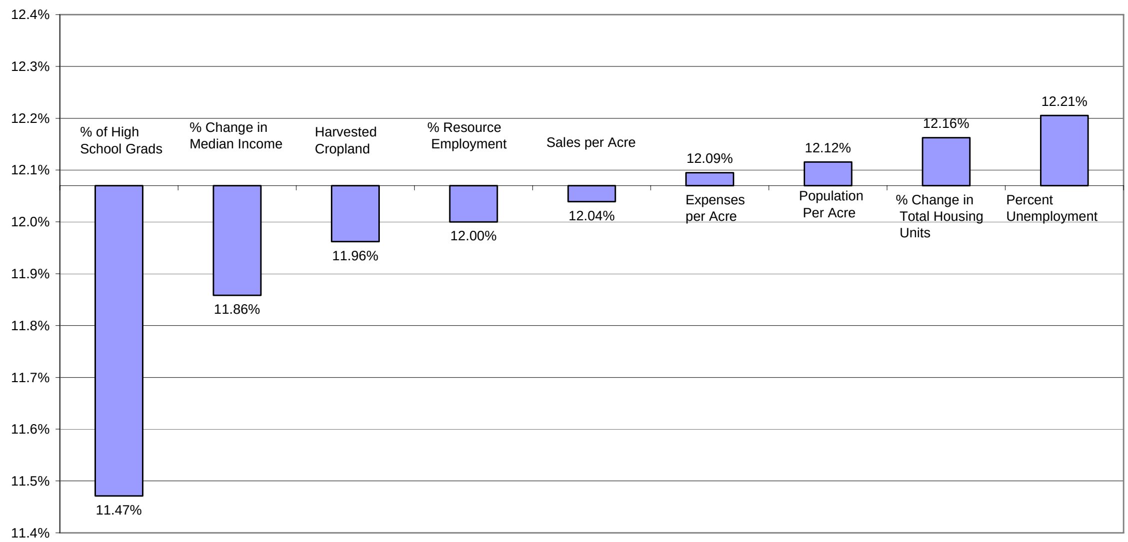

Figure 5. Change in the Rate of Farm Loss for a 10% Increase in Significant Variables (1949-1997)

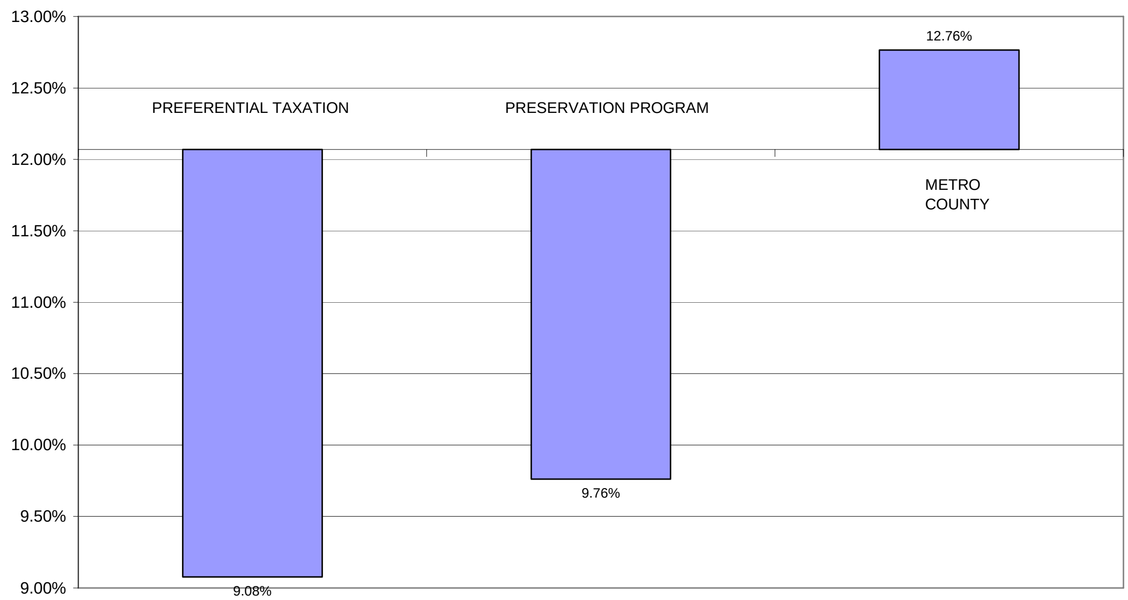

Figure 6. Change in the Rate of Farm Loss due to Having a Preferential Taxation Programs, Preservation Programs and Being a Metro County (1949-1997)

Appendix

Econometric Model

Several models were estimated to determine which of the following was the most appropriate econometric technique to use for the panel data: pooling the data, pooling the data with fixed effects representing each 5-year time period or crop reporting district, or estimating a random effects model. Lagrange multiplier (LM) and Hausman tests (HT) ($LM_{(2)}=1581.33$; $HT_{(14)}=17.53$) indicate that a random effects estimation procedure is more efficient. Thus the unexplained variation in the rate of farmland loss or the residual for the estimated model is composed of three parts: ε_{it}, μ_i, and w_t. The means of the three disturbances are assumed to be zero, and each has a variance equal to σ_ε^2, σ_μ^2, and σ_w^2, respectively. The covariances between the error terms are also assumed to be zero. The model incorporates both the within and between random components.

The random effects model to be estimated is defined by the following equation:

$$y_{it} = \alpha + \beta' x_{it} + \varepsilon_{it} + \mu_i + w_t \qquad (6\text{-}1)$$

(Greene 1995), where y_{it} is the vector of the county-level rate of farmland loss (or farm loss) for counties in crop reporting district *i* in the 5-year time period *t*; α is the vector of constants; β is the vector of estimated coefficients; and x_{it} is the matrix of county-level characteristics that explain farmland loss for crop reporting district *i* in the 5-year time period *t*, such as sales per acre, percent change in housing units, and the unemployment rate. ε_{it}, μ_i, and w_t are the error terms. They are the effects of unobserved variables that vary over both crop reporting district *i* and 5-year time period *t*, and within each crop reporting district and time period.

Endnotes

[1] Lori Lynch is associate professor at the Department of Agricultural and Resource Economics, University of Maryland. Support for this project was provided by the Maryland Center for Agro-Ecology. This chapter was based on Carpenter and Lynch 2002 and Lynch and Carpenter 2003.

[2] This is a different question than that posed in the 1970s, when citizens advocated farmland preservation for food security reasons. Several research studies, including those by Fischel (1982) and Dunford (1983), analyzed whether the rate of farmland conversion would affect the national agricultural production capacity. They found that although farmland was disappearing from certain regions, sufficient national land resources were still available to ensure the nation's food security.

[3] Alternatively, if smaller, locally based input and output firms are consolidated, permitting larger, more regionally focused businesses, they may achieve greater economies of scale. Then the major factor would be the effect of increased transportation costs on farmers' costs.

[4] Another possible method to study this issue would be to examine the cost structures of input suppliers and processing firms. Even if businesses would permit us to do so, however, many of those we would want to study have exited the region over the past 50 years.

[5] Independent cities of Virginia are also included in the analysis. In several cases, because of either aggregation in data or actual boundary changes during the study period, counties or independent cities have been combined for this analysis.

[6] A correlation existed among these three variables: percent change in median household income, percent of the county with high school education, and percent of the county that is unemployed. The percent of high school education and percent change of income variables have a correlation coefficient of –0.52, and percent of unemployment and percent change in income variables have one of –0.32. This may explain in part the insignificant parameter estimates on percent of high school education in this and the ensuing models.

[7] A likelihood ratio test indicated that estimating the two models separately for these time periods is statistically different from pooling the data ($\chi_{(13)}^2$=77.78).