Is There Evidence of a Critical Mass in the Mid-Atlantic Agriculture Sector Between 1949 and 1997?

Lori Lynch and Janet Carpenter

Ongoing farmland loss has led county planners to ask "is there a critical mass of farmland needed?" to retain a viable agricultural sector. This study examines whether counties lost farmland at a faster rate if the number of agricultural acres fell below a critical threshold. Results from six Mid-Atlantic states over the period 1949 to 1997 indicate that counties with fewer agricultural acres lost farmland at a faster rate. However, after splitting the study period into two time segments (1949–1978 and 1978–1997) and modeling separately, this result was not found for the later time period, suggesting a uniform critical mass level may not exist. Population growth in a county accelerated farmland loss over all time periods.

Key Words: critical mass, development pressure, farmland loss, panel data, use-value taxation

As farmland 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.[1] The total amount of land in farms decreased by 20% in the United States between 1949 and 1997. In the Mid-Atlantic region, the rate of decrease was 50%. Agricultural land has been converted to alternative uses at an even higher rate in metropolitan areas (Lockeretz, 1989; Gardner, 1994). Metropolitan residents have expressed concern about the loss of the amenities the farmland provides. Rural economies that are highly dependent on agricultural industries suffer negative consequences when agricultural land is converted. Society may want to retain an agricultural sector to maximize its welfare. Many counties are trying to determine how much agricultural land must be retained to ensure a viable agricultural economy and the preservation of these amenities. Government officials need to determine "how much agricultural land is enough" to ensure this retention. Therefore, knowing whether the rate of farmland loss is affected by the level of agricultural activity within an area is important.

Most land use models assume agricultural landowners will farm the land until the value in an alternative use exceeds the agricultural value. These models have focused on the effect of changes in the nonagricultural use values on the decision to convert rather than the effect of changes in the agricultural use value (e.g., Bockstael, 1996; Chicoine, 1981; Clonts, 1970; Dunford, Marti, and Mittelhammer, 1985; Hardie, Narayan, and Gardner, 2001; Bell and Bockstael, 2000; Muth, 1961; Nickerson and Lynch, 2001; Shi, Phipps, and Colyer, 1997).

The net market value in many developed uses is greater than in agricultural use. Thus, the market will allocate the land to this privately optimal developed use. However, the conversion of farmland to a developed use may not maximize society's welfare. First, the amenity benefits of farmland are lost.

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[1] This is a slightly different question than that posed in the 1970s when citizens advocated farmland preservation for food security reasons. Several research studies, including those in the early 1980s by Fischel (1982) and Dunford (1983), analyzed whether the rate of farmland conversion would affect the national agricultural production capacity. They found that while farmland was disappearing from certain regions, there were sufficient national land resources still available to ensure the nation's food security.

Second, the developed use may impact the surrounding farmland's use value. Some researchers have considered the external benefits of nearby land uses—such as agriculture, parks, or forest lands—on residential use values (Kitchen and Hendon, 1967; Weicher and Zerbst, 1973; Hammer, Coughlin, and Horn, 1974; McMillan, 1974; Peiser and Schwann, 1993; Irwin and Bockstael, 2001; Geoghegan, Wainger, and Bockstael, 1997; Geoghegan, 2002: Geoghegan, Lynch, and Bucholtz, 2003; Cheshire and Sheppard, 1995). However, few models have considered the external benefits or costs of adjacent land use on agricultural use value. If the landscape surrounding the existing farmland changes, the agricultural use value may also change. The agricultural use value could be affected by both the new uses on adjacent land and the resulting adjustment in the agricultural support sector to fewer farmland acres.

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 insects, noise, odor, dust, and slow-moving equipment on the roads, and may advocate limitations to these practices. Even in rural areas, incompatible activities in the surrounding landscape may affect the profitability of farms. Farmers may earn more profit operating within a thriving agricultural community than in an area dominated by other land uses—be they city, forest, or recreational. Alternatively, the proximity of nearby suburban cities may generate new marketing opportunities.

The loss of support industries may also affect the agricultural use value. The exodus of the support industries in an area may indicate that a critical mass of agricultural land is important to long-term viability. A critical mass threshold implies economies of scale exist in both input and output businesses which are essential to agriculture. Support businesses will close or relocate as farm production levels decrease below a certain threshold.

For example, growers in a region may specialize in peas. They sell the peas to a local processing plant that freezes and packages their product. The plant will remain in business as long as local production is sufficient to sustain the firm's production at competitive operating costs. If local pea production decreases, the processing plant may not achieve economies of scale and might close at this location. Remaining pea producers would face decreased returns, as the shipping costs to more distant processing plants are higher. Consequently, they might switch to producing another, less profitable crop. As the agricultural use value decreases, the relative return to converting the farmland increases. Thus the rate of farmland loss could increase.

Few studies have explored the existence of a critical mass for the agricultural sector. In an early study, Dhillon and Derr (1974) estimated the critical level of production necessary to operate at or close to the minimum per unit production cost level for various agricultural commodities grown in the Philadelphia–New York–Boston corridor. More recently, Daniels and Lapping (2001) proposed a critical mass threshold definition of (*a*) at least 100,000 acres, (*b*) $50 million in agricultural sales, and/or (*c*) 20,000 acres of preserved farmland in a county.

We conduct an econometric analysis to determine if we can find statistical evidence of, and the level of, a critical mass threshold for six Mid-Atlantic states. The research seeks to determine if a critical mass threshold exists. We analyze whether counties lost farmland at a faster rate if the number of acres fell below a "threshold" level of acres. The study area includes six Mid-Atlantic states over the period 1949 through 1997. Farmland loss can be affected by a variety of factors besides a critical mass. Thus, the effects of factors such as agricultural net returns and development pressure on the rate of farmland loss are also examined. We estimate the impacts and conduct a sensitivity analysis of these factors, and then explore whether the effects change over time.

The remainder of the paper proceeds as follows. The next section outlines the economic model and the econometric model and analysis. Next, a description of the data and the study area is provided. The results are then presented, including the sensitivity analysis. We close with a discussion of the results and offer some concluding remarks to guide future research efforts.

The Economic and Econometric Models

Researchers and policy makers hypothesize that a critical mass threshold exists in the agricultural sector. The basis for this notion is the existence of economies of scale in both input and output businesses which are essential to agriculture. As production levels decrease below a certain threshold, support businesses will close local facilities as their revenues decrease or their costs increase. After an input or output firm closes, the alternative input supplier or output buyer may be farther away. In addition, the new supplier or buyer might charge higher prices for inputs or pay lower prices for output due to less competition or higher operating costs.[2] The change in the local agricultural economy alters the agricultural use value. This, in turn, changes the relative returns of converting or of idling the remaining agricultural land.

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.[3] 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 possible 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 remains competitive. Thus farmland loss rates are hypothesized to be a function of the number of productive farmland acres, holding all other variables constant.

Farmland 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. 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. The farmland would be idled.

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 remaining in an agricultural use, thereby contributing to the retention of farmland acres and slowing the rate of farmland loss.

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

The 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 five-year time period and/or each crop reporting district, or estimating a random-effects model. A random-effects estimation procedure is found to be the most efficient, using Lagrange multiplier (LM) and Hausman tests (HT) ($LM_{[2]}$ = 1,581.33; $HT_{[14]}$ = 17.53). Thus, the unexplained variation in the rate of farmland loss, or the residual for the estimated model, is comprised 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, σ_w^2, respectively. The covariances between the error terms are also assumed to be zero. The model incorporates both the within and the between random components.

The random-effects model to be estimated is defined by the following equation (Greene, 1995):

$$(1) \qquad \mathbf{y}_{it} = \boldsymbol{\alpha} + \boldsymbol{\beta}'\mathbf{x}_{it} + \varepsilon_{it} + \mu_i + w_t,$$

where $\mathbf{y}_{it}$ is the vector of the county-level rate of farmland loss for counties in crop reporting district i in the five-year time period t, $\boldsymbol{\alpha}$ is the vector of constants, $\boldsymbol{\beta}$ is the vector of estimated coefficients, and $\mathbf{x}_{it}$ is the matrix of county-level characteristics that explain farmland loss for crop reporting district i in the five-year time period t, such as sales per acre, percentage change in housing units, and the unemployment rate. The error terms ε_{it}, μ_i, and w_t are the effects of unobserved variables that vary over both crop reporting district i and five-year time period t, and within each crop reporting district and within each time period.

The critical mass threshold 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 which are less reliant on these support industries. Farmers could shift to direct marketing rather than wholesaling.

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[2] Alternatively, if smaller input and output firms are consolidated, leaving fewer, larger firms, these remaining firms may achieve greater economies of scale. The major effect on farmers' costs would then be the increase in transportation costs.

[3] Another possible method for studying this issue would be to examine input suppliers' and processing firms' cost structure. However, even if businesses would permit us to do so, many of the businesses we would want to study have exited the region over the past 50 years.

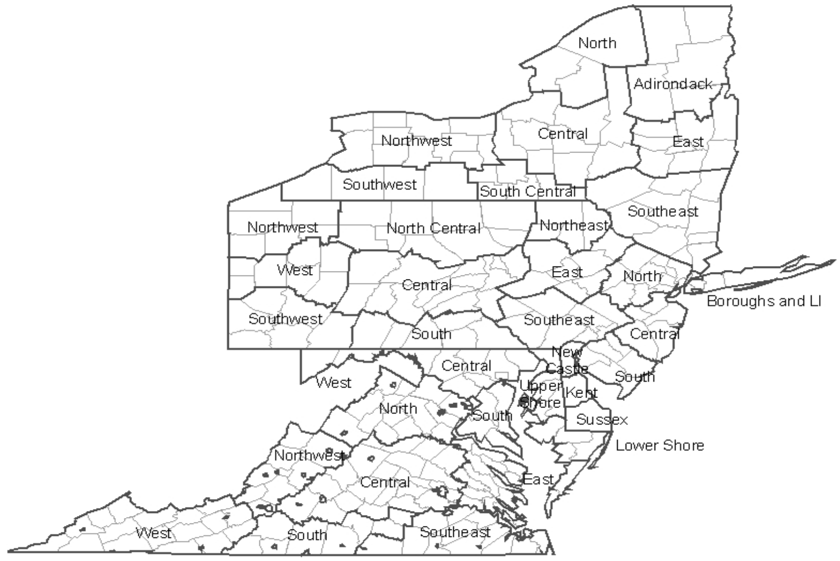

Figure 1. Distribution of counties among crop reporting districts in the six Mid-Atlantic states

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, due in part to mechanization and the consolidation of farms (Gardner, 2002). U.S. average farm size and output per farm grew rapidly through the 1970s, and have grown more slowly since then. Labor costs have decreased as a portion of total input costs beginning in the 1980s.

Because of these changes, we estimate a general model (model 1) for the entire time period (1949–1997), and then split the sample into two subperiods and estimate two additional models. The two subperiods are designated as 1949–1978 (model 2a) and 1978–1997 (model 2b). This approach allows us to determine if the critical mass threshold and importance of the other factors varied by time period.

Description of Data and Study Area

Data were compiled from the *Census of Agriculture* and the *Census of Population and Housing* at the county level for the years 1949 through 1997 [U.S. Department of Commerce, Bureau of the Census; U.S. Department of Agriculture, National Agricultural Statistics Service (USDA/NASS)]. The Mid-Atlantic states of Delaware, Maryland, New Jersey, New York, Pennsylvania, and Virginia are included in the data set. In 1997, these six Mid-Atlantic states accounted for over 26 million acres of farmland (3%) of total U.S. farmland and for $12 billion (6%) of total U.S. sales.

The analysis uses data on 269 counties[4] and 10 time periods of 4–5 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 periods. 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 1).

Because the two censuses were conducted on different schedules, population and housing census data were adjusted to coincide with the years of the agricultural census data. The population and housing census is collected every 10 years, while the agricultural census is collected every four to five years. The population and housing census data were interpolated by calculating a constant change in the variables between the census years. This constant change was used to adjust the population and housing census data to the year the agricultural census was collected. Thus, if the population change was

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

Table 1. Definitions of Variables and Descriptive Statistics for the Entire Sample (269 counties), 1949–1997

		Entire Sample	
Variable Name	Definition	Mean	Std. Dev.
PCFLAND	Percentage reduction in farmland (%)	7.58	0.1256
HCLAND	Harvested cropland (1,000 acres)	54.372	47.097
$HCLAND^2$	Harvested cropland squared (1,000,000,000 acres)	5.1724	9.710
PAGFFM	Percentage of adults employed in agriculture, forestry, fisheries, and mining (%)	9.99	0.1056
SALESPERA	Sales per acre (1997 $/acre)	549.07	2,394.11
EXPPERA	Expenses per acre (1997 $/acre)	331.51	2,227.93
POPPERA	Population per acre	0.5773	1.8430
MADUMMY	= 1 if county is in metropolitan area (%)	33.72	0.4728
PCTOTHU	Percentage change in total housing units (%)	8.09	0.0689
PCMFINC	Percentage change in median family income (%)	11.92	0.0838
PCMHVAL	Percentage change in median housing value (%)	11.66	0.1017
PHIGHSCH	Percentage 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

Note: The percentage change variables use the initial year of the time period as the ending year of the percentage change calculation. Thus the percentage change in housing units for time period *t* was calculated as $(HU_t ! HU_{t!1})/HU_{t!1}$, where HU_t is the total housing units at time *t*.

25% for the 10-year period, it was assumed the population grew 2.5% 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. These values were 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 fewer than five farms in 1949 were excluded from the entire analysis. Six counties were excluded due to limited agricultural activity in 1949: Bronx, Queens, Richmond, Kings, and New York counties of New York State, and Arlington County of 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 for the entire analysis.

Because farmland loss is affected by changes in agricultural returns per acre, demand for land for nonagricultural purposes, farmers' alternative employment opportunities, and preservation policies, variables are included to control for these factors. Table 1 gives the names, definitions, and descriptive statistics for the variables included in the analysis.

The dependent variable was the rate of farmland loss for time period *t*. It was calculated as

$$\frac{A_{t\%1} \,\&\, A_t}{A_t},$$

where A_t is the number of acres in the initial period. The rate of farmland loss averaged 7.58% over the study period. Some counties lost 100% of their farmland in a time period. One county gained 77.65% more farmland in *t* (many counties gained during the 1974–1978 period). Farmland is defined by the *U.S. Census of Agriculture* to consist of land used for crops, pasture, or grazing. Woodland and wasteland acres are included if they were part of the farm operator's total operation. Conservation Reserve Program and Wetlands Reserve Program acreage is also included in this count.

The percentage change variables use the initial year of the time period as the ending year of the percent change calculation. Thus the percentage 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 (*HCLAND*) in *t* proxy the critical mass threshold acres. Harvested cropland includes land from which crops were harvested or hay was cut, and land 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 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 support sector. It is hypothesized that the county's rate of farmland 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 harvested cropland in this manner, we can compute an acreage threshold required to ensure a critical mass. Harvested cropland acres averaged 54,372 acres per county. The highest number of harvested cropland acres in any one county was 334,294 acres.

The percentage of the county population employed in agricultural, forestry, fishing, or mining activities (*PAGFFM*) in *t* is also included to indicate the dominance of these resource-based activities in the county. Counties varied from almost no employment in this type of work to 70% of the adult population employed in these activities, with an average percentage of 9.99%.

The agricultural net returns are proxied by county-level agricultural sales per acre (*SALESPERA*) and expenses per acre (*EXPPERA*) 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% decrease in land devoted to agriculture in the six Mid-Atlantic states, total revenue has decreased by only 1% 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% of the study's counties derived their largest share of income from a different commodity or animal source than in 1949 (figure 2). Decreases in agricultural net returns may explain the farmland loss that occurred in areas where the population decreased. Figure 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.

Several variables are included to represent demand for land for nonfarm uses: the population level scaled by the number of acres in the county (*POPPERA*), whether the county is in a metropolitan area (*MADUMMY*), the percentage change in total housing units (*PCTOTHU*), the percentage change in median family income (*PCMFINC*), and the percentage change in median housing value (*PCMHVAL*). As population increases, demand for land in residential and commercial uses will also increase. Thus population growth is hypothesized to increase the rate of farmland loss. Total population in the six states has increased by 43% since 1950, climbing from 35 million to 50 million people.

Given that the number of individuals per housing unit has decreased, we 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 loss is expected to increase. The percentage change in total housing units averaged 8.09%, with some counties losing housing units at a rate of 19% while others had a growth rate of 60%. As family income increases, people may demand larger homes. Larger homes usually sit on larger parcels. Therefore, an increase in income is expected to increase the demand for farmland and accelerate the farmland loss rate. Similarly, an increase in the median housing value may indicate an increase in the demand for land (Hardie, Narayan, and Gardner, 2001) and accelerate the rate of farmland loss.

An increasing proportion of farmers supplement their farm income with off-farm employment. Only 33% of Mid-Atlantic farmers reported working over 100 days off the farm in 1949. By 1997, 44% did so. Their off-farm income opportunities will be greater if they are better educated and the unemployment rate in the county is low. However, an increase in off-farm opportunities 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 with at least a high school education (*PHIGHSCH*) and the percentage of unemployment (*PUNEMP*). These opportunities could have either a positive or negative effect on the rate of farmland loss. Education attainment increased over the 1949–1997 time period, with an average of 48.41% of adult residents having a high school education. The unemployment rate averaged 5.49%, with a range across counties of 0.07% to 14.5%. Increases in median family income might also signal a strong local economy and the possibility of more off-farm employment opportunities.

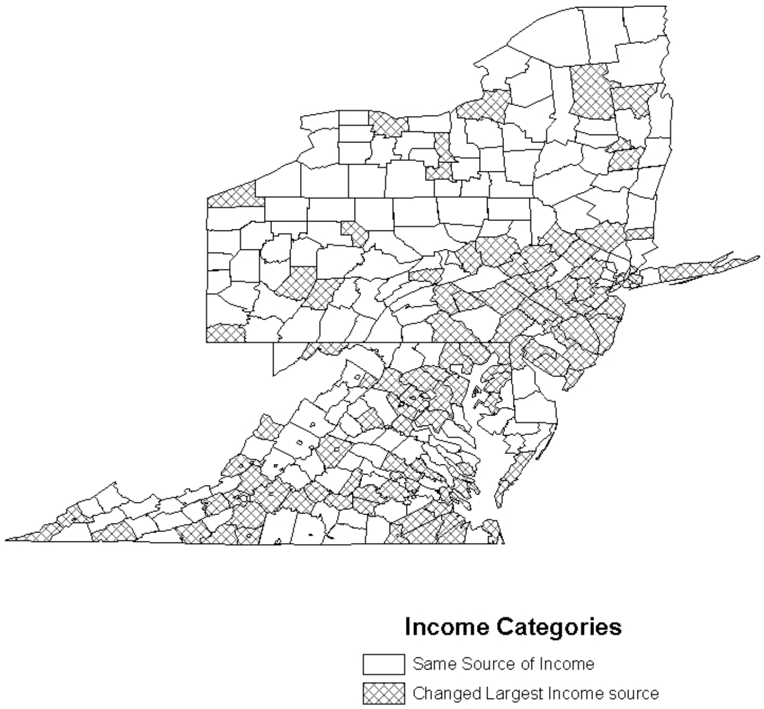

Figure 2. Counties in the six Mid-Atlantic states that changed crop or livestock commodity from which they received their largest share of gross income between 1949 and 1997

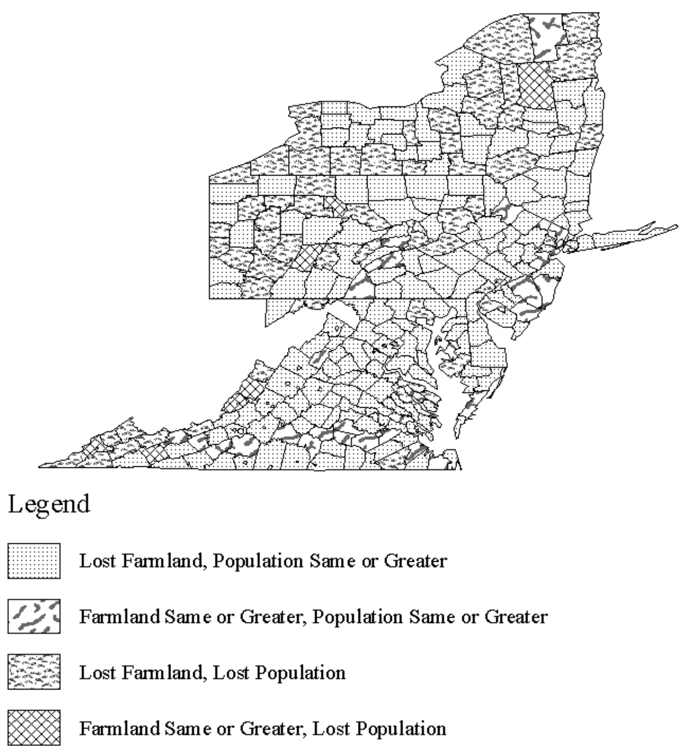

Figure 3. Changes in farmland and population in the six Mid-Atlantic states between 1987 and 1997

Policy variables are included to indicate whether the county has a preferential property tax program for agricultural land and/or some type of farmland preservation program. Preservation and taxation programs are hypothesized to slow the rate of farmland loss. We consider four different program 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. Information was collected on the existence of these programs by county (American Farmland Trust, 1997, 2001a,b,c). The binary variable *STAX* indicates whether the state had established a preferential property tax program by *t*, and the binary variable *PRESPROG* indicates if 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 one acre. By 1982, all the states had established preferential property tax programs. By 1997, 44% of the counties in the study area had a local or state preservation program in place.

Results

Results of Model 1

The estimated coefficient on harvested cropland acres indicates a negative relationship between cropland acres and the rate of farmland loss over the full study period 1949 to 1997 (table 2). Counties with fewer acres of harvested cropland had higher rates of farmland loss. The estimated coefficient on the squared term of harvested cropland is significant and positive. When a county has 189,240 harvested cropland acres, the slope of the rate of farmland loss as a function of harvested cropland acres equals zero. Thus counties below 189,240 harvested cropland acres have a higher rate of farmland loss. The identified threshold, however, is nearly out of the data range. Only 2–7 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.

The estimated coefficients in model 1 also suggest the rate of farmland loss is explained by sales per acre, expenses per acre, population per acre, unemployment rate, percentage change in median family income, and percentage change in housing units (table 2). The rate of farmland loss decreases as harvested cropland acres, sales, and percentage change in income increase. As expenses, population, percentage change in total housing units, and percentage unemployment increase, the rate of farmland loss increases. Counties with preferential taxation programs experienced a lower rate of farmland loss than counties without a program. All else the same, metropolitan counties lost farmland at a higher rate than nonmetropolitan counties.

The predicted rate of farmland loss for the 1949–1997 period is computed at the average value of the continuous variables and at zero for the binary variables using the estimated coefficients. The predicted rate of farmland loss is 7.9%. We then estimate how much the predicted rate will change for a 10% increase in each variable with a statistically significant parameter estimate. For the binary variables, the rate of farmland loss is computed if they were equal to one. Table 3 reports the predicted rate and the new rate given the 10% increase.

The farmland loss rates increase in counties with lower harvested cropland acres. The model predicted an average rate of farmland loss of 7.9%. The rate of farmland loss decreases to 7.67% if the harvested cropland acres are increased 10% (table 3).

The sales and expenses per acre affect the farmland loss rate. A 10% change in sales per acre has a greater effect than an equal percentage change in expenses. A 10% increase in sales per acre would decrease the rate of farmland loss to 7.83% (a change of ! 0.07), while a 10% increase in expenses per acre would increase the rate of farmland loss to 7.92% (a change of 0.02).

Changes in the proxies for development pressure also impact the rate of farmland loss in model 1. A 10% increase in the population per acre increases the rate of farmland loss to 8.01%. Similarly, if the growth of housing stock increases 10%, the rate of farmland loss increases to 8.02%. Metropolitan counties lost farmland at a rate of 8.94% compared to 7.9% for the nonmetropolitan counties.

Higher income growth levels and employment opportunities decrease the rate of farmland loss. A 10% increase in median family income growth lowers the rate of farmland loss to 7.73%. If the unemployment rate increases by 10%, the rate of farmland loss increases to 8.09%. Educational attainment has no impact on the rate of farmland loss.[5]

[5] There was correlation among the three variables *PCMFINC*, *PHIGHSCH*, and *PUNEMP*. The percentage of adults with high school education and the percentage change in family income variables have a correlation coefficient of ! 0.52; and the percentage of unemployment and percentage change in family income variables have a correlation coefficient of ! 0.32. This may explain in part the insignificant parameter estimates on *PHIGHSCH* in this and the two remaining models.

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

	Model 1 (1949–1997)	Model 2a (1949–1978)	Model 2b (1978–1997)
Variable	Coefficient (Std. Error)	Coefficient (Std. Error)	Coefficient (Std. Error)
HCLAND (harvested cropland)	!0.00058994***	!0.00969508***	!0.00004426
	(0.0001)	(0.0002)	(0.0002)
HCLAND^2 (harvested cropland squared)	0.0015587***	0.00268124***	!0.00015372
	(0.0006)	(0.0007)	(0.0010)
PAGFFM (% resource employment)	0.0415	0.0477	0.0500
	(0.0334)	(0.0381)	(0.0972)
SALESPERA (sales per acre)	!0.00001***	!0.00002***	0.00002***
	(0.0000)	(0.000002)	(0.000005)
EXPPERA (expenses per acre)	0.000005***	0.00001***	!0.00003***
	(0.0000)	(0.000002)	(0.00001)
POPPERA (population per acre)	0.0187***	0.0175***	0.0148***
	(0.0017)	(0.0019)	(0.0053)
MADUMMY (metropolitan area)	0.0103*	0.0193**	0.0078
	(0.0059)	(0.0082)	(0.0088)
PCTOTHU (% change in housing units)	0.1587***	0.1780***	0.0823
	(0.0401)	(0.0498)	(0.0861)
PCMFINC (% change in family income)	!0.1321**	!0.1416**	!0.0588
	(0.0540)	(0.0608)	(0.1311)
PCMHVAL (% change in housing value)	0.0236	!0.0025	0.0462
	(0.0307)	(0.0448)	(0.0651)
PHIGHSCH (% high school education)	0.0141	0.0251	!0.0032
	(0.0318)	(0.0462)	(0.0584)
PUNEMP (% unemployment)	0.3207*	0.3313**	0.2931
	(0.1255)	(0.1643)	(0.2201)
STAX (preferential tax)	!0.0404***	!0.0358***	
	(0.0105)	(0.0112)	
PRESPROG (preservation program)	!0.0047		!0.0082
	(0.0095)		(0.0111)
Constant	0.0875**	0.1162***	0.0172
	(0.0387)	(0.0415)	(0.0514)
R^2	0.1647	0.2344	0.0623
N	2,604	1,574	1,030

Note: Asterisks (*, **, and ***) indicate, based on an asymptotic *t*-test, the H_0: $B = 0$ is rejected using a 0.10, 0.05, and 0.01 criterion, respectively.

The 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% compared to counties without such a program at 7.9%. The presence of other programs (purchase of development rights, transfer of development rights, or purchase of agricultural conservation easements) did not impact the rate of farmland loss.

Results of Models 2a and 2b

Results of model 2a (covering subperiod 1949–1978) and model 2b (1978–1997) demonstrate that the effects of the variables changed over time. The rate of farmland loss slowed about halfway through the study period. The average five-year rate of farmland loss in 1949–1978 was 9.2%, and for 1978–1997, 5.1%. Both agriculture and the pattern of city and housing development changed during this time. Our findings reveal the variables' impacts were not consistent over the two time periods. A likelihood-ratio test indicated that estimating the two models separately for these time periods is statistically different than pooling the data ($\chi^2_{[13]} = 77.78$). Model 2a's results were similar to those reported above for model 1. Different results are found for model 2b. Estimated coefficients are reported in table 2.

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 (%)

Description	Model 1 1949–1997	Model 2a 1949–1978	Model 2b 1978–1997
Predicted Probability:	7.90	10.12	5.01
		Probability After 10% Increase	
Continuous Variables:			
HCLAND (harvested cropland)	7.67	9.82	
PCMFINC (% change in family income)	7.73	9.99	
SALESPERA (sales per acre)	7.83	10.08	5.10
EXPPERA (expenses per acre)	7.92	10.25	4.91
POPPERA (population per acre)	8.01	10.30	5.08
PCTOTHU (% change in 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	

The negative relationship between harvested cropland and the rate of farmland loss is statistically significant in the early period model (2a), but is not observed in the later period model (2b). The critical mass in model 2a was estimated to be 180,795 harvested cropland acres—similar to the threshold of 189,240 harvested acres in model 1. However, as before, few counties actually had more than 180,000 acres of harvested cropland acres. And given the insignificant coefficient on cropland acres in model 2b, the early period appears to drive the threshold result of model 1.

As observed from table 3, the predicted rate of farmland loss in model 2a was 10.12% and in model 2b was 5.01%. In the early model, a 10% increase in harvested cropland acreage resulted in a lower farmland loss rate of 9.82% (a change of 0.30), while in model 2b, the estimated coefficient for harvested cropland was not significant.

Similar to the results of model 1, a higher net revenue decreased the rate of farmland loss in model 2a. However, expenses per acre had a bigger impact than sales per acre. A 10% increase in sales per acre decreased the rate of farmland loss to 10.08% (a change of !0.04). If expenses increased by 10%, the rate of farmland loss increased to 10.25% (a change of 0.13). In the later period model, surprisingly, the opposite relationship is observed. In model 2b, a 10% increase in sales per acre increases the rate of farmland loss from the predicted 5.01% to 5.10%. A 10% increase in per acre expenses decreases the rate of farmland loss to 4.91%.

The effects of other variables in model 2a were similar to those reported above for model 1. The resulting farmland loss rate due to a 10% increase in these variables for model 2a can be found in table 3. In model 2b, except for population per acre, the other estimated parameters were insignificant. A 10% increase in population per acre increased the rate of farmland loss from 5.01% to 5.08%. The overall explanatory power of model 2a, while not high, was greater than that of model 2b. For the 1949–1978 period, model 2a yielded an R^2 of 0.23; the corresponding R^2 for model 2b for the 1978–1997 period was only 0.06. Thus, model 2b did not explain 94% of the variation in farmland loss rates for these counties between 1978 and 1997.

Discussion

Some evidence of a critical mass existed for the six-state Mid-Atlantic study area during the early period (1949–1978). However, the scale of agricultural activity in the latter part of the study period did not impact the rate of farmland loss. This finding raises some interesting questions. First, to what extent have farmers adapted to the difficulties associated with shrinking input and output markets by shifting to alternative crops or alternative marketing mechanisms? Further research is needed to determine the extent to which this has occurred, and to assess the implications of different changes. For 42% of the 269 counties examined here, the data reveal the agricultural activity receiving the highest gross income in 1997 was different from the activity that had generated the most income in 1949 (figure 2). Yet the implications of a county-level change from dairy to vegetables or from row crops to livestock need further investigation.

Second, had the major technological changes in agriculture, in terms of improved mechanization and yield improvements, occurred by the mid-1970s? Third, how did land development patterns change, due to either changes in housing consumers' preferences or changes in policies? How did these changes impact the rate of farmland 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 have considered in this analysis. However, other responses might be 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 confirmed—i.e., increased sales or decreased expenses resulted in a lower rate of farmland loss. However, from 1978 to 1997, the opposite result was found. Farmers with the most marginal agricultural land may have been the first to exit agriculture, leaving only the most productive land under cultivation. County average per acre sales therefore would increase. Also, as mentioned above, farmers could have switched crops. If farmers shifted to higher value, smaller acreage crops such as berries or vegetables, one would observe farmland loss simultaneously with higher per acre sales. Of course, this begs the question of why farmers had not shifted to higher value crops at an earlier time period.

The health of the local economy was also found to impact the rate of farmland conversion. Counties with higher median family incomes and lower unemployment experienced lower rates of farmland loss. These findings could be a function of better off-farm employment opportunities or people with higher incomes choosing to purchase a farm and keeping it in production. Farmers in counties with high unemployment may have had fewer off-farm opportunities for themselves or their family members, and may have chosen to sell the farm and relocate. Policies that focus attention on local or regional economic performance could promote farmland retention. Examining farmland prices, Hardie, Narayan, and Gardner (2001, p. 131) conclude: "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 resulted in higher rates of farmland loss in all three models. In the early period, the growth rate of the total number of housing units was also positively related to the rate of farmland loss. Population growth and housing development leads to 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 (2002) 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.

Metropolitan counties had higher rates of farmland loss over and above losses related to their population and changes in housing stock. Metropolitan counties may need to be even more active in implementing policies and programs to encourage farmland retention and to strengthen the agricultural economy. Alternatively, states might decide to target regions far from metropolitan areas for preservation and retention programs. 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 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 could potentially be financed through a higher conversion tax rate. The state or counties could thus 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.

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. Few of these programs existed before the 1980s. Some of them have not had the resources to preserve many acres. Farmland preservation programs may have more impact in the future if they have greater resources and can enroll a higher number of acres.

Conclusions

The results do not provide clear evidence of a critical mass in agricultural economies in the Mid-Atlantic region. The results suggest that counties with fewer farmland acres lost farmland at higher rates. An acreage threshold level was computed. 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%) in the Mid-Atlantic region. 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 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 the time period.

Additional research is needed to more fully identify factors affecting the rate of farmland loss and whether a critical mass exists. Farmers may have adapted to a more limited support sector 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, i.e., the farmers cannot continue to produce these commodities profitably. However, adaptation 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. A more micro-level analysis could reveal information obscured by the county-level analysis. A case study approach could provide insights about specific industries or agricultural sectors in specific regions during specific time periods. Or further analysis could consider the individual farming sectors in different areas and how they have evolved over time.

While this analysis does not provide a clear prognosis for the economic viability of the Mid-Atlantic's agricultural sector, the analysis suggests 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 loss. It 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. Decision makers need to examine other policy objectives to sustain a viable agricultural sector.

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