Does the Farm Sector Have a Critical Mass?

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Abstract: We examine if the farm sector has a critical mass. If a critical mass of farmland acres is needed to sustain a viable agricultural sector, agriculture profits may decline once a region has dropped below this threshold, causing the rate of farmland loss to accelerate. Agricultural census and population and housing census data were assembled as a panel by county and five-year time periods for the 50-year period (1949-1997) for six Mid-Atlantic States. Three random effects models were estimated. The general model indicates that having less than 189,240 harvested cropland acres accelerates a county's rate of farmland loss. As acres increase by 10% (5,400 acres), the 5-year loss rate decreases from the predicted 7.9% to 7.67%. As sales and percent change in income increase, the rate of farmland loss also decreases. The rate falls with the introduction of a preferential taxation program. As expenses, population density, percent change in total housing units, and percent unemployment increase, the rate of farmland loss accelerates. The rate accelerates if the county is metropolitan. Yet when the data is divided into an early (pre-1978) and late (post-1978) period, this threshold effect disappears in the later period. The earlier model's results are similar but in the later period, increases in population density and sales, increase the rate of loss. Conversely and counter-intuitively, as expenses increase, the rate of loss decreases. Apparently, even if a threshold existed, our results suggest it might dissipate overtime.

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Introduction

The Maryland Office of Planning predicts that if current trends continue, 500,000 more acres of farms, forests and other open spaces in Maryland will be converted to development over the next 25 years (Bay Journal 1997). In the Washington, D.C., metropolitan area, the rate at which land is being consumed exceeds the population growth rate by almost 2.5 times. If current trends continue, 800,000 more acres of resource lands will be developed by 2030 in the greater Washington, D.C., region (Chesapeake Bay Foundation, 2002). Will this continuing conversion of farmland to other uses result in too few acres or too little farm activity to sustain an agricultural economy in the region?[1]

Many land-use models focus on the demand for land and its value for agricultural and urban/suburban uses. The price of land in an urbanizing area is modeled as the net present value of the stream of annual net rents from agricultural and from non-agricultural uses such as residential or commercial development using a variety of proxies for these rents. Researchers have assumed that landowners will farm the land until an optimal conversion date (at which point the annual rent in an alternative use exceeds the annual rent in an agricultural use), after which it will be converted (Bockstael 1996; Chicoine 1981; Clonts 1970; Dunford, Marti, and Mittlehammer 1985; Hardie, Narayan, and Gardner 2001; Bell and Bockstael 2000; Muth 1961; Nickerson and Lynch 2001; Shi, Phipps, and Colyer 1997).

Some papers have considered how adjacent land uses such as open space or forest may influence the value in a residential use (Kitchen and Hendon 1967; Weicher and Zerbst 1973;

[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 in the early 1980s by Fischel and Dunford 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.

Hammer, Coughlin, and Horn 1974; McMillan 1974; Peiser and Schwann 1993; Irwin and Bockstael 2001; Geoghegan, Wainger, and Bockstael 1997; Cheshire and Sheppard 1995). However, few models have considered that the loss of nearby farmland and the resulting adjustment in the agricultural support sector and landscape may be affecting the value in an agricultural use. Yet, as the landscape around farmland changes, the agricultural rent may change. Rapid population growth near farming areas has created problems and opportunities for farmers. The proximity of non-farm neighbors has resulted in conflicts about traditional farming practices, insects, noise, dust and slow-moving equipment on the roads. On the other hand, closeness to urbanizing areas has generated additional marketing outlets.

In addition, the agricultural rent might be affected by whether there is a critical mass of agricultural land needed to sustain a viable farm sector. If so, then the value of land in an agricultural use may decrease as the region falls below this threshold. The concept of a critical mass is based on the idea that economies of scale exist in both input and output businesses that are essential to agriculture. As production levels decline below a threshold, costs will rise, and support businesses will close or relocate. If the input and output firms close, the closest input supplier may not only be farther away for a farmer but may also charge higher prices for inputs and services due to less competition and need to cover fixed costs.[2] Similarly, if the nearest processor or shipper/handler goes out of business because it cannot cover its fixed costs due to an insufficient supply of farm output as acreage decreases, the nearest market or processing outlet for the farm product could involve additional transportation costs and/or a lower purchase price, either raising farmers' production costs or decreasing their revenue. Changes in farmers' comparative advantage and their net revenues alter the relative returns to converting or idling the

[2] Alternatively, if smaller locally based input and output firms consolidated, permitting fewer but larger, more regionally focused businesses, these firms may achieve greater economies of scale. Then the major factor would be the effect of increased transportation costs on farmer's costs.

farmland. A decline in agriculture profits and thus a higher relative return for alternative uses of the land may increase the rate of loss of farmland in the area even when the population is not increasing.

The existence of a critical mass of farmland that must be maintained to ensure the economic viability of agriculture in an area has been hypothesized previously. Dhillon and Derr (1974) estimated the critical size necessary to operate at or close to the minimum per unit production costs level for various agricultural commodities grown in the Philadelphia-New York-Boston corridor. Daniels and Lapping (2001) proposed a critical mass threshold definition of 1) at least 100,000 acres, 2) $50 million in agricultural sales, and/or 3) 20,000 acres of preserved farmland.

In addition, several research studies that examine farmland loss specifically in metropolitan areas analyze whether population increases result in premature idling or conversion of farmland. Lockeretz (1986) found smaller farm sizes, a higher proportion of harvested cropland, a higher standard of living, and more reliance on crops than livestock in counties closer to metropolitan areas than in those farther away. Lockeretz (1989) found that farmland declined at a faster rate in metro counties than in non-metro counties. Gardner (1994) found that a 100% increase in the population resulted in an 11% decrease in farmland in metropolitan counties in the Northeast.

While population increases result in farmland loss, some crops do survive in the urbanizing landscape, suggesting that agriculture may remain viable in metropolitan areas. For example, Lopez, Adelaja, and Andrews (1988) found that vegetable producers received higher prices in urbanized areas. Larson, Findeis, and Smith (2001) found that more than half the value of total U.S. farm production is derived from counties facing urbanizing effects. Lockeretz

(1988) found that farmers respond by cropping more intensively in areas with high population density and growth.

Background

The Mid-Atlantic states of Delaware, Maryland, New Jersey, New York, Pennsylvania and Virginia together accounted for over 26 million acres of farmland in 1997, or 3% of the U.S. total. Higher than average sales per acre means that the region accounts for a larger portion of total agricultural sales, with nearly $12 billion total sales, or 6% of the U.S. total. While the U.S. experienced a 20% decrease in the amount of land in farms from 1949 to 1997, the Mid-Atlantic region experienced a 50% decrease. The six-state average 5-year rate of farmland conversion during this period was 7.58%. The average 5-year rate of farmland loss was higher in the earlier years, between 1949 and 1978, at 9.19%. In the later years, between 1978 and 1997, the rate dropped to 5.13%.

These states derive nearly two-thirds of total sales from livestock, compared to the U.S., which derives about half its sales from livestock. Dairy dominates in New York and Pennsylvania and portions of Maryland, while poultry dominates in areas of Delaware, Maryland, Virginia and Pennsylvania. Hogs dominate in some parts of Pennsylvania, fruits and vegetables in southern New Jersey, tobacco in southern Virginia, and nursery crops in New Jersey and New York metro areas. By 1997, 100 counties (42%) had changed the commodity or animal source from which they had received the largest share of their income in 1949 (Figure 1).[3]

Gross sales of all agricultural products totaled $11.9 billion in 1997, a decrease of only 1% in real terms from 1949. The average per acre sales in 1997 was $453, almost twice as much

[3] The number of "counties" as calculated for this study is 269; however, this includes some independent cities. Also, 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.

as in 1949. The value of land and buildings per acre had tripled on average, from $633/acre in 1949 to $2,142/acre in 1997. Thirty-three percent of Mid- Atlantic farmers reported working over 100 days off the farm in 1949, rising to 44% in 1997. Total population in the six states has increased by 43% since 1950, climbing from 35 million to 50.1 million people. Even though total population increased, some counties lost farmland even as their population was decreasing, as shown in Figure 2.[4]

During the last 50 years, in response to public concern about the loss of farmland, Mid-Atlantic state and local governments have introduced many different programs to stem the conversion: agricultural protection zoning, purchase of agricultural conservation easements, transfer of development rights, preferential taxation, right-to-farm laws, and agricultural districts. Preferential taxation or "use-value" property tax programs assess agricultural land at a lower rate, that is, its earning potential in an agricultural use rather than its "highest and best use" market value for property tax purposes. The purchase and transfer of easement and development rights programs remove the right to convert the land to residential, commercial and industrial uses in perpetuity and thus limit alternative land-use options. In 1956, Maryland was the first state to enact a preferential property tax assessment program. In 1972, Southampton, New York, created the first local purchase of development rights program, followed by Suffolk County, New York, in 1974. Maryland and Massachusetts each introduced state Purchase of Agricultural Conservation Easement (purchase of development rights programs (PDR/PACE)) programs in 1977. All six states had introduced some version of preferential taxation before 1982. In 1997, 44% of the counties in the sample had a local or state agricultural land preservation program in place.

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[4] Counties that had a zero farmland change or zero population change are included in the "Gain" category.

Model

As farmland acreage decreases, fewer purchasers of farm inputs and fewer sellers of farm outputs remain. If economies of scale exist in both the input and output sectors, then the decrease in number of acres would change the cost structure and decrease profits in the agricultural industry's support sector. If input and output firms exit the county, inputs costs could increase, output prices could drop, and/or transportation costs could increase. For example, there is a fixed cost of establishing and running a processing plant for frozen peas. A region with sufficient pea production could sustain a processing plant. However, if farmland decreases and the area does not continue to produce enough peas, then the processing plant could leave the area, decreasing the returns for the remaining pea producers.

To determine whether there *is* a critical mass of farmland, we analyze whether once a county's farmland falls below a certain number of acres, the rate of farmland loss accelerates, all else the same.[5] The rate of farmland loss in a county is modeled as a function of the net value in an agricultural use, the net value in a non-farm use, the number of agricultural acres, the existence of agricultural preservation policies, and the possible alternative income opportunities. We expect the net agricultural rental rate to be a function of the number of farmland acres. When farmland acres are numerous, then a sufficiently large support sector can exist to sustain a profitable farm sector. An agricultural preservation program or a preferential taxation program can contribute to the retention of these farmland acres. Conversely, if the value in a residential, commercial or industrial use were higher than in an agricultural use, one would expect land to be converted to these non-farm uses. If a county has a low value in residential, commercial or

[5] Another possible method to study 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 study have exited the region over the past 50 years.

industrial use but also has a negative or low value in agriculture, one can see farmland loss even as population is decreasing. Agricultural land can be idled or converted to forest rather than converted to a developed use. If off-farm income opportunities are high, farmers might choose to leave farming and enter other professions. Depending on the relative values in an agricultural use and the alternative income opportunities, one could see farmers engage in both agricultural production and off-farm employment activities. Off-farm income can be an important diversification strategy for farmers, greatly supplementing farm income, and therefore the presence of off-farm employment in the county may decrease the rate of farmland loss.

Data and Econometrics

Data from the agricultural census and population and housing census were collected and assembled by county for the approximately 50-year period (1949-1997) for six Mid-Atlantic states: Delaware, Maryland, New Jersey, New York, Pennsylvania, and Virginia. The analysis uses data on 269 counties and 10 five-year time periods.[6] The dependent variable is the percent loss of farmland from the beginning year of the period to the end year of the period: 1949-1954, 1954-1959, etc., through 1992-1997. The unit of observation is the county; the group is the crop-reporting district where the county is located (Figure 3). USDA's National Agricultural Statistics Service developed these crop-reporting districts based on geographic, soil and cropping similarities.

In order to create a dataset combining data from the Censuses of Agriculture and the Censuses of Population and Housing, the population and housing estimates were interpolated and extrapolated to the Census of Agriculture years. Interpolated estimates were calculated by

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[6] Certain counties were deleted from the analysis. If sales per acre data were not available for a county, the county was deleted for that period. In addition, counties with fewer than 5 farms were excluded. Six counties were excluded from the entire analysis due to limited agricultural activity in 1950: Bronx, Queens, Richmond, Kings, and New York counties, all in New York state, as well as Arlington, Virginia.

dividing the change in values between census years by ten, multiplying that annual change by the appropriate number of years, and adding that change to the earlier year. Extrapolations were calculated for years 1992 and 1997, based on estimated values from the 1980 and 1990 censuses. The annual percent change in the estimated value from 1980 to 1990 was calculated, then applied to 1990 data. Extrapolations were made assuming a constant percentage change.

We assembled the data as a panel by crop reporting district and by time period and tested to determine which of the following was the appropriate econometric technique: pooling the data, pooling the data with fixed effects representing each time period and/or each crop-reporting district, or estimating a random effects model. Using Lagrange Multiplier (LM) and Hausman tests (HT), we find that a random effects estimation procedure is more efficient *(*$LM_{(2)}$*=1581.33;* $HT_{(14)}$*= 17.53)*. Thus the unexplained variation in the rate of farmland loss or the residual 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, and σ_w^2, respectively. The covariances between the error terms are also assumed to be 0. The model incorporates both the within and the between random components.

The estimated random effects model is:

$$y_{it} = \alpha + \beta' x_{it} + \varepsilon_{it} + \mu_i + w_t$$

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

Because farmland loss is affected by changing agricultural conditions, demand for land for non-agricultural purposes, landowners' alternative employment opportunities, and preservation policies, we include variables to control for these factors. Table 1 provides the names, definitions, and descriptive statistics for the variables included in the analyses.

Harvested cropland acres in the initial year of the time period (1949, 1954, …. 1992) are used to proxy the critical mass threshold acres, as they are a better indicator than farmland acres of the level of economic 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 profitable agricultural support sector. A county is hypothesized to experience an increase in the overall rate of farmland loss if the level of harvested cropland falls below the threshold needed to sustain a profitable agricultural support sector. Harvested cropland acres are also included as a squared term. By including harvested cropland in a nonlinear manner, the computation of a threshold level can be executed. The percent of the county population in agricultural, forestry, fishing or mining activities in the initial year of the time period is also included to indicate the dominance of the agricultural sector in the county.

The net returns from agriculture are proxied by agricultural sales per acre and expenses per acre in the initial year of the time period. If sales increase more than expenses, a farmer's earnings increase and thus he or she may stay in agriculture. Price and technology changes are incorporated into these expenses and sales numbers. In addition, these numbers should reflect shifts to alternative crops.

Several variables are included to represent demand for land for non-farm uses: the population per acre (population density) in the initial year of the time period, whether the county is in a metropolitan area in the initial year of the time period, the percent change in total housing units over the five-year time period, percent change in median family income over the five-year time period, and percent change in median housing value over the five-year time period. As population increases, demand for land for houses and commercial structures will also increase, and therefore farmland loss is hypothesized to increase. Conversely, as population decreases in a county, farmland loss could decrease as returns in a residential use could decrease. Given that the number of individuals per housing unit has decreased, a direct indicator of the actual growth in the housing stock is included. As family incomes increase, people desire larger homes on larger parcels. An increase in income would increase demand for rural lands. Similarly, an increase in the median housing value may indicate an increase in the demand for land in a county (Hardie, Narayan and Gardner 2001) and accelerate the rate of farmland loss.

Many farmers have supplemented their on-farm income with off-farm employment. As mentioned above, 33% of Mid-Atlantic farmers reported working over 100 days off the farm in 1949, rising to 44% in 1997. Their off-farm income opportunities will be higher if they are better educated and the unemployment rate in the county is low. However, as off-farm opportunities increase, the relative benefit of selling the land and shifting full-time to alternative employment may be greater. Both the percent of the county population that has at least a high school education and the percent of unemployment are included as proxies for off-farm employment opportunities, which could have either a negative or positive effect on the rate of farmland loss.

In addition, policy variables indicating 1) if the county has a preferential property tax program for agricultural land in the first year of the time period and 2) if the county has some type of farmland preservation program in the first year of the time period are included. Four different types of preservation programs that are hypothesized to slow the rate of farmland loss are considered: 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. The presence of these easement/development rights programs in a county was consolidated into one variable. Information on the date of establishment of the programs was gathered (AFT 1997, 2001a, 2001b, 2001c). Counties were considered as having a transfer of development rights program if any township within the county has such a program. If a program exists but has preserved no acreage, it was not included.

Because over the 50-year time-span there have been many changes in both agriculture and the pattern of city and housing development, Models 2a-b were estimated to determine if the critical mass threshold and importance of the other factors varied by time period. Gardner (2002) found that the U.S. lost almost half its farms in the two decades between 1950 and 1970, for example. After 1940, he found that output per U.S. farm grew at a high rate until 1980, when it started to grow more slowly. Other changes included: labor became a smaller percent of input costs through the 1980s, and U.S. farm size grew more rapidly between 1950 and 1975 and less rapidly since 1980 (Gardner 2002). Given these findings and the years the census was taken, the sample is divided into 2 periods: 1949-1978 and 1978-1997.

Results

All else the same, Model 1's results indicate a critical threshold of harvested cropland acres of 189,240 acres per county (Table 2). If a county has less than 189,240 harvested cropland acres, its rate of farmland loss is higher. While a statistically significant result, the reality is that only 2 to 7 counties of the 269 counties studied exceeded this number of harvested cropland acres in any time period. However, as a county has fewer acres, its rate of farmland loss is higher. We find that as the number of harvested cropland acres increases by 10% (5,400 acres), the percentage loss decreases from the predicted 7.9% to 7.67% (Table 3).[7] The average amount of harvested cropland per county over the time period was 54,372 acres.

Many other factors explain the rate of farmland loss, including sales per acre, expenses per acre, population per acre, percent of unemployment, percent change in median family housing, and percent change in housing units. Figure 4 shows the relative change in the rate of farmland loss for a 10 percent increase in these variables. As harvested cropland, sales, and percent change in income increase, the rate of farmland loss falls. As expenses, population density, percent change in total housing units, and percent unemployment increase, the rate of farmland loss accelerates. As can be seen in Figure 5, a county with a preferential taxation program has a rate of farmland loss almost 4% lower than one without a program. A metropolitan county has a rate of farmland loss that is 1% greater than a rural county.

Results indicate that as the net returns to agriculture decrease in a county, the county will lose farmland at a faster rate. The average sales per acre were $549 and the average expenses were $332. If sales increased by 10% ($55 per acre), the rate of farmland loss decreased from 7.9% to 7.83%. If expenses increased by 10% ($33 per acre), the rate of farmland loss increased from 7.9% to 7.92%. Thus the same percentage change in dollars in sales per acre appears to have a bigger impact on the rate of farmland loss than does a change in expenses per acre.

The variables included to represent development pressure also explained farmland loss. If population per acre increased by 10% (the average population per acre was 0.56), the rate of

[7] The percentage changes are evaluated at the means of the variables.

farmland loss increased from 7.9% to 8.0%. Similarly, a 10% change in the growth rate of housing units caused the farmland loss to increase, from 7.9% to 8.02%. The rate of farmland loss was higher in metropolitan areas, increasing from 7.9% to 8.9%, assuming all else remained the same.

Interestingly, we find that an increase in the median family income decreased farmland loss. Gardner (1994) found that higher household income stems the loss of farms but not of farmland in metropolitan counties in the Northeast. A 10% increase in the rate of income change decreased the farmland loss rate from 7.9% to 7.73%. This 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. If the unemployment rate in the county was high, farmland loss rate increased. If unemployment increased by 10%, the rate of farmland loss increased from 7.9% to 8.09%. Farmers in counties with high unemployment may have had fewer off-farm opportunities for themselves or family members and thus sold the farm.

We also found that states and counties with a preferential property tax assessment for agricultural landowners experienced slower farmland loss. Counties where preferential taxation existed had a farmland loss rate 0.038 lower than counties without it, 4.06% compared to 7.9%. These preferential taxation programs were enacted by states and counties between 1956 and 1978. However, having a preservation program (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, and 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

Results of Models 2a and 2b

As mentioned above, over this 50-year time-span, many changes in both agriculture and the pattern of city and housing development have occurred. Therefore, we examine whether the included variables' impacts were consistent over the two time periods: 1949-1978 (Model 2a) and 1978-1997 (Model 2b). The average 5-year rate of farmland loss in 1949-1978 was 9.19%, and for 1978-1997, 5.13%. A log-likelihood test indicates that estimating two models by these time periods is statistically different than pooling the data $(\chi_2^2=77.78)$. While the results were remarkably similar for the earlier time period to those reported above for Model 1, they diverged in the later time period (Table 2).

The critical mass threshold in the early period (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 have more than 180,000 acres of harvested cropland. Thus a more interesting results is that if the number of harvested cropland acres increased by 10%, the percentage loss decreased from the predicted 10.2% to 9.82% (Table 3). If sales increased by 10% ($55 per acre), the rate of farmland loss decreased from the predicted 10.2% to 9.99% (Table 3). If expenses increased by 10% ($37 per acre), the rate of farmland loss increased from 10.2% to 10.25%. A change in sales and expenses had a greater impact on farmland conversion in this earlier period than in the general model. Many of the other variables estimated in this earlier period had the same impact as reported above for Model 1.

In the later period, the number of harvested cropland acres had no effect on the rate of farmland loss. One hypothesis for this is that the changes in agriculture and development patterns have altered the impact of the threshold, although direct measure of these patterns and possible alterations were not included in the analysis. Farmers could have shifted to alternative crops, found alternative marketing mechanisms (such as direct marketing rather than depending on processing plants), or begun using alternative distribution channels such as making purchases on the Internet or using delivery services to obtain their input needs. Additional investigation of what exactly are the strategies that have allowed counties to decrease their rate of farmland loss is warranted.

One surprising result in Model 2b is that a 10% ($55) increase in the dollar value of sales per acre actually increases farmland loss from the predicted value of 5.01% to 5.10%, and that a 10% ($27) increase in expenses per acre decreases the loss rate to 4.91% (Table 3). This suggests that as agricultural returns increase, farmland loss will increase. One hypothesis to explain this counterintuitive result is that those farmers who respond to changing signals by adopting new technologies and purchasing more costly inputs in order to increase yields are those most likely to stay on the land. One would also expect these farmers to have both higher sales and expenses. If one assumes that the marginal land is going out of production and that only the productive and adapting farmers are remaining in agriculture, the average sales per acre for the county would increase. Thus our result on the sales per acre suggests that where all the marginal land goes out of production and sales per acre on the remaining acres increase, one could see an increase in sales per acre accompanied by an increased rate of farmland loss.

No other variables besides population density were statistically significant in the later model. The rate of farmland loss increased from 5.01% to 5.08% when population density increased 10%. These results did not explain what is affecting farmland loss in counties where the population is decreasing. The R^2 for the early model equaled 0.2344; the R^2 for the second model was even lower, at 0.0623. Thus this second model did not explain 94% of the variation in farmland loss rates for these counties during the later time period.

Conclusions

We collected agricultural and population and housing census information for 269 counties in 6 Mid-Atlantic states -- Delaware, Maryland, New York, New Jersey, Pennsylvania, and Virginia -- for the period from 1949 to 1997. The average 5-year rate of farmland loss was 7.58%. However, the biggest rates of farmland loss occurred between 1949 and 1974, when farmland acres were actually at their highest. Eighty percent of the farmland that was removed from farming between 1949 and 1997 was lost before 1974. In addition, we find that the rate of farmland loss is greater than the rate of harvested cropland loss. Thus, it is possible that the most marginal land in a county is being removed from production first.

Farmland loss occurs if the relative profitability of the farm sector decreases, if farmers and farm families can earn more off the farm than on, and if the demand and thus price for land for residential or commercial uses increases. We include a range of variables to account for the trends in these levels. The number of harvested cropland acres and the percent of the county employed in resource-based industries serve as proxies for the existence and viability of the agricultural support sector. The average sales and expenses per acre on the farms are included to account for changes in agricultural profitability. Population density, percent change in the number of housing units, percent change in the median family income, and percent change in median housing values are proxies for development pressure. Alternative income opportunities are included, using the percent of unemployment in the county and the percent of the population that has finished at least high school.

Estimated using a random effects econometric procedure, Model 1 indicates that the number of harvested cropland acres in a county is inversely related to its farmland loss rate. In addition, a threshold was identified of harvested cropland acres of 189,240 acres per county.

However, less than 3% of the counties in the study actually have more than this number of harvested cropland acres. In addition, given the changes in agricultural technology and trade patterns and the introduction of land preservation programs during this 50-year period, even if the threshold result was convincingly strong, the actual threshold level may have altered in the later part of the study period. By the early 1980s, all counties had instituted preferential taxation programs for agriculture and some were implementing or at least considering farmland preservation programs. For this later time period (1978-1997), the level of harvested cropland acres is not found to have a statistically significant impact on the rate of farmland loss. The data also indicate that the rate of farmland loss has decreased since the early 1970s. The 5-year average rate of farmland loss for the six states between 1949 and 1978 was 9.19%, and between 1978 and 1997 had dropped to 5.13%.

Changes in agriculture and development patterns may have altered the impact of this critical mass variable, although we did not include variables depicting these patterns explicitly. It could be that farmers have shifted to alternative crops, have found alternative marketing mechanisms (such as direct marketing rather than depending on processing plants), or have begun using alternative distribution channels (such as making purchases on the Internet or using delivery services) to obtain their input needs. Further research is needed to identify the types of changes that aided in decreasing the rate of farmland loss. Efforts to support and encourage these adjustments may facilitate farmers' transition and success.

Many factors explain the rate of farmland loss for the entire 50-year period and for the early 1949-1978 period, including sales per acre, expenses per acre, population per acre, percent of unemployment, percent change in median family housing, and percent change in housing units. As harvested cropland, sales, and income increase, the rate of farmland loss falls.

Similarly, as expenses, population density, total housing units, and percent unemployment increase, the rate of farmland loss accelerates. A county with a preferential taxation program has a rate of farmland loss almost 4% lower than a county without one. A county in a metropolitan area has a rate of farmland loss one percent higher than one in a non-metropolitan county. We did not find in the general model that the percent of people employed in resource-based industries was significant in explaining farmland loss. Similarly in the farmland loss analysis, the median housing value was not important, nor was the education level of the county's residents. We also found that agricultural preservation programs did not impact the rate of farmland conversion. Most of these programs were introduced after the late 1970s, and some have faced financial constraints and thus have not been able to preserve many acres. Therefore, it is possible the impact of these programs will be greater in the future.

Model 2b -- for the most recent time period, 1978 to 1997 -- contradicts the findings in the other two models. Although as hypothesized population density increases the rate of farmland conversion in Model 2b, two of the variables -- sales per acre and expenses per acre -- have the opposite sign of what was hypothesized. None of the other estimated coefficients was statistically significant in explaining farmland loss. Given that all the counties had a preferential taxation program in place during this period, this variable was not included in the analysis.

From the results of two of the models (Model 1 and Model 2a), one finds that the relative profitability of the agricultural enterprise affects how quickly farmland is lost in a county. Programs that increase farm profitability thus would be expected to stem farmland loss. The health of the local economy also played a role in farmland conversion. Many farm families use off-farm employment to supplement farm income, so employment opportunities must be available in the immediate surroundings. As the percent of a county's unemployed population increased, more farmland was shifted out of agriculture. Similarly, local economic conditions such as a decrease in family median income increased farmland loss. Policies that focus attention on the county's and/or region's economic performance could promote farmland retention. Hardie, Narayan and Gardner (2001, pg 131) also 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.

Higher levels of demand for land for housing and commercial purposes resulted in higher rates of farmland loss. Increases in both the number of people per acre and the percent change in housing units increased farmland loss. Local communities can plan to both decrease the number of houses built and alter the pattern of the construction. Given the Chesapeake Bay Foundation's finding that the rate at which land is being consumed exceeds the population growth rate by almost 2.5 times, designing policies that focus on reducing land consumption may be the optimal strategy to limit the impacts of both population growth and housing development on agriculture.

Metropolitan counties had higher rates of farmland loss even when the change of housing units and population density were held constant. Metropolitan counties may need to be even more active in implementing policies and programs to encourage farmland retention and to strengthen the agricultural economy in the area. The introduction of a preferential taxation program in all 6 states slowed the loss of farmland. A re-evaluation of these programs may be warranted, as well as an examination of who participates and who does not. Perhaps a further reduction in the property tax could reduce the rate of farmland loss even more. Such a reduction could potentially be financed through a higher conversion tax rate that would recapture some of the benefits farmers accrue from the preferential tax program when landowners choose to convert the land from agriculture to a non-farm use.

The results of Model 2b call into question our conclusions about what would make a county successful in slowing farmland loss. With the counterintuitive results on sales and expenses per acre, one questions whether (while possibly a necessary condition) increased agricultural profitability is sufficient. However, that an increase in population density will increase farmland loss has been a consistent result throughout the analysis. But conversely, given the results in Model 2b, one questions what is affecting the farmland loss rate in counties where the population is actually decreasing. A measure for returns in forest or for recreational use was not included in the analysis; if returns in these uses are greater than in an agricultural use, this could be one explanation of farmland loss in areas with shrinking populations.

Further examination of whether there is a critical mass and what causes and what slows farmland loss is needed. Two striking features of the data were that 1) farmland loss occurred in many counties where the population was decreasing (Figure 2) and 2) the rate of farmland loss has decreased since 1974. These facts suggest that a more complicated model may be necessary to analyze this issue further. This analysis was conducted on the county level. Possibly a more micro approach examining individual parcels would provide some insights that the aggregation to county level is obscuring. Alternatively, if the study incorporated data for all counties in the U.S., the results may be more illuminating. A case study approach could also provide insights about specific industries or agricultural sectors in specific regions during a specific time period.

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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

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

	Model 1 (1949-1997)	Model 2a (1949 to 1978)	Model 2b (1978 to 1997)
	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)
HCLANDD	-0.0006 ***	-0.0010 ***	-0.00004
	(0.0001)	(0.0002)	(0.0002)
HCLAND2D	0.0016 ***	0.0027 ***	-0.0002
	(0.0006)	(0.0007)	(0.0010)
PAGFFM	0.0415	0.0477	0.0500
	(0.0334)	(0.0381)	(0.0972)
SALESPER	-0.00001 ***	-0.00002 ***	0.00002 ***
	(0.0000)	(0.000002)	(0.000005)
EXPPERA	0.000005 ***	0.00001 ***	-0.00003 ***
	(0.0000)	(0.000002)	(0.00001)
POPPERA	0.0187 ***	0.0175 ***	0.0148 ***
	(0.0017)	(0.0019)	(0.0053)
MADUMMY	0.0103 *	0.0193 **	0.0078
	(0.0059)	(0.0082)	(0.0088)
PCTOTHU	0.1587 ***	0.1780 ***	0.0823
	(0.0401)	(0.0498)	(0.0861)
PCMFINC	-0.1321 **	-0.1416 **	-0.0588
	(0.0540)	(0.0608)	(0.1311)
PCMHVAL	0.0236	-0.0025	0.0462
	(0.0307)	(0.0448)	(0.0651)
PHIGHSCH	0.0141	0.0251	-0.0032
	(0.0318)	(0.0462)	(0.0584)
PUNEMP	0.3207 *	0.3313 **	0.2931
	(0.1255)	(0.1643)	(0.2201)
STAX	-0.0404 ***	-0.0358 ***	
	(0.0105)	(0.0112)	
PRESPROG	-0.0047		-0.0082
	(0.0095)		(0.0111)
CONSTANT	0.0875 **	0.1162 ***	0.0172
	(0.0387)	(0.0415)	(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 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			
HCLANDD	7.67%	9.82%	
PCMFINC	7.73%	9.99%	
SALESPER	7.83%	10.08%	5.10%
EXPPERA	7.92%	10.25%	4.91%
POPPERA	8.01%	10.30%	5.08%
PCTOTHU	8.02%	10.36%	
PUNEMP	8.09%	10.37%	
Binary Variables			
STAX	4.06%	6.62%	
MADUMMY	8.94%	12.13%	

Figure 1. Counties That Changed Crop or Livestock Commodity from Which They Received Their Largest Share of Gross Income Between 1949 and 1997

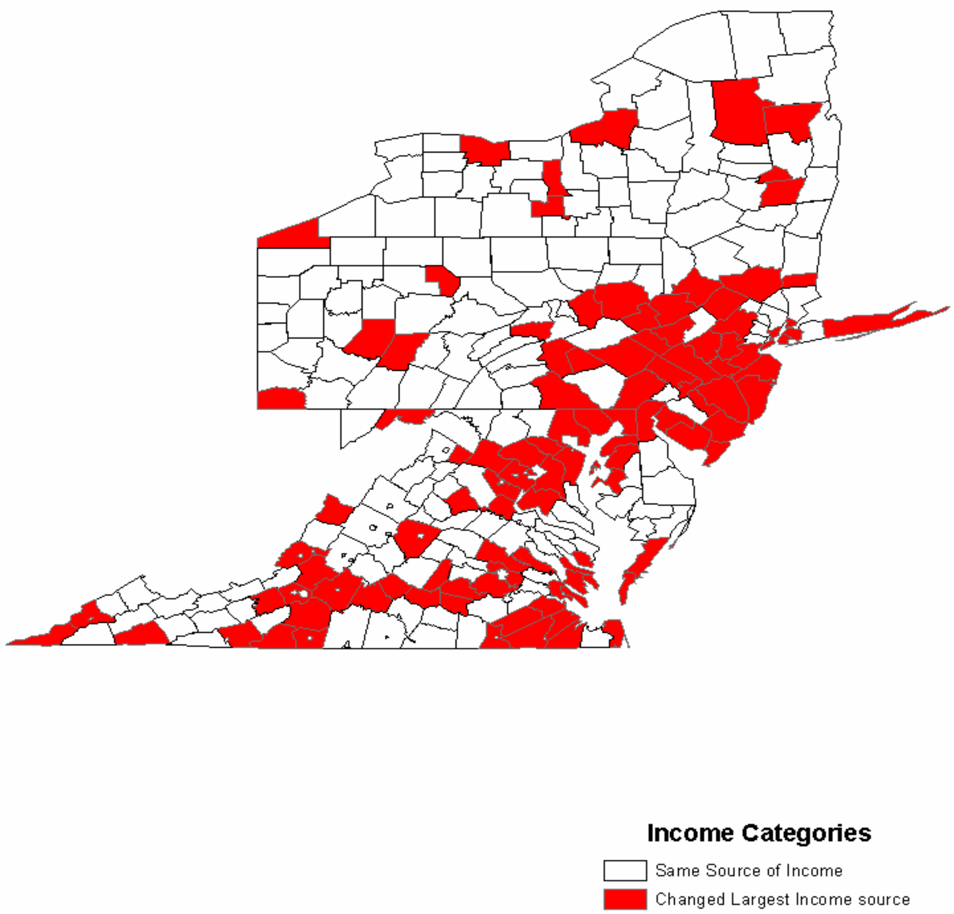

Figure 2. Changes in Farmland and Population between 1987 and 1997

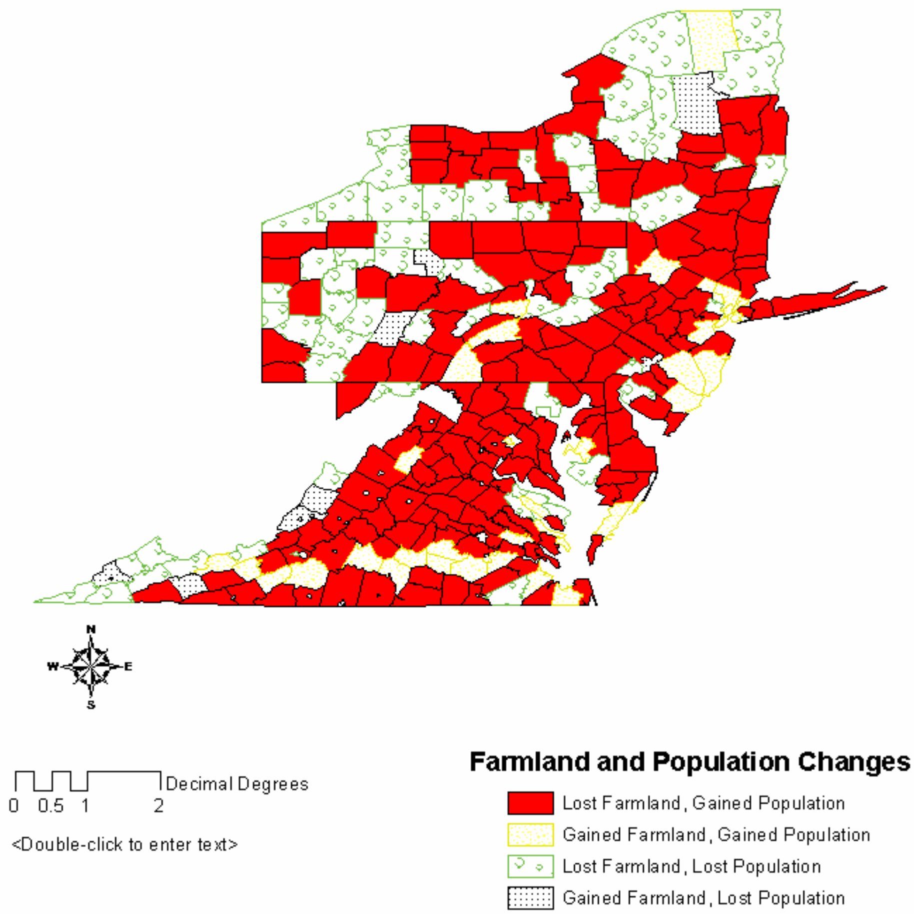

Figure 3. Distribution of Counties among Crop Reporting Districts

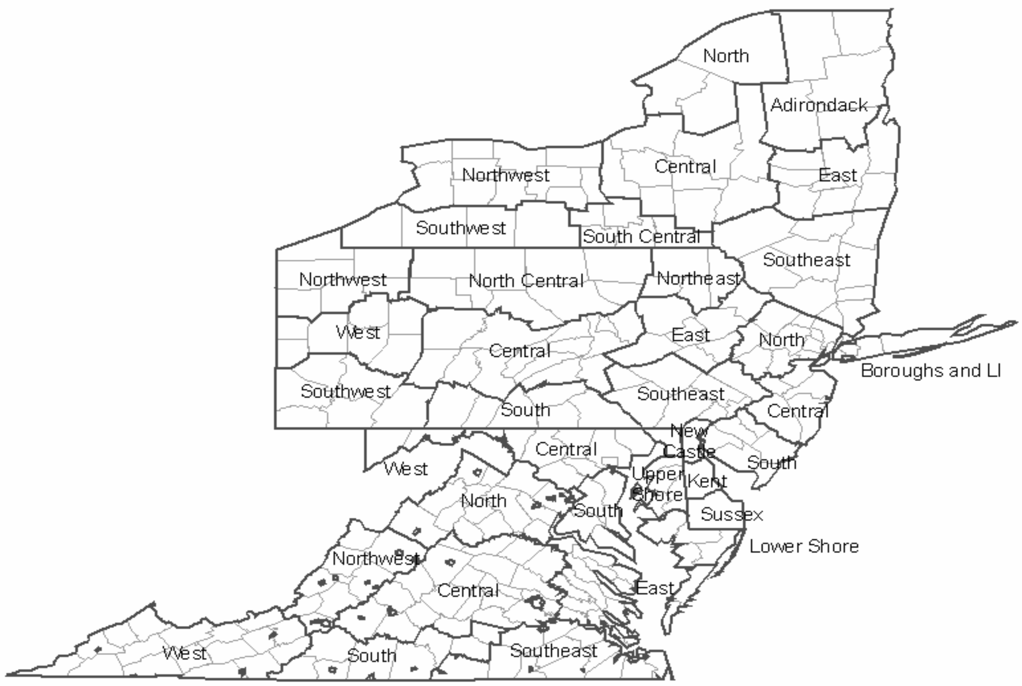

Figure 4. Change in the Rate of Farmland Loss for a 10% Increase in Variable

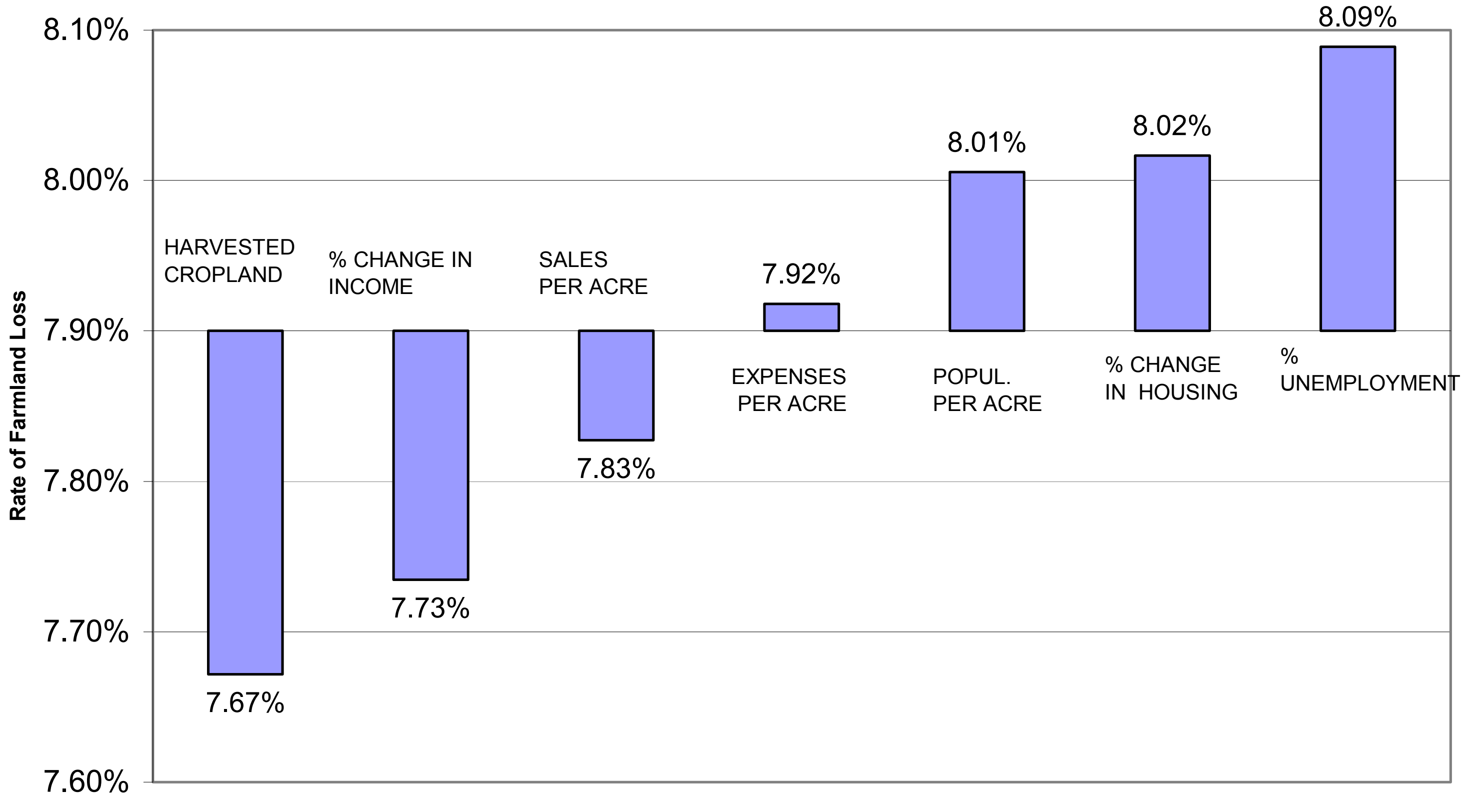

Figure 5. Change in the Rate of Farmland Loss due to Preferential Taxation Programs and Being a Metro County