Impact of Farmland Preservation Programs on the Rate of Urban Development

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Problem Statement

The role of state and federal government agencies in land management has evolved over time. Fedkiw (1989) notes that prior to the late 1800s federal land policy had been one of transferring the "public domain" to state and private ownership. However, the rapid decline in the forested area of the United States during the last half of the 1800s contributed to efforts to preserve and restore forests and other lands, both at the national and state levels. In 1916, the system of national parks was established with the founding of the National Parks Service. By the 2003, the federal government also preserved 187.86 million acres in the national forest system (National Forest Data Base, 2003). State parks also emerged near the end of the 19th century (Fedkiw), and today there are more than 12 million acres administered by state park agencies (NASPD). In 1964, Congress enacted the Land and Water Conservation Fund, and 5.6 million acres of local, state, and federal parks and recreation land have been acquired, largely near heavily populated areas.

Recent concerns focus on an urbanizing America with farmland in decline or being converted to other uses across the entire U.S. In the 1960's, interest in farmland protection evolved from a series of isolated, localized actions to a national movement. This set the stage for creation of local, federal, and state laws to protect private agricultural lands. Farmland protection programs are used to preserve farmland in the U.S. and specifically to influence land development decisions in a particular area. In addition, the farmland preservation programs were designed to ensure food security, create economic opportunities, protect natural resources, sustain quality of life, and allow for community investment in rural and agricultural infrastructure.

The adoption of farmland protection programs has followed a general progression over time. First, early preservation policies were often based on agricultural/rural residential zoning, which is a regulatory approach mainly, intended to isolate incompatible land uses and to limit the density of residential development (Solberg and Pfister). Given that zoning may be ineffective or viewed as unfairly infringing on landowner rights (Whyte), a second generation of policies emerged to increase the economic viability of agriculture. One example is differential tax assessment, which mandates that farmland be taxed at its agricultural value rather than its higher developed value. This policy is designed to delay urban development by providing tax savings to land owners. When the second generation policies were viewed as insufficient, a third generation of programs emerged to combine tax relief with the creation of regions in which agriculture is the preferred and protected use. These include the formation of agricultural districts, the passage of right-to-farm laws, and designation of urban growth boundaries. Fourth generation land preservation policies are largely based on the use of conservation easements, including purchase of development rights (PDR) and transfer of development rights (TDR).

State and county governments in all 50 states have adopted some type of farmland protection program. Consequently, it is pertinent to assess the impact of these programs on the rate of urban development. Rural-urban land use decisions may be affected by several factors across space and through time, and a targeted analysis of the farmland preservation programs must control for the influences of population dynamics, household income, farm revenue, and other land use determinants. The results of an analysis of rural-urban land-use patterns can help us understand the impact of existing farmland protection policies and may be able to provide guidance for the direction of future land preservation policies.

Objectives and Hypotheses

The overall objective of this study is to evaluate the impacts of farmland preservation programs in the Northeastern United States from 1982 to 1997. Specifically, the focus will be on the impact of active Purchase of Development Rights (PDR) or Purchase of Agricultural Conservation Easements (PACE) programs on urban development rates. Under PDR programs, the development rights to farmland are purchased and severed from the fee-simple bundle of ownership rights. PDR programs allow the government and other private organizations to permanently extinguish development rights to agricultural lands, and the private landowner is compensated for the forgone property right and retains all other rights, including the right to continue farming. To date, these programs have protected over 1.14 millions acres at a cost of $1.10 billion (AFT, 2004). In addition, the 2002 Farm Bill (Farm Security and Rural Investment Act) has authorized an average of $100 million per year over five years to assist in local preservation efforts.

Over the past three decades, PDR programs have been increasingly used to preserve farmland while avoiding problems associated with the other farmland protection methods. Farmers or other landowners are not forced to preserve the land but voluntarily sell the development rights to their land. However, once these development rights are sold, the land can never be developed as the easement applies to all subsequent owners (unless the program allows for buy-back or release of the rights to the owner at some future time). PDR programs do not give the public the right to use the land for recreational or other uses (AFT, 1997), but some other minor restrictions may be imposed to encourage wise stewardship of the land (e.g. using Best Management Practices for both agricultural and forestry activities). Otherwise there is no real change in how the farmer can use the land once the development rights have been sold.

The process for implementing a state or local PDR program tends to be more complicated than that of agricultural zoning ordinances. The state or municipality must first decide on an area or areas that will be targeted for farmland protection. Several factors are taken into consideration when selecting targeted preservation areas, including current development pressures, future development pressures, the productive capacity for agriculture, and the future viability of agriculture. One important goal of most PDR programs is to preserve enough farms in the preservation area to retain a critical mass of farmland (Daniels, 1991).

There are two basic ways that farmers are compensated for relinquishing their development rights. The first way is to pay the full difference between the fair market value (what it is worth if sold for potential development) and the fair agricultural value (what it is worth as agricultural land). It is important to note that the agricultural value and development value are the present value of discounted streams of future returns. An appraiser is usually retained to determine these values. For example, if the development rights are purchased on farmland that has a $2,000 per acre development value and a $500 per acre agricultural value, the development rights will sell for $1,500 per acre under this approach.

However, many localities offer less than the full difference between the development value and the agricultural value (Daniels and Bowers, 1997). This alternative compensation scheme is feasible because many farmers would rather not develop land that they have been working for decades and may have belonged to their family for generations. Thus the sentimental value of the farmland may influence the amount farmers are willing to accept for their development rights. The existence of this sentimental value is why many farmers choose not to develop their land when, from a strict financial standpoint, they may be much better off to sell. The PDR payment becomes the development value less the agricultural value plus the sentimental value of the farmland. In reality, however, the PDR payment may be the lowest price at which the program administrator would still expect to preserve enough farmland to meet program objectives.

There are many additional advantages to PDR programs. First, the compensation paid to farmers can provide working capital for farm operations and may aid in rejuvenating local farming economies (Daniels, 1997). Second, PDR programs may keep farmland at affordable prices for both current farm expansion or for beginning farmers entering the market because the development value of the land is essentially eliminated (Pfeffer and Lapping, 1994). The price of the land will be determined by farmers bidding on it for its value as productive agricultural land, not its value for development. Third, it can prevent land from being taxed out of agriculture because once the development rights have been separated from the land, the value of the parcel typically declines to its agricultural value thus reducing the inheritance tax liability.

There are some key disadvantages associated with the PDR programs. First and foremost, they can be expensive. State PDR programs have spent an average of $1,488 per acre to acquire development rights while local programs have spent an average of $1,704 per acre (AFT, 1997). High easement costs may prevent a significant amount of farmland from being preserved. At $1,500 per acre, a PDR program requires $30 million to preserve 20,000 acres or roughly 50 medium sized farms in the eastern U.S. Although most programs use general bonds that increase property taxes to fund PDR programs, it appears that most of the successful programs rely on more creative means such as real estate transfer taxes, agricultural transfer taxes, and sales tax increases (AFT, 1997). However, the timing of the PDR program implementation can help to reduce costs. The earlier the program is implemented, all other things being equal, the lower the cost of the conservation easements.

A second major disadvantage is that funding is often limited, and the amount of land offered for enrollment in PDR programs typically exceeds the available funds. The funding limitations often lead to long waiting lists for PDR enrollment, and some of this land may be developed before it is preserved. PDR programs may use such situations to their advantage by decreasing the price paid for the development rights. Program administrators may also let the market determine what price should be paid for the development rights. Given that farmers have different sentimental value for their land, those farmers whose sentimental values are highest would be willing to sell the development rights at a lower price. For example in the Maryland state PDR program and in some of the individual county programs, landowners bid in this competitive process and the lower bids are selected for PDR purchases (Daniels and Bowers, 1997).

Another method to balance funding needs and availability is to reduce the area targeted for the PDR program. This effectively reduces the aggregate development value of the eligible land.

Another disadvantage of PDR programs is that they are voluntary, and owners of targeted farmland may choose not to participate. This could lead programs to protect scattered parcels without preserving the critical mass of adjacent lands needed to keep farming viable (Daniels, 1991). As well, a contingency plan is needed if farming becomes unprofitable in the areas with PDR programs. All states except New Jersey allow a buyback of the easements if it can be demonstrated to the program administrator's satisfaction that farming can no longer be profitable or if there are too many conflicts with suburban neighbors (Daniels and Bowers, 1997).

A fourth disadvantage is the relatively high administrative costs of PDR programs, including establishment, implementation, monitoring, and enforcement of the program. Because the easement payment is a one-time transfer, future generations of farmers will not directly benefit from this initial payment. Finally, PDR programs may help control high-density land development, but, there may be pressures to use these lands for rural estates or recreational lands. This pressure would tend to drive up the land prices beyond what farmers can afford to pay for the productive value. To avoid this possibility, some programs require notification of all proposed sales and retain the right of first refusal, giving the government agency the option to buy the land with the intent to resell for agricultural use (Freedgood, 1991).

Overall, PDR programs possess a number of attributes that lend themselves to effective farmland preservation. On lands that have been protected, they maintain affordable farmland prices, provide permanent protection, eliminate the impermanence syndrome (characterized by a high degree of uncertainty among farmers about their ability to continue productive operations in areas beset by rapid population growth), protect water and other natural resources, provide open space amenities and contribute to local food sources.

In this paper, we seek to further our understanding of PDR programs by first reviewing some of the existing research findings. Then, we develop an analytical model of the effect of PDR programs on urban spatial development patterns and land prices. Our modeling approach is based on the intertemporal model developed by Capozza and Helsley (1989). We extend this model to include endogenously determined purchases of development rights from landowners, and derive comparative static effects. We then use county-level data on land conversion and PDR program activity in the Northeast U.S. and empirically analyze the impacts of PDR program activity on (1) the urban development rate within each county and (2) the urban development rate in neighboring counties (i.e., spillover effects). The tests are based on an econometric model that controls for demographic changes, levels of infrastructure, and factors related to landowners and farm returns. The concluding section includes remarks on the limitations of the analysis as well as ways in which this research may be extended.

Previous work on Farmland Protection Programs

Feather and Barnard (2003) analyze the benefits and costs of PDR programs and develop an econometric model of the factors influencing the creation of PDR programs and the amount of farmland preserved. Benefits are represented by "willingness to pay" and costs are represented by direct government costs of the PDR programs. A censored regression approach is used to identify the factors explaining the existence of PDR programs. In the first stage a probit model is estimated for the binary dependent variable indicating whether a given county has a PDR program. The independent variables are factors that may influence the adoption of a PDR program such as income, population density, and agricultural land density. The second stage of the analysis models the quantity of land preserved with a censored regression model. The independent variables are the inverse Mills ratio from the probit model and the variables used as independent variables in the first stage. State dummy variables are included in both models to account for regional variation. The county-level estimation is conducted with data from seven of the most active states (Pennsylvania, Maryland, New Jersey, Massachusetts, Connecticut, Delaware, and Vermont).

Results from the first-stage probit estimation shows that mean income and agricultural land density are both statistically significant and as expected have positive influence on the existence of a PDR program. Except in one case, urban influence and the change in urban influence have unexpected negative signs, and are not statistically different from zero. The change in agricultural density has a positive sign, but estimated coefficient is not statistically different from zero. As expected, state-specific dummies differ from each other in the model. In the censored regression model all variables except urban influence have the expected positive sign and all are statistically different from zero. All state dummy variables are statistically different from one another. To determine the impact of descriptive factors on land preserved, the authors calculate the associated elasticities. The results suggest that land preserved is quite responsive to income, urban influence and the change in urban influence.

Lynch and Musser (2001) evaluate the efficiency of agricultural land preservation under PDR and other programs in four Maryland counties using a Farrell efficiency analysis. The goals of these programs (e.g. maximizing the number of preserved parcels, preserving productive farms, and preserving parcels threatened by development pressure) are considered as a multiple outputs for evaluation under both technical and cost efficiency. The inputs are the characteristics of the individual land parcels.

The results suggest that the levels of cost and technical efficiency are quite high. Also it was found that the programs make trade-offs between different characteristics of preserved parcels. For example, an efficient parcel with a high percentage of crop land may be more distant from urban center if compared with a parcel close to urban center but with lower percentage of crop land. The parcel characteristics that appear to be relevant are the number of acres, percent of prime soil, and percent of crop land. The efficiency outcomes for all programs depend on the institutional environment. If the rules of the programs such as the assessment of development rights or the method of compensation were changed, the programs might achieve a higher level of efficiency. It was also determined that a combination of the instrumental tools of different programs may be necessary for achieving the desired objectives.

Wichelns and Nakao (2001) examine the changes in farming activities that have occurred over time on farms participating in PDR programs and determine whether these changes are consistent with program goals. The study area is 43 farms participating in Rhode Island's PDR program that started in 1983. The paper demonstrates that many of the farms participating in the PDR program had changed since enrollment. For example, six of twelve dairy farms had been converted to an alternative farm type such as vegetable farms, a heifer operation, and a horse riding farm. Three of six potato farms have become a vegetable farm, a field crop farm, and a fruit farm. These changes are very similar to changes on the parcels that were not active in the PDR programs. The authors conclude that agricultural production is maintained on the farms participating in PDR, but there is a noticeably shift towards value-added production and recreation business.

Nickerson and Lynch (2001) empirically test if the development restrictions imposed by permanent PDR/TDR (transfer of development rights) programs significantly reduce the farmland value in three selected counties in Maryland. The dependent variable in the model is the log of the sales price per acre of land sold in the county, and the independent variables are the vector of parcel characteristics that influence net returns both from agricultural and development uses, a binary variable for program participation, and the vector of the inverse Mills ratios to correct for selectivity bias due to voluntary participation.

To determine whether or not participation in PDR/TDR programs significantly reduce the sales prices of farmland, three modifications of the sale price model are employed. The first assumes the same marginal value for each parcel characteristic for unrestricted and restricted parcels. The second assumes different marginal values for restricted and unrestricted parcels. The third assumes lower sales prices for restricted parcels. The results of the first specification suggest that the parcels that are larger, farther from employment centers, or in forest areas receive a significantly lower price per acre, but preservation does not significantly reduce the price of a restricted parcel. The results of the second model show little evidence to support the hypothesis that restricted and unrestricted parcels have different marginal values. The results of the third model are quite similar to the first. Overall, the study provides little statistical evidence that the implementation of PDR/TDR programs in Maryland counties significantly decreases the farmland prices. In addition, there is little evidence to suggest that the sales price of a parcel depends on parcel characteristics such as distance to nearest city.

An Intertemporal Model of Land Development

Following Capozza and Helsley (1989), the urban area is assumed to reside on a homogenous two-dimensional plane. We add the assumption that the distance from the central business district (CBD) is bounded as $z \in \left[0, \pi^{-1/2}\right]$. As such, the region in which the urban area resides is a circle of area one, and the area of any subset within the circle may be interpreted as the share of the available land resource. The N(t) households in the urban area at time t are identical and consume X units of the composite good and $\bar{L} > 0$ units of the land good to generate utility $U\left(X, \bar{L}\right)$. The utility function is assumed to be homogeneous of degree one such that

$$(1) \qquad U\left(X, \bar{L}\right) = \bar{L}\, U\left(\frac{X}{\bar{L}}, 1\right) \equiv u\left(\frac{X}{\bar{L}}\right)$$

Consumers pay rent R for the fixed land good and commuting cost T > 0 per unit distance z from the central business district. The composite good is the numeraire good, and the consumer's budget constraint is $y = X + R\bar{L} + Tz$ given household income of y. If the land market is in equilibrium, the land consumed by all urban residents equals the area of the city such that

(2) $$N(t)\bar{L} = \pi \bar{z}(t)^2$$

where $\bar{z}(t)$ is the boundary (radius) of the urban area at time t

(3) $$\bar{z}(t) = \left[\frac{N(t)\bar{L}}{\pi}\right]^{1/2}$$

Capozza and Helsley also assume that the population of the urban area grows exponentially at rate g > 0 such that $N(t) = N(0)\exp(gt)$. By substitution, the urban boundary at time t is

(4) $$\bar{z}(t) = \left[\frac{N(0)\bar{L}}{\pi}\right]^{1/2} \exp(gt/2) = \bar{z}(0)\exp(gt/2)$$

and future boundary points are

(5) $$\bar{z}(\tau) = \bar{z}(t)\exp((\tau - t)/2)$$

for all $\tau \geq t$.

Let $R(t,z)$ represent the rent associated with urban property at time t and a location z distance units from the central business district. The price per unit of developed land at time t and location z is assumed to be the discounted net present value of future rents

(6) $$\begin{aligned} P^d(t,z) &= \int_t^\infty R(t,z)\exp(-r(\tau - t))\,d\tau \\ &= \underbrace{\frac{A}{r}}_{a} + \underbrace{C}_{b} + \underbrace{\frac{T}{r\bar{L}}(\bar{z}(t) - z)}_{c} + \underbrace{\frac{T}{r\bar{L}}\left(\frac{g}{2r - g}\right)\bar{z}(t)}_{d} \end{aligned}$$

where A is the return from agricultural production, r > 0 is the intertemporal discount rate, and C is the per unit cost of converting agricultural land to urban uses. The four components of P^d are (a) the present value of future agricultural returns, (b) the value of capital improvements created during conversion, (c) the value of accessibility to the central business district, and (d) the growth premium associated with future urban rents (We also implicitly assume *g* < *2r* in order for the future rents term (d) to be meaningful). For undeveloped agricultural land outside the urban area, $z > \bar{z}(t)$, the price

$$(7) \qquad P^a(t,z) = \underbrace{\frac{A}{r}}_{a} + \underbrace{\frac{T}{r\bar{L}}\left(\frac{g}{2r-g}\right)\bar{z}(t)\exp\left(-r\left(t^* - t\right)\right)}_{b}$$

is composed of (a) the present value of agricultural returns and (b) the present value of urban rents earned after the land is converted to urban use in some later period t*. Given that agricultural land has not been altered to support dwellings for households, the values of the post-development capital improvements C and accessibility to the central business district (i.e., components (b) and (c) in equation (6)) are not part of the agricultural land price. Capozza and Helsley demonstrate that certain properties of purely static models (e.g., rents falling with distance from the urban center to offset rising transportation costs, the price of land at the urban boundary equals the value of agricultural rents) do not hold in an intertemporal context.

Incorporating the Purchase of Development Rights

We now extend the basic intertemporal model to incorporate a purchase of development rights (PDR) program. The easements established under the PDR program permanently remove the right to develop this farmland for urban uses. Suppose a PDR program is established at time 0 so that only a fraction ($0 < \beta \le 1$) of the land outside the initial urban area $\bar{z}(0)$ may be developed for urban uses. The number of new residents added to the urban area from time 0 to time t is

(8) $$N(t) - N(0) = N(0)\left(\exp(gt) - 1\right)$$

and the urban boundary $\bar{z}(t)$ at time t must satisfy

(9) $$N(0)\bar{L}\left(\exp(gt) - 1\right) = \beta\pi\left(\bar{z}(t)^2 - \bar{z}(0)^2\right)$$

After rearranging terms, we derive the squared urban boundary at time t

(10) $$\bar{z}(t)^2 = \frac{N(0)\bar{L}\left(\exp(gt) - 1\right)}{\beta\pi} + \bar{z}(0)^2 = \frac{\bar{z}(0)^2 \exp(gt)}{\beta} - \frac{(1-\beta)\bar{z}(0)^2}{\beta}$$

The resulting value of $\bar{z}(t)$ will be slightly larger if we omit the second term in equation (10), but we can safely ignore this term if the initial urban area is small relative to the region (i.e., $\pi\bar{z}(0)^2$ is much less than 1) and the PDR program attracts a relatively small fraction of the available land (i.e., $1-\beta$ is near zero). When this holds, $\bar{z}(t)$ can be expressed as

(11) $$\bar{z}(t) = \frac{\bar{z}(0)\exp(gt/2)}{\beta^{1/2}}$$

Note that the price of agricultural land enrolled in the PDR program is only composed of the agricultural returns component, *A/r* (i.e., term (a) in equation (6) or (7)). By comparing the boundaries in equations (4) and (11), we find that the urban boundary must push farther from the central business district in order to satisfy the housing needs of the growing urban population if the PDR program is active (i.e., $\beta < 1$). The land added to the urban area (i.e., between $\bar{z}(t)$ and $\bar{z}(0)$) includes newly developed properties as well as agricultural land protected under the PDR program. The land that remains outside the urban boundary $\bar{z}(t)$ is unprotected agricultural land and agricultural land protected under the PDR program.

Given the new urban boundary, we can use the results of Capozza and Helsley (1989) to derive the prices per unit of developed land within $\bar{z}(t)$

$$(12) \qquad P^d(t,z) = \frac{A}{r} + C + \frac{T}{r\bar{L}}\left(\frac{\bar{z}(0)\exp(gt/2)}{\beta^{1/2}} - z\right) + \frac{T}{r\bar{L}\beta^{1/2}}\left(\frac{g}{2r-g}\right)\bar{z}(0)\exp(gt/2)$$

and unprotected agricultural land outside $\bar{z}(t)$

$$(13) \qquad P^a(t,z) = \frac{A}{r} + \frac{T}{r\bar{L}\beta^{1/2}}\left(\frac{g}{2r-g}\right)\bar{z}(0)\exp\left(gt/2 - r\left(t^* - t\right)\right)$$

under the PDR program. Note that both land prices increase under the PDR program because the future urban rents components (i.e., (d) in equation (6) and (b) in equation (7)) increase. In other words, land is more valuable because the optimal development time is advanced. The PDR program is not assumed to influence the agricultural returns A, the conversion cost C, or the urban accessibility value.

The share of land developed for urban uses β may be endogenously determined under suitable assumptions on the operation of the PDR program. Suppose the local government provides funds B(t) ≥ 0 to purchase development rights on land between time 0 and time t. If only returns on land investments matter to landowners, the landowners will be indifferent between participation in the PDR program and holding the land for later development if the easement payment equals the option value associated with the post-development urban rents (i.e., second term in (13)). In practice, landowners may be willing to sell the easements for less than the option value for several reasons. First, the easement payment provides a source of cash flow that may ease debt constraints. Such constraints have been cited as one significant source of management concern for agricultural landowners. Second, the increased liquidity generated by the easement sale may help landowners with estate planning considerations.

To simplify the problem, we assume the average value of the easement payments equals the option value associated with land developed at the mid-point of the program period

$$(14) \qquad E(t) = \frac{T}{r\bar{L}\beta^{1/2}}\left(\frac{g}{2r-g}\right)\bar{z}(0)\exp\left(t(g-r)/2\right)$$

and the parcels enrolled in the PDR program are assumed to be uniformly distributed outside the urban boundary $\bar{z}(0)$. Our use of the average easement payment (14) to derive the number of land units enrolled in the PDR program (15) does not imply that the easement payments are identical for all parcels protected under the program. If there exists latent heterogeneity in the easement payments, those landowners who receive easement offers greater than their reservation price (i.e., option value) will enroll land in the PDR program. Further, the assumed uniform distribution of enrolled land is not unrealistic. Some PDR agencies purposefully attempt to preserve land in spatially uniform patterns for equity reasons. Also, there is some evidence that even in programs in which non-uniform preservation patterns are preferred by agencies (e.g., clusters of preserved parcels) there is little evidence such patterns are achieved (Lynch and Musser; Nickerson and Bockstael).

The number of land units enrolled in the PDR program is the program expenditure B(t) divided by the average easement payment

$$(15) \qquad \frac{B(t)}{E(t)} = \frac{B(t)r\bar{L}\beta^{1/2}(2r-g)\exp\left(t(r-g)/2\right)}{Tg\bar{z}(0)}$$

Given that the total area in the region is normalized to one, the land enrolled in the PDR program represents the share of all land outside the initial urban area that is now protected from development

$$(16)\qquad (1-\beta)\left(1-\pi\bar{z}(0)^2\right)=\frac{B(t)r\bar{L}\beta^{1/2}(2r-g)\exp\left(t(r-g)/2\right)}{Tg\bar{z}(0)}$$

A spatial equilibrium is achieved at the value of β that satisfies this implicit expression.

Comparative Static Analysis

To evaluate the impact of changes in PDR program expenditures B(t) and other exogenous factors on the share of unprotected agricultural land converted to urban uses, we conduct a comparative static analysis based on the spatial equilibrium condition (16). To simplify this condition, we rearrange terms to derive the following polynomial expression

$$(17)\qquad \eta(\beta)\equiv\beta+\beta^{1/2}\frac{B(t)r\bar{L}(2r-g)\exp\left(t(r-g)/2\right)}{Tg\bar{z}(0)\left(1-\pi\bar{z}(0)^2\right)}-1$$

The spatial equilibrium land-use share is $\hat{\beta}$ such that $\eta(\hat{\beta})=0$. The equilibrium outcome is $\hat{\beta}=1$ if the PDR program is inactive (i.e., B(t) = 0), and $\hat{\beta}<1$ if B(t) > 0.

The differential of the polynomial $\eta(\beta)=0$ with respect to β and B(t) is

$$(18)\qquad d\beta\left[1+\frac{B(t)r\bar{L}(2r-g)\exp\left(t(r-g)/2\right)}{2\beta^{1/2}Tg\bar{z}(0)\left(1-\pi\bar{z}(0)^2\right)}\right]+dB\left[\frac{\beta^{1/2}r\bar{L}(2r-g)\exp\left(t(r-g)/2\right)}{Tg\bar{z}(0)\left(1-\pi\bar{z}(0)^2\right)}\right]=0$$

and the implicit derivative of interest is

$$\text{(19)} \qquad \frac{d\beta}{dB} = -\frac{2\beta r\bar{L}(2r-g)\exp\left(t(r-g)/2\right)}{2\beta^{1/2}Tg\bar{z}(0)\left(1-\pi\bar{z}(0)^2\right)+B(t)r\bar{L}(2r-g)\exp\left(t(r-g)/2\right)} < 0$$

The numerator is unambiguously positive for all $\beta > 0$, and the denominator is strictly positive if the PDR program is active (i.e., $B(t) > 0$) or if there is positive population growth (i.e., $g > 0$). Consequently, an increase in PDR program expenditures decreases the share of land within the urban boundary $\bar{z}(t)$ that is developed for urban uses.

The comparative static effects of the other exogenous variables may be determined in similar fashion, and the signs of the associated derivatives are reported in the second column of Table 1. As expected, an increase in the urban population growth rate (g) increases the share of land developed for urban uses. Also, an increase in the fixed amount of the land good consumed by households ($\bar{L}$) induces sprawl by increasing the urban boundary $\bar{z}(t)$. We assume that marginal changes in $\bar{L}$ at time *t* do not affect the amount of the land good consumed by households existing at time 0 such that $\partial\bar{z}(0)/\partial\bar{L} = 0$ for all $t > 0$. Although we might expect this source of development pressure to increase the share of land converted to urban uses, the change actually has the opposite effect on β. Given that the earning capacity of each unit of land is reduced under lower density development, the price per unit of agricultural land price P^a declines as $\bar{L}$ increases. As such, the PDR program can make smaller easement payments per unit of land E(t) and use the available funds B(t) to protect more farmland. In similar fashion, an increase in the intertemporal discount rate r also decreases the easement payment E(t), attracts more land into the PDR program, and decreases the share of land converted to urban uses. Finally, an increase in the commuting cost T increases land prices, reduces the amount of land that can be protected under the PDR program, and increases the share of land within the urban boundary $\bar{z}(t)$ developed for urban uses.

We can also measure the impact of changes in the exogenous variables on the urban land price $P^d(t,z)$, and these comparative static effects are summarized in the third and fourth columns of Table 1. By the Chain Rule, the derivative of $P^d(t,z)$ with respect to changes in the exogenous variables is composed of direct and indirect effects. The direct effect of the exogenous variable is the partial derivative of $P^d(t,z)$ with respect to the exogenous variable of interest. If the PDR program is active (β < 1), we note that equation (16) implies that the equilibrium value of β is an implicit function of the exogenous variables. The indirect effect is the impact of an increase in the exogenous variable of interest on $P^d(t,z)$ through the share of land available for development (β) if the PDR program is active. For example, the direct and indirect effects of an increase in $\bar{L}$ on $P^d(t,z)$ is

$$(20) \qquad \frac{dP^d(t,z)}{d\bar{L}} = \underbrace{\frac{\partial P^d(t,z)}{\partial \bar{L}}}_{\text{direct}} + \underbrace{\frac{\partial P^d(t,z)}{\partial \beta}\frac{d\beta}{d\bar{L}}}_{\text{indirect}}$$

In each case, the marginal effect of an increase in β on $P^d(t,z)$

$$(21) \qquad \frac{\partial P^d(t,z)}{\partial \beta} = -\frac{T\bar{z}(0)\exp(gt/2)}{\beta^{1/2}\bar{L}(2r-g)} < 0$$

is negative, so the indirect effect and the marginal effect of an increase in the exogenous variable on β have opposing signs. Thus, the direct effect of changes in the exogenous variables is partially mitigated if the program is active. For example, an increase in $\bar{L}$ decreases the urban land price, but the direct effect of this change is partially offset by the positive indirect effect resulting from the increase in β --- fewer land units can be protected under the PDR program due to the higher land price. The exogenous variables also have comparable direct and indirect effects on the price of undeveloped agricultural land $P^a(t,z)$, and the signs on these effects are identical to the urban land price results stated in Table 1.

Empirical Model and Estimation Results

An econometric model is used to account for the impact of PDR programs on the farmland conversion rate over time and across the study area (Maine-ME, New Hampshire-NH, Vermont-VT, Massachusetts-MA, Rhode Island-RI, Connecticut-CT, New York-NY, Pennsylvania-PA, Delaware-DE, and Maryland-MD). The model is specified and estimated for 190 counties in these states for three distinct Census periods, 1982-1987, 1987-1992, 1992-1997. A summary of the land converted to urban uses and preserved under PDR programs in these states is provided in Table 2, the variables and data sources used in this analysis are presented in Table 3, and descriptive statistics appear in Table 4. Figures 1-4 illustrate the level of the farmland preservation effort in the region.

The empirical model for this study will be specified as a linear regression model of the form:

$$Y_{it} = \beta_{1t} + \mathrm{D}_{\mathrm{i}}\beta_{2t} + P_{it}\beta_{3t} + N_{it}\beta_{4t} + X_{it}\beta_{5t} + \varepsilon_{it} \qquad (22)$$

where the dependent variable Y_{it} is the number of farmland acres per 1,000 acres of total land in county $i = 1,...,n$ that was converted from rural to urban uses over the five year period before time t (1987, 1992, 1997). The data are obtained from the National

Resources Inventory (NRI) database and other sources (see Table 3). The explanatory variables in the model include an intercept or constant term and state-specific dummy variables (D_{it}) for each state. The explanatory variables also include a binary variable that indicates PDR activity in each county (P_{it}), a binary variable indicates PDR activity in neighboring contiguous county (N_{it}), and other factors that may influence the conversion of farmland to urban uses (X_{it}).

The Ordinary Least Squares (OLS) estimator is used to estimate the model parameters for the three specified time periods, and the model estimation results are presented in Table 5. The R^2 statistics range from 0.57 to 0.68, suggesting that on average 60 percent of the dependent variable is explained by the specified independent variables. For each time period seven state-specific dummy variables are included in the model, Connecticut, Maine, Maryland, New York, Pennsylvania, New Hampshire and Rhode Island. The results suggest that urbanization varies by state and over time. Some states such as Maine are progressively significant over time. Others such as New Hampshire demonstrate decreasing significance over time, and some states such as Pennsylvania demonstrate mixed results.

For the first estimation period, the parameter estimate suggests that PDRs may have reduced urbanization. During the other two time periods the presence of an active PDR program displays a positive influence on the urban development rate, but these effects are not statistically significant. The neighboring PDR variable is not statistically significant but has a negative sign, which suggests that the presence of active PDR programs does not cause positive spillover effects on neighboring counties. The parameter estimate is larger and more significant in the third time period. In two of the three periods, the natural amenity scale has a positive sign suggesting that the higher the livability of the county the more likely it will be converted from farmland to residential use. The urban influence code is significant and has a negative sign for all three time periods, suggesting that a decrease in the urban influence code (less urban character) decreases the rate of urban land development. The parameter for road miles is positive and significant suggesting that the larger the road infrastructure in a specific county the more likely that land in that county will be converted to urban use. The coefficient on the percent of farmers over 60 is positive and is consistent with *a priori* expectations that older farmers are more likely to sell their farmland for development. Thus, we conclude that farmers' demographics do impact the rate of urbanization. The coefficient for income is positive and significant suggesting that the higher the income level in the county the higher the demand for urban land. Population growth is positive and as expected a population increase moves land out of agriculture and into housing. Finally, as the percent of farmers in the county who work more than 200 days off-farm increases, the rate of conversion of farmland from rural to urban use increases.

Conclusions

This study examines the impact of PDR programs on the rate of farmland conversion in the Northeast United States. Data for 190 counties across four Census periods (1982-97) is used to specify and estimate an econometric model. The results of the model strongly suggest that PDR programs may have slowed or prevented farmland conversion during the first sub-sample period (1982 to 1987). However, the results suggest that PDR programs may not have curbed the rate of urban development during the second and third sub-sample periods. For all time periods that presence of an active PDR program in a neighboring county does not result in positive spillover effects. In addition, the results indicate that other variables included in the model such as income exert a significant influence on the rate of farmland conversion.

Although the statistical evidence of direct PDR program impact is mixed, it is important to note that there are other potential benefits from these farmland preservation programs. First, farmers can benefits from the PDR programs as they are allowed to continue farming while their land is enrolled in a PDR program. As well, the lump-sum easement payments may be used to make capital investments or to shift the operation into other enterprises that help to sustain the farming business for future generations. Finally, many studies have shown that there are positive amenity benefits (e.g., open space, scenic views) associated with the preserved land, and residents of a given area may be willing to pay for these benefits (and support the preservation effort) even if the PDR programs do not have a substantial impact on the rate of urban development.

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Table 1. Comparative static effects on shares of developed land and urban land price

Exogenous variables	Share of developed land, (β)	Direct effect on the urban land price, P^d	Indirect effect on the urban land price, P^d
PDR expenditures, *B(t)*	-	None	+
Population growth, *g*	+	+	-
Discount rate, *r*	-	-	+
Land per household, $\overline{L}$	-	-	+
Commuting cost, *T*	+	+	-

Note: see equations (20) and (21) and the surrounding discussion for definitions and interpretation of the direct and indirect effects.

Table 2. Summary of Development and PDR Preservation Activity in the Study Area

State	Year of First PDR Easement Acquisition (state or local program)	Farmland Acres Preserved (1982-1997)	Farmland Acres Converted (1982-1997)
Connecticut	1979	23,209	23,800
Delaware	1994	16,406	39,100
Maryland	1980	202,051	166,200
Massachusetts	1980	34,317	65,100
New Hampshire	1981	30,733	24,500
New York	1974	8,091	247,500
Pennsylvania	1982	120,720	508,100
Rhode Island	1985	2,901	6,200
Vermont	1988	63,031	21,600

Table 3: Definition of Major Explanatory Variables

Variable	**Description**
Farmland Converted	1000 acres of land converted per county
Active PDR program	Binary variable that equals 1 if the local PDR program enrolled new parcels during the sample period. *Source: county and state PDR program data*
Neighboring PDR program	Binary variable that equals 1 if a neighboring county had an active PDR program during the same period. *Source: county and state PDR program data*
Road miles	Thousand of miles of improved roads in the county in 1997. *Source: Department of Transportation*
Urban influence code	Integer values 1-9: 1 equals a metro county with at least 1 million people and 9 equals a non-metro county with no towns larger than 2,500 people. Source: USDA
Percent of farmers older than 60	Percent of farmers in the county who are 60 years of age or older *Source:1997 Census of Agriculture*
Farmers working 200+ days off-farm	Percent of farmers in the county who work 200 or more days at an off-farm (1=1 percent of farmers) *Source: 1997 census of Agriculture*
Income	Thousand of U.S. dollars *Source: Census of Population*
Government payments per acre	U.S. dollars per acre Source: *1997 Census of Agriculture*
Natural amenity scale	Composite scale of livability factors (higher values indicate that the county is more attractive place to live) *Source: USDA*
Population growth rate	Percent change in county population form 1980 to 2000 (1.00=1 percent change) *Source: 1980 and 2000 Census of Population*

Table 4: Descriptive Statistics of Data

Variable	Mean	Standard Deviation	Minimum	Maximum
New York Dummy	0.27	0.45	0	1
Maine Dummy	0.68	0.25	0	1
Rhode Island Dummy	0.32	0.18	0	1
Connecticut Dummy	0.42	0.21	0	1
New Hampshire Dummy	0.05	0.22	0	1
Massachusetts Dummy	0.07	0.25	0	1
Maryland Dummy	0.12	0.32	0	1
Pennsylvania Dummy	0.33	0.47	0	1
Conversion Rate				
(1982-1987)	9.21	10.23	0	52.54
(1987-1992)	12.27	12.18	0	56.14
(1992-1997)	17.79	17.99	0.32	96.23
Active PDR Program				
(1982-1987)	0.25	0.44	0	1
(1987-1992)	0.42	0.50	0	1
(1992-1997)	0.57	0.50	0	1
Neighboring PDR Programs				
(1982-1987)	0.43	0.50	0	1
(1987-1992)	0.73	0.45	0	1
(1992-1997)	0.86	0.34	0	1
Natural Amenity Scale	-0.13	1.00	-2.94	2.89
Urban Influence Code	3.642	2.43	1.00	9.00
Road Miles	1758.99	1064.95	173.06	7308.62
Percent of farmers over 60 years				
(1982-1987)	0.34	0.05	0.17	0.59
(1987-1992)	0.35	0.05	0.18	0.46
(1992-1997)	0.35	0.05	0.19	0.47
Median Household Income	30267	7184	19195	54348
Population Growth Rate	15.22	23.20	-16.73	153.42
Farmers working 200+ days off-farm				
(1982-1987)	0.34	0.68	0.16	0.57
(1987-1992)	0.31	0.59	0.17	0.46
(1992-1997)	0.34	0.63	0.18	0.57

Table 5: Parameter Estimates (OLS)

Explanatory Variable	1982-1987	1987-1992	1992-1997
Intercept	-12.83 (-2.18)	-18.35 (-2.38)	-37.13 (-3.37)
Connecticut dummy	-2.33 (-0.57)	-8.27 (-1.89)	-14.68 (-2.57)
Maine dummy	9.55 (2.78)	10.63 (3.09)	19.29 (4.53)
Maryland dummy	-0.91 (-0.27)	-6.80 (-2.22)	9.66 2.39
New York dummy	-7.44 (-3.35)	-2.41 (-0.75)	1.71 (0.44)
Pennsylvania dummy	-3.02 (-1.41)	9.31 (3.57)	-6.42 (-1.19)
New Hampshire dummy	6.29 (2.12)	0.67 (0.19)	-0.76 (-0.16)
Rhode Island dummy	2.11 (0.56)	8.38 (1.90)	-6.75 (-1.17)
Active PDR program	-3.30 (-1.32)	2.14 (1.19)	2.40 (1.10)
Neighboring PDR program	-1.58 (-0.96)	-1.12 (-0.51)	-3.86 (-1.42)
Natural Amenity Scale	0.97 (1.45)	0.41 (0.51)	-0.74 (-0.71)
Urban influence code	-0.46 (-1.72)	-0.79 (-2.38)	-1.07 (-2.46)
Road miles	1.62e-04 (2.58)	1.57e-04 (2.01)	3.73e-04 (3.67)
Percent of farmers over 60 years	19.82 (1.77)	34.22 (2.28)	17.28 (0.91)
Median Household income	5.45e-05 (4.31)	4.187e-05 (2.63)	1.130e-04 (5.60)
Population Growth rate	0.05 (1.79)	0.13 (3.28)	0.91 (1.89)
Farmers working 200+ days off-farm	2.41 (0.29)	0.013 (0.01)	19.23 (1.35)
R^2 *Adjusted* R^2	0.61 0.57	0.57 0.53	0.68 0.65

Numbers in parentheses are asymptotic T-ratios.

Figure 1: Timing of First Acquisition of Development Rights in PDR Programs
(Study area includes VT, NH, MA, RI, CT, NY, PA, MD, DE)

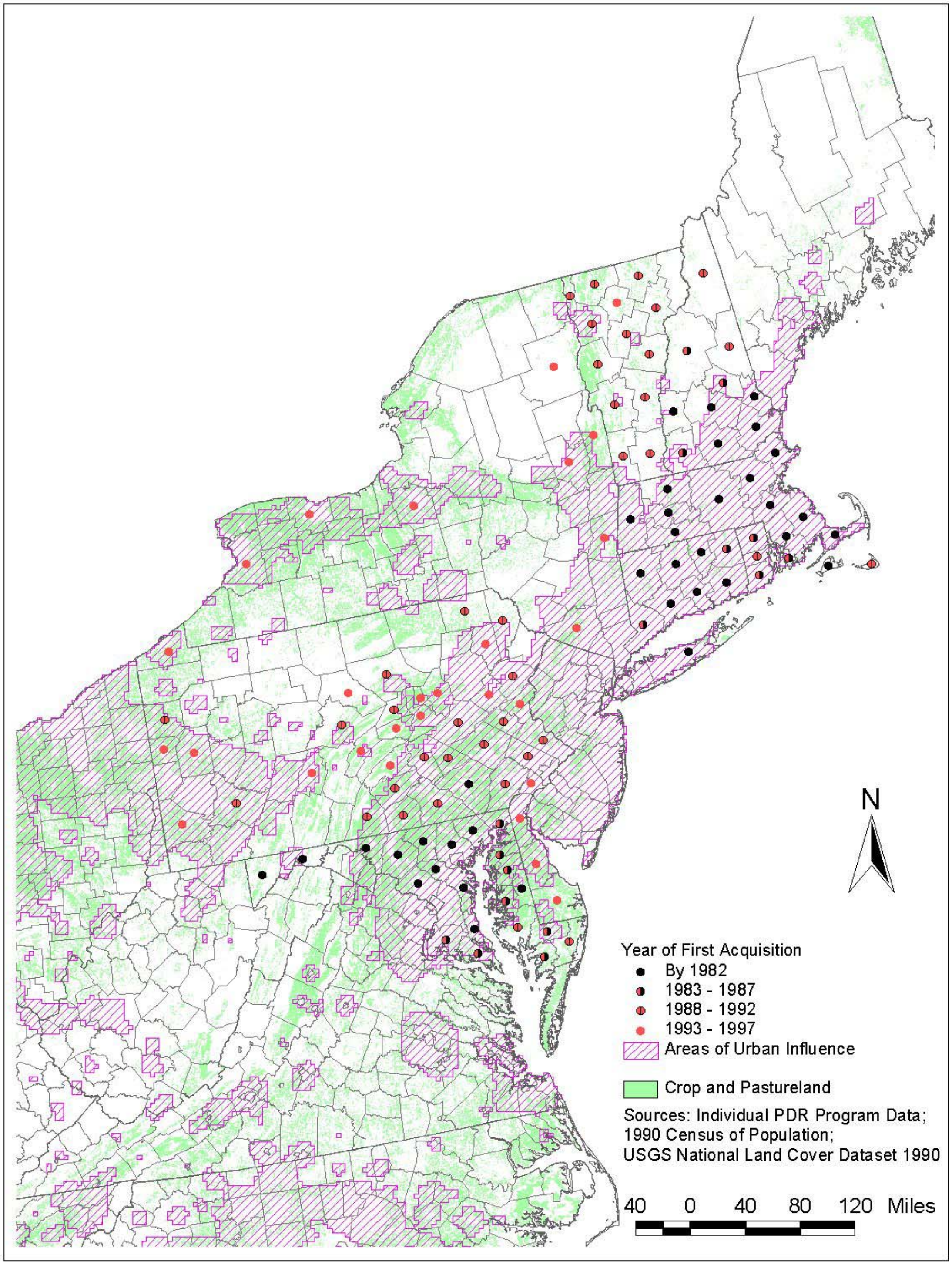

Figure 2: Acres Preserved in PDR Programs by 1997
(Study area includes VT, NH, MA, RI, CT, NY, PA, MD, DE)

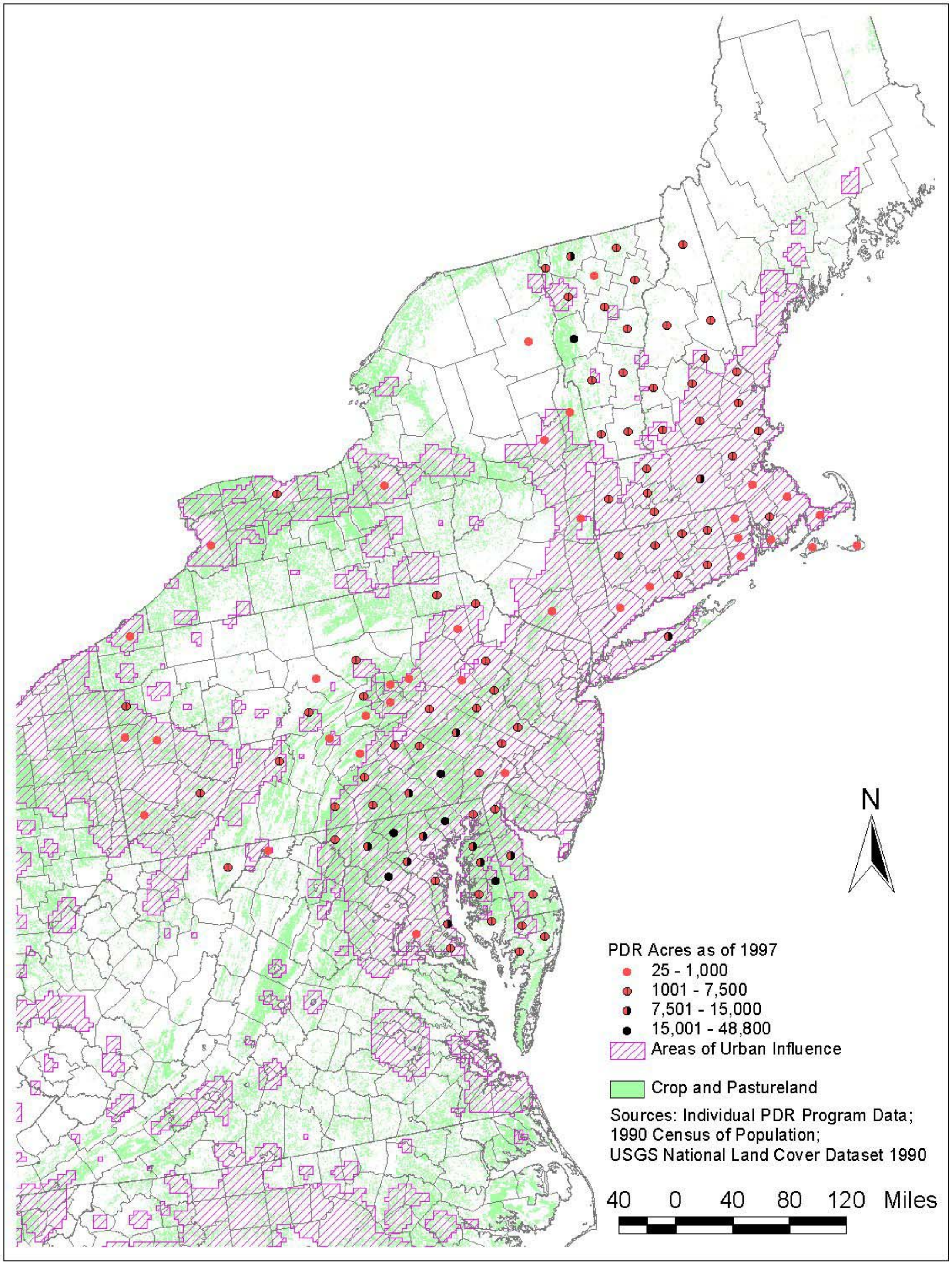

Figure 3: Percent of County's 1982 Farmland Preserved by 1997
(Study area includes VT, NH, MA, RI, CT, NY, PA, MD, DE)

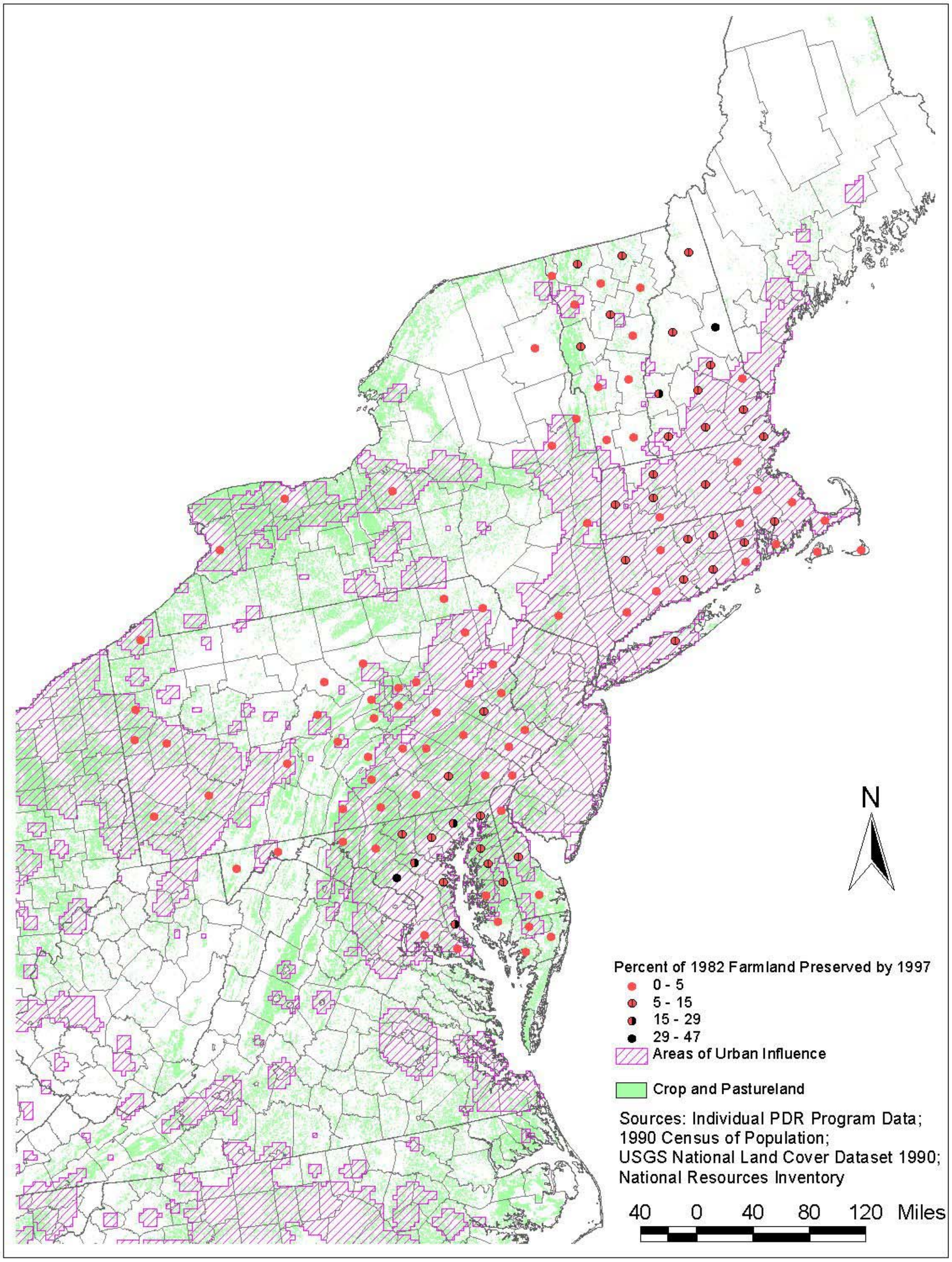

Figure 4: Ratio of Farmland Converted to Farmland Preserved during 1982 – 1997
(Study area includes VT, NH, MA, RI, CT, NY, PA, MD, DE)