Invited Presentation

The Optimal Quantity of Land in Agriculture[1]

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Introduction

In 1952, when T. W. Schultz declared that land had lost its place as a unique factor of production, he was certainly right about U.S. agriculture. For the almost four decades since Schultz's prophetic analysis, output of U.S. agriculture has increased steadily while the exploited land base has slightly decreased. Land has not proved a constraint to production. Many varieties of technical change have kept the marginal product of land from falling, despite its increasingly intensive use.

Land's decline as a factor of production for agriculture does not mean it has declined in economic importance. The growth of urban population, incomes and leisure have enhanced land as a source of aesthetic, visual, environmental and recreational services. A century ago, when a large proportion of the population lived on farms, the open spaces and amenity flows from land were part of the everyday experience of most people. However, the demand for the amenities from land by people who do not live on land can be expected to grow over time. This is not the same as saying that the demand for preserving farmland is growing over time, as I shall argue below. Rather, it is an argument for providing the services from open space, undeveloped natural resources. Agricultural land provides some of these services, but not all.

In many areas, the decline in the importance of land as a factor of production is reflected in a substantial decline in the number of farms and acres of farmland. The evidence on this decline in farmland is well-known but bears summary. Over the period 1950–1985, for the U.S., farmland declined at an average annual rate of .57 percent. In the East the rate of decline was greater. For example, in Maryland, the rate of decline was 1.48 percent, in Virginia it was 1.64 percent, and in New Jersey 1.95 percent.[2] Indeed, over this period only two states in the U.S. (Nevada and Idaho) showed an increase in the amount of land in farms.[3]

It would seem logical that the declining economic importance of land in agriculture would lead to a decline in the quantity of land in agriculture, as we have observed. It would also seem that the decline in farmland would be efficient, given the changing marginal social values of its uses. Yet the movement of land from farming to other uses is viewed more frequently with concern than indifference. This concern has spawned a variety of research projects on disappearing farmland. More important than the research, public policies have been implemented or defended in the name of saving farmland. Policies ranging from the outright purchase of farmland to the granting of tax breaks are typically designed to preserve farmland.

Are we doing too much or too little to preserve farmland? This is a question of the efficient use of resources. Like any problem in the efficient use of resources, there is in principle an optimization problem which implies the efficient quantity of land in agriculture. This paper attempts to place the debate on the preservation of farmland into the framework of a simple model of optimal land use. It is clearly not the first paper to address this problem. Both Fischel and Gardner have

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[2] These percent changes are based on the parameter estimates from the model log (farm acres) = $b_0 + b_1$ year, where farm acres come from *Farm Real Estate: Historical Series Data: 1950–1986* (USDA).

[3] From the USDA publication: *Farm Real Estate* (op. cit.)

forcefully argued the case against preservation of farmland. But the goal of this paper is to give some insight into the determinants of the optimal quantity of farmland. As the debate stands now, we tend to focus on the issue of preserving farmland, not how much to preserve or what we get from its preservation.

The Prescriptions for Land in Agriculture

Both government intervention and the focusing of research on the declining farmland suggest a problem worthy of attention. There are several different perspectives on declining farmland. Research in environmental and resource economics suggests that the amount of land in agriculture is probably too great because of the externalities from many cultivation practices and because of subsidies from farm support programs. This partial equilibrium view ignores the potential for open space externalities from farmland. If the environmental view is expressed at all in policy, it is in the Conservation Reserve Program, which is designed to withdraw fragile lands from active cultivation (but not from agriculture).

A second perspective arises from the question of the adequacy of agricultural land in general. This question, which gave rise to the National Agricultural Lands study, asks whether in the long run our agricultural land base is sufficient to meet the demand for agricultural products. The question was formulated at a time when agricultural exports had risen dramatically and these increases were forecast to continue. (For a summary of this research, see the volume edited by Crosson.) While the conclusions of this research were not unanimous, there was some agreement on the question of the adequacy of agricultural lands. Crosson summarizes the evidence of a symposium on agricultural lands in terms of the economic costs of production:

> "[M]eeting demands for food and fiber over the next several decades will put sufficient pressure on the nation's land and other agricultural resources to increase the economic and environmental costs of agricultural production . . . [B]ut it does not now appear to pose a broad threat to the national welfare or to those abroad . . ." (p. 21).

This conclusion is a forward-looking confirmation of Schultz's hypothesis.

A third perspective on land use comes from investigation of land use in urban areas. This type of research tends to be positive, in that it investigates the various local policy instruments that are used to keep land in agriculture. These local instruments are quite varied. Differential tax rates and circuit-breaker laws favor the agricultural use of land. The purchase of development rights and the prospect of future programs to purchase development rights increase the demand for farmland and tend to keep land in agriculture, all else equal. There has been limited normative research on local policy instruments, perhaps more on the transfer of development rights than on the tax-break measures. In summarizing research on the transfer and preservation of development rights, Pitt et al. recognize the limited rationale for intervening in agricultural land markets. "Economic efficiency arguments have been used to reject all of the goals of agricultural land preservation except the provision of open space and environmental amenities" (p. 3). But other arguments have been made for the preservation of agricultural land. For example, in the document, "Use Value Assessment of Agricultural Land in the Northeast," it is argued that in addition to the preservation of environmental amenities such as habitat and watershed protection, agricultural land improves the economic base and limits the dependence on imported food (p. 4).

The Costs and Benefits of Preserving Farmland

If preserving agricultural land were costless, then the absence of consensus about optimal strategies would be of little concern. But preserving agricultural land imposes several kinds of costs on society. The most obvious expenditures are the payments from the public to farmers to purchase land outright or the development rights of land. These are not economic costs—just transfer payments. However, there are real payments from taxpayers to farmers. If the supply of land for nonfarm uses is restricted, the price paid by businesses and households will rise, imposing a resource cost on them.

The real issue is the opportunity cost of farmland. What services can it provide and what is its best use? If the only services produced by land are efficiently transacted by markets, then the market will determine the best use of land. But there are services from land which cannot be efficiently traded by the markets. The flow of these services is greater when land is in farms than when land is built up, but perhaps less than if land were in other uses, such as public parks and forests. And so the question of how much land should be in agriculture is not qualitative, but quantitative. It depends on the value of the external economies and diseconomies farmland produces as well as the flow of services which requires direct access.

The introduction of nonmarket benefits into the debate about preserving farmland is critical. The traditional view has been expressed by Gardner: the only reason (other than distributional motives) for wanting to retain farmland is the aesthetic benefits of farmland. There is evidence (see papers by Bergstrom, Dillman and Stoll and by Halstead) that people *are* willing to pay for preserving farmland. But precisely what is it that they get, and are there institutional arrangements which would give the public more for its money?

When the public acquires the development rights to agricultural land, it gets a variety of services. There are the usual amenities for people who prefer seeing farmland to homes or shopping centers. Depending on the potential for development, the preservation of farmland may provide a lower environmental loading than alternative uses. There may be less congestion in the area where development has been averted, but this is distributional since it means greater congestion elsewhere. In some cases, depending on the intensity of the farming practices and the nature of the local ecology, preserving farmland provides habitat for wildlife.

What the public does not get when farmland is preserved is the active use of the land. There are many kinds of outdoor recreation which can be supported by land in farms if the public had access to the lands. Camping, hiking, picnicking and other types of outdoor recreation are all activities for which there is growing demand not met by the preservation of farmland.

Because the preservation of farmland only provides a subset of the public land services demanded by the public, other kinds of public land are needed. This suggests a choice in strategies between preserving farmland and acquiring land for the public which can provide the full set of services that are available when the public owns the land rather than its development rights.

A Simple Model of Land Use

The question of preserving farmland is quantitative: what is the optimal quantity of farmland? This question differs from the kinds of analysis found in Crosson et al. where the focus is on the adequacy of the land base for agricultural production. I develop a model of optimal land use which addresses this question. This model will be useful if it allows us to compare optimal land use changes with actual use land changes. This model is designed for considering land use changes in a mixed agricultural and suburban environment. Land is neither wholly agricultural, as it would be in central Nebraska, nor wholly urban as it would be in the heart of Manhattan. It is perhaps useful to think of this model as applicable to many regions in the eastern United States, where metropolitan areas mingle with rural areas.

The problem of optimal land use can be viewed as one of maximizing the social returns to land in its different uses. Consider three kinds of land use: agricultural, park and public, and urban. As with any classifying scheme, this one is arbitrary. The park and public land use is meant to define open access undeveloped land: state, regional, and national parks and forests, wildlife refuges, game management areas—that is, the kind of land that is available to the public in a relatively natural way for outdoor recreation and aesthetic ends and which is available on an open-access basis. Urban land is any land which is built up so that it is not readily used for agriculture or by the public for outdoor amenities. Define the social benefits to the users as a separable function of the land in each use. Then the total benefits are the sum of the individual land use benefits:

$$(1) \qquad B^a(L_a) + B^p(L_p) + B^u(L_u)$$

where a = agriculture, p = public land, u = urban, and L_i = quantity of land in use i and $B^i(L_i)$ is the social value (in dollars) of land in use i. These returns are the standard measures of the social value of employing resources: the social willingness to pay (or to accept compensation) for the services of the resource. These values are concave functions of the amount of land. In some cases, the marginal social return to farmland use is approximately the value of the marginal product of an acre in production. In the presence of external effects from agriculture, the costs of these externalities would have to be subtracted from the value of the marginal product. In the case of crops in commodity programs, the value of the marginal product would have to be adjusted to reflect the excess of commodity price above social marginal value. The return to park land is the willingness to pay for the services of land as a public natural resource. The return to urban land use is the total willingness to pay for such use, best approximated by the rental value of built-up land.

These returns are to be maximized subject to the constraint on the total amount of land available:

$$(2) \qquad L_a + L_p + L_u = L.$$

This aggregation of all land into three categories requires a suspension of disbelief. Some of the problems of aggregation are discussed below. The optimal quantity of land is derived from maximizing

$$(3) \quad \max_{L_a, L_p, L_u} B^a(L_a) + B^p(L_p) + B^u(L_u) + \lambda(L - L_a - L_p - L_u)$$

yielding the conditions

$$(4) \quad \begin{cases} B^a_1(L_a) = \lambda \\ B^p_1(L_p) = \lambda \\ B^u_1(L_u) = \lambda \end{cases}$$

where $B^i_1 = \partial B^i/\partial L_i$ (and for future reference, $B^i_{11} = \partial^2 B^i/\partial L_i^2$). These conditions require equality of the marginal contribution of land to the social returns of the i^{th} land use.

Without specific functional forms we cannot solve for the land uses L_a, L_p, L_u. But we can observe how they change over time in response to exogenous change. Suppose that the social returns to land uses evolve over time:

$$B^i(L_i) = B^i(L_i, t).$$

Then we can assess the changes in optimal land use patterns over time. The real forces behind time in the benefit function are myriad. Underlying changes in the demands for goods and services imply changes in the social returns to different land uses. Population increases and growth in household income may lead to such demand changes. Technical changes in agricultural production for example can simultaneously increase the productivity of land in producing agricultural commodities and lower the price of agricultural products, making the temporal evolution of $B^a(L_a, t)$ ambiguous.

Recognizing the dependence of the system on t allows a measure of comparative statics. Differentiating with respect to t yields

$$(5) \quad \begin{cases} B^a_{11} \cdot \dot{L}_a + \dot{B}^a_1 = \dot{\lambda} \\ B^p_{11} \cdot \dot{L}_p + \dot{B}^p_1 = \dot{\lambda} \\ B^u_{11} \cdot \dot{L}_u + \dot{B}^u_1 = \dot{\lambda} \\ \dot{L}_a + \dot{L}_p + \dot{L}_u = 0 \end{cases}.$$

The terms $\dot{B}^i_1$ are the arithmetic growth rates of marginal value *with land held constant,* not the full arithmetic growth rates.[4] (That is, $\dot{B}^i_1$ is a partial derivative: $\partial B^i_1/\partial L_i$.) They may be thought of as the shift in demand with $B^i_{11}\dot{L}_i$ being the movement along the demand curve. If the quantity of land has no impact on the marginal social value ($B^i_{11} = 0$), then $\dot{B}^i_1$ is the full arithmetic growth rate. This would not be a bad assumption for agriculture. For empirical purposes, one could calculate $\dot{B}^i_1$ by subtracting $B^i_{11}\dot{L}_i$ from the rate of change in the marginal social value of land. Note that if the market were functioning perfectly, we would observe $\dot{B}^i_1 + B^i_{11}\dot{L}_i$ as the rental rate changes, not $\dot{B}^i_1$. The observed change corresponds to $\dot{B}^i_1$ if $B^i_{11} = 0$ (a perfectly elastic marginal value schedule) or $\dot{L}_1 = 0$ (a perfectly inelastic supply schedule). Hence $\dot{B}^i_1$ is smaller than the total change when $\dot{L}_i$ is negative and larger than the total change when $\dot{L}_i$ is positive.

The expressions in (5) involve arithmetic growth in the social value and quantities of land. The system (5) can be expressed partially in terms of percent changes:

$$(6) \quad \begin{cases} (B^a_{11}/B^a_1)\dot{L}_a + G_{m_a} = G_\lambda \\ (B^p_{11}/B^p_1)\dot{L}_p + G_{m_p} = G_\lambda \\ (B^u_{11}/B^u_1)\dot{L}_u + G_{m_u} = G_\lambda \end{cases}$$

where

$G_{m_i} = \dot{B}^i_1/B^i_{11}$ = percent growth rate in social marginal value of land use i with land held constant.

The G_{m_i} are simply the percent shifts in the marginal social value function for land with land held constant.

This system can be solved for the growth in land use:

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[4] Jim Shortle and Wes Musser corrected this error in an earlier draft.

$$(7)\quad \begin{bmatrix} \dot{L}_a \\ \dot{L}_p \\ \dot{L}_u \\ G_\lambda \end{bmatrix} = -\Delta^{-1} \begin{bmatrix} \Delta\theta_a - \theta_a^2 & -\theta_a\theta_p & -\theta_a\theta_u & -\theta_a \\ \cdot & \Delta\theta_p - \theta_p^2 & -\theta_p\theta_u & -\theta_p \\ \cdot & \cdot & \Delta\theta_u - \theta_u^2 & -\theta_u \\ \cdot & \cdot & \cdot & 1 \end{bmatrix} \begin{bmatrix} G_{m_a} \\ G_{m_p} \\ G_{m_u} \\ 0 \end{bmatrix}$$

where $\theta_i = B_l^i/B_{ll}^i < 0$ and $\Delta = \Sigma\theta_i$, $i = a,p,u$, $\Delta < 0$. The common coin of land use discussions is percent change. With some manipulation one can solve for the individual land use growth rates.[5] For example, the growth rate in agricultural land is

$$(8)\quad G_{L_a} = \left[-(r_{ap}\beta_p + r_{au}\beta_u)\frac{G_{m_a}}{\gamma_a} + r_{ap}\beta_p \frac{G_{m_p}}{\gamma_a} + r_{au}\beta_u \frac{G_{m_u}}{\gamma_a} \right]$$

where

$G_{L_a} = \dot{L}_a/L_a$ = percent growth rate in agricultural land

$r_{ij} = L_j/L_i$ ratio of land in use j to land in use i

e.g.,

$r_{ap} = L_p/L_a$ = land in public use/land in agriculture

$\beta_i = [\partial \log B_l^i/\partial \log L_i]^{-1}$ $\quad i = a,p,u$

= reciprocal of elasticity of marginal social value product

$$\gamma_a = 1 + r_{ap}\frac{\beta_p}{\beta_a} + r_{au}\frac{\beta_u}{\beta_a}.$$

By analogy, the solution for G_{Lp} is

$$G_{Lp} = \left(-(r_{pa}\beta_a + r_{pu}\beta_u)\frac{G_{m_p}}{\gamma_p} + r_{pa}\beta_a \frac{G_{m_a}}{\gamma_p} + r_{pu}\beta_u \frac{G_{m_u}}{\gamma_p} \right)$$

and similarly for G_{Lu}.

The components of the calculation of the growth rate in land uses are the relative proportions of land in different uses, the elasticities of the marginal social value functions and the land-constant growth rate in the marginal social values. The higher the land in agriculture, relative to other uses, the lower the value of r_{ap} and r_{au} and the less the influence of other elasticities of marginal products. All else equal, increases in G_{m_a} increase the growth rate of agricultural land, while increases in the other demand shifts $[G_{m_u}, G_{m_p}]$ decrease the growth in agricultural land. The elasticities of the social marginal products of land (or their reciprocals, β_i) are negative, although in some interesting and realistic cases they may be zero (and their reciprocals undefined). Further, $\gamma_a > 0$, because $\beta_i/\beta_j > 0$ and $r_{ij} > 0$. G_{La} (or any other land use growth rate) may be positive even when its rental growth rate (G_{m_a}) is zero.

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[5] The derivation of (8) is as follows. First, multiply through by the vector on the right-hand side and solve for $\dot{L}_a$:

$$\text{(i)}\quad \dot{L}_a = -\Delta^{-1}[(\Delta\theta_a - \theta_a^2)G_{m_a} - \theta_a\theta_p G_{m_p} - \theta_a\theta_u G_{m_u}]$$
$$= -\left(\frac{\Delta\theta_a - \theta_a^2}{\Delta}\right)G_{m_a} - \frac{\theta_a\theta_p}{\Delta}G_{m_p} - \frac{\theta_a\theta_u}{\Delta}G_{m_u}$$

Do the arithmetic on $\Delta\theta_a - \theta_a^2$:

$$\Delta\theta_a - \theta_a^2 = (\theta_a + \theta_p + \theta_u)\theta_a - \theta_a^2$$
$$= \theta_a\theta_p + \theta_a\theta_u$$

So that

$$\text{(ii)}\quad \frac{\Delta\theta_a - \theta_a^2}{\Delta} = \frac{\frac{B_l^a}{B_{ll}^a}\left(\frac{B_l^p}{B_{ll}^p} + \frac{B_l^u}{B_{ll}^u}\right)}{\frac{B_l^a}{B_{ll}^a} + \frac{B_l^p}{B_{ll}^p} + \frac{B_l^u}{B_{ll}^u}}$$

$$= \frac{\left(\frac{B_l^p}{B_{ll}^p} + \frac{B_l^u}{B_{ll}^u}\right)}{\frac{B_{ll}^a}{B_l^a}\left(\frac{B_l^a}{B_{ll}^a} + \frac{B_l^p}{B_{ll}^p} + \frac{B_l^u}{B_{ll}^u}\right)}$$

Divide both sides of (i) by L_a to convert the left-hand side to percent change. Then (ii) becomes

$$\frac{1}{L_a}\frac{\Delta\theta_a - \theta_a^2}{\Delta} = \frac{\left(\frac{B_l^p}{B_{ll}^p} + \frac{B_l^u}{B_{ll}^u}\right)}{\frac{L_a B_{ll}^a}{B_l^a}\left(\frac{B_l^a}{B_{ll}^a} + \frac{B_l^p}{B_{ll}^p} + \frac{B_l^u}{B_{ll}^u}\right)}$$
$$= \frac{\theta_p\theta_u}{B_a^{-1}(\Sigma\theta_i)}$$

Note that by definition

$$L_i\beta_i = \theta_i$$

so

$$\frac{1}{L_a}\frac{\Delta\theta_a - \theta_a^2}{\Delta} = \frac{L_p\beta_p + L_u\beta_u}{B_a^{-1}(\Sigma L_i B_i)}$$

Divide the denominator and the numerator by L_a:

$$\frac{1}{L_a}\frac{\Delta\theta_a - \theta_a^2}{\Delta} = \frac{(L_p/L_a)\beta_p + (L_u/L_a)\beta_u}{B_a^{-1}(\Sigma(L_i/L_a)B_i)}$$

and let $r_{ai} = L_i/L_a$ so

$$\frac{1}{L_a}\frac{\Delta\theta_a - \theta_a^2}{\Delta} = \frac{r_{ap}\beta_p + r_{au}\beta_u}{1 + r_{ap}\beta_p/\beta_a + r_{au}\beta_u/\beta_a}$$

The other terms work out analogously.

Making the Model Work

In this section I use the formula for the rates of change in "optimal" land use to calculate these rates of change. The rates of change can be calculated with nine parameters. In the following, I fix these parameters and use them to compute my estimates of the optimal rates of change of agricultural land use. These optimal rates can then be compared with the observed rate.

There are three kinds of parameters:

(i) Elasticities of social marginal products: β_i^{-1}, i = a,p,u. These elasticities show the percent change in social marginal product with a percent change in land use. My approach to specifying them is to suppose that the average social product of land in use i is given by the following function:

$$(9) \qquad B^i(L_i)/L_i = \alpha_i L_i^{b_i} \quad i = a,p,u$$

where α_i may depend on many variables, but b_i is assumed approximately constant. The elasticities are

$$(10) \qquad \partial \ln B_i^i/\partial \ln L_i = b_i$$

Practically, the b_i are in the negative unit interval. Positive b_i implies increasing marginal returns to land use, while $b_i < -1$ implies negative marginal products to land. For agriculture, $b_a = 0$ is a reasonable assumption. Simply add fixed bundles of inputs to land to increase product. For the other uses (urban and public), it is reasonable to believe a value of b_i closer to $-.5$ or less, because land has declining value. Different values of b_i will be experimented with. If there are external effects which are proportional to the benefits of land use, they will not affect the correct choice of b_i.

(ii) Ratios of different land uses; r_{ij}, i,j = a,p,u. These are the ratios of optimal land uses, but we will have to be satisfied with actual land uses. The figures for Maryland were obtained from several persons at the Economic Research Service.[6] Although there are six values for r_{ij}, i,j = a,p,u, only two are needed because

$$r_{ij} = L_j/L_i = 1/r_{ij}$$

and

$$r_{ij}/r_{ik} = (L_j/L_i)/(L_k/L_i) = L_j/L_k = r_{kj}.$$

[6] I thank Ralph Heimlich and Art Dougherty for help with these numbers.

(iii) The rates of change in the land-constant social marginal products of land: G_{m_i}, i = a,p,u. These are the changes in shadow values of different uses. They deviate from market rental rates to the extent that there are externalities or government intervention in market forces. First consider agriculture. Suppose that the profit function for agriculture is given by

$$\Pi(p, w, t, L_a) = \max_x\{pf(x, t, L_a) - w \cdot x\}$$

when x is an input vector, w the associated price vector, p output price and the production function with t being a proxy for technical change. The profit function becomes $\Pi(p(t), w(t), t, L_a)$ as exogenous forces change input and output prices. The marginal social value of land is

$$\Pi_{L_a} = p(t)f_{L_a}(x(w(t), p(t), t), L_a)$$

and the growth rate in Π_{L_a} with L_a held constant is

$$G_{m_a} = \dot{p}/p + \frac{\partial f_{L_a}/\partial x(x_w\dot{w} + x_p\dot{p}) + \partial f_{L_a}/\partial t}{f_{L_a}}$$

The elements of G_{m_a} are observable: $\dot{p}/p$ is the rate of price change for agricultural output; the second term on the right-hand side of G_{m_a} is the combined effect of changes in input prices and technical change, holding L_a constant. Further, $\dot{\Pi}_{L_a}/\Pi_{L_a}$ is also observable as the rate of change in rents for agriculture, and when the yield per acre is independent of the number of acres, $\dot{\Pi}_{L_a}/\Pi_{L_a}$ equals G_{m_a}. But the market is imperfect in several ways. First there are various kinds of subsidies to agriculture, as well as production controls. Second, there are both external economies and diseconomies which are not reflected in market price. It is hard to determine on balance where the biggest effect is. The subsidies and production controls tend to offset one another.

The rate of change of the marginal social value of the public land is the most difficult. This number must come from the work on the value of nonmarket resources. This literature is quite site-specific. Further, it generally fails to address how these values can be expected to change over time. I assume that the income elasticity of the demand for the nonmarket services is equal to one, and that benefits from public lands are proportional to population. Hence the marginal social value increases at the rate of population increase plus per capita income increase.

For the urban use, the extent of intervention in the market and the pervasiveness of externalities are incalculable. Recall that from the conditions of equation (5)

$$dB_1^u/dt = \dot{\lambda} = B_{11}^u \dot{L}_u + \dot{B}_1^u$$

or

$$\frac{dB_1^u/dt}{B_1^u} = \frac{B_{11}^u}{B_1^u}\dot{L}_u + \frac{\dot{B}_1^u}{B_1^u} = \frac{B_{11}^u}{B_1^u}\dot{L}_u + G_{m_u}$$

The left-hand side would be the observed rate of change in rents, and the rate of change in the marginal social value of public land if the market were efficient. But what we need for the computations is the exogenous component, G_{m_u}. This will be greater than the observed rental rate changes in an efficient market because B_{11}^u/B_1^u is negative (the rate of movement down the demand curve) and $\dot{L}_u$ is positive. I use figures for G_{m_u} which exceed rental rate or price increases.

Table 1 shows some results for various values of parameters. These results provide a stylized model for the state of Maryland.

The parameters in Table 1 are not based on actual numbers. But they are thought to be reasonable. Within the range of reasonable parameters, the decline in agricultural land use ranges from 4.2 percent to .098 percent. In general, one can see that the optimal land in agriculture is declining.

It is more interesting to pick out particular groupings of parameters which are more closely connected with the historical data. One data series which has become available recently contains an exhaustive set of categories by major land use, by year and by state. The advantage of this series is that it allows the construction of observations which conform with the model. This series allows the construction of the r_{ij}'s which conform with historic land use practices. From this series, I calculate three sets of ratios of land use, based on the mean of the land uses from 1945 to 1984. The ratios differ depending on the inclusion of an "other" category and depending on whether nongrazing forestland is included in agriculture or public land. Table 2 presents some variations on parameters drawn from historic data series.

In Table 2 the ratios of land use are based on data available through ERS. In scenario 1, nongrazing forestland and other land is assigned to the public domain. In scenario 2, only parkland is assigned to the public domain, while forestland is assigned to agriculture. In scenario 3, nongrazing forestland is left out (a reasonable assumption because its quantity in Maryland is roughly constant over the post-war period). Scenario 4 is the same as scenario 1 except that the growth rates in social marginal values are changed. The growth rate for the social marginal value of land in agriculture is set at −2 percent, to reflect subsidies in the price of agricultural commodities and increases in input prices. The growth in the marginal social value of public land is set at 3 percent, roughly equal to the sum of the population growth rate and per-capita income growth rate. The growth in the marginal value of urban land is set at 8 percent to reflect a four-fold increase in land rents in the Baltimore/Washington SMSA since 1970.

Table 1.

Optimal Rate of Change in Ag. Land	Land Proportions		Elasticities of Social Marginal Products			Growth Rates of Marginal Social Products		
G_{L_a}	r_{ap}	r_{au}	b_a	b_p	b_u	G_{m_a}	G_{m_p}	G_{m_u}
−.00098	.1	.05	0	−.8	−.5	0	.03	.06
−.0012	.1	.05	0	−.5	−.5	0	.03	.06
−.036	.1	.05	0	−.1	−.5	0	.03	.06
−.009	.05	.05	0	−.5	−.5	0	.03	.06
−.010	.2	.05	0	−.5	−.5	0	.03	.06
−.036	.2	.2	0	−.5	−.5	0	.03	.06
−.042	.2	.2	0	−.5	−.5	0	.045	.06
−.018	.1	.1	0	−.5	−.5	0	.03	.06
−.022	.1	.1	0	−.5	−.5	−.01	.03	.06
−.018	.05	.1	0	−.5	−.5	−.01	.03	.06
−.0175	.05	.1	−.1	−.5	−.5	−.01	.03	.06

Table 2.

	Optimal Rate of Change in Ag. Land	Land Proportions		Elasticities of Social Marginal Products			Growth Rates of Marginal Social Products		
Scenario	G_{L_a}	r_{ap}	r_{au}	b_a	b_p	b_u	G_{m_a}	G_{m_p}	G_{m_u}
1	−.023	1.13	.205	0	−.5	−.5	0	.03	.06
2	−.0035	.0258	.1042	0	−.5	−.5	0	.03	.06
3	−.0055	.1614	.1042	0	−.5	−.5	0	.03	.06
4	−.1297	1.13	.205	−.2	−.5	−.5	−.02	.03	.08

With these scenarios, the rate of decline in agricultural land use ranges from .35 percent to 12.97 percent. My favorites—in the sense that they are interesting speculations about the situation in Maryland—are scenarios 1 and 4. They show a fairly severe decline in farmland of 2.3 percent to 12.97 percent compared to the actual rate of decline of about 1.5 percent.

The numbers can be stretched in many ways to show different rates of change in agricultural land. But it seems fairly unlikely that a reasonable set of parameters would reveal optimally positive growth for agricultural land. There may be more efficient ways to use the money that is spent on saving farmland. Without knowledge of externalities, these numbers should make us look carefully at programs to preserve agricultural land.

The Approximately Optimal and Its Bearing on a More Exact Model

The assertion that optimal land use can be determined from a simple static maximization problem is bold. It is worth recognizing some of the more obvious shortcomings of this model.

Irreversibilities

A more sophisticated model of land use would recognize that, as a stylized fact, certain land use changes are irreversible. In the case of this model, one might posit two kinds of irreversible changes. Land cannot move from urban to agriculture or public/park. In the model, this means that G_{L_u} should be non-negative. These irreversibilities are essentially multiple-use generalizations of the Fisher-Krutilla-Cichetti model of preservation and development. The damage that is done by ignoring the irreversibilities depends on the extent to which the benefits of preservation and development are cyclical. If the benefits trend in the same direction, then there are no economic forces working for reversing land use. If there are no cyclical movements in these benefits, then ignoring the irreversibilities does no great damage to the results.

The Costs of Land-Use Changes

There are costs of converting land from public/park to agriculture and urban use and from agriculture to urban use. They are private costs, such as clearing land of stumps or grading land. There are also potential environmental costs from the conversion of land. The runoff of sediment from construction cleared land is thought to be a considerable source of stream loadings of sediment.

The costs of land-use change are closely connected to problems of irreversibility. The higher the cost of conversion, the less the benefits from changing land use. And as Cummings and Norton argue in the context of the Fisher-Krutilla-Cicchetti model, very high conversion costs are equivalent to irreversibility.

The Number of Land-Use Categories

Aggregation of lands of different uses into one use imposes restrictions on production and preference functions, just as is done by the aggregation of commodities, or prices. The real question is whether the insights from an aggregate model compensate for the restrictions that are implicitly imposed to achieve aggregation. The problem of aggregation can be handled in part by introducing a residual which can change with time: $L_r = L_r(t)$. Aggregation is a necessary evil in all economic analysis, and it is not likely that aggregation of land-use types is worse than aggregation in other kinds of models which have yielded useful insights.

The Spatial Aspect

A whole field of economics has grown up around the analysis of the spatial aspects of land. Theories of the density of urban areas and rental rates are based on distances of land from the center of cities. Ignoring the spatial aspect does an unknown disservice to reality which is similar to the aggregation of different land types. And like aggregation, ignoring the spatial aspects of land is a necessary evil.

Uncertainty

There are two basic ways in which uncertainty can influence this model. The first is the static effect of incomplete knowledge about the social benefits of different types of land use. *A priori,* one would expect that the greatest uncertainty would be attached to the social benefits of public land. This would suggest a policy of less land in public use if one brought risk aversion into the decision framework. The biggest effect of uncertainty is perhaps to the long-run effects in a dynamic model. For the static formulation given here to be a good approximation of reality, it is necessary that one be sure of the future path of benefits.

Nonseparability

It is probably wrong to write the benefits separately because reducing agricultural land may increase the benefits from public land and because agricultural land and public lands are substitutes. These benefits are a decreasing function of the quantity of land in farms. That is, there is substitution, albeit imperfect, between publicly provided land and farmland. In particular, the aesthetic services from open space can be obtained from either kind of land. Also, people on farms receive their natural resource services directly, and are less likely to have additional demands for outdoor amenities than people who live in urban areas. Thus we could specify the benefits for services from public land as

$$B^p = B^p(L_p, L_a, P_a, t)$$

where P_a is the farm population and t as time represents other influences such as population and income growth. A reasonable specification would support

$B_2^p \equiv \partial D/\partial L_a < 0$: declining farm acreage increases the benefits from public land services,

$B_3^p \equiv \partial D/\partial P_a < 0$: declining farm population increases the benefits from public land services,

When the benefits are specified in this way, B^p and B^a are no longer separable. The resulting model, analyzed in a working paper version in the appendix, is considerably complicated.

Conclusion

This paper has attempted to address the question of land in agriculture by developing a simple model of the social returns to land of different uses. The motive for developing the model is to stimulate thinking about what the public gets from preserving farmland. A natural way of addressing that question is to ask if there are other land uses which yield greater social returns than agriculture.

I have presented a crude method for calculating the optimal rate of change in agricultural land. The numbers are meant to stimulate thinking, not to be confused with robust and defensible estimates of the optimal quantity of farmland. It is obvious that the issue of land use and the methods of nonmarket valuation are closely connected. Any argument for intervening in the land markets which is not based on changes in the distribution of income must be capable of being framed in terms of externalities. The role of nonmarket valuation is to measure the economic costs and benefits of externalities.

There is also some methodological interest in joining the issues of nonmarket values and the preservation of farmlands. Researchers in the areas only rarely consult one another's findings. Economists working on nonmarket valuation proceed as if resources for outdoor recreation can be simply drawn from the air. Nonmarket valuation work tends to be highly site specific: what is the value of one resource at one point in time. Rarely is the practice of nonmarket valuation placed in the context of the broader problem of resource allocation. Economists working on the retention of farmland have not exploited the methods of nonmarket valuation to the extent that they appear warranted in a situation where the market process is claimed to be inefficient. (To my knowledge, there are only three studies which attempt to measure the aesthetic benefits of the preservation of farmland. These are cited in Pitt et al.) While it is easy to say that economists can gain by expanding their dialogue with those working in different areas, the problem of retention of farmlands seems an especially fruitful area for people working in different branches of a subdiscipline to do joint work.

References

Bergstrom, J. C., B. L. Dillman and J. R. Stoll. 1985. "Public Environmental Amenity Benefits of Private Land: The Case of Prime Agricultural Land." *Southern Journal of Agricultural Economics* 139–148.

Coughlin, R. E. and John C. Keene. *The Protection of Farmland*. U.S. Government Printing Office. Washington, D.C. 1986.

Crosson, Pierre. "The Long Term Adequacy of Agricultural Land" in Pierre Crosson (ed.) *The Cropland Crisis*, Resources for the Future, 1982.

Cummings., R. G., and Norton, V. "The Economics of Environmental Preservation: Comment." *American Economic Review* 64(1974):4.

Fisher, A. C., Krutilla, J. V., and Cicchetti, C. J. "The Economics of Environmental Preservation: A Theoretical and Empirical Analysis." *American Economic Review* 62(1972):605–619.

Gardner, B. D. 1977. "The Economics of Agricultural Land Preservation." *American Journal of Agricultural Economics* 1027–1036.

Halstead, J. M. 1984. "Measuring the Nonmarket Value of Massachusetts Agricultural Land: A Case Study." *Journal of Northeast Agricultural Economics Council* 13:12–19.

Pitt, D. G., T. Phipps, R. Bonsignore and B. V. Lessley. "Evaluating Transfer or Purchase of Development Rights Programs." Paper presented at workshop on Land Use Transition in Urbanizing Areas: Research and Information Needs, USDA, Washington, D.C., June 6–7, 1988.

Schultz, T. W. *The Economic Organization of Agriculture*. New York: McGraw-Hill, 1952.

U.S. Department of Agriculture. 1985. *Farm Real Estate: Historical Series Data: 1950–1984*. Statistical Bulletin 738.

"Use Value Assessment of Agricultural Land in the Northeast." 1987. Agricultural Experiment Station Bulletin 694, University of Vermont.