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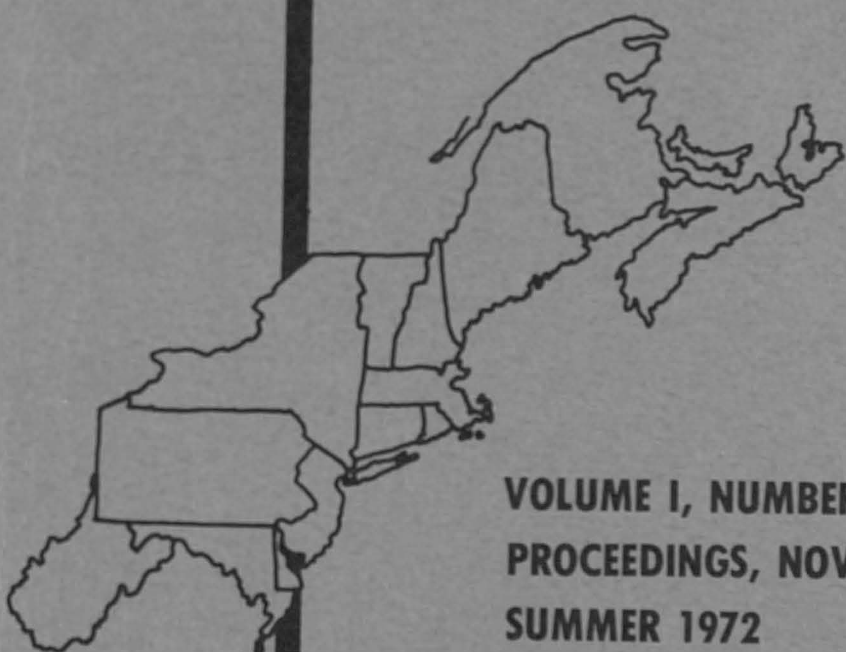

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EVALUATING LAND-USE ALTERNATIVES IN RURAL-URBAN FRINGE AREAS

Robert E. Lee
Research Associate
and
Robert L. Christensen
Associate Professor
Department of Agricultural and Food Economics
University of Massachusetts
Amherst, Massachusetts

INTRODUCTION

Rural-Urban Conflicts

In rapidly urbanizing areas, conflicts exist between agricultural and urban uses of land. There has been both a concentration of people in metropolitan area boundaries and a spreading of those boundaries, a move away from the densely populated urban centers. Urban people and industry have been moving outward into fringe areas in a search for more living space, the amenities offered by a pastoral landscape, and to escape from the congestion, high living costs, and lack of privacy in more concentrated urban areas.

Much of the land being converted to urban uses, however, is agricultural land, often prime agricultural land. To compound matters, more land is removed from agricultural production than is needed for urban expansion. Nationally, a net withdrawal of land from agricultural use of 1.4 million acres is estimated, and about 30 percent or 420,000 acres is converted to urban use [6, p. 8]. Allee, et. al. have reported a similar pattern in New York State. They have estimated that approximately 200,000 acres annually are removed from agricultural production, while only 10,000 acres per year are put into urban uses. Much of the agricultural land is idled in "anticipation of urban use because the pattern of urban growth is such as to make the land impossible to farm at a profit [1, p. 6]."

These same authors have noted that just "a few nonconforming units can destroy the integrity of a rural area [1, p. 8]." Haphazard urban growth leaves much unused land, but normally not enough usable open space. The undeveloped land is usually scattered, may be difficult to get to, and is often so untended as to be more of an eyesore than an asset. It is paradoxical that by moving to the fringe areas the urban population may be destroying many of the very qualities it is seeking.

Monetary and Non-Monetary Costs

At first glance building on prime agricultural land has many advantages for developers, municipal officials and potential buyers alike. The same properties -- relatively level, good drainage, and deep soils -- which make the land desirable for agriculture also make it desirable for urban development. The costs of construction, sewer and water installation, and landscaping and drainage are lower on these soils.

Some questions have arisen, however, about the sensibility of locating houses in rural-urban fringe areas. There appear to be both monetary and non-monetary costs involved in such placement which have not been properly accounted for. For instance, in New York State one town found capital outlays for utilities and services differed by approximately $1,250 per house between more scattered and less scattered houses. Of this amount, $225 was borne by the developer and the remaining $1,025 was borne by the taxpayer and utility rate payer [1, p. 7]. In addition to these costs, agricultural land was unnecessarily encroached upon and open space was unnecessarily violated.

Agricultural land use, in many situations, is quite compatible with the provision of open space. It has been said that "agriculture is the only open space use which provides automatic costless maintenance and care of the open space [3]." It may be the only land use on the rural-urban fringe that simultaneously provides both private returns to the owner and social benefits to society.

One of the critical questions of the economist dealing with the issue of open space and agricultural land use relates to the efficacy of the market mechanism in serving the goals of society. It is widely acknowledged that society bears most of the costs associated with the loss of environmental amenities. As prosperity grows, people are becoming less willing to substitute additional goods and services for the quality of their environment. Thus, the economic issues surrounding the role of agriculture in providing a high quality environment provide a focus for study.

Evaluating Land-Use Alternatives

Nothing stated above is particularly surprising or new. The notion that uncontrolled urban sprawl in fringe areas is costly to the local community has been reported since the early 1950's (see Wheaton and Schussheim [8]), and concern over environmental degradation resulting from urban sprawl existed at least as long ago as 1961 when Jean Gottman wrote his book Megalopolis [4]. Despite concern over these problems, little has been accomplished in the way of solving them, partially because research hasn't yet sorted out all the variables relevant to land-use trade-offs on the fringe, and partially because sufficient methodology to evaluate the problem hasn't been developed.

The study being discussed here is designed to fill some of the gaps in the methodological research. The researchers are utilizing mathematical programming to select among alternative uses for land in urban fringe areas.

Any change in land use will have impacts on the finances of the local community and also on the open space of that community. For instance, when land is converted from agricultural to residential use there will be changes in both the tax revenues gathered by that land and the public costs of providing services appropriate to the new use. At the same time, there will be changes in the characteristics of the community and, in particular, a change in open space location and availability.

If we look at the community as a whole, we can see that land-use changes in the fringe areas will either improve, degrade or not affect the collective well-being of the community. The effect upon that collective well-being consists of both the monetary and non-monetary impacts resulting from various land uses evaluated over time. We have defined monetary impacts as including both tax revenues generated by a particular land use and the public sector costs associated with that land use. Public sector costs are those incurred for such services as sewer and water, police and fire protection, schools, roads, etc. They may have both variable and fixed dimensions. Normal operating and maintenance costs will be included directly in the coefficients, whereas major capital costs will be discounted over an appropriate time span (20 years). The non-monetary impacts are expressed through the measurement of two variables: the quantity of open space and recreation land available.

It is recognized that many other variables could be included in a definition of community welfare -- air and water pollution, noise pollution, quality of schools, quality of police and fire protection, etc. The present analysis has not attempted an economic analysis of these factors but has assumed them to be held constant at current levels. If at a later stage it becomes possible and desirable to consider the indirect relationships, the model could be modified to explicitly include them.

The variables considered in the model can be related in the following manner:

$$\text{Community impact} = f(\Delta\text{Property tax revenues}, \Delta\text{Local public sector costs}, \Delta\text{Open space}, \Delta\text{Recreation space})$$

The variables are presented in terms of magnitude of change because it is the marginal impact of land-use change on the fringe that is the focus of this analysis. Some point in time will be taken as a base point, say 1970; then the population change will be projected for some future time period and the changes in selected land-use alternatives which could be associated with that change in population will be examined. Different land-use alternatives will have different impacts on the community situation and the relative differences among the impacts can be compared.

Amherst, a town in Western Massachusetts, was selected for a case study to test the model. It has a township form of government which, much like county governments in other areas, oversees both rural and urban lands within a contiguous 28 square mile area. Furthermore, it has a population growing rapidly enough to lead the Town Planning Board to say "...'land-use' for the various types of housing takes on new meaning as the town continues to lose its open space that was once utilized for agriculture [2, p. 6]."

METHODOLOGY

Mathematical programming is used in the current study to select an optimum land-use mix. The model can be run in a recursive manner and in annual increments to simulate the impacts through time of land-use changes in fringe areas. Sensitivity analysis utilized after the original solution should provide important additional information about the ranges within which the constraints and activities in the optimal solution remain unchanged.

Objective Function

A net revenue objective function is maximized subject to land, housing, environmental quality, and other constraints (see Figure 1). Land-use alternatives are variables in the objective function and they are weighted by the relevant net revenue coefficients. For instance, land on the fringe may be currently used for orchards, dairy or other farming, public recreation, or other uses. Each of these uses will be a variable in the objective function. If the population is growing in the area selected for study, it is likely that during the next twenty year period much of this land will be converted to the more intensive residential, commercial, and industrial uses.[1/] Different densities and types of housing should have marked differences in both monetary and non-monetary impacts, so housing is separated into several subcategories. The major groupings are single family homes and multi-

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1/ In terms of importance, residential use has by far usurped the most acreage. Partially for this reason, and partially because commercial and industrial development is particularly unimportant in the locale used for the case study, residential land use will be the only intensive use considered in this study.

Figure 1.
Specification of the Objective Function and Constraints

MAXIMIZE:

$$\text{Net revenue} = \sum_{j=1}^{p} c_j \text{ single family home}_j + \sum_{j=p+1}^{q} c_j \text{ multi-family home}_j + c_{q+1} \text{ dairy} + c_{q+2} \text{ other cropland} + c_{q+3} \text{ orchards} + c_{q+4} \text{ other land} + c_{q+5} \text{ recreation space}$$

SUBJECT TO:

$$\sum_{j=1}^{p} a_{1,j} \text{ single family home}_j + \sum_{j=p+1}^{q} a_{1,j} \text{ multi-family home}_j + \ldots \ldots + a_{1,q+5} \text{ recreation space} \le 1{,}500 \text{ acres}$$

$$\vdots$$

$$\sum_{j=1}^{p} a_{18,j} \text{ single family home}_j + \sum_{j=p+1}^{q} a_{18,j} \text{ multi-family home}_j + \ldots \ldots + a_{18,q+5} \text{ recreation space} \le 48{,}680 \text{ quality points}$$

Constraint		
Land		
Zone$_1$		
Suitable for housing	≤	1,500 acres
Sewer and water available	≤	8,000 acres
Zone$_2$		
Suitable for housing	≤	225 acres
Sewer and water available	≤	2,000 acres
Housing		
Single family homes		
<$20,000	≤	150 dwelling units
$20,000-$24,999	≤	40 dwelling units
$25,000-$49,999	≤	500 dwelling units
Eight-unit apartments		
$100-$149/mo.	≤	630 dwelling units
$150-$199/mo.	≤	500 dwelling units
$200/mo.	≤	235 dwelling units
Total housing (lower)	≥	2,050 dwelling units
Public Service Capacities		
Water system	≤	16,106 dwelling units
Sewerage system	≤	700 dwelling units
Recreation Space		
Hiking and picnicking	≥	0.0 acres
Team sports	≥	0.0 acres
Environmental Quality		
Proximity to natural state	≤	48,680 quality points
Visual amenity		
Openness	≤	48,680 quality points
Order	≤	48,680 quality points

family homes (apartments). These have been further separated into different value categories, and in the case of the apartments, into different sized multi-family units. Each of these sub-categories is a variable in the objective function.

The coefficients in the objective function are net revenue values. These contain strictly monetary elements constructed by estimating the local tax revenue generated by the particular land use and then subtracting the costs of providing the public services needed by that particular use. The primary tax associated with land is the real estate tax. Various forms of personal and business property taxes may also apply to some land uses in particular areas. If so, these revenues should be added to the real estate tax to provide a total revenue figure. The public sector costs associated with the particular land use are the estimated marginal costs per acre of supplying police and fire protection, roads, sewer and water, etc.

It might be argued that the nature of the objective function is such that it would lead to maximization of tax revenues and minimization of municipal services. However, the constraints incorporated into the model provide both rationality and a measure of stability to the analysis. These constraints are discussed in more detail in the following sections.

Constraints

The constraints can be categorized into land, housing, service capacities, recreation space, and environmental quality components as seen in Figure 1. Within the land category, constraints can take the form of zoning regulations, suitability of land for intensive development, or the existing locational availability of public services. Housing constraints can act as a proxy for demand, roughly separating the demands for single family homes from apartments and to establish ranges for the values of such dwelling units. Such constraints will also insure that adequate housing will be supplied for the projected population increase.2/

The service capacity constraints are simply the number of additional dwelling units that each of the existing particular municipal services can handle without net capital investment. It is possible in the model to permit capital resources to be used for the construction of necessary additions.

2/ Furthermore they will prevent the program from wildly building dwelling units should one of the housing activities create high net revenues.

Recreation constraints are used to insure that adequate recreation lands are maintained to service the growing community. Two sub-categories are utilized to account for the two quite separate forms of recreation -- playing fields for team sports and areas suitable for hiking and picnicking. For a starting point the existing relationship between the acreage of recreation space and dwelling units in the town can be maintained. Later the requirements can be varied over a range compatible with the potential desires of the community's citizens.

The environmental quality constraints. The most unusual constraints in the model are those dealing with environmental quality. The three constraints included are proximity to nature, openness, and order, the latter two being sub-categories of the visual amenity.

An area that has been undisturbed by man in the last 100 years will have growing within it a wide range of flora and fauna and would be characterized, in the Northeast, as a forest in a comparatively advanced stage of ecological development. Land in this situation is in the natural state. All other land will be related in some degree to this natural state, depending on flora, fauna, and population density. From an environmental quality viewpoint, the closer a land use is to the natural state the more desirable it is.[3/]

One of the elements contributing to the visual amenity is openness, the degree to which a land use contributes to an open vista and the antithesis of population density. The other element is order, defined by Floyd Newby as "the existence of some similarity of physical characteristics among the parts or of some discernibly harmonious space relation among them [5, p. 70]."[4/] This concept of order is complemented here with another concept -- neatness.

Both categories of visual amenity are important since it is quite possible for a land use to be open but be neither neat nor orderly. It is also possible to have a high degree of order, but provide no vista at all. There can be quite a difference in the quality of the visual experience, for instance, between two dairy farms of equal acreage, one with well maintained buildings, barnyard and fields, and the other with weather-beaten buildings, rusting machinery junked in the barnyard and collapsing fence rows.

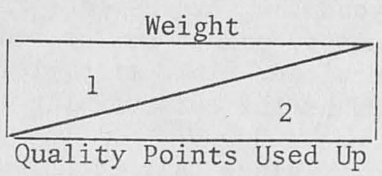
3/ This statement is a gross overgeneralization, but it is a fairly accurate representation of the feelings typical in rapidly urbanizing areas - those areas of concern in this study.

4/ Paraphrased by Newby from Litton, R. Burton, Jr., A Summary Report to the U. S. Forest Service on Landscape Management Terminology, University of California, Department of Landscape Architecture, Berkeley, 1965.

It is an understatement to say that it is difficult to place a value on variables such as these. Considerable research is currently underway to evaluate open space and other non-monetary elements affecting the quality of life, but no reliable figures appear to be currently available. Consequently, a series of index numbers were constructed from scaled numbers called "environmental quality points". A scale from 1 to 10 was used to relate the severity of the impact from a particular land use on the constraint item. For example, in evaluating the constraint "proximity to nature", if a plot of land was in the natural state it would be allotted 10 quality points, the maximum. Land developed by man was allotted some lesser number of quality points - in effect the development process had "used up" some quality points. Land in agricultural use was a less severe departure from the natural state than in single family homes, so it used up fewer quality points than did the residential use. Similarly, in evaluating openness of land, agricultural pasture and cropland is most open so it will use up fewer quality points than other land uses.

These subjective values were then weighted by the proportion of an acre affected by the interaction. Generally these weights equalled 1, indicating that all of the land in the particular use had the same impact. If the weight was other than 1, it was necessary to make double entries, in which case the two weights summed to 1, each being associated with a different number of quality points. All of this information has been organized into an environmental quality matrix with diagonally divided boxes, similar to the approach used by the U. S. Geological Survey [7]. Each box has either two or four entries in it. If the weight equals 1, there are two entries, the one to the upper left indicating the proportion of an acre affected, and the one to the lower right indicating the number of quality points used up. (See Figure 2.) For example, all of a dairy farm has been assumed to contribute equally to openness. The weight in the upper left corner then is 1 and the quality points used up in the lower right corner is 2.

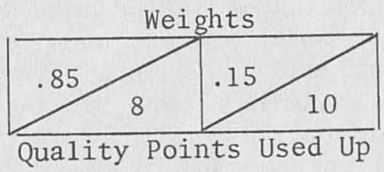
Figure 2
One Element of Environmental Quality Matrix-Single Weight



When not all of the land use affects the environmental constraint equally, the box is divided in half, each half having two entries. (See Figure 3.) The numbers on either side of the diagonal line are interpreted exactly the same as above. Those to the upper left are the weights and those to the lower right are the corresponding quality point assignments. The example here shows the relationship between a single family home in Zone 1 and the openness component of visual amenity.

Figure 3

One Element of Environmental Quality Matrix-Double Weights



According to that zoning ordinance a home can occupy no more than 15 percent of the lot. Using this maximum figure for the space taken by buildings, 10 quality points are used up and they are weighted by .15. The remaining 85 percent of the lot might be considered as open space, but contributes practically nothing to an open vista, so it uses up 8 quality points which are then weighted by .85.

The technical coefficients for the programming model can be calculated from these figures by multiplying the quality points used up by the appropriate weights and summing the two products. Using the numbers in the example above,

$$\text{Technical Coefficient} = (.85)(8) + (.15)(10) = 8.3$$

In order to use this type of index as a constraint in a programming model it is necessary to relate all of these individual coefficients to some constraint level. One way of calculating a constraint level is to multiply the total number of acres that can be affected by the environmental quality constraint by 10, the maximum number of quality points per acre. This yields the maximum number of quality points the community has available. If it is desired to maintain some proportion of these quality points beyond the forecasting period under consideration the total number of quality points can be reduced by "X", the minimal proportion to be maintained. This step yields the "usable quality points" which are then used as the constraining level in the programming model.

Needless to say, since this technique is based upon subjective scaling not all people will agree with the quality points assigned. It is critical when using any technique of this type to carefully explain each of the values that is assigned. Then at least, the results can be interpreted with some consistency and any disagreement will have to be equally well supported, perhaps leading to a better understanding of the difficulty. This is, after all, the primary purpose of using an index of this sort in the first place. Hopefully, there will be general agreement as to the relative positions of the land uses, however. For if general agreement of the relative positions cannot be found, the procedure breaks down entirely.

Concluding Comments

Unfortunately, no usable results have yet been obtained. However, it is felt that certain concluding comments are in order.

First, the nature of the input data to this model at this point in time causes one to be skeptical of the accuracy of the output. A great deal of further research needs to be conducted before accurate and adequate data is available to allow a model of this type to perform up to its capabilities. Even then, however, the model will act only as a guide and analytical tool. It should never be expected to provide the "correct" answer.

Second, the technique shows great promise for helping planners and researchers understand the implications of various population and land policies within a community. Different hypothesized population growth rates can be tested for their impacts on land utilization and open space, or different open space requirements can be evaluated as they may interact with population growth.

Third, another step has been taken towards estimating the open space value of agriculture to the local urban society. By perfecting techniques such as this it may one day be possible to eliminate the paradox between the kind of environment people say they want and the kind of environment they actually create.

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