

The Cost of Agricultural Land Preservation and the Siting of Urban Development

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In North America a disproportionately high percentage of prime agricultural land is converted for urban development. Much controversy exists about this irreversible loss. Some claim that it will result in future food shortages, while others argue that technological advance has made agricultural land less scarce. There is no evidence of a looming food scarcity in the western world. Nevertheless, the future scarcity issue is shrouded in great uncertainty.

Preserving prime land is a policy option to avoid possible future food contingencies. Preservation is not a costless undertaking, however. Costs are always defined in relation to the objectives pursued. In social economics the objective is usually defined as maximizing the net contribution to national product. This is not a meaningful objective if long time horizons, extreme uncertainty, and irreversibility are involved. In that case it is better to minimize possible maximum losses. This is akin to an insurance policy. The problem then is to choose premium payments and benefits in such a way that maximum possible future losses are minimized.

The premium that society pays for preserving prime land is identified as the possible additional development, servicing, commuting, and environmental costs on lower compared to prime quality land minus the gain in productivity on prime compared to lower grade land. The premium is then compared to the benefits of the policy.

Urbanization in North America is absorbing a disproportionately high percentage of prime agricultural land. For example, Gierman (1977) found that between 1966 and 1971, 18,132 acres in 24 urban areas in Ontario were annually converted from rural to urban use. Of these, 79 percent had been prime agricultural land. The loss of such prime land remains a contentious issue.

Concern over long term adequacy of agricultural land for production of food and fiber has a long history, dating back at least to the time of Malthus. Malthus inaccurately postulated that a finite amount of agricultural land together with a continually increasing population would ultimately eventuate a decline in output

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per capita and a cessation of growth. Agricultural land, in fact, has become relatively less scarce over time in the western world reflected in declining agricultural rents as a proportion of total national product (Schultz, 1951). The decreasing scarcity is the result of rapid growth in productivity. In Ontario, for example, agricultural productivity increased by a factor of 2.4 between 1951 and 1986 despite a 33 percent decrease in the agricultural land base, during which time the provincial population doubled. In general, productivity growth rates in the western world have outpaced those in population.

The likelihood that future food shortages will occur because of prime land conversion to nonagricultural uses seems remote under currently foreseeable circumstances. Nevertheless, the idea that urbanization is a threat to food security is widespread and it has resulted in most states and provinces in North America adopting some form of an agricultural land preservation program (Furuseth, 1985; Glenn, 1985; Volkman, 1987; Schnidman et al., 1990). The National Agricultural Lands Study (NALS) contributed to the pessimistic view regarding the supply of agricultural land. It concluded that the United States will not have enough farmland to meet world food demand at the turn of the century at 1976 real prices (NALS, 1981). The study has been criticized by Fischel (1982) and by Raup (1982) for using unreliable data sources and questionable assumptions and for ignoring economic theory in predicting future land use patterns.

Future adequacy of agricultural land is difficult to foretell, because it depends on a host of factors which magnitudes are not predictable with precision, such as population growth rates, technological innovations and their environmental impacts, institutional change and climate change. Thus, future adequacy of the supply of agricultural land is subject to uncertainty. To minimize this uncertainty and guard against possible future food and fibre shortages by preserving prime agricultural land entails costs.

Land should be allocated in such a way that society gains the greatest benefit from it now as well as in the future. Future benefits become particularly important if irreversible land use change is involved. Difficulties in measuring long term benefits will be explored first. Because long term benefits cannot be quantified, allocation decisions are hampered. This study develops the argument that because of the uncertain nature of supply adequacy, pursuing a food security insurance policy can make sense. For developing such a policy the magnitude of premium payments must be established relative to the benefits of the policy. Next, the various components comprising the premium will be elaborated. Several components are hard to quantify and value. The first part of the paper presents a conceptual framework for calculating the premium for a food security policy. Even though all components cannot be easily quantified, they must still be considered in decision-making. Lands preserved under prevailing policies are almost exclusively designated on the basis of physical land quality measures, not on the basis of what society gains and sacrifices from preservation. Since land quality measures loom so large in preservation programs, the empirical part of the study

examines the relationship between land quality and two cost components for which data are available, site preparation and service installation costs.

The agricultural land preservation debate has been dominated by two diametrically opposed points of view. The first states that there is no compelling reason to preserve since there is plenty of potential land which could be exploited for agriculture. In addition, the amount of land used for urbanization is relatively small. Moreover, substitution possibilities mitigate land scarcity. The market is perfectly able to take care of food security (Gardner, 1977; Frankena and Scheffman, 1980; Fischel, 1982; Batie and Healy, 1983). The alternative point of view is that the rate of prime agricultural land loss exceeds the rate of total agricultural land loss, since the bulk of urbanization takes place on prime land. The stock of prime land is limited, particularly in Canada. Loss of prime land necessitates utilizing marginal lands for agricultural use. Use of marginal lands entails huge environmental costs (NALS, 1981; Sampson, 1981). In the literature little attention has been paid to the fact that preservation is usually attained at a cost. Costs in relation to benefits should be decisive in determining whether or not to preserve a particular area. These costs are seldom considered in preservation programs. The purpose of this study is to explore the cost of agricultural land preservation in greater detail.

Preservation of prime agricultural land can be accomplished by greater urban development density on such farmland or by using land of lower quality for such development. This study will concentrate on the latter since diversion of urban development plays a crucial role in the food security debate.

BENEFITS AND COSTS ASSOCIATED WITH LAND USE CHANGES

Prime land preservation is economically justified if it leads to positive net economic benefits for society. Measurement of such net benefits is usually accomplished by cost-benefit analysis. To obtain insight into the welfare effects of land conversion, two alternative sites for the same urban development must be compared: A, being prime and B, low-grade agricultural land.

The two sites will most likely differ in benefits derived from urban development as well as in costs making such benefits possible. Benefits are derived from the value of land as living and working space, highly affected by the economic activity in the area and by amenity values. Topography, mature trees and proximity to rivers, lakes or parks, are attributes of amenity value. These benefits can be expressed as UV_A and UV_B . Subscripts refer to the site. Both sites are located some distance away from the central business district. Thus, travel costs are involved for working, shopping, and entertainment purposes called T_A and T_B . The sites may have open space value, say for wildlife habitat, for aesthetic reasons or as recharge areas for aquifers, OS_A and OS_B . Such values will be sacrificed if the parcel is developed for urban use.

There are also differences in development costs. It is useful to distinguish between costs of providing major city systems as opposed to development of a building site or subdivision. The former costs include such items as waste treatment facilities and major trunk lines. The latter include provision of water, sanitary, and storm sewer connections to the city systems, and street, sidewalk and streetlamp installations. The cost of providing or extending major city services is indicated as CC_A and CC_B . The cost of developing the site for urban use can be divided into two components: pre-development or site preparation cost and development or servicing cost. Pre-development or site preparation costs are mainly those of levelling hills, draining wet areas, filling pits and excavating bedrock near the soil surface. These activities can be performed by the developer (usually the owner of the site) prior to submitting a subdivision plan. Pre-development costs will be indicated as PC_A and PC_B . These costs become higher the more undulating and poorly drained the site. Servicing costs are indicated as C_A and C_B .

If the site is converted to urban development, net agricultural output value is foregone. This foregone value is the annual land rent of the property, R_A and R_B . Land rent does not reflect the true social value of the site if agriculture is subsidized, particularly if the subsidy is dependent on yield as is now the case in Canada. The effects of subsidies on land rent are indicated as S_A and S_B .

There are also environmental costs associated with both agricultural use and urban development, such as damage from soil erosion. If the site is developed for urban use, possible environmental costs are imposed from development while environmental costs from agriculture cease to exist. The environmental costs are indicated as $ECdev_A$, $ECagr_A$, $ECdev_B$, and $ECagr_B$.

Urban development of a site because of urban demand could result in net social benefits from that use. These net benefits can be expressed as:

$$UV - T - (R - S) - OS - CC - PC - C - (ECdev - ECagr).$$

Some of these costs occur on an annual basis such as T , R , S , and EC , while others are in the form of a lump sum such as CC , PC , and C . For comparative purposes it is best to convert all benefits and costs to annual amounts by converting lump sum capital values into annuity values. In the remainder of this paper it is assumed that all these terms are expressed in annual values.

$$\text{If: } UV_A - T_A - (R - S)_A - OS_A - CC_A - PC_A - C_A - (ECdev - ECagr)_A >$$

$$UV_B - T_B - (R - S)_B - OS_B - CC_B - PC_B - C_B - (ECdev - ECagr)_B \quad \text{then}$$

the highest annual benefits to society are obtained if prime site A is developed for urban use rather than site B.

Rearranging terms, the general form of this inequality can be written as follows:

$$\begin{aligned} & (UV_A - UV_B) + (T_B - T_A) + (OS_B - OS_A) + (CC_B - CC_A) + (PC_B - PC_A) \\ & + (C_B - C_A) + [(ECdev - ECagr)_B - (ECdev - ECagr)_A] \leq (R - S)_A - (R - S)_B \end{aligned} \quad (1)$$

The left-hand side of the inequality expresses annual urban benefits and costs with associated environmental and public good impacts from site A compared to those of site B. The right-hand side expresses the net annual agricultural value of site A compared to that of site B.

ASSESSING THE ACCURACY OF WELFARE CHANGE MEASUREMENTS

The market is not able to determine the above inequality accurately. The market deletes OS, EC, and S. Neither is CC usually transmitted through a market. The cost of such items as major sewer trunks is not usually borne exclusively by the area to be serviced but is paid for from public funds.

In addition to market failure there are difficulties in quantifying welfare changes caused by a land use change. To decide whether or not to urbanize a particular parcel, the present value of the annual cost and revenue streams (either marketed or non-marketed) must be calculated. Since urbanization is an irreversible land use change, these annual values must be discounted in perpetuity. Two problems emerge in the discounting process. First, uncertainties about the probability distributions of urban benefits and costs, and even more so those of agriculture, increase over time, making any meaningful quantification illusory, because their most probable future values cannot be established. Second, a discount rate over such a long time period does not exist (Randall, 1987). However, the magnitude of the discount rate is crucial to the outcome. For these reasons, quantifying the impact of a land use change on long-term human welfare becomes meaningless. It is more meaningful to minimize maximum possible losses (Luce and Raiffa, 1957). This is akin to an insurance policy which guards against serious losses resistant to quantitative measurement (Ciriacy-Wantrup, 1964). For planning purposes it is necessary to establish annual premium payments for the insurance. These payments must be weighed against the benefit of avoiding food contingencies by preserving prime agricultural land.

PHYSICAL SOIL QUALITY AS DECISION-CRITERION

If the left hand side of inequality (1) exceeds the right hand side, then site A currently provides higher net benefits in urban use than site B. In that case preservation of site A by administrative decision-making entails a cost. Annual

preservation costs or an annual premium (P) for guarding against possible future food contingencies can then be expressed as:

$$P = (UV_A - UV_B) + (T_B - T_A) + (OS_B - OS_A) + (CC_B - CC_A) + (PC_B - PC_A) + (C_B - C_A) + [(ECdev - ECagr)_B - (ECdev - ECagr)_A] - [(R - S)_A - (R - S)_B] \quad (2)$$

Note that P can vary over time and even become negative from a certain date onwards. For example, transportation costs or agricultural land rents could drastically change in the future. Preservation becomes costless when P becomes negative.

If land allocation decisions are removed from an unregulated market, then ideally equation (2) should be quantified in order to arrive at a value for P. The magnitude of P relative to the benefits derived from the contribution of land preservation in avoiding possible future food contingencies is important for policy makers and planners in deciding whether or not to preserve site A for agriculture. In reality these calculations are seldom, if ever, performed. Instead P is considered irrelevant or too cumbersome and costly to calculate. In place of economic considerations, physical criteria are used in deciding on prime agricultural land preservation in administrative decision-making (Gardner, 1977; U.S. Dept. of Agriculture, 1975; Government of Ontario, 1978). Such criteria make sense if all the terms in the left hand side of inequality (1) are highly correlated with the quality of agricultural land. This is, however, not the case. Urban transportation cost, open space value, and environmental costs associated with agriculture and urbanization are all site specific and have little or no relationship with land quality.

Land quality is expected to be related to CC, PC and C. These costs are assumed to be lower on flat, well-drained prime, than on undulated, poorly drained and stoney land. Whether or not such relationships exist is a matter for empirical investigation. The remainder of this study will investigate the relationship between land quality and site preparation expense as well as between land quality and service installation cost.

METHOD

The empirical investigation consists of a case study of 19 subdivisions for residential development in Guelph, Ontario, for 1986 to 1989 inclusive. Major trunk lines were already in existence for each of the 19 subdivisions. The distances from the trunk line to all subdivisions are virtually identical. The emphasis of this investigation is on pre-development or site preparation cost and on subdivision service costs of installing sanitary and storm sewers, water mains and roads.

Guelph contains a variety of soil qualities. Soils are grouped into seven agricultural capability classes according to the Canada Land Inventory System. Hazards

to agriculture such as adverse drainage conditions, topography, texture and stoniness increase in severity from class 1 to class 7. Classes 1 to 3 are considered prime for agriculture. The 7 classes measured in 'points' as proposed by Hoffman (1968, 1974) are differentiated in numerical terms by class margins and an average class index, called the composite soil index, and are presented in Table 1. Land without any hazards is assigned a value of 100 in this system. The greater the degree of a particular hazard, the more points deducted from 100. Dependent on amount and degree of hazards, each soil falls into a particular soil class. To arrive at an overall quality index for a subdivision, a weighted average index is computed. Weights are the proportions of each area of a particular soil class in each subdivision. These weights are multiplied by the composite soil index of each matching soil class from Table 1. Soil information was obtained from soil maps and confirmed by field survey.

Table 1: Canada land inventory soil capability classes and corresponding soil indices and soil index intervals.

<i>Soil class</i>	<i>Class interval</i>	<i>Composite soil index</i>
1	100–85	92.5
2	80–70	75
3	65–55	60
4	50–40	45
5	35–25	30
6	20–10	15
7	10–0	5

SITE PREPARATION COST

Data pertinent to site preparation were obtained from developers. Due to reluctance on the part of developers to reveal their cost figures, data from only five sites could be obtained, and this in the form of amount of soil moved rather than in actual dollar costs. Site preparation refers mainly to levelling and filling. The amount of soil moved is a crucial variable and expected to be correlated with soil class. Cost of moving the soil depends largely on distance of transportation. Some sites require additional soil for filling, some have an excess from levelling requiring hauling from the site, while others have soil able to be moved within the site. Site preparation costs therefore are to a significant extent site specific. The purpose of this analysis then is to investigate the relationship between the amount of soil moved per hectare and soil quality.

Ordinary least-square regression analysis is used to test if a statistically significant relationship exists. The amount of soil moved per hectare is regressed on the

land quality index as described above. Two regression equations (3a) and (3b) are estimated:

$$SM = b_0 + b_1S + u \quad (3a)$$

$$SM = b_0 + b_1S^2 + u \quad (3b)$$

SM = amount of soil moved/ha. in m³
 S = weighted average soil points/subdivision
 u = error term

The equation that fits best will be used. The greater the soil points, the smaller the hazards to agriculture. Soil points in both equations therefore are expected to have a negative relationship with the amount of soil moved per hectare.

SERVICE INSTALLATION COST

Subdivision service contracts are administered by the City of Guelph with the Engineering Department acting as engineer. Service costs were obtained for installation of storm and sanitary sewers, water mains and roads. Costs are separated into those of material (fittings, manholes, culverts, etc.) and those of installation. Since the cost of material obviously has no relationship to soil quality, only non-material installation costs for sanitary and storm sewers and for water mains are used.

Regression analysis is used to test if a statistically significant relationship exists between installation costs of subdivision services and land quality. Ordinary least-squares regression analysis is applied in deriving estimators of the equation. The dependent variable is the total servicing cost being the sum of non-material installation costs of water mains, sanitary and storm sewers as well as total road construction costs. Explanatory variables include road construction length for each subdivision (which is highly correlated with the lengths of water mains as well as those of sanitary and storm sewers) and soil quality and drainage condition of the soil. Equation (4) can be written as follows:

$$Sc = b_0 + b_1L + b_2S^{-1} + b_3Dr + u \quad (4)$$

Sc = servicing cost in dollars/subdivision
 L = length of road construction in meters/subdivision
 S = weighted average soil points/subdivision
 Dr = weighted average drainage hazard points/subdivision
 u = error term

Road construction distance is expected to have a positive relationship with servicing cost. One expects an increase in servicing costs the poorer the soil quality. Note from Table 1 that the higher the soil points, the better the soil quality. The weighted average soil points in equation (4) appear in the form of a hyperbolic

function, implying an expected positive regression coefficient. The higher the drainage hazard points, the poorer the drainage condition. An increase in drainage hazard is expected to increase service installation cost.

RESULTS

Site preparation cost

Although only five observations were available to estimate equations (3a) and (3b), the results in Table 2 indicate that a statistically significant relationship exists between soil quality and the amount of earth moved per hectare to prepare the site for servicing. The linear relationship in equation (3a) gives slightly better results than the quadratic one in equation (3b). The regression coefficients have the right sign and are significant at the 5% level. Since only five observations are available, it is worth pointing out that the observations are spatially dispersed and not bunched in two separate clusters which could result in a high R^2 . The average amount of earth moved per hectare by soil type can be calculated from equation (3a) by substituting the composite soil index of a particular soil type for S along with the estimated values for b_0 and b_1 . On average, 21,000 m³/ha. more earth must be moved on a class 4 compared to a class 1 soil.

Table 2: Statistics and estimated regression coefficients of various regression equations.¹

<i>Explanatory variables and statistics</i>	<i>Equation (3a)</i>	<i>Equation (3b)</i>	<i>Equation (4)</i>
Intercept	43812	33098	-1.19
Soil index	-438.58*** (-3.33)	-3.608*** (-3.07)	5722172.22* (1.53)
Road length	-	-	449.5*** (9.21)
Drainage index	-	-	28830.91 (.404)
Adjusted R^2	.72	.68	.88
F	11.06***	9.4**	36.23***
Degrees of freedom	3	3	15

¹ Figures in brackets refer to t-values.

* Significant at the 15% probability level by a two-tailed t-test.

** Significant at the 10% probability level by a two-tailed t-test.

*** Significant at the 5% probability level by a two-tailed t-test.

Service installation cost

Explanatory variables in equation (4) in Table 2 explain a large part of the variability in service installation costs among the 19 subdivisions. All regression coefficients have the right sign. Although soil quality in equation (4) has the right sign, it is only significant at the 15 percent level. If this significance level is acceptable, then estimates of service installation costs/ha. on the various soil classes can be derived from this regression equation. On average, service installation costs are \$12,000/ha. higher on a class 4 when compared to a class 1 soil.

SUMMARY AND CONCLUSIONS

Removing the allocation process from an unregulated market does not automatically lead to greater well-being for society. Proponents of administrative decision-making overemphasize prime agricultural land retention as a hedge against possible future food shortages and underemphasize consumer preferences, environmental effects and travel cost impacts associated with such preservation. They are singularly concerned with the waste of good farmland, but not with the waste of resources generally, including the environment. Given uncertainty about the future, guarding against possible future food contingencies through prime agricultural land preservation may be a worthwhile objective to pursue, provided that the cost is reasonable.

Average additional cost from diverting urban development from a class 1 to a class 4 soil can be calculated from the empirical results. On average, about 21,000 m³/ha. more earth must be moved on class 4 than on class 1 land. Earth moving cost is roughly \$3 to \$4/m³ and could run considerably higher. These costs are highly site specific, dependent on moving distance as well as on individual business deals. Average additional site preparation cost of such diversion would be roughly between \$ 63,000 to \$84,000/ha. On average, additional costs for installing services is around \$12,000/ha. The difference in agricultural land rent between a class 1 and class 4 soil, exclusive of the impact of subsidies, is \$150/ha. at most. Capitalized at a real interest rate of 4 percent gives an agricultural advantage of \$3750/ha. for a class 1 compared to a class 4 soil. On the basis only of agricultural use value, site preparation and service installation costs, urbanization on class 4 land would cost at least \$70,000 to \$90,000/ha. more than on class 1 land.

These figures must be interpreted with great caution. They are derived from one particular case study. Calculation of site preparation costs were based on only five observations, although there is a strong relationship between these costs and soil quality. The regression coefficient expressing the relationship between soil quality and service installation costs was only significant at the 15% level. More conclusive evidence must be gained from additional investigations in other locations in order to draw more general conclusions. Even if service installation

costs are ignored, since they dwarf compared to site preparation costs, the above figures appear to hint that diverting urban development from class 1 to class 4 land in order to safeguard against possible future food shortages, is costly. Additional site preparation cost is only partly offset by additional agricultural land rent on soil class 1. If future food shortages emerge, it is highly unlikely that one hectare of prime land would be valued at over \$60,000. Moreover, the preservation policy does not contribute greatly to preventing possible future food shortages. Compared to the total stock of prime agricultural land in Ontario, the converted portion to urban use is relatively small (Frankena and Scheffman, 1980). There will be a strong impetus to develop prime lands on the basis of land quality alone.

The above figures are not the final cost of agricultural land preservation. The cost components from equation (2) not considered in this empirical investigation and usually not related to land quality could either increase or decrease preservation costs. If they increase the above cost figures, agricultural land preservation becomes an even more expensive objective. On the other hand, if some of the deleted terms from equation (2) are negative, the cost of prime land preservation might become reasonable. Negative terms indicate higher urban use values on class 4 land and higher transportation cost, open space value, and net environmental cost on prime land. In that case the purpose of prime land preservation is not exclusively limited to being a hedge against possible future food shortages. Aside from the insurance function, preservation is then pursued because it yields other benefits not related to food security.

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