Benefit-Cost Principles for Land Information Systems

Gregory L. Poe, Richard C. Bishop and Jeffrey A. Cochrane

Gregory L. Poe is a doctoral candidate in natural resource economics in the Department of Agricultural Economics, University of Wisconsin-Madison. His research interests include management of environmental risk and externalities, non-market valuation, and evaluation of natural resource and environmental policies.

Richard C. Bishop is a professor in the Department of Agricultural Economics, the Center for Resource Policy Studies, and the Institute for Environmental Studies at the University of Wisconsin-Madison. His duties include teaching in environmental and resource economics and benefit-cost analysis.

Jeffrey A. Cochrane is a doctoral candidate in resource economics in the Department of Agricultural Economics, University of Wisconsin-Madison. His research interests include exploration of interdisciplinary social theories to understand collective decision-making with respect to resources.

Abstract: *Past investigations into the economics of land information have focused on the cost aspects of alternative systems, with the benefits perceived as intangible. This paper reviews the economic concepts that relate to the valuation of information systems and demonstrates that cost comparisons generally provide a biased estimate of the net social benefits of improved land information systems. For this reason, application of the avoided cost approach could lead to misguided advice about which systems are most desirable from an economic perspective. Possible methods for more accurate estimation of the net social benefits are suggested.*

With some notable exceptions (e.g., Blaine and Randall 1987; Wunderlich and Moyer 1984) past investigations into the economics of land information systems have apparently concluded that information-economics has little to offer in the evaluation of alternative information systems. These investigations then proceed either to conduct cost comparisons of alternative information systems using avoided cost techniques, or to discuss in broad terms the 'intangible' aspects of information and information systems (e.g., Epstein and Duchesneau 1990; Gurda *et al.* 1987; Moyer and Niemann 1990).

The objective of this paper is to review the economic concepts that relate to the valuation of information systems and to suggest principles for the proper accounting of benefits and costs of improved land information systems. The motivating assumption is that the economic potential of land information systems cannot be adequately addressed until the underlying economic foundations are understood.

Note: *This project was supported by the College of Agricultural and Life Sciences, University of Wisconsin-Madison, and funding was provided, in part, by the U.S. Department of Agriculture Soil Conservation Service through the CONSOIL project.*

Particular emphasis is given to the demand characteristics and value of information, an area of study that has received much attention in the general economic literature but is notably limited in studies concerned with the benefits and costs of land information.

The prevailing view in the land information economics literature is that the avoided cost approach underestimates the value of improvements in land information system services (Blaine and Randall 1987; Epstein and Duchesneau 1990). A careful examination of the economics of land information provision will show that either underestimation or overestimation of the "true" benefits will occur when the avoided cost approach is applied. Possible methods for more accurate estimation are suggested.

Concepts in Land Information Economics

The objective of applied information economics is to identify the information system that will maximize net social benefits over time (Eisgruber 1973; Marschak 1968). This section develops a simple static graphical approach to evaluating the economic desirability of alternative information systems, and demonstrates that the avoided cost approach will, in general, provide a biased estimate of the net benefits of alternative information systems.

A 'Market' for Information

Information can be viewed as an intermediate product in an inquiry- and decision-making process (Chavas and Pope 1984; Marschak 1968). It is the output of a data system or inquiry process that organizes, stores and transmits data, and it serves as an input into decision-making processes. In this manner it is possible to envision a land information market that incorporates both 'supply' and 'demand' characteristics.

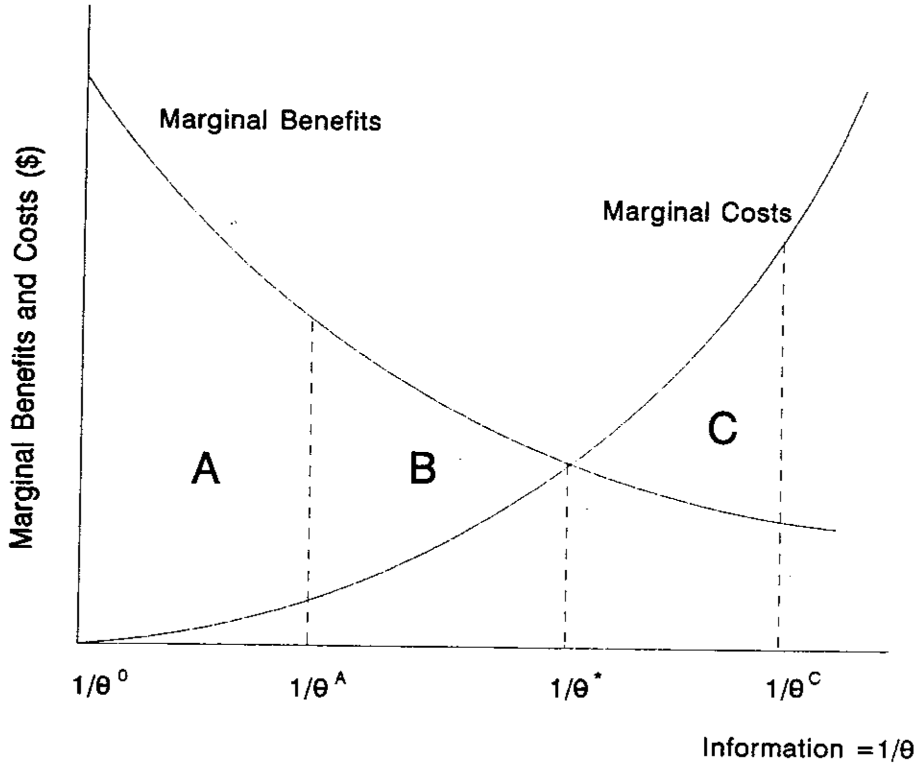
Our conceptualization of this land information market focuses on land information that is publicly provided and has public good characteristics, factors that make land information quite a bit different from conventional commodities (e.g., oranges, cars, etc.) wherein market supply and demand curves represent consumer and producer quantity responses at different prices. This distinction is important for two reasons. First, the quality of publicly provided information is determined exogenously by policy makers, information specialists, land conservation committees and so on. Thus, it is likely that the level of information provision will deviate from 'market clearing' or 'equilibrium' conditions where the marginal social costs of producing information equal the marginal social benefits. Similarly, the price charged for information is not necessarily related to the marginal cost of provision. It is typically the case that public land information fees are set administratively, not by market interactions.

Second, the public goods characteristics of information necessitate a different method of conceptualizing a market than conventional analyses of supply and demand (Samuelson 1954; Boadway and Wildasen 1984). For most goods and services, the aggregate demand represents the horizontal summation of all individual demands. For public goods, however, the level of the good is fixed and individuals instead attach a marginal benefit or a willingness to pay for the good, a value which may vary considerably across individuals. The aggregate 'demand' for public goods represents the vertical summation of the marginal benefits attributed to the service by all individuals[1].

Within this framework, a hypothetical market for information can be graphically depicted (Figure 1). In this figure, information is represented on the horizontal axis by the inverse uncertainty parameter, $1/\theta$. The parameter θ might be interpreted as the standard deviation of the distribution of a random variable. A distribution with a smaller standard deviation is said to provide more information about the random variable. The vertical axis in Figure 1, which is expressed in monetary units, measures the marginal benefits and costs of additional improvements of information.

In Figure 1 the marginal benefits or maximum willingness-to-pay curve is defined as the vertical summation of individual bid/valuation curves for incremental improvements in information. It is assumed that the willingness to pay for additional units of information is characterized by diminishing returns: initial reductions in uncertainty are valued highly by individuals, while subsequent units have

FIGURE 1.
Marginal Benefits and Costs of Information.



decreasing marginal benefits. The marginal-cost curve represents the costs associated with providing additional units of information, and is assumed to be a convex function of information. That is, the 'production' of information (reductions in uncertainty) is characterized by rising marginal costs. Implicitly, this formulation recognizes that although perfect information exists in concept, a degree of uncertainty will always remain in practice.

As an example, suppose that a county government is interested in providing better information about the productivity of agricultural soils based on a comprehensive countywide soil-testing program. The goal, and perceived benefits, of this program would be to provide an objective analysis of soil productivity for potential agricultural land buyers that would reduce the asymmetry in information about land productivity in land transactions. The decision variable is the number of tests per acre, which could conceivably range from very small to very large. Assuming no tests existed prior to this program, initial soil tests of one per every 10 acres would greatly reduce uncertainty about the productivity potential of the soil and be highly valued by the potential buyer of the land. Additional tests would also have incremental benefits, but the increments will diminish with each subsequent soil test, which is reflected by a downward sloping marginal benefits curve for additional tests. Using similar logic, and noting that each subsequent test costs the same but has a lower impact on reducing uncertainty, provides a rationale for the rising and convex marginal cost curve.

Benefit-Cost Analysis for Land Information Systems

Across disciplines benefit-cost analysis (BCA) has taken on a variety of interpretations. For economists, BCA is the application of the tools of welfare analysis to evaluate how a particular investment or monetary decision affects economic efficiency or net social benefits. The area underneath the marginal benefits curve in Figure 1 provides a monetary measure of the total benefits associated with each subsequent improvement in information. Similarly, the total costs for each level of information are measured by the area beneath the marginal cost curve. The difference in the area under the marginal benefits curve and the area below the marginal cost curve defines economic surplus—a monetary measure of social welfare.[2] For example, A+B denotes the economic surplus at the equilibrium value of $1/\theta^*$ in Figure 1. If, instead, only $1/\theta^A$ was supplied, then the surplus value would only be A. Similarly, if information were supplied at level $1/\theta^c$, then the surplus value would be A+B−C. Clearly, surplus is maximized where marginal benefits equal the marginal costs of information.

Benefit-cost analysis measures how the aggregate surplus value changes with new policies or projects. These changes in surplus are called the net benefits, or simply the benefits, of the project or policy change. Basically, the criterion for project acceptance is that there is a net gain in economic surplus resulting from the project (Boadway and Bruce 1984; Just, Hueth and Schmitz 1982; Anderson and Settle 1977). In practice, this is measured by subtracting the change in total costs from the change in total benefits.

The prevailing technique used in evaluating improvements in land information systems is based on the following avoided-cost philosophy:

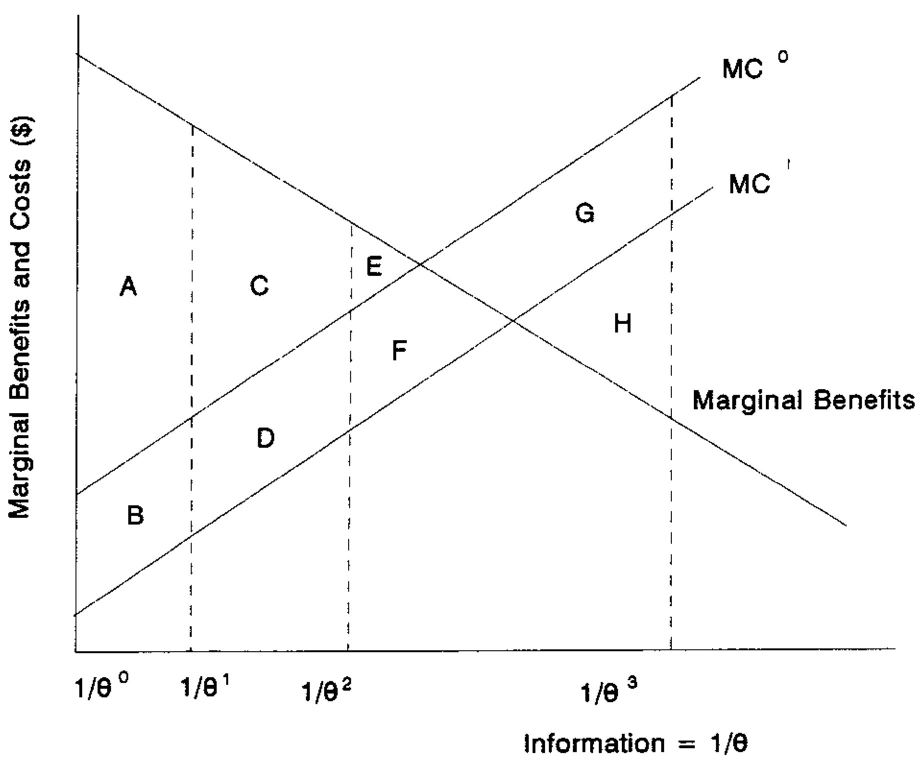
The benefits generated from a government operation can be represented by the costs avoided as the result of the operation. These savings are properly interpreted as benefits. The rationale, in terms of demand and expenditure, is that one would be willing to pay an amount equal to the cost savings in order to obtain the savings.

(Epstein and Duchesneau 1984, p. 7)

While relatively simple and easily applied in an accounting framework, the avoided cost approach only provides an exact (or 'true') measure of changes in surplus under the very restrictive assumption that the level of information services is fixed by the public sector both before and after a technological change. For example, in Figure 2, assume that a technological change results in a downward shift in the marginal cost of providing information from MC^0 to MC^1. If the quality of information remains at $1/\theta^1$ both before and after this shift, then the avoided cost benefit measure, B, would exactly equal the change in surplus. Under these conditions, the avoided cost approach does provide a valid and complete measure of the net benefits of the change according to benefit-cost theory. In essence, this has been the motivation for the parity approach adopted by the Dane County Multipurpose Land Information System (MPLIS) (see Gurda *et al* 1987.).

It is more common, however, that shifts in the supply of information are accompanied by a change in the quality of information allocated by the public sector. Computerized methods, for example, may offer greater precision as well as reducing the cost of land information provision. In these instances the avoided cost technique will provide a biased measure of change in surplus; the direction and the magnitude of the bias will depend upon the relation between the equilibrium point (where marginal benefits equal the marginal costs of information) and the actual level of information provision. For example, if the level of information were set at $1/\theta^1$ before the supply shift and $1/\theta^2$ afterwards, the true benefits measure would equal B+C+D. In contrast, the avoided cost benefit measure would correspond to area B+D. Thus, in situations where information provision is set at levels at or below the equilibrium, the avoided cost measure of benefits provides an underestimate of

FIGURE 2.
Measurement of Net Benefits.



the true benefits of improvements in information provision.[3]. The belief that this type of disequilibrium represents the situation in the real world appears to be the motivating factor for investing in many land information systems.

Quite a different result occurs if the level of information provision is set at levels exceeding the market clearing conditions. Such a case might at first seem somewhat counterintuitive, but could occur in instances where technological advances are so rapid that they exceed the needs of information users. Our observations of overzealous information technicians who are infatuated with the technology indicate that indeed this situation is not so unlikely. These conditions are demonstrated graphically in Figure 2 in a move from $1/\theta^2$ to $1/\theta^3$, where, in this case, $1/\theta^2$ is assumed to represent the initial conditions. Under these assumptions the true benefits are given by $B+D+E+F-H$, while the benefits as measured by the avoided costs approach are $B+D+F+G$. As such, the avoided cost approach provides an overestimate of the benefits of the new information system.

The implication of the above analysis is that, in cases where information is publicly provided, the avoided cost approach does not, in general, provide an unbiased measure of the 'true' benefits of an improvement in land information services. Knowledge of, or strong assumptions about, the demand for information and the structure of the information market are required before broad statements about the direction and degree of the biases associated with the avoided costs approach can be made.

In a similar vein, a second limitation of the avoided cost approach is that it may be an invalid measure of benefits in evaluating new types of information. The question of validity would arise when either the old system could not provide the new type of information at any cost or the costs of providing information with the old system exceed society's ability to pay for that type of information. In the former case, there are simply no costs with which to make a comparison.[4] In the latter case, the costs of providing the new information with the old system do not serve as a valid base for comparison. In this instance, cost savings using the old system's costs to provide the additional information do not represent a true benefit to society. Instead, the correct theoretical measure of the benefits from previously unavailable information is the resulting increase in economic surplus.

The Economic Value of Information

The previous section demonstrated that both the costs and benefits of information should be considered in evaluating the economic desirability of alternative information systems. The obvious question is how do we get beyond descriptive discussions of the benefits of information to derive a monetary measure of such values. Economic theory has identified two, not necessarily unrelated, sources of the economic value of information which could provide a framework for valuation. First, improved information enables individual agents, acting in isolation, to make better economic decisions. Even Robinson Crusoe would have been willing to allocate some of his limited resources to obtain better information about the agricultural seasons. The second source of economic value is that information facilitates transactions between interacting agents. Such transactions need not be limited to conventional goods and services, and could be broadly defined to include government participation in environmental policies. These two sources of value are considered separately in the following section under the headings of decision and transactions cost analysis.

Decision Analysis

Theory. Decision analysis typically employs an expected utility framework incorporating Bayesian updating (Anderson, Dillon and Hardaker 1977; LaValle 1978; Winkler 1972). Consider a simple example from Baquet, Halter and Conklin (1976). A pear farmer believes there is a chance that frost will hit on a particular night. The farmer must then decide whether or not to use costly heaters to protect the crop. Under the expected utility framework, the farmer is assumed to choose an action which maximizes expected utility.[5]

Suppose there is frost and the farmer did decide to use heaters. The farmer is assumed to know what level of income will thereby be achieved, and can assess the utility derived from that income. Suppose then that frost does not occur, but the farmer did still decide to use heaters. (Obviously, the decision is made before the farmer knows whether there will be frost.) The farmer can again calculate net income and utility under this scenario. The expected utility framework posits that this farmer compares the two possible utilities resulting from a decision to heat, multiplies them by the respective probabilities of frost, and adds them together. This total is the expected utility from a decision to heat. The process is repeated for a decision not to heat. The two expected utilities are compared, and the farmer then makes that decision which results in highest expected benefits.

Of course the farmer may wish to purchase information in the form of a weather forecast, knowing that the weather forecaster has access to considerably more data. Assume that the farmer has previous experience with weather forecasts, and knows that they enable better prediction of frost. More precisely, the farmer has an idea about the likelihood of a prediction of frost given that frost actually will occur. The farmer then must decide whether or not this "information service" (Hirshleifer and Riley 1979) that generates information is worth purchasing.

Under Bayesian updating, the farmer will utilize the weather forecast to update the assessment of expected utilities by combining the likelihood of a true forecast with prior beliefs about the probability of frost, using the well-known laws of probability derived by Bayes. By comparing expected utility with and without information, the farmer can determine the *ex ante* (before acquisition) value of an information service. This is sometimes termed the farmer's "willingness-to-pay" or "bid price" for an information service.[6]

Application. While interesting from a theoretical standpoint, calculation of the bid price for information via decision analysis is extremely data intensive. It requires the elicitation of subjective prior probabilities for all the possible states of the world (in the orchard example there were only two), knowledge of the consequences of each action for each state (in the example there were four consequences to consider), direct elicitation of preferences and determination of utilities for each consequence (again, four), and elicitation of subjective likelihoods of true information messages (in the example there were two kinds of forecasts, times two states, yielding four likelihoods). This approach may be feasible only for very simple types of information to be used for very simple decisions. Moreover, there is some concern, expressed more frequently by non-economists, whether particular decision-makers behave in a manner consistent with Bayesian updating and the expected utility axioms.

Returning to the example of the farmer and the weather forecast, presumably the farmer's assessment of the likelihood of a true forecast was based on previous experience with such forecasts. The decision to purchase a new forecast was based on the evaluation of the consequences of frost damage, not on any change in the likelihood of a true forecast. What if an entirely new type of forecast suddenly becomes available? For example, suppose that the expert now has access to satellite data, where previously she/he relied on ground-sensing devices. The farmer has no terms of reference with which to reassess the likelihood of a true forecast.

For more complicated problems, or for problems in which assessment of likelihoods is difficult, an alternative method entails the direct determination of the bid price of information through "contingent valuation" (Mitchell and Carson 1989). Essentially, this method employs personal or telephone interviews, or mail surveys to ask people about the values that they would place on non-marketed commodities "*contingent* on the existence of a market or other means of payment" (Anderson and Bishop 1986, p. 91). The farmer in the example could be asked to specify a bid price for a forecast that has a certain, presumably higher, likelihood of being true.

The contingent valuation method is increasingly accepted as a useful tool for benefit-cost analysis. It was authorized for the valuation of outdoor recreation in the *Economic and Environmental Principles and Guidelines for Water and Related Land*

Resources Implementation Studies (U.S. Water Resources Council 1983). Later, the U.S. Army Corp of Engineers prepared its own manual for applying the method (Moser and Dunning 1986) and has conducted many contingent valuation studies (Mitchell and Carson 1989, p. 13). The contingent valuation method was deemed acceptable by the U.S. Fish and Wildlife Service for human use and evaluation studies (U.S. Fish and Wildlife Service 1985). The U.S. Environmental Protection Agency, in its *Guidelines for Performing Regulatory Impact Analysis*, lists contingent valuation as one of the four basic methods for valuing the environmental benefits of proposed regulations (U.S. Environmental Protection Agency 1983, p. 9). With some caveats, the contingent valuation method was endorsed for estimating the damages done by releases of oil and toxic chemicals into the environment under procedures promulgated by the U.S. Department of the Interior (1986) to implement the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and amendments to the Clean Water Act. While contingent valuation has not, to our knowledge, been applied to the evaluation of land information systems or such other technologies, research to evaluate its potential might pay rich dividends.

In an application to land information systems, individuals might be asked their willingness to pay (bid price) for specific types of land information products. Individuals would be presented with an array of land information products from, say, a zoning map and separate topographic map printed to different scales requiring visits to separate offices in different parts of town, to a computer-generated map containing both zoning and topographic data overlain with satellite imagery of ground cover and sent via electronic data transfer directly to the consumer's office.[7] The potential success of contingent valuation in specific applications depends on the ability of survey respondents to imagine the purchase of a product outside of their experience. Significant progress has been made in recent years in assessing the reliability and validity of contingent valuation, and in the design of surveys to elicit the most accurate values (Mitchell and Carson 1989; Bishop and Heberlein 1990; Cummings, Brookshire and Schulze 1986).

Transactions Cost Analysis

Decision analysis requires direct determination of the demand for information. In contrast, transactions costs analysis involves measuring the effect of information on supply and demand of goods for which information is used. In this analysis, it is posited that market transactions are impeded by lack of information, a factor that increases the costs of voluntary exchange and reduces the aggregate welfare of society. In a seminal article, Coase (1960) noted:

> *In order to carry out a market transaction it is necessary to discover who it is that one wishes to deal with, to inform people that one wishes to deal and on what terms, to conduct negotiations leading up to a bargain, to draw up a contract, to undertake the inspection to see that the terms of contract are being observed, and so on. These operations are often extremely costly, sufficiently costly at any rate to prevent many transactions that would be carried out in a world in which the pricing system worked without cost. (p. 15)*

Dahlman (1979) categorized these transactions costs, and relates all transactions costs to resource losses and imperfect information.

> *Both search and [market] transaction costs owe their existence to imperfect information about the existence and location of trading opportunities or about the quality or characteristics of items available for trade. The case is the same for bargaining and decision costs: these represent resources spent in finding out the desire of economic agents to participate in trading at certain prices and conditions. What is being revealed in a bargaining situation is information about willingness to trade on certain conditions, and decision costs are resources spent in determining the terms of trade are mutually agreeable. Policing and enforcement costs are incurred because there is a lack of knowledge as to whether one (or both) of the parties involved in the agreement will violate his part of the bargain. . . . Therefore, it is really necessary to talk only about one type of transaction cost: resource losses incurred due to imperfect information. (p. 148)*

In brief, three general forms of transactions costs are recognized: market information costs, contracting costs, and enforcement costs. A convenient way of remembering this taxonomy is the acronym ICE (Bromley 1986). It is important to note that the type of information captured by this taxonomy is subtly different from that considered under decision analysis. In transactions cost analysis, information is viewed as a required input into the market process. With it, there will be a transaction; without it, there will not. Information here is akin to a transportation cost to ship a product to a retailer, or a telephone charge for service required to take orders from consumers. Note that probability does not enter into this type of analysis.

The ICE conceptualization is particularly relevant to the valuation of improved land information systems. Blaine and Randall (1987) argue that there is a demand, and thus a value, for improved market information.

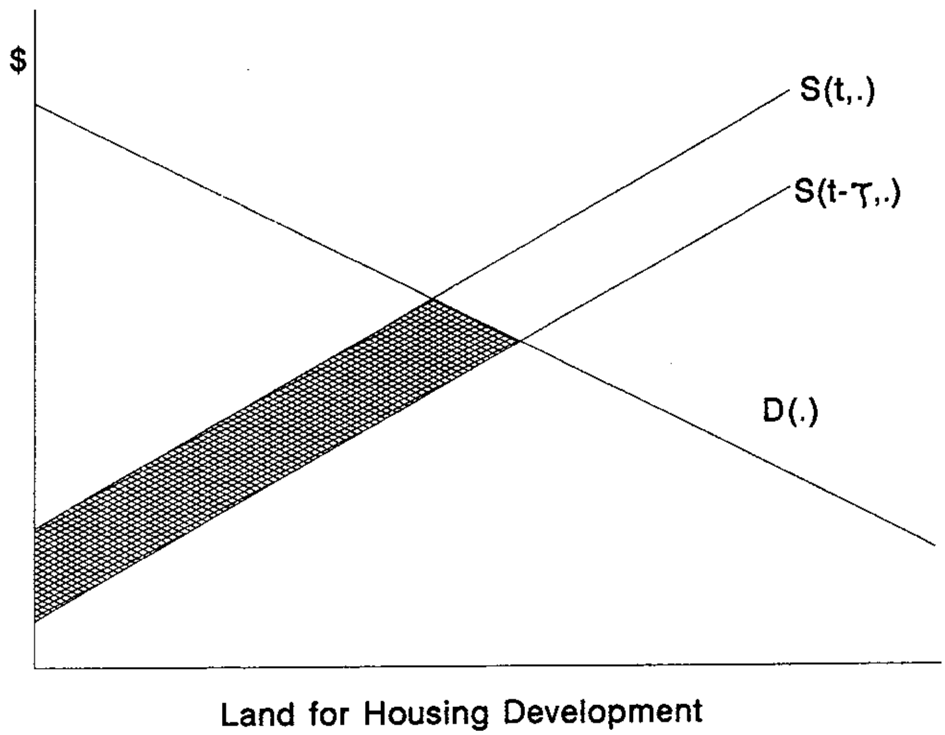
The buyer is willing to pay for a certain amount of parcel quality information to help him identify the parcel which contains the characteristics he desires. In the traditional land market literature the implicit values of these characteristics are capitalized into the total value of the parcel. In a world of imperfect information, this capitalization will be imprecise and perhaps biased. . . . Even if the implicit values of the parcel characteristics are perfectly capitalized into parcel values, the individual buyer is unable to observe either the implicit values or the characteristics. (p. 6)

Information of this type reduces costs to achieve established objectives, e.g., the purchase of a parcel with particular characteristics. With good quality information, the buyer may find the parcel quickly. Without good quality information, the buyer may need to spend considerable time and money locating the parcel using low quality information. This subtracts from the buyer's ability to pay for the parcel once it is found, reducing effective demand for the parcel. This transaction cost is not distributed to anyone; it is lost. Society gains by reducing such costs.

Similarly, the contracting of soil and water conservation programs is facilitated by improved land information systems. For example, the computerized MPLIS in Dane County enabled contractors to prepare 20 percent of all conservation plans in Wisconsin, even though the county comprises only 4 percent of all the agricultural land in the state. This difference in rates is attributed to improved land information technology in Dane County (Moyer 1989; Licht 1989). There is also some evidence that improved land information services may aid in the enforcement of conservation mandates. Moyer and Niemann (1990) argued that the failure to share information layers has impeded enforcement of the "swampbuster provisions" of the 1985 Food Security Act in the prairie pothole region. Ventura (1988) demonstrated that a MPLIS can be used to target highly erosive parcels for conservation planning.

Using a land market for new housing development as an example, Figure 3 demonstrates a theoretical approach to valuing changes in transactions costs.[8] In this figure, D(.) represents the demand for land by housing de-

FIGURE 3.
Transactions Cost Method of Valuing Improved Information.



velopers, a demand that is, in itself, derived from consumer demands for new housing units. The supply curve of land units represents the marginal cost of each additional unit of land. This supply curve, S(t,.) not only accounts for the opportunity cost associated with each parcel, but is also defined to include a unit transactions cost, t, associated with each unit of land purchased[9,10]. These latter costs primarily consist of search costs for locating parcels that have suitable site characteristics, zoning patterns, current ownership patterns, soil and subsoil characteristics, location relative to major arteries, etc. Suppose that an improvement in information provision reduces these costs to $t-\tau$ such that the new supply of land is specified by $S(t-\tau,.)$. When all demand and supply effects are considered, the shaded area represents the benefit from an improved information system.

Application. As with the decision-analysis approach, transactions cost analysis poses formidable data-collection requirements. In this case the difficulty lies in determining supply and demand characteristics in all markets that might conceivably use the new information system. In each market, estimation of demand and supply would be required. In instances where various markets are related, estimation of cross-market effects might also be required.

If the "good" in question is an environmental good or natural resource such as erosion abatement, wetlands protection, or groundwater quality, the determination of demand and supply is particularly difficult. For these goods there are no demand or supply functions *per se*, but it is still possible to estimate marginal benefits and costs for specific levels of quality that could be used to guide public sector activity. Once again, contingent valuation may be the only feasible approach. In this case, the shaded area in Figure 3 would be estimated by asking "consumers" of, say, an A1 quality trout stream that has been negatively affected by agricultural runoff how much they would be willing to pay for better water quality, and presumably better fishing. These values would then be linked to improved information systems that would reduce runoff by facilitating more efficient farm planning. The state would, in a sense, be "supplying" better fishing quality via the information system. Aggregation across all "consumers" would yield the shaded area for the stream quality "market", the total net benefit attributed to the improved fishing quality from improved information system. Aggregation across all affected markets besides the market for stream protection would also be required for a complete accounting of benefits[11].

Case Study

The principle aim of this paper has been to conceptualize benefits and costs of information, and to demonstrate, in a theoretical framework, that both benefit and cost characteristics should be considered in evaluating alternative information systems. This final section outlines how these theoretical principles might be extended to the proper accounting of benefits and costs in a case study.

Project Description

An interesting case in point which utilizes transactions cost analysis is that of the Land Conservation Committee (LCC) in Dane County, Wisconsin, which uses data from a number of sources, and processes the data using a MPLIS. Prior to the installation of a MPLIS at the LCC, these data were processed manually by visually comparing maps drawn to different specifications. The process of identifying and developing farm plans for those farms with erodible soils was highly labor intensive and time-consuming. The product of the MPLIS is a single-tract map overlain with soils data showing an erosion index and parcel ownership information.

The primary benefit of this system is perceived to be the acceleration of the contracting of conservation programs that require the development of farm plans. Secondary benefits may accrue to individuals if the information is made available to the public. These additional benefits might be analyzed using decision analysis as discussed previously.

At some point it may also be possible to link this MPLIS to satellite photographs identifying tillage practices and crop rotations. It would then be possible not only to identify erosion problems and facilitate the development of farm plans, but also to generate maps highlighting farms that do not appear to be in compliance with the plans. The MPLIS could generate lists of names and addresses for use by field agents in making on-site inspections, and notification letters asking farmers to comply with their plans or risk losing program benefits.

The benefits that may be achieved under such a program stem from three primary sources:

1) Data processing cost savings,
2) Compliance enforcement cost savings, and
3) Increased compliance with the conservation restrictions resulting in lessened soil erosion.

Benefits from savings in the cost of data processing occur when the process of identifying erodible soils, notifying farmers, and developing farm plans is made more efficient. The costs of new hardware and staff training must be weighed against labor savings in processing data manually from soil and tract maps. Compliance enforcement is made more efficient if, by eliminating the need for visual inspection of farms, labor cost savings outweigh increased costs in remote sensing. The degree to which compliance will lessen soil erosion and the associated on-site costs (primarily present and future productivity losses) and off-site costs (in-stream damages—biological impacts, recreational impacts, water storage damage, navigation, and other "preservation values": off-stream damages—sediments in water conveyance, flood damage, water treatment) of erosion must be evaluated.[12] For some policy applications it may be appropriate to weigh these benefits against any increased costs incurred by farmers in changing their practices, crop rotations, machinery requirements, and so on (e.g., Mueller, Klemme and Daniel 1985).

Proper Accounting of the Benefits and Costs

In the Dane County case, the extent to which the implementation of farm plans and compliance enforcement would have been undertaken by the LCC in the absence of an improvement in the information system must be considered before evaluating the change in costs. If it is determined that the LCC would have undertaken the process of planning and examining the same acreage even without this new system, then costs savings from the MPLIS will represent a valid partial measure of benefits to the county.

As Licht has demonstrated, however, counties that do not have computerized systems tend to complete many fewer farm plans. It is simply not feasible for counties to engage in such a massive program when labor costs associated with contracting are prohibitively high. If this is true for Dane County, the entire cost of the proposed MPLIS at the new, higher level of identification and planning should be subtracted only from those expenditures which would have truly been made under a smaller program in the absence of a MPLIS. Intuitively, given the high start-up costs of a MPLIS, it may be the case that cost savings in this area will be quite low or even negative if it can be shown that Dane County would not have been very enthusiastic about soil conservation in the absence of a MPLIS. Total benefits will then be total costs at the old, manual level of identification, planning and enforcement less the full costs of the proposed information system, plus benefits from increased production and lessened pollution, less any additional costs to the farmer. These considerations are summarized in Table 1.

Although this approach to benefit measurement will not completely capture the benefit gain associated with the movement along an erosion-abate-

TABLE 1:
Summary of the Economic Benefits of a Hypothetical MPLIS

1. DATA PROCESSING COST SAVINGS = (Costs to process data to achieve the current or expected level of erosion identification and conservation planning under a manual system)—(Costs to achieve the new, high level identification and planning under the MPLIS)
2. COMPLIANCE ENFORCEMENT COST SAVING = (Costs under a manual system to process data, perform field inspections, etc. to achieve the current level or expected level of enforcement)—(Costs under an MPLIS to achieve the new, high level of enforcement)
3. BENEFITS FROM COMPLIANCE = (Benefits from increased compliance resulting in greater production and less pollution)—(Increased costs to farmers resulting from changed farming practices as a result of compliance)

ment demand curve, it does provide a closer approximation to the true change in economic benefits than methods that only consider cost characteristics. This difference in estimates may have an impact on the decision to invest in information services.

Conclusion

Past studies have tended to focus on only the cost aspects of information systems, with benefits perceived as intangible. This paper has shown, in a theoretical framework, that such methods generally provide a biased estimate of the net social benefits of improved information systems and could lead to misguided advice about which information systems are most desirable from an economic perspective. Using concepts from welfare economics, a demonstration of this method was outlined in a case study.

Acknowledgements

We thank Jean-Paul Chavas, D. David Moyer and the anonymous reviewers for their helpful comments.

Notes

1. The approach taken here deviates considerably from the information-as-a-product approach taken in Blain and Randall and Wunderlich and Moyer. Here, land information is assumed to have public goods characteristics of non-rivalness in consumption and non-excludability. As an anonymous reviewer pointed out, most information systems contain elements of both public and private goods. For example, some public information systems (FBI, IRS) generate excludable, or highly restricted, information and some private information systems generate information with public attributes, such as multiple listings. As with monopoly and perfect competition in the theory of markets, the approach taken in this paper and that adopted in the information-as-a-product literature are two extremes in a continuum of possibilities. Interestingly enough, as will be discussed later in this paper, these extreme approaches provide a very similar critique of the avoided-cost method. Refer to Epstein and Duchesneau (1990) for further discussion about public good characteristics of land information systems.
2. In other words, this economic surplus is the amount of money that would just compensate society (including producers and consumers) not to 'consume' information.
3. Blaine and Randall offer a market-based method for demonstrating that the avoided costs approach will underestimate the change in economic surplus when information is treated as a product and the information market is always assumed to adjust to a market clearing equilibrium. We note that some difficulties do arise with this approach in defining what constitutes a unit of information and for accounting for differences in quantity and quality of information. In spite of these difficulties, the Blaine and Randall presentation offers very strong insights about the relationship between the avoided cost and the 'true' benefits of improved information.
4. This can be presented in graphical terms using Figure 2, where instead the marginal cost curve, MC^0, would become verticle at some level of information. This perfectly inelastic section of the curve would indicate that the existing system could not reduce uncertainty beyond a certain point.
5. In economic theory utility is defined to be the level of well-being or happiness associated with a course of action.
6. Formally, the farmer calculates the bid price of information defined as

$$\gamma = \left\{ \gamma \,\middle|\, E_m \left[\max_a E\left[u(y_{s,a} - \gamma \,;\, \pi_{s:1})\right] \right) = \max_a E\left[u(y_{s,a} \,;\, \pi_{s:0})\right] \right\}$$

where
a = action (heat, don't heat)
$y_{s,a}$ = income when state *s* occurs and decision *a* has been taken
γ = bid price of (willingness to pay for) information
$\pi_{s:m}$ = posterior subjective probability of state *s* occurring given information m
u = utility.

The posterior subjective probabilities, $\pi_{s:m}$, are calculated using Bayes' Theorem from likelihoods and prior probabilities (Mood, Graybill and Boes), i.e., from the farmer's assessment of the likelihood of a true forecast and from the farmer's prior (without a forecast) beliefs about the probability of frost occurring. The expectation operator, E, is over possible states, while E_m is over possible forecasts.
7. A separate survey design might also attempt to measure the option price of an information service which individuals presently do not use but have some non-zero probability of use in the future (see Luzar and Hanemann for a discussion).
8. Figure 3 represents a market for a traditional private economic good in which supply and demand reflect the aggregate quantity responses across individuals in the market. In contrast to previous graphs, these aggregate curves represent the horizontal summation of individual curves.
9. In this instance, the unit transactions cost is attached to the supply curve. Alternatively, with similar results, the transactions costs could be incorporated into an effective demand curve. In both cases the transactions costs drive a wedge between the seller's price and the buyer's willingness to pay. In actuality, it is unlikely that transactions costs will fall only on the producer or the consumer. Rather, a portion of the transactions costs will typically fall on both groups. For example, people selling land may incur the costs of a realtor to locate buyers, while purchasers may expend time and resources in search.
10. As Nicholson (p. 372) notes, this analysis of transactions costs is somewhat limited by its failure to consider agents that benefit from such costs such as middleman brokers in real estate transactions. Discussion of such benefits is beyond the scope of this paper.
11. To this point, our analysis has focused on a land information market with a single use. The extension of this analysis to a MPLIS cannot be depicted in a single graph, but is, nevertheless, analogous to the single market case. For a MPLIS one would add up the benefits in all affected markets and compare them to the change in the cost of information provision.
12. Poe *et al.* develop a method for translating soil loss into economic values. See also Crosson and Stout, Clark, Haverkamp and Chapman, and Ribaudo for discussions of the economic costs of erosion.

References

Anderson, G.D., and R.C. Bishop. 1986. "The Valuation Problem", in Bromley, D.W., ed., *Natural Resource Economics: Policy Problems and Contemporary Analysis*. Kluwer-Nijhoff Publishing, Boston: 89–138.

Anderson, J.R., J.L. Dillon, and J.B. Hardaker. 1977. *Agricultural Decision Analysis*. Iowa State University, Ames.

Anderson, L.G., and R.F. Settle. 1977. *Benefit-Cost Analysis: A Practical Guide*. Lexington Books, Toronto.

Baquet, A.E., A.N. Halter, and F.S. Conklin. 1976. "The Value of Frost Forecasting: A Bayesian Appraisal", *American Journal of Agricultural Economics*, 58:511–20.

Bishop, R.C., and T.A. Heberlein. 1990. "The Contingent Valuation Method", in R.L. Johnson and G.V. Johnson, Eds., *Economic Valuation of Natural Resources: Issues, Theory, and Application*. Westview Press, Boulder, CO.

Blaine, T.W., and A. Randall. 1987. "The 'Avoided Cost' Approach to Valuing Improvements in Land Information System (LIS) Services Underestimates the True Value", in Wunderlich, G., Ed. *The Economics of Land Information: A Symposium of The Institute for Land Information*. ACSM-ASPRS Convention, Baltimore, Maryland: 5–14.

Boadway, R.W., and N. Bruce. 1984. *Welfare Economics*. Basil Blackwell.

______, and D.E. Wildasen. 1984. *Public Sector Economics*. Little, Brown and Co., Boston.

Bromley, D.W. 1986. "Markets and Externalities", in Bromley, D.W., Ed., *Natural Resource Economics: Policy Problems and Contemporary Analysis*. Kluwer-Nijhoff Publishing, Boston: 37–68.

Chavas, J-P, and R.D. Pope. 1984. "Information: Its Measurement and Valuation," *American Journal of Agricultural Economics*, 66:705–27.

Clark, E.H. II, J.A. Haverkamp, and W. Chapman. 1985. *Eroding Soils: The Off-Farm Impacts*. The Conservation Foundation, Washington, D.C.

Coase, R.H. 1960. "The Problem of Social Cost", *Journal of Law and Economics*, 3:1–44.

Crosson, P.R., and A.T. Stout. 1983. *Productivity Effects of Cropland Erosion in the United States*. Resources for the Future, Washington, D.C.

Cummings, R.G., D.S. Brookshire, and W.D. Schulze. 1986. *Valuing Environmental Goods*. Rowman Allanheld, Publishers, Totowa, N.J.

Dahlman, C.J. 1979. "The Problem of Externality", *Journal of Law and Economics*, 22:141–162.

Eisgruber, L.M. 1973. "Managerial Information and Data Systems", *American Journal of Agricultural Economics*, 55:921–36.

______. 1978. "Developments in the Economic Theory of Information", *American Journal of Agricultural Economics*, 60: 901–905.

Epstein, E.F., and T.D. Duchesneau. 1984. *The Use and Value of a Geodetic Reference System*. University of Maine, Orono.

______. 1990. "The Use and Value of a Geodetic Reference System". *Journal of the Urban and Regional Information Systems Association*, 2:11–25.

Gurda, R.F. *et al.* 1987. "Costs and Benefits of GIS: Problems of Comparison", *International Geographic Information Systems (IGIS) Symposium: The Research Agenda*, 3:215–224.

Hanemann, W.M. 1988. "Information and the Concept of Option Value", *Journal of Environmental Economics and Management*, 16:23–37.

Hirshleifer, J., and J. Riley. 1979. "The Analytics of Uncertainty and Information: An Expository Survey", *Journal of Economic Literature*, 17:1375–421.

Just, R.E., D.L. Hueth, and A. Schmitz. 1982. *Applied Welfare Economics and Public Policy*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Lavalle, I.H. 1978. *Fundamentals of Decision Analysis*. Holt, Rinehart and Wilson, New York.

Licht, J.C. 1989. *The Impact of Computerization Planning on Conservation in Wisconsin*. Unpublished M.S. Thesis, Land Resources, University of Wisconsin-Madison.

Luzar, J. 1987. "The Economics of Precision: A Learning Theory Approach", Wunderlich, G., Ed. *The Economics of Land Information: A Symposium of The Institute for Land Information*, ACSM-ASPRS Convention, Baltimore, Maryland.

Marschak, J. 1968a. *Economics of Inquiring, Communicating, Deciding*, Working Paper 134, Western Science Management Institute, University of California, Los Angeles.

______. 1968b. *Efficient Choice of Information Services*, Working Paper 136, Western Science Management Institute, University of California, Los Angeles.

Mitchell, R.C., and R.T. Carson. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Resources for the Future, Washington, D.C.

Mood, A.M., F.A. Graybill and D.C. Boes. 1974. *Introduction to the Theory of Statistics*, third ed., McGraw-Hill, New York.

Moser, D.A., and C.M. Dunning. 1986. *A Guide for Using the Contingent Value Methodology in Recreation Studies, Volume II*. U.S. Army Corps of Engineers Water Resources Support Center, Fort Belvoir, VA.

Moyer, D.D. 1989. "Economic Impacts of Multipurpose Land Information Systems, *Proc. URPIS-17* (Perth, Western Australia).

______. and B.J. Niemann, Jr. 1990. "Economic Impacts of LIS/GIS Technology upon Sustainable Natural Resource and Agricultural Management", *Technical Papers 1990 ACSM/ASPRS Annual Convention*. (Denver, Colorado), 3:221–230.

______. *et al.* 1989. "Comparing the Costs: Manual Versus Automated Procedures for Handling Land Records", *Proc. ACSM/ASPRS* (St. Louis, Mo.) 5:198–206.

Mueller, D.H., R.M. Klemme, and T.C. Daniel. 1985. "Short- and Long-Term Cost Comparisons of Conventional and Conservation Tillage Systems in Corn Production", *Journal of Soil and Water Conservation*, 40:466–70.

Nicholson, W. 1985. *Microeconomic Theory*. Third Edition, The Dryden Press, Chicago.

Poe, G.L., R.M. Klemme, S.J. McComb, and J.E. Ambrosius. 1991. "Commodity Programs and the Internalization of Erosion Costs: Do they Affect Crop Rotation Decisions?", *Review of Agricultural Economics*, 13(2):223–235.

Ribaudo, M.O. 1986. "Regional Estimates of Off-Site Costs of Soil Erosion", in T.E. Wadell, Ed., *Proceedings of A Symposium Held in May 1985*, The Conservation Foundation, Washington, D.C.

Samuelson, P.A. 1954. "Pure Theory of Public Expenditure", *Review of Economics and Statistics*, 36:387–389.

Sudgen, R., and A. Williams. 1978. *The Principles of Practical Cost-Benefit Analysis*. Oxford University Press, Oxford.

U.S. Environmental Protection Agency. 1983. *Guidelines for Performing Regulatory Impact Analysis*. Washington, D.C.

U.S. Fish and Wildlife Service. 1985. *Human Use and Economic Valuation*. Washington, D.C.

U.S. Water Resources Council. 1983. *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*. Washington, D.C.

Ventura, S.J. 1988. *Dane County Soil Erosion Plan*. Dane County Land Conservation Committee, Madison, Wisconsin.

Winkler, R.L. 1972. *An Introduction to Bayesian Inference and Decision-Making*. Rinehart and Winston, Inc., New York.

Wunderlich, G. and D.D. Moyer. 1984. Economic Features of Land Information Systems, in B.J. Niemann, Jr. Ed., *Seminar on the Multipurpose Cadastre: Modernizing Land Information Systems in North America*. IES Report 123, Institute for Environmental Studies, University of Wisconsin-Madison, p. 183–202.