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Economic Analyses in Watershed Management Planning: Methods, Applications and Education

J.E. de Steiguer and Theresa Mau-Crimmins
School of Renewable Natural Resources, The University of Arizona, Tucson, 85721-0043, USA.

Abstract: The management of watersheds is most commonly thought to involve the hydrological, physical, biological and engineering sciences. However, economics also has a role in watershed management planning. Cost-benefit analysis (CBA) is the most common type of economic analysis used for watershed planning. CBA measures, in monetary terms, a project's inputs and outputs over the service life of the project. Under CBA, a project that yields discounted net benefits which exceed costs, is said to be "economically efficient." Economically efficient projects are desirable because they represent a potential Pareto improvement, which is to say that society can gain an economic surplus, hence a net improvement, from the activity. CBA is a useful decision method when the watershed manager must make a decision based solely upon economic efficiency. However, watershed managers frequently must deal with multiple decision criteria. Multi-Criteria Decision Models (MCDMs) have been developed for such situations. "Economics" can enter into MCDMs as one of the decision criteria. Examples of MCDMs include linear and goal programming, Multi-Attribute Utility Theory and the Analytic Hierarchy Process. With regard to the study of economics in watershed management curricula in American universities, economics and the management sciences play a small but important role in watershed education. However, with the trend toward greater stakeholder participation in watershed decisions, future curricula could see a greater demand for more social and management science courses.

Key words: Watershed management, economics, multi-criteria decision methods, cost-benefit analysis.

The Watershed and Economics

The watershed, which is defined as "the region draining into a river system, river or body of water" (Morris, 1976), has long-interested natural resource managers. This is true not only because of the watershed's obvious connection with hydrologic resources, but also because it is the source of many other commodity and environmental resources which are important to society. The management of watersheds for commodity outputs and environmental protection is most commonly thought to involve the hydrological, physical, biological and engineering sciences. However, economics also has a role in watershed management planning. This is true because watershed management planning deals with decisions about the allocation of scarce resources among competing production possibilities. And this – the optimal allocation of scarce resources among competing needs – is the purpose of economics (Ferguson and Maurice, 1974).

The purpose of this article is to illuminate the role of economics in watershed management for multiple use and environmental planning. The first section contains an overview of cost-benefit analysis, the most commonly-used economic analysis method for watershed planning. The second section provides examples of Multi-Criteria Decision Models which can make use of economic criteria. This is followed by a discussion of some applications of economic analysis to watershed management planning. The fourth section deals with economics education within university watershed management curricula. Finally, the article concludes with a view of some likely future trends in watershed economic analyses.

Cost-benefit Analysis

Watershed management projects for multiple-use and environmental protection are, most often, public projects. Indeed, many watershed improvement projects are conducted by government agencies on government-owned lands. Such projects might include efforts to reduce soil erosion, improve water quality, control flooding, provide for recreation or harvesting of timber. Multiple-use and environmental planning by private companies, such as those engaged in forestry, are less common than for public agencies. However, there is reportedly increased pressure upon private concerns to broaden the scope of their planning to include non-commodity resources (Loehle *et al.*, 2002).

Government involvement in watershed planning in predominantly market economies stems from the desire to remedy existing market failures such as externalities, open access resources or public goods situations. The presence of such market failures results in a less than socially-optimal allocation of resources as manifest through an under-production of environmental goods and services.

The purpose, then, of public cost-benefit analysis (CBA) is to determine if government intervention might improve economic welfare. This intervention can be viewed as a type of production process with project inputs and outputs. CBA measures, in monetary terms, a project's inputs and outputs over the service life of the project. Under CBA, a project that yields discounted net benefits which exceed costs, is said to be "economically efficient." Economically efficient projects are desirable because they represent a potential Pareto improvement, which is to say that society can gain an economic surplus, hence a net improvement, from the activity.

Cost-benefit analysis of public projects, as a formal method of economic analysis, began in the 1930s in response to concerns about government spending on large hydrologic projects in the American West (Field, 1994). The purpose of CBA was to help government allocate society's scarce resources to their most productive use. The scope of CBA has expanded during the last quarter century to include non- commodity and even non-use (e.g., existence and bequest values) benefits. Today, CBA is the principal analytical framework used to evaluate public expenditure decisions (Field, 1994). This is true despite criticisms that CBA is flawed as a form of policy analysis because it fails to differentiate between moral and economic values (Sagoff, 1988), or that certain policy decision may be correct even though the costs outweigh the benefits (Kelman, 1981), or that CBA has promised more than it has delivered as a policy decision tool

(Tietenberg, 1988). Its popularity is illustrated by the fact that nearly all western countries have developed protocols for CBA of government projects.

Assigning Monetary Values

A distinguishing attribute of CBA is that all project costs and benefits are converted into monetary units. The reason for this "monetization" is to provide a common unit of measure for all project inputs and outputs. Money is the common unit of measure because this is precisely the function it plays in society, i.e., the common measuring rod to facilitate exchange rather than bartering of goods and services.

Money valuation of environmental and natural resources strikes some people as improper, even immoral. But money functions in CBA simply as a common measure; it does not urge greed nor exploitation of resources. Philosophers and ecologists have suggested alternative non-monetary valuation systems, but these too involve the use of value-derived weights. Furthermore, the use of non-comparable measuring units does not avoid a value judgment, it merely postpones it (Turner *et al.*, 1994).

The costs for a watershed CBA are derived from valuation of project inputs. The guideline regarding input costs is that inputs must be priced at their social opportunity cost. In most cases, actual budgetary outlays may equal opportunity cost. However, situations can occur where budgetary outlay and opportunity costs diverge. For example, the project may demand such a large share of the market output, thus generating noticeable price effects on the rest of the society. An example would be a dam that requires a lot of concrete, thus bidding up regional concrete prices. Also, there may be significant externalities in the input market (e.g., environmental damages associated with the concrete production). In such cases, the input prices must be adjusted to reflect their true social opportunity cost.

Valuation of project benefits presents some special challenges. For those items which are traded in competitive cash markets, changes in market demand and supply functions can be used to value the benefits to producers and consumers. However, estimating market supply and demand curves, even if the market transaction data exist, is a complex statistical undertaking. Still other so-called "shadow pricing" methods are required for valuation of non-market uses such as outdoor recreation, environmental services, option values, and also for non-use values. Methods available include both indirect valuation methods, where value is revealed through behavior (e.g., travel cost method), and direct valuation methods where values are obtained from surveys of consumer preference (e.g., contingent valuation method).

Benefit estimation, because of its complexity, is often impractical for analysts, especially when faced with a deadline. Indeed, such non-market benefit valuation efforts can become major studies within themselves. Consequently, analysts increasingly rely upon existing studies as sources for borrowing benefit values (Boardman *et al.*, 1996). Economists have devoted substantial effort toward providing such "plug-in" values in the form of estimated values, price elasticities and per-unit impact values. The practice of transferring of these existing benefit values from one CBA study to another is now well-accepted.

Net Present Value Criterion

Watershed management projects always occur over a period of time as, for example, from the beginning of a water quality improvement project to the realization of benefits. Because of this time element, a number of project CBA criterion have been devised which take into account the time dimension by discounting future costs and benefits to the present. Such discounting makes costs and benefits that occur at different times during the life of a project are algebraically comparable. Examples of project CBA criterion include net present value, benefit-cost ratio and the internal rate of return. For comparing multiple projects of varying durations, there are criteria such as equivalent annual rent.

The net present value (NPV) criterion is favored as a project evaluation criterion because a positive NPV insures a potential Pareto improvement (i.e., a net economic gain). Net present value is the discounted benefits minus discounted costs as they occur over time. The formula for NPV is:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t}$$

where,
n = the total length of the project in years,
t = year of benefit or cost occurrence,
B = benefits, C = costs, i = the social discount rate.

The social discount rate (SDR), a key element in public project net present value calculations, is intended to represent society's preference for current over future consumption (Field, 1994). However, despite general agreement on what the SDR should represent, there is controversy over exactly what discount rate should be used in practice. The debate ranges from those who advocate 0% discount rates to those who say that SDR should equal the positive marginal earning rates for private business investments. The choice of a discount rate is important, because it carries implications regarding the size of government and income distribution between present and future generations. In practice, most discount rates used by agencies of the US government range between 3% real (i.e., less inflation) and 7% nominal (i.e., inclusive of inflation) (Loomis, 2002).

Steps in a Cost-Benefit Analysis

Boardman *et al*. (1996) have identified the major steps in a cost-benefit analysis as follows:

1. Choose a project evaluation criteria: The most preferred project evaluation criterion, as previously noted, is maximization of net present value. However, the analyst has options and must choose the one best suited to his/her objectives.
2. Determine the accounting stance: The economist must select the proper accounting perspective for the analysis in order to determine whose benefits and costs will be counted.
3. Select the alternative projects: The analyst must determine if it is a single watershed project which will undergo CBA or are their several competing projects.
4. Identify the types of physical inputs and outputs: Because the watershed project

is a production process, there must be inputs and outputs. The analyst must determine the types of inputs it will take to get the job done. Determining the outputs of a project, i.e., benefits, can, however, be troublesome. There may also be "bad" outputs such as sedimentation from more logging. The bad physical outputs must be accounted for as negative benefits.

5. Quantify outputs over the life of the project: Quantify the total physical amounts of the outputs over the life of the project, e.g., how many RVDs, the amount of timber harvested, how much less flooding or the amount of sedimentation? This is a difficult phase of a CBA study depending upon: a) science, b) observation, c) or even estimates by experts.
6. Monetize all inputs and outputs: This is the process of determining the dollar value of benefits and costs. Benefit valuation should ideally be performed for both commodity and environmental goods and services.
7. Select a discount rate: The analyst must select a social rate for discounting future benefits and costs. Often, however, these discount rates are mandated by government policy.
8. Determine net present value: The economist must discount and sum the net values of project costs and benefits. Computer spreadsheets can help here.
9. Perform sensitivity analyses: Sensitivity analyses are an attempt to deal with uncertainty. They may involve varying discount rates or other factors in the analysis, such as physical inputs or outputs, or values of benefits or costs. Sensitivity analysis will result in a variety of answers rather than one single answer. Often providing a range of answers is the best way to deal with uncertainty.
10. Recommend the preferred alternative: Prepare a report and recommend the project that performs the "best" according to the chosen criterion.

Multi-Criteria Decision Models

CBA is a useful decision method when the watershed manager must make a decision based solely upon economic efficiency. However, watershed managers frequently must deal with multiple decision criteria. Fortunately, Multi-Criteria Decision Models (MCDMs) have been developed for such situations. "Economics" can enter into MCDMs as one of the decision criteria. For example, Loomis (2002) suggests five general categories of criteria for natural resource multi-criteria decisions: (i) physical and biological feasibility, (ii) economic efficiency, (iii) distributional equity, (iv) social and cultural acceptability, and (iv) administrative feasibility. From these categories, it can be seen that economic efficiency is only one of the five possible factors which govern the decision.

First developed during World War II for strategic decision-making, MCDMs have since been applied to a diversity of decision problems. Watersheds, and more generally natural resources management, are among the many types of MCDM applications. Because MCDMs comprise a large number of analytical methods, they are often classified for convenience as either Multi-Objective Decision Models (MODMs) or Multi-Attribute Decision Models (MADMs) (DeMontis *et* *al*., 2000). MODMs are those used to support the design of separate decision alternatives. MODM methods include techniques such as linear, goal and integer programming.

Linear programming uses a single decision objective function subject to possibly several decision constraints. These decision constraints, in effect, embody multiple decision criteria. Economic criteria often enter into the objective function as, for example, "to maximize the net benefits of watershed management," where the constraints could embody ecological and social criteria. For example, the previously stated objective function, "to maximize the net benefits of watershed management," could be constrained by a desire to achieve certain water quality standards or to minimize soil erosion.

Goal programming is a MODM which requires the decision-maker to set quantitative target attainment goals for each separate criteria and, as a programming objective, attempt to minimize the collective deviation from these goals (Anderson *et al*., 1994). The goals, using the five Loomis (2002) criteria as a general framework, would involve quantitative targets for physical and biological impacts, economic efficiency and so forth. Weights supplied by the decision-maker would indicate the relative importance of the criteria.

Integer programming is a mathematical problem-solving approach like linear programming. However, the decision variables are integers rather than continuous values. Furthermore, the integer variables may be 0 to 1 (i.e., binary variable) to indicate "yes-no" watershed management decisions such as: do we build a flood control structure: "yes or no?"

MADMs, in contrast, are used to support the selection of the one "best" decision alternative from among several possible alternatives. MADM methods include techniques such as the Multi-Attribute Utility Theory and the Analytic Hierarchy Process. The Analytic Hierarchy Process (AHP) is a popular MADM method. AHP provides a systematic procedure for comparison and weighting of decision criteria and alternatives. Although different from goal programming, AHP nevertheless permits the simultaneous consideration of a number of decision criteria including economic efficiency. The steps in the AHP method are as follows (adapted from Saaty, 2000): (i) structure a problem in the form of a hierarchy with a goal, criteria and alternatives, (ii) elicit judgments regarding a decision-maker's relative preferences for criteria and alternatives and represent those judgments with numbers, (iii) use the numbers to calculate the priorities of the criteria and alternatives in the hierarchy, and (iv) complete the synthesis of those results to determine the preferred alternative.

An AHP hierarchy for watershed management decision-making can have as many levels as needed to fully characterize a particular decision situation. For example, consider the following hypothetical two- level (i.e., one set of choice criteria and one set of choice alternatives) public lands decision situation (Fig. 1). Assume that a manager's goal is to select the best possible watershed plan from three alternatives plans: A, B and C. Assume also that there are four criteria which enter into this decision one of which deals with economics: (i) economic efficiency, (ii) ecological impacts, (iii) social/cultural impacts, and (iv) water quality impacts.

The decision-maker expresses his/her opinion regarding the relative importance of the criteria and preferences among the alternatives using a pairwise comparisons and 9-point system ranging from 1 (the two choice options are equally preferred) to 9 (one choice option is extremely preferred over the other). If, however, one criteria is preferred less than the comparison criteria, the reciprocal of the preference score is assigned. These preference scores next undergo a synthesis process (Saaty, 2000) in order to calculate a priority weight vector for the criteria. The final result in this example is a 1 x 4 vector of normalized, i.e., summing to 1, criteria preference scores. Once the scoring and synthesis process has been completed for the criteria, it is conducted for the alternatives. In this example, there are three alternatives, hence three vectors of weights, which are arranged to form a 4 x 3 (i.e., four criteria by three alternatives) matrix of normalized preference scores.

The final step in the AHP process is to complete the synthesis by multiply the 1 x 4 "criteria vector" by the 4 x 3 "alternatives matrix" in order to obtain a 1 x 3 vector of normalized unit-less weighted preference scores for each of the three alternative sites. For example, this hypothetical AHP exercise might have yielded final weighted preference scores for the three watershed plans as follows: plan A = 0.35 + plan B = 0.25 + plan C = 0.40 = 1.0. Plan C then is the decision-maker's preferred plan based upon his/her subjective judgment. The score (i.e., 0.40 out a possible 1.0) indicates the relative strength of that preference.

Review of Economic Applications

This section is an annotated bibliography of articles about applications of cost-benefit analysis and Multi-Criteria Decision Models to watershed problems. Its purpose is to complement the previous methods section by providing descriptions of actual economic applications. These particular articles were chosen because they represent a sample of studies from both developed and developing economies.

Braden and van Ierland (1999) highlight methods for applying economic principles to sustainable water management. Cost-benefit analysis, contingent valuation method, cost effectiveness studies, multi-criteria analysis, and multiple goal programming are discussed. The authors identify water supply, treating and reclaiming sanitary wastes, irrigation, and watershed management as areas which can benefit from the use of these decision-making tools.

McDonald and Johns (1999) discuss social benefit-cost accounting, applying the method to a watershed in Bogota, Columbia. One advantage of this technique mentioned in this paper is a greater understanding of watershed project costs and benefits by all stakeholders. Additionally, participants' interests are given equal consideration.

Ninan and Lakshmikanthamma (2001) performed a social cost-benefit analysis of a watershed development project in India. Net present value, benefit-cost ratio, and

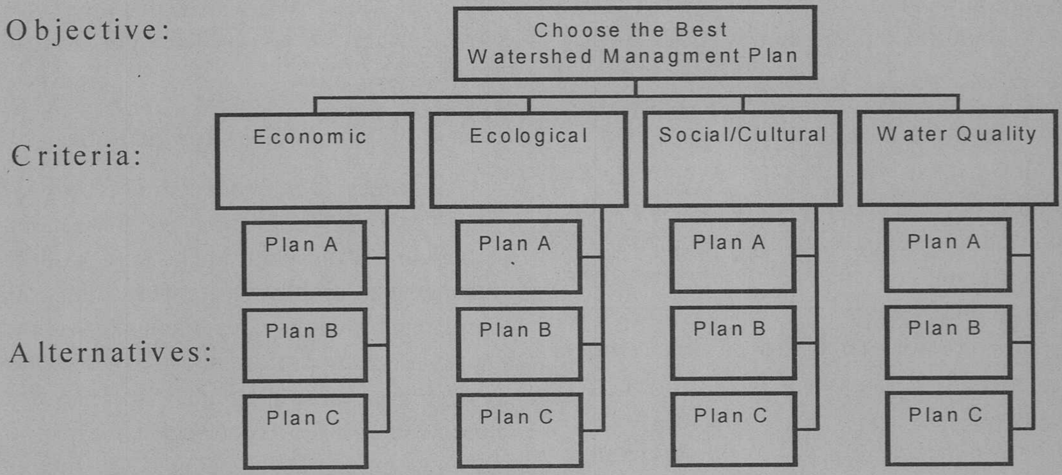

Fig. 1. Illustration of the hierarchical structure of a watershed management decision for use with the Analytic Hierarchy Process. The objective is to choose the best watershed management plan from among three alternative plans (A, B and C) using four criteria: economic impacts, ecological impacts, social/cultural impacts and water quality.

internal rate of return were used to assess the potential benefits or losses of the adoption of the development project. The findings of this study demonstrated that watershed development projects in India's dry and semi-arid regions are socially desirable and economically feasible.

Vieth *et al.* (2001) applied social cost-benefit analysis to soil erosion in Sri Lanka. This study suggested that soil conservation practices are not only socially desirable, but are economically viable for individual farmers to adopt. On-site benefits are estimated to be greater than off-site benefits. This approach was also undertaken by Eisen-Hecht and Kramer (2002), who performed a cost-benefit analysis of maintaining current water quality levels in the Catawba River (North Carolina, USA) basin. Stated preference survey methods were used to estimate stakeholder's willingness to pay. The outcome of the analysis estimated the benefits outweighed the costs by nearly $100 million.

Rein (1999) evaluated the benefits and costs to farmers and to society of implementing vegetative buffer strips adjacent to riparian areas. Results show extensive benefits to both growers and society.

Cacho (2001) performed a formal economic analysis on the role of agroforestry at the level of a watershed. The potential costs of incentives, land degradation, and forest externalities were estimated. The methods discussed in this paper are translatable to watersheds seeking a common-property approach to land management.

Table 1. Undergraduate economics and management science course offerings in selected American university watershed management curricula

University	Watershed management degree or option	Number of economics course offerings	Number of management science course offerings
Humboldt State University (California)	Watershed Management – minor	2	1
University of New Hampshire	B.S. Water Resources Management	2	0
Pennsylvania State University	B.S. Watershed Management	2	0
Colorado State University	B.S. Watershed Studies	0	0
Texas A&M University	Watershed Certificate in the Rangeland Ecology and Management degree	1	1
University of Wyoming	B.S. Range, Ecology and Watershed Management	3	1
Utah State University	Utah State University	3	0
University of Arizona	Watershed Hydrology & Management option	2	1

Abildtrup and Strange (2000) applied option value analysis to the decision whether to convert natural or semi-natural forest into Christmas tree production, a significant contributor to non-point source pollution to groundwater. The authors of this paper suggested that in addition to the options of conversion and no-conversion, the option of postponing conversion to collect additional information should be included. Economic value of the forest increased by 12% when the option value was included.

Acharya and Bennett (2001) adopted hedonic property value analysis for an urban watershed to determine the variables affecting human choice of housing preference. This study demonstrated that structural, socio-economic, land use, and environmental characteristics all played a role in the housing selection process.

Clark *et al.* (2002) incorporated economic models of willingness to pay with hydrologic models of flood control, biotic models of ecological risk, and psychological models of perceived risk for evaluation of policy options. Estimation of willingness to pay offered insight into residents' financial commitments to flood control projects and to ecological risk reduction.

Cooper (1997) used the contingent valuation method combined with actual market data to estimate the minimum incentive required for farmers to adopt best management practices to protect water quality. This combined approach resulted in a much higher predicted adoption rate than from hypothetical data and discrete choices. DeVuyst and Ipe (1999), Ipe *et al.* (2001) have also investigated the use of incentives to encourage farmers to adopt best management practices.

Blomquist *et al.* (2000) employed surveys to reveal marginal willingness-to- pay for water quality improvement programs in

Kentucky, USA. The highest ranking options included prevention of illegal dumping, treating sewage, and preventing hazardous wastes disposal; farming-related soil erosion was the lowest-ranking choice.

Shadow price valuations of stream improvements were generated by Farber and Griner (2000) through conjoint analysis and the use of a random utility model. Binary choice and intensity of preference values were used to represent participants' preferences. Results showed that respondents living within approximately 50 miles of a stream placed economic value on the stream quality. Gottfried (1992) adopted another form of economic valuation at the watershed scale; in this paper, a watershed is viewed as a series of linked multiproduct assets. Issues such as boundaries, defensive expenditures, and sustainability are explored as factors which affect the economic valuation of the watershed.

Richards (1997) used economic valuation to demonstrate the importance of watershed protection activities in Bolivia. Some benefits quantified in this study included flood prevention, aquifer recharge, and greater profits to farmers adopting soil erosion control measures. The author recommended the protection measures be adopted, and that the project costs should be paid by local beneficiaries.

Schleich and White (1997) utilized linear programming to determine the economically optimal method to reach water pollution targets in a watershed in Wisconsin, USA. Model inputs included sources and loadings of phosphorus and total suspended solids at all input locations within the watershed. Results of the model identified the most cost-effective areas to target for pollution reduction and attention to the sensitivity of target selection.

A linear programming model was developed by Önal *et al.* (1998) maximizing economic returns to farmers while working within the constraints of water quality controls and soil erosion measures in Illinois, USA. The model incorporated both environmental and social equity objectives into the economic analysis. The model was used to demonstrate that incentives offered to farmers are approximately equivalent to the costs of agricultural pollution and soil erosion controls when costs are shared equally among farmers.

Dissart *et al.* (2000) employed mixed integer programming to examine the economics of soil erosion control practices on three case farms in Quebec, Canada. Combining mixed integer programming with geographic information systems modeling, the authors determined that farms with higher net revenues would benefit from the adoption of the controls, where farms with lower net incomes would result in net losses.

Lu *et al.* (2002) developed a goal program to identify optimal land development scenarios while simultaneously meeting goals of soil erosion reduction, increased income and land use sustainability in China. Results show that use of this model as a planning tool has led to infrastructure improvements as well as ecological and social benefits.

Gomez-Limon and Berbel (2000) estimated the economic, social and environmental implications of pricing irrigation water in Spain using goal programming. Modeling was used to estimate a surrogate worth utility function of the farmer's decision process. Results of this study indicate that the estimated water-demand curve differs when multi-criteria methods are used to assess the problem rather than the traditional profit maximization assumptions.

Chang *et al.* (1997) evaluated watershed development and management plans using a fuzzy multi-objective programming model. By varying the weight distributions assigned to the model inputs, fuzzy outputs were generated. A case-study was presented in the Tweng-Wen reservoir in Taiwan. The results more accurately represented complexity of the system, leading to more realistic management policies.

Prato (1999) discussed the advantage of MADMs over conventional approaches to economic valuation of ecosystem services. A MADM is presented which incorporates utility maximization, surrogate worth tradeoff, free iterative search, the Analytic Hierarchy Process (AHP), and stochastic dominance. The MADM explains how the most preferred land and water resource management systems are selected by a property manager based on several attributes.

Prato and Hajkowicz (1999) developed a spatial decision support system based on a MADM to assist in management decisions at a watershed scale. Economic and environmental input variables were modeled separately.

Thirumalaivasan (2001) combined the Analytic Hierarchy Process (AHP), geographic information systems technology and hydrologic modeling to estimate the vulnerability of aquifers in India to contamination due to human activities. The graphical user interface developed as a part of this project has the potential to be adopted widely for use in India. Reynolds and Peets (2001) used AHP to prioritize watersheds for protection and restoration in a study located in the Chewaucan Basin of Oregon, USA. A second AHP the ranked reaches of the selected rivers for initial protection and restoration.

Johnson *et al.* (1999) described a contingent choice survey in which participants selected among packages of watershed outcomes. An empirical application of the model used data collected from Indiana, Nebraska, Pennsylvania, and Washington, USA. This study analyzed willingness-to-pay for individual variables as well as for the watershed packages.

Turner *et al.* (2000) discussed a combination of methods to develop a sustainable, welfare-optimizing approach to wetland management. Recognizing that the world-wide loss of wetlands stems from policy failures, exploitation by the public, and imposed externalities, the authors propose a multi-faceted approach combining economic valuation, integrated ecological-economic modeling, stakeholder analysis, and multi-criteria decision making.

Economics in Watershed Education

In order to assess the status of economics and management sciences in watershed education, we examined the curriculum requirements of eight American watershed management university undergraduate programs. We also examined the content of current watershed management textbooks to determine the quantity and quality of economics and management science material available to students.

Eight American university curricula were examined. Each offers either bachelors degrees or minors in watershed management or some closely related field. The universities were Humboldt State University (California), the University of New Hampshire, Pennsylvania State University, Colorado State University, Texas A&M University, the University of Wyoming, Utah State University and the University of Arizona. The watershed programs at these institutions are dominated, as one might suspect, by the biological and physical sciences. The economics and management science offerings, both required and electives, are relatively few in number. A variety of economics courses are routinely offered (Table 1). Each institution except one requires at least one economics course and most offer at least two. In contrast, however, management science offerings were few. It is likely, however, that some of the economics courses contain management science material.

We also examined two watershed management textbooks, *Integrated Watershed Management: Principles and Practice* (Heathcote, 1998) and *Hydrology and the Management of Watershed* (Brooks *et al.*, 1997) to determine the emphasis placed by the authors upon economics and management sciences. About 30% of the total pages of *Integrated Watershed Management: Principles and Practice* was devoted to economics and management. Furthermore, this text discusses, as a part of cost-benefit analysis, methods for non-market as well as market valuation. Non-market techniques such as the travel cost method, contingent valuation and the Hedonic price method are mentioned. This introduction of non-market valuation methods represents the most significant innovation over earlier economics education. In contrast, *Hydrology and the Management of Watershed* devotes just 14% of its pages to the economics and management. The primary emphasis is upon financial cost-benefit analysis of market-traded goods and services. However, neither text devoted much text copy to the explanation of quantitative management science methods.

Conclusions

Economic analysis has, for decades, played an important role in the management of watersheds for multiple-use and environmental services. The predominant form of economic analysis has been cost-benefit analysis. However, CBA has changed over the past 25 years to now include a variety of benefits other than those just for commodities traded in markets. Today, non-market and non-use benefits have become increasingly important in CBA calculations.

Multi-Criteria Decision Models such as linear and goal programming which contain economic objective functions or constraints have been applied to a host of watershed and water management decision problems. Initially, MCDM applications were dominated by Multi-Objective Decision Models such as linear and goal programming. Increasingly, however, Multi-Attribute Decision Models are being employed for watershed and natural resource planning. Their popularity may be due to the fact that MADM methods, such as the Analytic Hierarchy Process, permit a great deal of stakeholder participation in the decision process.

With regard to university education, watershed curricula continue to be dominated by the physical, biological and engineering sciences. Economics and management sciences play, as they traditional have, a small but important role in watershed education. However, with the trend toward greater stakeholder participation in watershed decisions, future curricula could see a greater demand for more social and management science courses.

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