5 Policy analysis for sustainable development: An operational approach to natural park management

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5.1 Environmental issues and the concept of ‘sustainable development’

In recent years, the issue of conservation of cultural heritage and environmental quality has often been put in the context of sustainable development, and therefore it seems relevant to focus attention on this issue more specifically.

Traditionally, Gross National Product (GNP) has been considered as the best performance indicator for measuring national economy and welfare. But if resource depletion and degradation are factored into economic trends, what emerges is a radically different picture from that depicted by conventional methods. Daly and Cobb (1990) have attempted to adjust GNP to account mainly for depletion of natural capital, pollution effects and income distribution effects by producing an ‘Index of Sustainable Economic Welfare’ (ISEW). A second version (ISEW2) also includes adjustments for depletion of nonrenewable resources and long-term environmental damage. They conclude that while GNP in the United States rose over the 1956-1986 interval, ISEW remained relatively unchanged since about 1970. Is our traditional analytical framework able to incorporate conflicting issues caused by social and environmental costs?

Conventional economic frameworks are essentially based on a closed economic system consisting of a set of production functions, cost functions, and final demand functions, in which resources, commodities and services can in principle be generated in any combination within the system concerned. Furthermore, perfect information availability to all actors is assumed. Given these assumptions, the existence of a static equilibrium and different extensions to the dynamic case have been demonstrated in the economic literature (Arrow and Debreu, 1954; Solow, 1974). But, real world economic systems are open systems utilizing material and energy resources provided by nature. Therefore, a series of interrelated feedbacks in the economic system has to be taken into account. Consequently, as Georgescu-Roegen (1971) has correctly pointed out, the real economy is a dissipative system, not a self-perpetuating one.

The concept of sustainability has already a long history. The most widely accepted definition of sustainable development is the one given by the World Commission on Environment and Development (1987) where sustainable
development is defined as "paths of human progress which meet the needs and aspirations of the present generation without compromising the ability of future generations to meet their needs".

Goodland and Leduc (1987) define sustainable development as: "a pattern of social and structural economic transformations which optimizes the benefits available in the present without jeopardizing the likely potential for similar benefits in the future". This definition implicitly assumes a need to maintain yields from renewable natural systems over long periods of time.

Other approaches to the concept of sustainable development focus on the physical or natural resource base of any economy. Pearce and Turner (1990) claim that sustainable development implies maintenance over time of aggregate resource stocks, such as the potential to generate welfare is not allowed to fall below the current level. Clearly, this viewpoint raises important questions concerning the measurability of environmental quality.

According to Costanza, "sustainability does not necessarily mean a stagnant economy, but we must be careful to distinguish between "growth" and "development". Economic growth which is an increase in quantity cannot be sustainable indefinitely on a finite planet. Economic development which is an improvement in the quality of life without necessarily causing an increase in quantity of resources consumed, may be sustainable. Sustainable growth is an impossibility. Sustainable development must become our primary long-term policy goal". Hence the sustainability of natural resources and the environment explicitly are to direct economic development. A working global definition of sustainability is the following: "Sustainability is a relationship between dynamic human economic systems and larger dynamic, but normally slower-changing ecological systems, in which 1) human life can continue indefinitely, 2) human individuals can flourish, and 3) human cultures can develop; but in which effects of human activities remain within bounds, so as not to destroy the diversity, complexity, and function of the ecological life support system (Costanza et al., 1991, p. 8)".

5.2 Economy-environment interactions and economic approaches

A first meaningful step to get a better grasp of environmental issues is to improve our understanding of economy-environment interactions.

Three main economic functions of the natural system can be distinguished (Pearce and Turner, 1990). The first function of natural environment is to provide resource inputs to the productive system. Economic production of any commodity needs natural resources, and the transformation of natural resources, from discovery, extraction, refinement and so on, into useful raw materials and eventually into humanely produced goods and services, requires the use of industrial energy as well as the support by ecosystems driven by solar energy. The economic subsystem (although it is a social system) rests on its physical foundations, such as the laws of thermodynamics.

Given the flow of natural resources, R, production P, is aimed at producing consumer goods, C, and capital goods, K. In turn, capital goods produce consumption in the future. The purpose of consumption is to create utility, U,
or welfare. Unfortunately waste (W) arises at each stage of the production process. The processing of resources creates waste in different forms; production creates waste in the form of industrial effluent and air pollution and solid waste; final consumers create waste by generating sewage, litter, and municipal refuse. While the natural systems tend to recycle their waste, economies have no such in-built tendency to recycle, thus natural environments are the ultimate repositories of waste products (2nd function of natural environments). If the production going to create capital stock is not taken into account, then the first law of thermodynamics (stating that it is not possible to create or destroy energy and matter) ensures that the amount of waste in any period is equal to the amount of natural resources used up (Boulding, 1966). According to Boulding, Earth is a closed economic system in which the economy and environment are not characterized by linear interlinkages, but by a circular relationship; everything is an input into everything else (see Figure 5.1). The box r is recycling (it is possible to take some of the waste, W, and convert it back to resources).

![Figure 5.1 Boulding's Circular System](from Pearce and Turner, 1990, p. 38)

As Georgescu-Roegen (1971) has pointed out, there is a basic reason for the lack of a complete recycling, this is the second law of thermodynamics (stating that entropy increases in any irreversible process). A closed system is one that exchanges neither matter or energy with its surroundings; indeed all real world processes are irreversible, hence total entropy increases in virtually every real world process. When entropy increases the energy in the system becomes less available to do useful work. A simple implication of this law is that all energy conversion systems and matter conversion systems require more available energy inputs than they yield as outputs. In other words, all biological and industrial processes are less than 100% efficient (Ayres and Kneese, 1990). Furthermore given that the availability of exhaustible resources determines a
finite life to the system, the circular economy will still work until the environment has the capability to absorb wastes and to convert them back into harmless or ecologically useful products. But if we dispose of waste in such a way that environment's assimilative capacity is damaged, then the function of the environment as a waste sink will be impaired. Unlike most mineral and many biotic resources, whose access is regulated by the market, the use of the environment as a depository for many types of wastes is widely recognized as being beyond the control of the market system.

The third function of the environment is to supply utility directly in the form of aesthetic and spiritual comfort. These three economic functions, resource supply, waste assimilation and aesthetic commodity, can be regarded as components of one general function of natural environments, the function of life support.

The life support function of ecosystems is connected to their physical, chemical, and biological role in the overall system. Ecosystems can be divided into three categories (Odum, 1989):

1. natural environments or natural solar-powered ecosystems (open oceans, wetlands, rain forests, etc.);
2. domesticated environments or man-subsided solar-powered ecosystems (agriculture lands, aquaculture, woodlands, etc.);
3. fabricated environments or fuel-powered urban-industrial systems (cities, industrial areas, airports, etc.).

It is evident that fabricated environments are not self-supporting or self-maintaining. To be sustained they are dependent on the solar-powered natural and domesticated environments (life-supporting ecosystems). Stress caused by the disposal of wastes and pollutants, negatively affects recycling, feedback loops and control mechanisms in the life-supporting ecosystem and thereby the production and maintenance of environmental goods and services.

In the standard economic framework, the value of a commodity is related to its price, so that the utility of a commodity can be reflected by means of an unambiguous quantitative measure. Environmental functions are economic functions because they all have a positive economic value; in theory, if we bought and sold these functions in the marketplace they would all have positive prices. But in real world decisions, we normally do not recognize the positive prices for these economic functions; free commodities (such as air and water) have no price. Since the market prices do not reflect exactly the relative scarcity of environmental resources, it is necessary from a political economic point of view, in order to avoid an over exploitation of these resources, to impose appropriate regulatory measures by public authorities. In fact, since the rational decisions of individual agents lead necessarily to an outcome that is inconsistent with the best interests of society, a 'social trap' (Costanza, 1987) exists. The exploiters of a common resource stock have little incentive for the conservation of that resource. Hardin (1968) has called this the "tragedy of the commons". For example, as long as fish in the sea can be caught profitably, fishermen will wish to do so, and this may lead to severe over fishing (Clark, 1990). In order to cope with such externalities, policy measures have to be introduced. As pointed out by Baumol and Oates (1975), these measures can
take the form of direct regulations (e.g. maximum pollution emissions) or the form of economic disincentives (pricing systems based on social costs in the form of taxes and subsidies).

A different position is the so called ‘property rights approach’. The ‘Coase theorem’ (Coase, 1960) is used as the theoretical basis for a noninterventionist pollution control policy. Environmental pollution is a form of market failure because of the over exploitation of resources held as common property or not owned at all; therefore the market fails when property rights are inadequately specified. According to the property rights approach, increased government intervention should be resisted because public ownership of many natural resources is the real root of resource control conflicts: there is a policy failure. According to Coase, given certain assumptions, the most efficient solution to a pollution damage situation is a bargaining process between polluter and sufferer. Each could compensate the other according to who possesses property rights: if the polluter has the right, the sufferer can compensate him not to pollute; if the sufferer has the right, the polluter can compensate him to tolerate damage.

From the ecological economic perspective, the expansion of the economic subsystem is limited by the size of the overall finite global ecosystem, by its dependence on the life support sustained by intricate ecological connections which are more easily disrupted as the scale of the economic subsystem grows relative to the overall system. Since the human expansion, with the associated exploitation and disposal of waste and pollutants, not only affects the natural environment as such, but also the level and composition of environmentally produced goods and services required to sustain society, the economic subsystem will be limited by the impacts of its own actions on the environment (Folke, 1991). A central issue then is: does any optimal scale exist for the economy? This point has especially been tackled by Daly. The term scale is shorthand for “the physical scale or size of the human presence in the ecosystem, as measured by population times per capita resource use” (Daly, 1991, p. 35). Traditionally, the theoretical focus of economics is on prices and the issue is to internalize external environmental costs to arrive at prices that reflect full social marginal opportunity costs. In this way, in theory the problem of efficient allocation can be solved. Under ideal conditions the market can find an optimal allocation in the sense of Pareto. Another problem is the just distribution; the market’s criterion for distributing income is to provide an incentive for efficient allocation, not to attain justice. These two values can conflict, and the market does not automatically resolve this conflict. Generally there is agreement that it is better to let prices serve efficiency, and to serve equity with income distribution policy. But the market cannot find an optimal scale any more than it can find an optimal distribution. The latter requires the addition of ethical criteria, the former requires the addition of ecological criteria. The independence of allocation from distribution is widely recognized, the independence of allocation from scale is not as widely recognized, but is easily understood. In theory, it is possible to double the population and the per capita resource use rate, or to cut them in half, and the market will still grind out a Pareto optimal allocation for every scale.

Thus the standard economics point of view about economic growth seems quite optimistic. But as an economy grows, it increases in scale. Scale has a
maximum limit defined either by the regenerative or absorptive capacity of the ecosystem, therefore "until the surface of the earth begins to grow at a rate equal to the rate of interest, one should not take this answer too seriously" (Daly, 1991, p. 40). In conclusion, we can identify three main conflictual values of economics, allocation (efficiency), distribution (equity), and scale (sustainability). While an optimal allocation in theory could result from the individualistic marketplace, the attainment of an optimal scale (or at least of any scale that is not above the maximum carrying capacity) requires collective action by the community on a regional, national or international level according to the problems faced.

The present paper focuses on regional spatial dimensions of environmental management. At a meso scale of analysis, the concept of evaluation process is of great importance. Evaluation aims at rationalizing planning and decision problems by systematically structuring all relevant aspects of policy choices (for instance, the assessment of impacts of alternative choice possibilities).

It should be noted that different kinds of evaluation can be distinguished in a policy analysis, one of the most important discriminating characteristics being between monetary and non-monetary evaluation. A monetary evaluation is characterized by an attempt to measure all effects in monetary units, whereas a non-monetary evaluation utilizes a wide variety of measurement units to assess the effects. Cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) are well-known examples of a monetary evaluation (Pearce and Nash, 1989). Multicriteria methods (MCDA) belong to the family of non-monetary evaluation methods.

Given the complexity inherent in the concept of sustainable development, any method trying to operationalize this in a planning context, can be considered a kind of "second best". Given this starting assumption, this paper will investigate the possibilities of using multicriteria methods to operationalize efficiency, equity and sustainability issues in a planning context.

5.3 Multicriteria evaluation methods

Environmental management is essentially conflict analysis characterized by technical, socioeconomic, environmental and political value judgements. Therefore, in an environmental planning process it is very difficult to arrive at straightforward and unambiguous solutions. This implies that such a multirelated planning process will always be characterized by the search for acceptable compromise solutions, an activity which requires an adequate evaluation methodology. Multiple criteria evaluation techniques aim at providing such a set of tools. Multicriteria methods provide a flexible way of dealing with qualitative multidimensional environmental effects of decisions. However, this does not mean that multicriteria evaluation is a panacea which can be used in all circumstances without difficulties; it has its own problems.

During the last two decades, it has increasingly been understood that welfare is a multidimensional variable which includes, inter alia, average income, growth, environmental quality, distribution equity, supply of public facilities, accessibility, etc. This implies that a systematic evaluation of public plans or projects has to be based on the distinction and measurement of a broad set of
criteria. These criteria can be different in nature: private economic (investment costs, rate of return, etc.), socioeconomic (employment, income distribution, access to facilities, etc.), environmental (pollution, deterioration of natural areas, noise, etc.), energy (use of energy, technological innovation, risk, etc.), physical planning (congestion, population density, accessibility, etc.) and so forth (Nijkamp et al., 1990). Multicriteria evaluation can be considered as the evolution of the preceding theory: in fact it enables the use of several decision criteria.

A great number of multicriteria methods has been developed and applied for different policy purposes in different contexts (Bana e Costa, 1990; Nijkamp et al., 1990).

In general, a multicriteria model presents the following aspects:

1. There is no solution optimizing all the criteria at the same time and therefore the decision-maker has to find compromise solutions.
2. The relations of preference and indifference are not enough in this approach, because when an action is better than another one for some criteria, it is usually worse for others, so that many pairs of actions remain incomparable with respect to dominance relation.

The main advantage of these models is that they make it possible to consider a large number of data, relations and objectives (often in conflict) which are generally present in a specific real-world decision problem, so that the decision problem at hand can be studied from multiple angles.

The main disadvantage of a multicriteria model is that an action ‘a’ may be better than an action ‘b’ according to one criterion and worse according to another. Thus when different conflicting evaluation criteria are taken into consideration, a multicriteria problem is mathematically ill-defined. The consequence is that a complete axiomatization of multicriteria decision theory is quite difficult. As Vincke (1985) has observed, in these cases the following attitudes are unproductive:

1. Leave the decision-maker entire liberty for the decision,
2. Introduce conscious or non-restrictive hypotheses, so that the problem can be solved by a classical method. The methods used in multicriteria analysis lie between these two extremes: they are based on models constructed partly from necessarily restrictive mathematical hypotheses, and from information gathered from the decision-maker”.

5.4 First objective of economic theory: efficiency

Two opposite positions in tackling decision problems may be distinguished (Munda, 1993a):

Decisionism in practice maintains that decisions are blind actions, inspired by the subconscious and by instinct, so that the act of reasoning over a decision is meaningless.

On the contrary, rationalism assumes that in any decision problem an optimal precise solution always exists and that it is possible to find it by reasoning over the problem. Thus (using Socrates’ words) ignorance is the only cause of
foolish or evil acts. The maximization and the weighting premises of neoclassical economics can be considered as a part of this school of thought.

The rationality behind cost-benefit analysis assumes that any individual makes rational decisions only if he weighs up the advantages and disadvantages of a particular action, so that some kind of best decision can always be made. A basic idea of conventional economics is that prices of goods and services are signals reflecting consumer desires. The free interplay of market forces should therefore allocate resources to goods and goods to people in such a way as to secure the maximum welfare of society, where welfare is equated with the satisfaction of wants. No modern economist seriously believes that any real world economy operates in such a way as to maximize welfare. Rather, the idea that there exist some configurations of prices which will achieve this optimum is used as a yardstick against which to measure the degree of imperfection in an economy and hence the extent to which policies should be directed towards correcting those deviations.

Multicriteria models have the aim, with the aid above all of the mathematical instrument, of leading to concrete decisions. Of course multicriteria models are not pure axiomatic systems but beyond the application aspect, multicriteria evaluation represents a specific mathematical theory and, as such, should respect the general principles proposed by the formalistic school and therefore indicate clearly the axioms on which the development of the model should depend. Now from this observation, it is possible to deduce that, like in non-Euclidean geometries, the development of the different hypotheses and therefore the formulation of the various models multiply at great speed.

Multicriteria models are factual in the sense that the hypotheses on which they are based must be close to reality, but an approach of an exclusively descriptive type does not appear suitable for the purposes that decision analysis should have. This type of approach is common to those who assume an essentially platonistic attitude, believing in an 'objective world' which exists on its own behalf and in optimal solutions that the researcher has only to discover. An approach of this type may be useful in particular cases, such as some problems of technical optimisation, but in general it is not considered desirable. Those assumptions which hypothesize the ability of the decision-maker to express in clear terms his utility function, or his absolutely consistent preferences of a transitive type, do not in fact appear to be very realistic, as a consequence an evident antinomy is formed with a hypothesis of descriptivity.

The prescriptive approach does no more than propose a series of rules which the decision-maker should respect if he wishes to reach a specific objective. Simon (1983) proposes a behavioral model according to which human rationality is 'bounded' and rational decision making only requires the application of a set of personal values to solve specific problems a person faces, in a way that is 'satisfactory' for that person. Thus the concept of 'decision process' has an essential importance. "In general it is impossible to say that a decision is a good one or a bad one by referring only to a mathematical model: organizational, pedagogical and cultural aspects of the whole decision process which leads to a given decision also contribute to its quality and success..." (Roy, 1990b, p. 27). Thus, it becomes impossible to found the validity of a procedure either on a notion of approximation (i.e., discovering pre-existing truths) or on a mathematical property of convergence.
(i.e. does the decision automatically lead, in a finite number of steps, to the optimum \( a^* \)). The final solution is more like a 'creation' than a discovery. In *multiple criteria decision aid* (MCDA) (Roy, 1985, 1990b, 1990c), the principal aim is not to discover a solution, but to construct or create something which is viewed as liable to help "an actor taking part in a decision process either to shape, and/or to argue, and/or to transform his preferences, or to make a decision in conformity with his goals" (*constructive or creative approach*) (Roy, 1990a, p. 28).

Finally, we can conclude that the validity of a given procedure depends on two main factors:

- mathematical properties which make it conform to given requirements;
- the way it is used and integrated in a decision process.

The constructive approach is much less ambitious in its objectives than rationalism, but if we really wish that the application of mathematics to socioeconomic problems is meaningful, it is the best we can do. However, one has to note that the main approaches by which subjectivity is taken into account in decision models (weighting of criteria and interactive procedures) are open to criticism (Munda, 1993a).

5.5 Second objective of economics: equity

Cost-benefit analysis tends to equate the social view with what society wants. The notion of individual preference that is relevant to CBA is the preference that is recorded in the market place (or which would be recorded if there were a market), and not the preference recorded by a simple vote. The result of a cost-benefit analysis, therefore, will not necessarily coincide with the results of a simple majority voting procedure. There is a problem then of making CBA compatible with democratic decision making. This kind of "economic voting" is preferred to classical political voting procedures for the main reason that political systems other than in very well defined referenda, involve voting not for issues so much as for individuals to represent the constituent's view. Market or economic voting is far more true to the voters' intentions: by definition if the voter does not want it, he does not buy it; in any case, even if referenda were desirable, they cannot be held everyday on every economic decision that has to be made (Pearce and Nash, 1989).

Unfortunately, for environmental problems a basic problem arises: in order to be consistent with the objective of maximizing social welfare, it is necessary that the prices attached to the physical benefits and costs reflect society's valuations of the final goods and resources involved; then a question immediately arises, If markets do not exist, how are surrogate prices to be derived which, in turn, reflect social valuations?

The aim of contingent valuation is to elicit valuations (or 'bids') which are close to those that would be revealed if an actual market existed. Respondents say that they would be willing to pay or willing to accept if a market existed for the good in question. Now, either people are not really asked to pay and then
they may easily answer strategically (free rider problem), or they really have to pay; but in this case WTP depends upon the ability to pay, thus projects which benefit higher income groups are generally considered to be the best.

Generally it is said that cost-benefit analysis focuses on efficiency criteria. But, any policy decision affects the welfare positions of individuals, regions or groups in different ways; consequently, the public support for a certain policy decision will very much depend on the distribution effects of such a decision. Given that society is unlikely to be indifferent between various distribution of income, some ways of integrating the distributional aspects into the analysis have to be found. Some revisions of cost-benefit analysis try to include distribution values directly in the analysis by using different weights for different social groups (Helmers, 1979). The main limit of this approach is that it is not clear how to derive such weights and who should attach these ones. In any case, if weights are used, it has to be recognized that no completely objective analysis is possible, and therefore no optimal solution exists. Finally, it has to be noted that failures to use any weighting system implies making the value judgements that the existing distribution of income is optimal. If, and only if one is happy with such a value judgement, it is reasonably possible to use unweighted market valuations to measure costs and benefits. Therefore, there is no escape from value judgements.

Furthermore, society as a whole, may have values that deviate from aggregated individual values. Society has a much longer life expectancy than individuals, thus the value society attaches to natural resources and the environment is likely to deviate from individual values, since the simple summation of individual preferences may imply the extinction of species and ecosystems. This implies that environmental policy cannot be merely based upon the aggregation of individual values, and estimation of willingness to pay at any particular point of time (Klaassen and Opschoor, 1991).

From an operational point of view, the major strength of multicriteria methods is their ability to address problems marked by various conflicting evaluations. However it has to be noted that all results obtained can provide ‘justifiable’ or ‘defendable’ decisions (from a technical point of view) to policy makers, but in real world decision making, it is necessary to interact with many actors (often each single actor is represented by complex organizations like town councils, trade unions, different associations and so on) each of them having different goals and values. Therefore, since, real-world problems are generally not direct win-lose situations and a certain degree of compromise is needed, a procedure aimed at supporting real policy-makers would ideally consider this problem of different (and often conflicting) evaluations. Multicriteria evaluation techniques can not solve all these conflicts, but they can help to provide more insight into the nature of these conflicts and into ways to arrive at political compromises in case of divergent preferences in a multi-group or committee system so increasing the transparency of the choice process. Again multicriteria evaluation is less ambitious than CBA, it is just a tool of analysis, not of democracy!

In multicriteria evaluation equity issues can be considered in three different ways:

1. by the weighting criteria (but this is always difficult);
2. by introducing a set of ethical criteria (but this could lead to an excessive
In Munda (1993b) it has been proposed to integrate multicriteria evaluation with conflict analysis procedures. In particular, equity issues are taken into consideration by means of a fuzzy conflict analysis procedure. Starting with a matrix showing the impacts of different courses of action on each different interest/income group, a fuzzy clustering procedure aimed at indicating the interest groups whose interests are closer in comparison with the other ones is used.

5.6 Third objective of economics: sustainability

Pearce and Turner (1990) devote their attention to the desirability and meaning of maintaining the natural capital stock as a condition for sustainable development.

But what does a constant capital stock mean? Measurements of natural capital stock made exclusively in physical terms are problematic because of the difficulty in adding up different physical quantities expressed in different units. By valuing each resource stock in money terms, the total value of natural capital can be measured. One obvious problem here is that many natural resources (e.g., air, water, wilderness) do not have observable prices. Thus one would need to find implicit or shadow prices in some way. Even those prices that do exist may not be useful; they may be affected by market imperfections and taxes, and they may exclude externalities involved with the production and use of the resource. Pearce and Turner recognize some of the shortcomings of each of the possible definitions of a constant stock of natural capital, other weak points have been indicated by Victor (1991). These problems are unlikely to be overcome easily. Indeed the problem of measuring capital has been one of the fundamental sources of criticism of conventional economics levelled by the Post-Keynesian school. The so-called "Cambridge Controversy" (Harcourt, 1972) deals with the problem of measurability of capital. Capital here refers to manmade capital, but the results can easily be extended to natural capital. The difficulties involved in finding theoretically sound, robust measures of the stock of natural capital may be even greater than those identified by the Post-Keynesians for manufactured capital. Although the idea of a constant capital stock is quite important and desirable (maintaining the natural capital is an important prerequisite for sustainability), one should admit that the development of relevant indicators of sustainability connected to this idea is quite difficult.

Is CBA consistent with a goal of sustainable development? If the Pearce and Turner definition of sustainable development is accepted, the answer is yes. This is providing that the government receives sufficient shadow projects to offset environmental damages, so that across a portfolio of public investments, net environmental damage is zero. However, besides the aggregation problems inherent in this definition of sustainability already discussed, there are problems here, both in measuring environmental impacts and in designing shadow projects which fully compensate. Moreover, allowing for shadow projects may even increase the level of environmental degradation, since natural resources fulfil many functions, and the future consequences of shadow
projects may be many and uncertain (Munro and Hanley, 1991; Nijkamp and
Is multicriteria evaluation consistent with sustainable development? In order
to operationalize sustainable development in a regional context, issues such as
economic-ecological integration, multiple use, interregional spatial links and
tradeoffs, and uncertainty are of a fundamental importance (van den Bergh and
Nijkamp, 1991; Munda et al., 1994).
A proper use of multicriteria analysis presupposes, the existence of an
adequate environmental-economic impact system or model. Nowadays, it is
increasingly taken for granted that environmental and resource problems
generally have at least far reaching economic and ecological implications, often
of an unpriced nature. Models aiming at structuring these cross-boundary
problems of an economic and environmental nature are therefore called
'economic-environmental' or 'economic-ecological' models (Braat and van
In designing models for environmental and resource policy-making the
following three main types of policy objectives may be distinguished (Braat
and van Lierop, 1987):

1. nature conservation objectives, e.g. ‘minimum exploitation of natural
   systems’, ‘optimum yield’;
2. socioeconomic objectives, e.g. ‘maximum production of goods and
   services at minimum (private and social) cost’;
3. mixed objectives, e.g. ‘maximum sustainable use of resources and
   environmental services’.

It is clear that in policy-relevant economic-environmental evaluation models,
socioeconomic and nature conservation objectives are to be considered
simultaneously. Consequently, multicriteria methods are in principle, an
appropriate modelling tool for combined economic-environmental evaluation
issues. Given the assumption of a second best world, multicriteria evaluation
may be considered an appropriate tool to operationalize efficiency and
sustainability criteria. This is mainly because, according to the
economic-ecological integration philosophy, multicriteria evaluation allows one
to tackle families of conflictual socioeconomic and environmental criteria
simultaneously. Given the problem of the differences in the measurement levels
of the variables used for economic ecological modelling, multicriteria methods
able to deal with mixed information can be considered particularly useful.
Ideally, the information should be precise, certain, exhaustive and
unequivocal. But in reality, it is often necessary to use information which does
not have those characteristics so that one has to face the uncertainty of a
stochastic and/or fuzzy nature present in the data. If it is impossible to establish
exactly the future state of the problem faced, a stochastic uncertainty is created;
this type of uncertainty is well known it has been thoroughly studied in
probability theory and statistics. Another type of uncertainty derives from the
ambiguity of this information, since in the majority of the particularly complex
problems involving man, much of the information is expressed in linguistic
terms, so that it is essential to come to grips with the fuzziness that is either
intrinsic or informational typical of all natural languages.

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Fuzzy uncertainty (Zadeh, 1965) does not concern the occurrence of an event but the event itself, in the sense that it cannot be described unambiguously. This situation is very common in human systems. Spatial environmental systems in particular, are complex systems characterized by subjectivity, incompleteness and imprecision (e.g., ecological processes are quite uncertain and little is known about their sensitivity to stress factors such as various types of pollution).

In traditional mathematics, variables are assumed to be precise, but when we are dealing with our daily language, imprecision usually prevails. Intrinsically, daily languages cannot be precisely characterized on either the syntactic or semantic level. Therefore, a word in our daily language can technically be regarded as a fuzzy set. Fuzzy sets as formulated by Zadeh are based on the simple idea of introducing a degree of membership of an element with respect to some sets. The physical meaning is that a gradual instead of an abrupt transition from membership to non-membership is taken into account. An important feature of multicriteria evaluation methods is the possibility of also taking into account fuzzy information (Munda, 1993b).

Multiple use refers to the simultaneous use of natural resources, for different social and economic objectives, e.g. a forest which is used for outdoor recreation as well as timber production at the same time. Such situations almost always lead to conflicts of interest and damage to the environment. The consequences range from sub optimal use due to unregulated access, to degradation of resource systems due to limited knowledge of the ecological processes involved. Thus, in the area of environmental and resource management and in policies aiming at an ecologically sustainable development, many conflicting issues and interests emerge.

In the next section, a real-world application of multicriteria evaluation will be shortly illustrated.

5.7 A case study on the river Po Delta

From an ecological point of view, one of the most important areas in the river Po basin is the Delta region; in this region it has been decided to establish a natural park. The Mesola wood is a part of exceptional environmental value of the Po Delta natural park. In this wood, a sharp conflict between environmental and economic aspects seems to exist. Moreover, different interest/income groups are present. More information on this case study can be found in Munda (1993b).

The Po Delta Organisation, formed in 1951, began to set up a project to transform the Delta, which was intended to affect the valleys around the 'Boscone della Mesola' also. This project to clean up the lagoon valleys completely, was aimed at the setting up of a defence system against sea storms. In 1969, despite the landscape constraint to which the Falce Valley was subjected from 1963, the Ministry of Agriculture and Forests gave the go-ahead for its exploitation, although prescribing actions to safeguard the wood by irrigation. The drainage works were completed in 1970, but the forest defence works were not started. The next year the wood began to show some signs of stress in the areas near to the drained valley: there were some
drying-out phenomena, it has been evaluated that 120.73 hectares of wood have been damaged. Because of this, a project of flooding the Falce Valley has been proposed by the technicians of IDROSER (1985). It should be noted that if the flooding project were to be carried out, it is necessary to find out new economic activities able to substitute the agricultural land use. The most promising one is fish rearing. From the economic point of view, indications of the presumed management costs and the yields for the assumed fish rearing uses are very approximate; here the uncertainties on use of labour, productivity of the valley, price of the various species of fish (from the point of view both of buying young fish and selling the product) are so large that the figures given should be taken conditionally. Important factors to be borne in mind are the incidence of epidemic diseases or water pollution, which can reduce the quantity and quality of the catch yield drastically.

There is no doubt that the flooding of the Falce valley will have excellent environmental consequences, in particular, on the ecological equilibrium of the wood. However, one should note that a conflict between ecological and economic ends, seems to exist: the flooding of the valley implies the lost of actual agricultural production with serious repercussions in terms of income and employment on the whole area. As a consequence, it is necessary to explore the possibility of finding a kind of economic-ecological equilibrium, i.e. economic activities substituting the agricultural one, compatible with the flooding of the valley. Thus, a comparison between the future possible economic scenario and the so called 'option-zero' (business as usual) has to be considered.

A comprehensive economic-environmental evaluation of alternative courses of action can be carried out by means of multicriteria analysis. The alternatives taken into consideration are:

1. business as usual,
2. optimized agriculture,
3. flooding of the Falce Valley,
4. partial flooding in combination with business as usual,
5. partial flooding in combination with optimized agriculture.

The following set of evaluation criteria has been used:

1. Gross profit
2. Employment
3. Tourist attractiveness
4. Recreational attractiveness
5. Ecological equilibrium of the wood
6. Risk of causing ecological damages.

The impact matrix related to the "boscone della Mesola" problem is shown in Table 5.1. As one can see, this evaluation matrix is mixed in nature. Given the nature of the information contained in this impact matrix, the use of the NAIADE method (Munda, 1993b) seems appropriate. It is a discrete multicriteria method whose impact (or evaluation) matrix may include either crisp, stochastic or fuzzy measurements of the performance of an alternative an with respect to a judgement criterion gmZ thus it is very flexible for real-world applications. From an empirical point of view, this model is
particularly suitable for economic-ecological modelling incorporating various degrees of precision of the variables taken into consideration. From a methodological point of view, two main issues are then faced:

- the problem of equivalence of the procedures used in order to standardize the various evaluations (of a mixed type) of the performance of alternatives according to different criteria;
- the problem of comparison of fuzzy numbers typical of all fuzzy multicriteria methods.

The NAIADE method presents different theoretical properties which are not shared by traditional multicriteria methods in a fuzzy environment. Since in a fuzzy context, any attempt to reach a high degree of precision on the results tends to be somewhat artificial, a pairwise linguistic evaluation of alternatives is used. This is done by means of the notion of fuzzy relations (based on the new semantic distance) and linguistic quantifiers. In the aggregation process, particular attention is paid to the problem of diversity of the single evaluations, while the entropy concept is used as a measure of the associated ‘fuzziness’. Such linguistic evaluations can be used in different ways according to the decision environment at hand.

**Table 5.1**

A fuzzy impact matrix for different land uses of the Falce Valley

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>criteria</th>
<th>units</th>
<th>business as usual</th>
<th>optimised agriculture</th>
<th>flooding</th>
<th>partial flooding current agriculture</th>
<th>partial flooding optimised agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
<td>(d)</td>
<td>(e)</td>
</tr>
<tr>
<td>g1</td>
<td>Italian Lire</td>
<td>64,000,000</td>
<td>159,000,000</td>
<td>approximately</td>
<td>143,000,000</td>
<td>approximately 95,000,000</td>
<td>approximately 147,000,000</td>
</tr>
<tr>
<td>g2</td>
<td>men/year</td>
<td>20</td>
<td>9</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g3</td>
<td>linguistic</td>
<td>bad</td>
<td>bad</td>
<td>good</td>
<td>moderate</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>g4</td>
<td>linguistic</td>
<td>moderate</td>
<td>moderate</td>
<td>good</td>
<td>moderate</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>g5</td>
<td>linguistic</td>
<td>bad</td>
<td>good</td>
<td>good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g6</td>
<td>linguistic</td>
<td>moderate</td>
<td>bad</td>
<td>good</td>
<td>bad</td>
<td>bad</td>
<td></td>
</tr>
</tbody>
</table>

By applying the NAIADE method the following ranking of feasible actions is obtained.

```
   c   b   d   a
     |   e
```

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From an economic-environmental perspective it is not possible to defend the business as usual option (a), also the mix between current agriculture and flooding (d) is very weak. The flooding option (c) seems to be better than the ideal optimised agriculture situation (b). The mix between optimized agriculture and flooding (e) is difficult to compare with both optimized agriculture and flooding; however, since flooding looks better than optimized agriculture, the final decision should be made between flooding and the mix between optimized agriculture and flooding.

Following the philosophy of the planning balance sheet method, the matrix presented in shows the impact of the different courses of action on different income/interest groups. It appears that the information concerning the diverse plan impact is rather inaccurate; the degree of uncertainty on the impacts of the plans is high, so that a representation of such impact in fuzzy terms seems very appropriate. The impacts have been evaluated on the basis of heuristic principles, by interacting with people of the region and some experts.

Six main interest groups can be distinguished:
- Farmers
- Environmentalists
- Recreationers
- Landless Labourers
- Residents in the Po Delta Area
- Future Generations

### Table 5.2
Fuzzy evaluations of impacts of different alternative courses of action on different interest groups

<table>
<thead>
<tr>
<th>Interest Groups</th>
<th>business as usual</th>
<th>optimised agriculture</th>
<th>flooding</th>
<th>partial flooding current agriculture</th>
<th>partial flooding optimised agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers (1)</td>
<td>good</td>
<td>very good</td>
<td>very bad</td>
<td>bad</td>
<td>moderate</td>
</tr>
<tr>
<td>Environmentalists (2)</td>
<td>bad</td>
<td>bad</td>
<td>very good</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Recreationers (3)</td>
<td>bad</td>
<td>bad</td>
<td>good</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>Landless Labourers (4)</td>
<td>moderate</td>
<td>moderate</td>
<td>good</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>Residents in the Po Delta Area (5)</td>
<td>bad</td>
<td>bad</td>
<td>good</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Future Generations (6)</td>
<td>bad</td>
<td>moderate</td>
<td>very good</td>
<td>moderate</td>
<td>good</td>
</tr>
</tbody>
</table>
Thus the application of the clustering procedure leads to the following results (see Figure 5.2). The results of the coalition formation process are clear. The interests of environmentalists (2) and of the residents in the Po Delta area (5) bear a very close correspondence. Recreationers (3), landless labourers (4) and the special ‘interest group’ of future generations (6) join quite soon the coalition, thus no serious conflict seems to exist and therefore the probability of finding a compromise solution is high. The interest group of farmers (1) presents a more individualistic character, unreconcilable differences between this group and all the others seem to exist.

The alternative that presents the best impact on environmentalists and residents in the Po Delta area is the flooding project. On recreationers, landless labourers and future generations all the different types of flooding projects (complete or partial) have good impacts. However, overall the complete flooding seems slightly preferable to the other options. Moreover, it has to be noted that the mix between flooding and current agriculture is not defendable from an economic-environmental point of view. Farmers are the only ones taking advantages from ‘business as usual’ or optimised agriculture options, but unfortunately both courses of action are not defendable.

Figure 5.2 Dendogram of the Coalition Formation Process
Finally, it is possible to conclude that only the flooding or the partial flooding plus optimized agriculture options are completely defendable (from economic, environmental and equity points of view). The complete flooding project seems slightly better (above all from an environmental point of view), however the mix between optimized agriculture and flooding is the only project that minimizes the conflict with the interest group of farmers.

From the experience made in this case study, it is possible to draw some conclusions. First of all, one has to admit that the use of fuzzy sets can be a very useful tool in modelling environmental management problems characterized by deep uncertainties and approximate evaluations. As a consequence, the development of the NAIADE method seems a meaningful step for improving environmental management techniques. According to MCDA philosophy, no optimal solution has been found, while some actions considered defendable have been identified.

A major point is that these actions can in principle be identified by taking into account all three conflictual values of economics, viz. efficiency, equity and sustainability. In particular, given the complexity inherent in the concept of sustainability, this has been operationalized in a rough way, just by taking into consideration both economic and environmental consequences of the problem; intergenerational equity has been considered too. Of course, this is a second best approach, but given the state of the art, our approach seems to be a meaningful undertaking in an operational framework.

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