Introduction

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This book is devoted to sustainable development, with special reference to its implications in terms of policy implementation and assessment. As development can only be sustainable if it considers its environmental, social and economic implications, this book therefore relies on the common understanding that implementation of sustainable development must be approached by establishing a bridge between the environmental and social sciences. Although the chapters have different focuses, some more methodological, others more empirical, they all possess profound implications in the way sustainability is understood and assessed. In different ways, they also indicate that the black box of modelling and integrated assessment should be revealed in order to increase transparency, interdisciplinarity and meaningful participation of all the stakeholders in the decision-making process.

Sustainable development definitely entered the political agenda following the report by the World Commission on Development and the Environment (WCED, 1987). The often quoted definition given by the WCED is that 'sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their needs' (ibid., p. 43). Sustainable development is the foundation of Agenda 21 and of the Rio Declaration on Environment and Development. Since then, it has become the guiding principle of environmental and development policies. However, at the present time, there is no clear and common understanding of the real implications of sustainable development or ways to develop methods for addressing and assessing sustainability – be it at the local and project level or at the global level. There is, nevertheless, some general agreement on some key dimensions of sustainable development.

The concept of sustainability is usually grounded on three criteria, bio-physical (or environmental), social (or ethical) and economic. As pointed out by Daly (1987), these three criteria may be interpreted as defining three filters in deciding respectively what is (physically) possible; what is possible and (socially) desirable; and finally what is possible, desirable and (economically) feasible. Assessing sustainability is thus by definition an interdisciplinary effort. This argument is reinforced by the focus of sustain-

able development on meeting people's needs and thus increasing their welfare. Of course, welfare has very different components, such as produced goods and services, income and wealth distribution, leisure time, employment security, health, freedom, and environmental goods and services (see Huetting, 1990). Therefore development should not only imply a quantitative increase in economic goods and services, as production growth may be in conflict with other elements that contribute to welfare, such as in diminished environmental services resulting from pollution and degradation of natural resources.

Another important dimension introduced by sustainable development is the long-term setting in which projects and policies have to be assessed. On the one hand, quantitative increases in produced economic goods that are material- and energy-intensive cannot be sustained indefinitely, because our material world is a finite one. On the other hand, sustainability explicitly emphasizes the welfare interdependence between generations (see Faucheux *et al.*, 1996). In this context, sustainability is also related to the debate on governance and participatory approaches. In particular, to avoid the constraints of current choices impinging on the freedom of future generations institutions should preferably be designed so as to impose social controls combined with a minimal sacrifice of personal freedom. Discussions on institutional changes have sometime split the debate between advocates of state intervention and supporters of free market mechanisms, and strengthened the widespread conflict between individualism and collectivism, and between a market-oriented and a civil society (cf. Bürgenmeier, 1999).

Part I of this volume is concerned with the methodological implications of sustainability and with the resulting ramifications for decision-making processes. Confronted by the fundamental issues implied by sustainable development, an analysis of environmental problems from the perspective of natural sciences alone is indeed insufficient and often inadequate. These issues are actually closely related to conflicting values and stem from the failure of institutions to control access to resources, which includes their exploitation and distribution. As a consequence, as Judith Bradbury and Steve Rayner point out in Chapter 1, social scientists have increasingly been included in the integrated assessment of policies. However, the authors observe that social sciences have mainly provided highly aggregated data that are compatible within the framework already established by the natural sciences. This chapter thus argues that it is essential to incorporate data that provide further insights into human behaviour and motivations, and the associated ethical and distributive implications. In other words, Bradbury and Rayner assert that the basis of disagreement about policy issues affecting the relationship between human activities and the ecosystems is societal rather than technical. The chapter then explores research

into technical controversies related to nuclear waste and chemical weapons disposal in the United States to demonstrate the necessity of addressing issues pertaining to the meaning of proposed policies to those affected.

Martin O'Connor explores this argument further in Chapter 2. Although the author also supports the argument that sustainability demands more than just a descriptive (for example, resource inventory) type of analysis, he adopts a different starting point. Indeed, O'Connor stresses that a central question raised by sustainability is how to reconcile preoccupations with the future with those of the present. In other words, policies for ecological, social and economic sustainability involve choices for the redistribution through time of economic opportunities and of access to services and benefits provided by the biophysical environment. The chapter discusses the guiding concepts that might be appropriate for informed decision making as the scope of concern widens to the ecosystems of the planet and the long term. In that context, the response of conventional economics has been to extend cost–benefit analysis across time, through the valuation of environmental damages and of economy–environment trade-offs through time, using the discounting procedure. However, high uncertainties, the irreversibility of many impacts and the divergences of opinion about the basis for resolving questions of fairness imply that the cost–benefit optimizing approach may not be sufficient as a guide for decision making. Using examples of water resources and forests, the chapter thus develops the theme of the distribution of sustainability, placing an emphasis on managing and investing in the reproduction, transformation and renewal of the habitats that are our life-support systems. Valuation for sustainability means the appraisal of options whose effect is to sustain a given form or way of life, and this is inseparable from the question of the communities of interest to be sustained.

The environment as an area of conflict between competing values and interests, and the different groups and communities that represent them, is also highlighted by Silvio Funtowicz, Juan Martinez-Alier, Giuseppe Munda and Jerry Ravetz (Chapter 3). Those authors use 'post-normal science' to build a bridge between complex systems and environmental policy. This approach focuses on aspects of problem solving that tend to be neglected in traditional accounts of scientific practice, namely uncertainty and value loading. It also provides a coherent explanation of the need for greater participation in science-policy processes. Using that approach, and given that welfare is a multidimensional concept, they question the assumption of value commensurability used by conventional economics in the context of conflict resolution. Instead, the authors use multicriteria evaluation as a tool for conflict management, given its ability to address problems marked by various conflicting evaluations. In particular, multicriteria evaluation techniques can help provide more insight into the nature of the conflicts and

into ways to arrive at political compromises, thereby increasing the transparency of the choice processes. Examples of land use conflicts in The Netherlands and of water management issues in Italy illustrate how conflictual policy issues can be opened up for resolution with multicriteria evaluation. The authors also discuss how multicriteria evaluation may address macroeconomic issues, in relation to green national accounting and physical indices of sustainability.

Chapter 4, by Jan Rotmans and Marjolein van Asselt, is also concerned with the multidimensionality and interdisciplinary tasks related to sustainable development. The chapter provides a survey of current and past practices in integrated assessment (IA), focusing on modelling, scenario development and participatory methods. In order to improve the credibility of integrated assessment as an approach for complex issues, the authors also develop a code of good practice and quality criteria. The framework for quality assessment is based on a distinction between analytical quality, methodological quality and usability. In addition, Rotmans and van Asselt further appraise integrated assessment practices by critically assessing an existing IA model, TARGETS ('Tool to Assess Regional and Global Environmental and health Targets for Sustainability'). The TARGETS project can be considered as a scientific assessment of global change taking into account plural social and cultural objectives. The model enables evaluation of a number of environmental, social and economic consequences of several human activities simultaneously. The reflexive assessment upon the TARGETS project (which both authors have led) and the identification of gaps in knowledge are used for setting an agenda for future developments in integrated assessment. The areas pointed out for future research include the development of scientific methods for participatory processes; protocols for integrated uncertainty management, aggregation and disaggregation; and elaboration of the link between different spatial and temporal scales to identify the role of individuals and institutions, and their systems of governance. Some of these issues are explored further in Part II and Part III.

The contributions in Part I show that sustainable development decisions are particularly complex and uncertain, and have different implications for people. The decision-making process is very often confronted by conflicting social objectives and contrasting stakeholders' perspectives and interests. The choice of analytical methodologies, technical assumptions and scale and time dimensions are not neutral and are themselves policy decisions, which should not be taken without consideration of the people and interests involved. However, much research is still needed on participatory approaches and how models could be linked to stakeholders' perspectives. Part II of this book is thus devoted to the exploration of possible ways in which stakeholders may be included in complex environmental management problems.

Chapter 5, by Emiko Kawakami de Resende and Sylvia Tognetti, focuses on the implications for decision making of using information derived from different approaches. It also analyses the potential consequences of the proposed Paraguay–Paraná waterway (‘Hidrovia’) project, giving special attention to the conservation of biodiversity in the Pantanal. They argue that attempts to analyse costs and benefits of the project depend on how the problem is defined and are based on questionable and often arbitrary assumptions, which are in turn influenced by the interests and perspectives that have a voice in the decision-making process. Insufficient data and the complexity of the Pantanal ecosystem suggest limits to precise predictions of the impacts of the Hidrovia project. In addition, the project has the potential for large-scale irreversible impacts at the local and regional level. The authors contend that this kind of complex problem is beyond the capacities of existing institutions, and that it may be impossible to capture it in a technical framework and by standard valuation methods. Therefore they suggest an adaptive approach to valuation which provides stakeholders with opportunities for mutual learning, to reframe the problem in a broader context including the indirect effects of the Hidrovia project, to reconsider their values based on new information, and to engage in a process of negotiation and conflict resolution regarding what is to be sustained. The results of this process can then provide a set of criteria for evaluating the success of development efforts and for identifying trade-offs. Valuation thus becomes an institutional problem of access to the decision-making process. In this chapter, the value of the participatory process is also discussed with reference to other water development projects.

The relationship between increased public participation in the decision-making process and democracy is explored further by Claudia Natenzon and Héctor Poggiese in Chapter 6. These authors propose a methodology for participatory planning and co-management for application to critical situations in Latin America. This methodology involves formulation of public policies, elaboration of development projects that consolidate the democratic process, and consideration of environmentally sustainable interventions. Its main features are analysed in one of the cases to which it was applied, the Development Plan of Province Zudáñez in Bolivia. The project was initiated by a non-governmental organization which originally directed its actions towards rural development and, more specifically, towards the improvement of peasant agricultural production. However, it was realized that modernization of agricultural techniques was not possible without considering basic structural issues affecting the population, such as education, health, nutrition and cultural values. In addition, it was necessary to address political issues both within the local community and in its relation to other levels of public management. In other words, in this context it was necessary to develop a strategy for collaboration which included finding the common ground be-

tween traditionally opposed actors possessing distinct perceptions of reality and different cultural backgrounds. The methodology proposed by Natenzon and Poggiuese involves the actors in a continuous process of modelling the reality that they want to transform and generating conditions conducive to the emergence of new social actors. It involves two working tools, referred to as the 'methodological cycle' and the 'logical sequence'. The authors' final objective is to show the existence of tested methods for the collaborative construction of the future.

In the context of climate change, Chapter 7, by Stewart Cohen, focuses on collaboration between various stakeholders and the scientific community. The starting point for Cohen is that research and the current discussion on climate change are focused on uncertainties in climate projections and calculation of mitigation options (that is, how to reduce greenhouse gas emissions). Consequently, most integrated assessment efforts have been directed at the mitigation component and comparatively less information is provided on the benefits of impacts avoided, including adaptation options. However, the author points out that the problem of climate change is really about the potential effects on ecosystems, resources and the societies that depend on them. These effects will be unique to each region and country, depending on their vulnerabilities and adaptive capacities. Cohen argues that the narrow dimensions of the current debate on climate change may be a consequence of the lack of attention given to the needs of stakeholders who may be affected by the impacts of climate change. The purpose of this chapter is thus to explore a more holistic approach to integrated assessment of climate change impacts and adaptation which can complement continental/global-scale integrated assessment modelling efforts that largely focus on emissions limitation. This approach includes stakeholder participation in the formation of research questions, the generation of new information, and the discussion on results and recommendations. It is suggested that a broad 'scientists-stakeholder collaborative' could be a useful framework for an IA of climate change impacts on regions and countries, which would include modelling and non-modelling approaches, and incorporate institutional and stakeholder issues that do not readily lend themselves to economic analyses. The collaborative process can also help in capacity building, providing the foundation for creating a common property institution that focuses on climate change stewardship. The discussion is highlighted by a case study from Canada (the Mackenzie Basin Impact Study), which explores the regional impacts of climate change by involving both scientists and stakeholders.

Starting from a different perspective, Chapter 8 presents a possible way to involve users in models that are conceived as an aid to decision-making processes. In this chapter, Dale Rothman, John Robinson and Dave Biggs discuss how the relationship between indicators, models of sustainability and

users has been approached in the development of QUEST ('Quite Useful Ecosystem Scenario Tool'). QUEST is a microcomputer-based scenario generation and evaluation system which is intended to encourage thinking about sustainability in a regional context. It is being applied in different contexts in Canada, Latin America, Europe and Asia. Through QUEST, an individual user or a group of users can explore different possible future scenarios in terms of their social, economic and environmental characteristics and consequences. Recognizing that much of the value of models is also the learning that takes place during their construction, QUEST is intended to allow the users to actually construct and evaluate scenarios based on their own needs. These scenarios and consequences can be actively created by users in the form of a computer game. The objective is to acquaint users with the complex realities of the decision-making process, specifically the uncertainties involved, the necessary trade-offs and the role of subjective values.

Part III of the volume presents issues and case studies that are more related to the modelling aspect of integrated assessment. In Chapter 9, Jeroen van den Bergh surveys the spatial and temporal aspects of integrated environmental-economic modelling from the perspective of formal modelling and evaluation in a sustainable development policy context. To clarify this context, the author presents an overview of different perspectives on sustainable development, along with the corresponding modelling implications. Several ecological-economic models are then presented and compared, and the possibilities of integration discussed. Van den Bergh examines the relevance of thermodynamics for integrated models and its implications, for example in relation to specification of production functions and substitution possibilities. Observing that the spatial dimension of sustainable development has received less attention than the global context, the author discusses some of the main advantages of performing integrated studies at the regional level. This forms the basis for a critical discussion of a very aggregated indicator, the 'ecological footprint'. Since sustainable development is inherently dynamic, van den Bergh then considers various types and aspects of dynamic integrated models. Compared with neoclassical models, the two most important differential characteristics of evolutionary models are non-determinism and non-average behaviour. It is argued that standard growth theory may be interpreted as dealing with a rather short-term horizon and a stable economic regime characterized by a set of homogeneous firms, whereas evolutionary theory is concerned with a longer time frame in which diversity has an essential impact. In this sense, the author suggests that the two fields are rather complementary. An additional dimension analysed by van den Bergh is related to dynamic and spatial indicators, which may be generated by integrated models. The issue of aggregation, discounting and uncertainty in this context is emphasized. To illustrate how some of those ideas can be operationalized, the

chapter presents two examples. The first integrates elements from growth theory with a multisectoral economic structure and a materials flow model, based on dynamic mass balance production functions. The model allows for an analysis of limits to growth and sustainable development through numerical simulations of scenarios. The second example refers to the Sporades, an island region in Greece. It is a systems modelling study linking dynamic and spatial models into one comprehensive model. Scenario analysis and multicriteria evaluation are used to examine which policy options aimed at sustainable regional development are the most attractive.

Non-average behaviour and variability, spatial heterogeneity, time and dynamics, and indicators are also at the heart of Chapter 10, by Maryam Niamir-Fuller. This chapter reviews some of the theoretical background and points out some guidelines for monitoring and evaluating ecosystem function, structure and health in arid and semi-arid environments. The objective is to translate theoretical advances in ecological theory into appropriate policies and development activities. The discussion concentrates on African drylands, where development interventions in the last three decades have often been labelled failures. Such failures were often related to inappropriate paradigms used by scientists and development workers on the relationship between man and the environment. Anthropological work in the last decades, together with a greater understanding of non-equilibrium systems, has helped to improve appreciation of the way pastoral systems function, in order to understand the relationships between long-term and short-term strategies, and avoid an underestimation of their true economic value, for example in terms of production. This chapter shows some of the theoretical and practical differences between equilibrium and non-equilibrium systems, and draws implications for better monitoring and evaluation. Non-equilibrium ecological theory recognizes three characteristics of arid ecosystems: ecological variability, unpredictability and resilience. As a consequence, indicators that track variability (that is, range as opposed to average) appear more appropriate in capturing the complexity and uncertainty of arid lands. In addition, non-equilibrium systems require more frequent measurement, more sampling to cover space variability, more reliance on ground measures rather than on remote sensing, and more emphasis on monitoring soil and climatic factors, rather than on vegetation. The additional costs implied by this approach can be reduced through a decentralized system, which includes the local land users and their organizations. Non-equilibrium theory also maintains that the mobility of traditional extensive grazing systems in Africa was the key factor in ensuring ecological sustainability, since it is a mechanism which adapts to the variability and unpredictability of the ecosystem. In this context, appropriate social indicators of the viability of pastoral production and livelihood systems must consider several interrelated factors, ranging from production parameters to land ten-

ure security. Niamir-Fuller thus shows that sustainable development in arid systems requires fundamental changes in the way the system is evaluated and monitored. The variability and uncertainty in arid systems requires modification of research networks, monitoring programmes and the process of indicator selection. Management-oriented decision-making and monitoring programmes need to be decentralized and participatory in order to account for the inherent variability in time, and heterogeneity in space and scale.

In Chapter 11, Maria Willumsen is concerned with possible trade-offs between alternative growth strategies and environmental degradation, more specifically the interactions between production activities and deforestation in the Eastern Amazon region of Brazil (the Carajás Region). This region has experienced rapid growth and settlement over the last three decades, particularly after the discovery of a large deposit of strategic minerals. This growth process has been followed by significant depletion of natural resources, in particular deforestation. Exploration of the region's iron ore mines for export and the emergence of the pig iron industry – which relies on charcoal as an energy source – have been held responsible for the high level of deforestation. However, environmental assessments focused mainly on the direct effects of the growth process, and did not extend beyond the immediate project area. Other studies pointed out the role of infrastructures, population, subsidies and property rights, but Willumsen argues that they contained little formal analysis of the determinants of deforestation. Therefore the methodology presented in this chapter is designed to overcome the limitations of previous studies by capturing a wide range of interactions among different economic sectors and between these sectors and other aspects of society, including the environment. Willumsen develops an input–output (I–O) model representing the basic economic interactions between sectors, and between the broader Carajás Region and the more immediately affected Carajás area. The structure of the model is relatively simple and designed to allow a clear exposition of the existing relationship between production and environmental degradation. It explicitly integrates socioeconomic information with technical aspects of production and the environment, and is able to generate an integrated account of the effects of production and deforestation. Simulation results show that, contrary to common belief, the impact of industrial production (including the pig iron industry) on deforestation has been indirect and not significant at this stage. In fact, the study points out that the major impacts are due to agriculture and livestock. Willumsen argues that I–O models offer a flexible framework that is useful for visualizing complex interactions and are thus an interesting tool to support decision-making processes.

Another example of an applied integrated assessment model is given by Matthias Ruth in Chapter 12. This chapter shows how to model and analyse energy use and carbon emissions through a dynamic computer model which

explicitly incorporates the expertise of decision makers in industry and government agencies. Many industries are in a situation that requires rapid adjustments to changes in their markets for inputs and outputs, and to the policy environment in which they operate. The necessary investments to make these changes are typically large, and the consequences of the decisions are often felt for decades. Adjustments in one part of the industry may require and trigger adjustments elsewhere. The resulting dynamics of the industrial system are highly complex. To understand these dynamics requires detailed knowledge of the industry, and simultaneously, of the aggregate behaviour that results from changes in each individual part of the industry in their relationship to the factor and product markets. The development of a dynamic computer model can help put the individual pieces together and provide insight into the likely responses of the aggregate system. The dynamic computer model can also facilitate dialogue among scientists, engineers, modellers, the integrated assessment community and decision makers in industry and policy. Generating and maintaining such dialogue requires that adequate emphasis be placed on the modelling process, rather than solely on the results of a model. Using these premises, Ruth develops a dynamic model of the USA iron and steel industry, using the graphical programming language STELLA, a transparent modelling approach that facilitated dialogue among stakeholders. Several actors and types of information were used at various levels of modelling. The author establishes a baseline for likely future energy use and emissions based on time-series analysis of the industry. Engineering-based forecasts and different assumptions on climate change policies defined alternative scenarios. The model is used to investigate which segments within the industry would be most responsive to climate policies. In addition, climate change policies are prioritized on the basis of their effectiveness in reducing carbon emissions. The results obtained by Ruth show that the dynamics that describe technology change and fuel choice are fundamental in assessing market-based climate policies in the US iron and steel industry. The effectiveness of policies depends on the technical details of the production process and on past technology lock-in.

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