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# Introduction

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## SETTING THE SCENE

Economic analysis of causes and impact of biophysical changes like climate change, ecosystem services and biodiversity loss has commanded special attention in academic research as well as policy discourse. While the economic dimension of climate change has entered into a stage of being embraced and accepted by nearly everyone, it would be presumptuous to say this for ecosystem and biodiversity changes. How society is affected as a result of changes in the status and condition of ecosystems like forest and wetlands is clearly understood, at least to a great extent; the question remains how to capture those changes? One of the possible approaches typically suggested by the economics profession (admitting that economics is not a monolithic discipline) is to value the changes based on consumers' and producers' surplus-based concepts. However, the outcomes obtained through these approaches also create confusion and propel the need for credibility. In fact it may not be an exaggeration to state here that the bulk of the literature in economics of ecosystems and biodiversity is devoted to methodological nuances.

Economic valuation of ecosystem services helps to identify and resolve the trade-offs between different stakeholders engaged in managing ecosystems. Ecosystem management plans often result in net gains for some sections of society and net losses for others. For example, forest conservation might increase carbon sequestration (a global benefit), but as a result, local populations might be deprived of access to forest and services like timber and non-timber forest products. Valuation of ecosystem services is a tool that can help to ensure that the decision-making process incorporates considerations of equity and sustainability.

Economic valuation of ecosystem services also helps to link the conservation strategy with mainstream policies at national and regional levels. For any ecosystem service, its social value must be equated with the discounted net present value of the flow of that service (Hanley and Barbier, 2009). In theory, decision-makers can then see how the marginal benefits, for example the value of urban or coastal wetland conservation, equates with the marginal costs of conservation. Estimating the economic value of services like timber and fish, known as provisioning services, is relatively easy because they enter the domain of the market. However, this is not the case for regulating or indirect services, which can be defined as the benefits people obtain from the regulation of ecosystem processes, including, for example, the regulation of climate, water and some human diseases (Heal et al., 2005; Kumar and Wood, 2010). Typically, these regulating services are ignored as they are outside the conventional market. As a result, the marginal cost of conservation exceeds the marginal benefit, which sends the wrong signal to policy-makers.

One area of confusion in the valuation of regulating services has been the decision on what should be valued. Biogeochemical processes and subsequent functions of an ecosystem create services, but not all of these services are appropriated by society. Only

those benefits that people obtain from ecosystems should be considered as services (MA, 2003, 2005). Thus, valuation should target final rather than intermediate services (Fisher and Turner, 2008). Most of the regulating services are public goods and intermediate in character, but some of the services, like groundwater flow maintained by forests, could be used by lowland people for drinking (consumption) or industrial use (production). Economic valuation of ecosystem services is instrumental, anthropocentric, individual-based, subjective, context-dependent, marginal and state-dependent (Goulder and Kennedy, 1997; Nunes and van den Bergh, 2001; Freeman, 2003; Baumgartner et al., 2006; Barbier et al., 2009; Dasgupta, 2009, 2013). The value of ecosystem services is essentially a marginal concept arising out of scarcity and depends on the ecosystem condition and the social-cultural context in which people make choices (Heal, 2000; Barbier and Heal, 2006; Kumar, 2012). Thus, those who undertake ecosystem valuations should focus on ecosystems that are socially important, evaluate ecological responses in economic value-relevant terms, and consider the possible use of a broad range of valuation methodologies to estimate values (EPA, 2009).

While this discourse on economic valuation of ecosystem services and biodiversity still continues, there are other equally important issues like estimating natural wealth and income, trade affecting natural capital and ecosystems, role of governance and property rights in better management of ecosystems and biodiversity, and an entire range of issues like distribution and ownership of ecosystems and biodiversity, pushing the discussion into the political economy arena. They are equally critical in understanding the complexity of economics of ecosystems and biodiversity.

In the last ten years or so we have observed an interesting and probably encouraging phenomenon of the emergence of a need for a global consensus on the issue of economics of ecosystems and biodiversity. The global community and policy-makers have clearly expressed and articulated their demand for synthesis on valuation, accounting and mainstreaming of ecosystem services into conventional decision-making frameworks of fiscal and monetary policies, trade and investment measures and use of economic instruments in response to policies for biodiversity, ecosystems and climate change.

The United Nations supported probably the largest ever scientific assessment – the Millennium Ecosystem Assessment (MA, 2005) – which aimed to assess the capacity of ecosystems to support human well-being, and showed that over the last half-century humans have changed ecosystems more rapidly and extensively, which has resulted in a substantial and largely irreversible loss in the diversity of life on earth. These problems of changes, unless addressed, will considerably reduce the benefits of ecosystems and increase the risks of non-linear changes, and the aggravation of poverty. The MA's prominence on ecosystem services and their role in human well-being is widely acknowledged and is considered one of the key influential reports on clarifying the linkage between biodiversity conservation and poverty alleviation. The MA also recommended a greater use of economic principles while developing intervention strategies for management.

Although the MA created public awareness about how ecosystem services influence the constituents and determinants of human well-being, on economic aspects of ecosystems it was not as vocal as The Economics of Ecosystems and Biodiversity (TEEB) report, which came after the Stern Review (2006) on climate change. TEEB (2010) was a global initiative aiming to increase awareness on the economic paybacks of ecosystem services and biodiversity. In all, five volumes of compiled evidence and practical case examples

have highlighted that value of the natural capital is systematically underestimated and thus goes unnoticed in economic decisions. The TEEB guided policy-makers on how to incorporate use and conservation of natural resources and the services they provide into decision-making. The TEEB report also provided economic evidence on why, how and where ecosystems and biodiversity are essential for human well-being and play an important role for economic development. The report substantiates that valuing ecosystem services makes economic sense and argues that economic growth could be increasingly compromised by the continued reduction of natural capital. It was very logical that after the MA and TEEB, multilateral environmental agreements like the Strategic Plan for Biodiversity 2011–2020 with its Aichi Biodiversity Targets, adopted by the Convention on Biological Diversity (CBD, 2010), aim to address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society; to reduce the direct pressures on biodiversity and promote sustainable use; to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity; to enhance the benefits to all from biodiversity and ecosystem services; and finally to enhance implementation through participatory planning, knowledge management and capacity building. One of the Aichi Targets is to substantially increase financial resources from current levels. In support of the implementation of the Strategic Plan for Biodiversity 2011–2020, adequate, predictable and timely new and additional financial resources have to be provided.

After the completion of the MA in 2005, a plethora of national assessments and sub national assessments followed the economic assessments of ecosystems and biodiversity with greater vigour and confidence as reliable estimates and studies clearly showed the relationship between changing ecosystems and their impacts on people, especially the poor. The outcomes and recommendations following from the MA paved the way for the creation of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), which aims to assess the condition of the world's ecosystems, synthesize knowledge on the issue to be used by policy-makers, and develop capacity to assess and use scientific information for better decisions leading to enhanced human well-being. The UK's Ecosystem Services for Poverty Alleviation (ESPA) programme is also producing impactful research to manage ecosystems sustainably to reduce poverty. The evidence and tools for decision-makers are aimed to improve understanding of how ecosystems operate, the services humans acquire, and their connection with the economy and sustainable development.

Ecosystem and poverty dynamics also became the centre of attention after UNEP--UNDP Poverty-Environment Initiative (UNPEI) was launched in 2007. In brief, PEI supports developing countries' policy-makers and various stakeholders in managing the natural capital by focusing on improving livelihoods. The programme has provided financial and technical support to nine countries across Africa – Botswana, Burkina Faso, Kenya, Malawi, Mali, Mauritania, Mozambique, Rwanda and Tanzania; five countries in Asia – Bangladesh, Bhutan, Lao PDR, Nepal and Thailand; and four countries in Europe and Latin America – Kyrgyzstan, Tajikistan, Uruguay and Dominican Republic – to build capacity for mainstreaming poverty–environment linkages into national development planning processes.

Similarly, the United Nations Environment Programme (UNEP) Global Environment Facility-funded Project for Ecosystem Services (ProEcoServ) is being implemented in five countries – Chile, South Africa, Lesotho, Trinidad and Tobago, and Vietnam. The

overall goal of the project is to better integrate ecosystem assessment, scenario development and economic valuation of ecosystem services into national sustainable development planning. Country teams have developed very strong relationships with the relevant governmental organizations in implementing the project; and the teams have significantly advanced in the area of providing support and inputs to the targeted policy development mechanisms in pilot sites.

The Ecosystems Services for Poverty Alleviation (ESPA) primarily focused on research excellence and capacity development in the area of ecosystem management and poverty alleviation in the UK. The national ecosystem assessment furnishes a complete synopsis of the state of the natural capital. The assessment successfully reveals that natural wealth has been under-valued. Five hundred experts from the natural sciences, economics and the social sciences have contributed to this first ever national-scale assessment. The team collected, analysed and synthesized a significant body of peer-reviewed empirical evidence and information about the UK's environment. Within this process new tools for valuing the worth of the natural capital were developed. Valuing the ecosystem service properly may lead to better-informed decisions on investment, job creation and enhancement of human well-being.

UNEP's Green Economy Initiative defines the green economy as an economy whose growth in income and employment is driven by the investments that also reduce carbon emissions and pollution, improve resource efficiency, and ensure a continuous flow of ecosystem services by preventing the loss of biodiversity and ecosystem services. This path of creating economic prosperity depends on maintaining, restoring and enhancing natural capital. In most economic decisions, natural capital should be considered a critical economic asset and source of public benefits. First, the ecosystem is the main provider of various raw materials that serve as an engine for economic development. Second, this would also link poverty alleviation policies with economic development policies since livelihoods and security of poor people depend strongly on nature.

The degradation of ecosystems and loss of biodiversity have led some communities to experience a decline in their well-being. If the degradation continues, ecosystems may lose ability to regulate the climate and this could lead to further, unanticipated, and potentially permanent changes in the system and reductions in life-supporting ecosystem services. Therefore, the protection and restoration of ecosystems is at the core of the 'green economy'. Governments can play a key role in influencing and catalysing the green investment by targeted public expenditure policy reforms. For instance, investment in green forestry can preserve the economic livelihoods of more than 1 billion people who live from timber, paper and fibre products.

It is evident that the national-level economic assessment of ecosystems has gained momentum after the MA and has also led to serious questions regarding use of GDP as a measure of progress on the one hand, and framing approaches and methodologies involving ecosystem accounts on the other. The UNEP-led Inclusive Wealth Index emphasizes the need to estimate wealth of all types including natural capital, in order to say something on the sustainability of economy and society. The United Nations Statistics Division (UNSD) through its System of Environmental-Economic Accounting (SEEA) and Experimental Ecosystem Accounting (EEA) takes the System of National Accounts (SNA) to its logical culmination where Statistics recognizes the need for indicators to better capture the global and national sustainability discourse. Countries willing

to implement natural capital accounting (NCA) are also backed up by The World Bank's Wealth Accounting and the Valuation of Ecosystem Services (WAVES) programme. This partnership comprises several UN agencies, governments, NGOs and scholars. The programme is helping Botswana, Colombia, Costa Rica, Madagascar and the Philippines to establish natural capital accounts and integrate them within the national accounts. The UNEP led new initiative Valuation and Accounting of Natural Capital for Green Economy known as VANTAGE lays down the strategy to embrace and integrate contribution of natural capital especially in poorer parts of the world to attain the elements of Green Economy. This also includes the UNEP-IHDP led Inclusive Wealth Index (IWI) which advocates the need to account wealth-natural, produced and human to say something meaning on the direction and sustainability of Economy.

These initiatives fill the gap in environment–economy literature but create a void too where new paradigms of analysis and approaches seek identity and credibility. Indeed, the growing interest of the researchers and practitioners of ecosystem conservation and use over the last two decades has led to the proliferation of new modelling approaches and management tools. As a result, there is an increasing need for clarifying the scope and the limits of the various models, for improving our understanding of their use in decision-making, and for building tools for model choice in interaction with the key stakeholders. The chapters in this volume address these challenges by presenting the latest developments in the economic analysis of ecosystem services and by identifying the key research needs that have to be addressed in order to move the field forward. Nearly all the chapters in the volume present original in-depth case study research to substantiate their argument. Therefore, in addition, the book contains a wealth of case study material on the assessment of ecosystem services and biodiversity conservation of unique breadth and policy relevance.

## STRUCTURE OF THIS BOOK

Innovative approaches have been developed by economists to analyse various types of services and natural ecosystems. Part I of the handbook 'Setting the scene: the need for ecosystem service valuation' lays the basis for the further analysis in the book by a series of chapters on the usefulness and the limits of innovative approaches for improving and motivating policy action. Chapter 1 presents the general framework of natural capital accounting as part of a more comprehensive approach for measuring long-term economic well-being. The analysis of natural wealth accounts over the decade from 1995 to 2008 shows how economic development can be understood as a process towards building wealth. In this process, the composition of wealth has changed over the last decade: shifting away from natural capital and toward produced capital and, increasingly, intangible capital. This changing composition has in return an impact on long-term human welfare. The accounting exercises provide the basic framework to better assess such impacts and the many trade-offs between the various forms of capital – for example, decay in natural capital can have an impact through the moral and aesthetic satisfactions afforded by preserving wild areas and the biodiversity they shelter. As highlighted by the authors, the main challenges in these accounting exercises is data availability and the development of more fine-grained indicators that can range from the building of single composite

indexes to complex multi-criteria indicators that do not presuppose substitutability among the different forms of capital.

The subsequent chapters in Part I address precisely this question of data contribution and modelling of various forms of capital by discussing specific case studies of biodiversity conservation and ecosystem management. Chapter 2 addresses the question of the protective value of estuarine and coastal ecosystems, mainly through their ability to attenuate waves or buffer winds in the case of storm and coastal floods. Chapter 3 extends this analysis of ecosystem services by addressing the long-term recreational value of ecosystems, through an analysis of the ecological and social footprint of cruise tourism in Belize. Chapters 4 to 6 add to the analysis by integrating the indirect climate-related human impacts on ecosystem services and biodiversity conservation into the model. These chapters respectively address the issue of marine fisheries, coral reefs and other marine ecosystems and show that when climate change has an adverse impact on ecosystem services, economic losses related to ecosystems decay can dramatically increase. All in all, the chapters in Part I show the need to integrate contributions by researchers from multiple disciplines, including economists, natural scientists and sociologists, to address the complex linkages between natural and socioeconomic processes in the flow of the various ecosystem-related services.

One of the core problems in the economic valuation of ecosystem services is to account for the evolution of the actor's preferences regarding the value of the services and the variation of these preferences according to social and cultural factors that lead to different outcomes at various spatial scales of analysis. Part II on 'Emerging economic valuation methods' presents recent work on valuation addressing this issue, by broadening the conventional toolbox and integrating deliberative, spatially heterogeneous and macro-level assessment techniques.

Chapter 7 presents the general limits of the conventional Walrasian welfare model for understanding human motivations for conservation and management choices regarding ecosystem services. The cornerstone of the Walrasian welfare model is an approach of human behaviour that characterizes consumer preferences as stable, consistent, insatiable and independent of the preferences of others. Recent work in economics has exposed flaws in this conventional model, in particular by showing that many preferences are 'other' regarding, as well as 'nature' regarding, and that these preferences vary significantly according to cultural conditioning, relative positioning and other reference points. Therefore, understanding the social process of preference formation and the integration of welfare modelling in broader spatial macroeconomic frameworks has become critical to formulating sound economic policies. Deliberative methods can contribute to this goal, along with the mapping of trade-offs and values at a macro level of analysis. This broadened toolbox should facilitate clearer communication to decision-makers and the public and thereby could contribute to the formation of more collective preferences on biodiversity conservation and management of ecosystem services.

Chapters 8 and 9 show that it is possible to use a general equilibrium framework to assess micro-level welfare impacts of macro-level evolutions such as climate change and agricultural production. Results highlight some well-known aspects of these macro-micro interactions such as the contrast between regions that would benefit from climate-change-induced impacts, such as Mediterranean Europe, and regions that would suffer, such as many developing countries. Chapters 10 to 12 contribute further to the toolkit of

methods that can ensure better knowledge generation for concerned stakeholders (including public officials, scientific experts and decision-makers). More specifically, Chapter 10 analyses the use of an important software tool, Artificial Intelligence for Ecosystem Services (ARIES) by the US Bureau of Land Management. This software tool integrates a set of agent-based algorithms that allow accounting for the spatial dynamics of ecosystem service flows. Chapters 11 and 12 present respectively a selection algorithm for land allocation for the conservation of keystone species (Chapter 11) and a decision support tool, QUICKS for exploring various scenarios of land cover/use, which is applied to the case of the EU agricultural and environmental policy (Chapter 12). The common point highlighted by the authors of these various chapters is the importance of a proper design for the process of model choice and use. In particular, proper attention should be given to ensuring transparency in tool development, capacity strengthening to use a diversified toolbox and communicating results and improving exchange between developers and users (e.g., technicians, decision-makers, etc.).

The extent to which the choices of protecting biodiversity versus promoting biodiversity-related ecosystem services are likely to coincide depends on complex and yet little understood interactions between biodiversity and ecosystem services. However, biodiversity and ecosystem services are in serious jeopardy and the best hope to protect them is to create and align diverse incentives for conservation wherever possible and to integrate these into the larger policy-maker arena. Part III on 'Ecosystem services and conservation policy' applies the insights on natural capital accounting, modelling and economic valuation developed in Parts I and II to this complex nexus between protection of biodiversity and management of biodiversity-related ecosystem services.

Chapter 13 sets the stage of this analysis by presenting a simple model of land allocation that integrates the economic opportunity costs of biodiversity conservation and provision of ecosystem services on the same land, the effectiveness of conservation and management efforts and population density. Some themes that emerge from the stylized model is that greater reliance on ecosystem services is not always attractive to a country – as alternative land uses might be preferred – and that the potential for synergies between biodiversity conservation and ecosystem services will increase with the number of ecosystem services that are considered (see also Chapter 19). These points underscore the importance of relying on a wide diversity of mechanisms to address conservation, some of which can be based on marketable ecosystem services, while others might address non-marketable services such as moral and aesthetic satisfaction through subsidy schemes such as payments for ecosystem services.

Chapters 14 and 15 analyse the impact on conservation decisions of the availability of marketable products from ecosystems, such as the valuable research derived from biodiversity prospecting or the presence of fisheries adjacent to marine protected areas. The analysis in these chapters shows the temptation of actors to only consider the private benefit from the use of the marketable products, while such strategic or short-term self-interested behaviour does not always lead to the most socially desirable outcome. The further development of such studies at the intersection of conservation policy and management of ecosystem services, however, depends on the availability of richer data and more sophisticated data aggregation tools, as also stressed in Part I. Chapters 16 and 17 contrast the data needs and the role of uncertainty in the modelling in the case of valuation of ecosystem services and the case of the assessment of optimal biodiversity

preservation policies respectively. Particularly in the first case, lack of high-quality data is a major barrier. As shown in Chapter 16, the building of a data portal for accessing all the existing valuation studies and a more systematic use of spatial data in these studies could contribute to alleviating this problem. Chapters 18 and 19 finally broaden the analysis of the synergies between ecosystem services and biodiversity conservation by reviewing the literature on biodiversity, poverty and development on the one hand (Chapter 18) and the ecological-oriented literature on irreversibility and scale-dependency of certain services on the other (Chapter 19). In order to take into account this broader social context, both chapters advise looking at payments for ecosystem services (PES) as an important tool to provide the necessary incentives for local conservation activities that yield wider social benefits.

When looking at the types of valuation methods used in those studies that link valuation to policy and management approaches, there is a clear bias in favour of market-based methods in most of them. As also highlighted in Part III, this is unfortunate as it means that some important services are excluded, such as existence values or aesthetic values, leading to the possibility of placing zero value on such services. Part IV on 'Shedding light on non-market values of ecosystem services' presents a wealth of original case study research showing the importance of the non-market values within the ecosystem services framework.

Chapters 20 to 22 use choice experiments and contingent valuation techniques to value the non-use values in wetlands and coastal areas. The findings of these studies indicate the preference of users for more environmentally sound management scenarios, whether it is in the case of visits to coral reefs (Chapter 20) or restoration of wetlands (Chapters 21 and 22). However, even though these studies provide unambiguous evidence of the importance of the non-use values, further research is needed to better assess the social costs of investment in the management and restoration of these areas. Chapters 23 and 24 aim at better integrating this cost dimension by using a total economic value method for integrating the market price in the evaluation of the benefits, cost evaluation methods and data on non-use values gathered by choice experiments and contingent valuation. The resulting analysis of the value of unextracted groundwater in an aquifer in Greece (Chapter 23) shows that the incorporation of the groundwater's indirect ecosystem value and the non-use value increase the overall value of the groundwater-related ecosystem services in the assessment exercise. In a similar way, the non-use values estimated in the study of Jardines de la Reina National Park in Cuba (Chapter 24) are higher than the use values in the two management scenarios that are analysed in the case study. Chapter 25, finally, shows the interesting result that, although respondents to a contingent valuation survey show a clear interest in and demand for man-made wetlands, they indicate a zero willingness to pay. Indeed, the respondents would prefer to allocate public payments for the construction of man-made wetlands, exploited on a commercial basis. The latter result provides an interesting alternative to the more conventional choice for a public management scenario, such as envisioned in the study of the management of groundwater in a groundwater-dependent ecosystem in Northern Finland (Chapter 26).

While the debate on the economic tools and the synergies between biodiversity conservation and ecosystem service management is clearly at the heart of the major innovations in the field over the last decade, there are other equally important issues that determine conservation policies, which were already mentioned above, like the role of governance



and property rights, and the entire range of issues of distribution of ownership of ecosystems and biodiversity. Part V on 'The role of governance and science-policy-business interface in bringing visible ecosystem values' aims to provide an outlook on this broader set of issues by following the same combination of original case study material and literature review used in the other parts of the handbook.

Chapters 27 and 28 show the importance of broad stakeholder participation both in ecosystem management and in producing the science that supports such management. Chapter 27 analyses extensive survey data on governance of marine management areas based on different governance arrangements, such as national governance, co-management and community governance. In all these different forms increased participation leads to increased sustainable use and information gathering on use of resources in marine protected areas. However, as shown in the chapter, for effective participation to occur, one must critically examine the transparency of the processes involved in the development of the management plans and search for mechanisms to more effectively include the social actors that are really interested and affected by the creation of the marine managed areas. A similar caveat applies to the analysis of participation by stakeholders and policy-makers in the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), which is analysed in Chapter 28. Indeed, as stated in the chapter, the success of IPBES will to a large extent be dependent on the governance structures put in place, especially the participation of government representatives with a strong science background.

Chapter 29 provides an extensive review of the emerging discourse on the transition to the green economy, which allows better understanding of the various distributional issues that have to be considered in moving towards effective ecosystem management. Indeed, while the transition to the green economy will lead to many win-wins, it may also mean losses for certain groups and trade-offs across sectors and countries over time. These impacts need to be duly accounted for in transition plans. Some of the necessary steps that are essential components of such an effort are analysed in more depth in this chapter. First, discussions on the green economy need to build on a sound understanding of the value of nature and the role it plays in crucial issues such as poverty alleviation, the promotion of economic growth and the realization of multiple policy objectives simultaneously. Second, addressing these multiple values will require a combination of market and non-market tools, the most important of which are payment for ecosystem services, regulation and spatial planning.

Finally, Chapter 30 closes with an industry perspective on the use of some of the models that have been presented in the various chapters of the handbook. Indeed, if the interest in the economics of ecosystem services continues to grow, then it is likely that companies will need to employ new ecosystem-services-related risk and impact assessment protocols to identify potential effects of new projects and possible disruptions to supply chains based on changes in ecosystem services flows. The chapter discusses a case study to compare the various models – the location of a hypothetical residential housing project in the US San Pedro Watershed in Arizona. As shown through this analysis, it is both possible and desirable to combine a set of approaches to modelling and assessment. A possible scenario presented in the chapter is, for example, to offer a structure for priority setting through approaches that integrate stakeholder preferences, then conduct a landscape-level assessment through approaches that are primarily focused on ecological

data (such as those analysed in Part II), and finally use a tool that can assist with site-level analysis. Therefore, as highlighted throughout the contributions of the handbook, further progress in the design of the economic tools for assessing ecosystem services and the synergies between biodiversity conservation and ecosystem service management is to be found in multi-method research and integration of stakeholder preferences in assessment and modelling exercises.

We sincerely hope that broader constituencies of policy-makers and researchers in economics of ecosystems and biodiversity will find this volume useful not only in their daily work but coax them to take the discourse further, which we think has a long way to go.

## CONCLUDING REMARKS

How can we use the ideas presented here to formulate an integrated, effective framework to assess the value of ecosystem services and biodiversity? And what can we learn from current valuation studies in terms of their role in the design of economic policy? The answers to these questions require, *inter alia*, that a clear ecosystem service be chosen, that a concrete policy change scenario be formulated, that the relevant ecosystem services changes be described, and within certain boundaries, and that the particular perspective on value be made explicit.

So far, most studies lack a uniform and clear perspective on ecosystem services as a distinct, univocal concept. In addition, at present we have a rather poor knowledge about, for example, how biodiversity is affecting the overall ecosystem performance, including the provision of ecosystem services, as well as the level of resilience that this system, and relative ecosystem service supply capacity, has. For this reason alone, it is very difficult to assess the economic value of ecosystem services. To completely answer the question, 'What is the value of ecosystem services?' we have to include the value of the variety of interrelationships in which species exist in different ecosystems, the functions among ecosystems, and all the respective interactions, and impact, in terms of provision of ecosystem services. Therefore, the range and degree of ecosystem functioning needs be estimated, especially in terms of ecosystem-functional relationships and the respective outputs, including ecosystem services. Furthermore, we should have a clear understanding of beneficiaries, that is, the people and communities, who indeed receive welfare from the consumption or experience of the ecosystem service(s) under consideration. Without any doubt, full monetary assessment is impossible or would be subject to much debate. An additional problem is that, at the global level, ecosystem values can differ significantly, even for similar entities, due to unequal international income distribution.

The physical assessment of the functions performed by ecosystems is an essential prerequisite of any ecosystem services evaluation. However, simply identifying these functions is insufficient if we want to present resource managers and policy-makers with relevant policy response options. It is necessary to develop criteria for the expression of the functions in a form that allows for evaluation. For example, one can identify the range of management strategies by exploring the use of spatial modelling, including data such as the Red Data Species List, biological diversity indexes and ecosystem productivity. Computer models have become available to help decision-making by simulating differ-

ent policy scenarios. Models have been applied to calculate minimum dynamic areas that support the minimum viable population of a certain species. In addition, computer models have been used for ecosystem services evaluation, predicting conservation values under different development scenarios. This approach to ecological evaluation allows for a direct comparison of management or conservation strategies.

From an economic perspective, certain aspects of ecosystem services and biodiversity are scarce and highly desirable, which is the reason why they have economic value. The concept of economic value is founded in welfare economics, which developed around the theory of consumer behaviour. Economic valuation assumes interaction between a subject – a human being – and an object – for example, ecosystem services. As a result, economic value is distinct from the notion of intrinsic value, which assumes that an object has or can have value in the absence of any (human) subject. It is important to recognize that economists do not pursue absolute value assessment of environmental systems or all the ecosystem services they contain, but always focus attention on valuing environmental system changes. This means that the terms ‘economic value’ and ‘welfare change’ are two sides of the same coin. Economics can thus assess the human welfare significance of ecosystem changes, namely through the determination of changes in the provision of biodiversity-related goods and services – including ecosystem services – and their consequent impacts on the well-being of humans who derive – use or non-use – benefits from their provision.

Integrated economic-ecological modelling can contribute to, and may even be essential for, a thorough understanding of the intricate relationship between ecosystem functioning and ecosystem services and economic dynamics. Although integrated modelling has something of a tradition, both at the ecosystem level and at the global level, applications to ecosystem valuation and economic policy are still in their infancy. Integrated modelling can be linked to ecosystem performance and evaluation of ecosystem services in various ways. Integrated models can generate a set of biological and economic, possibly monetary indicators that can be further aggregated through multi-criteria analysis techniques. In addition, it is possible to provide for a closer, innovative connection between modelling and valuation, among other methods, by generating conditional values for specific environment–economic scenarios, using scenario modelling outcomes such as tables and graphs in valuation studies, and using spatial models to aggregate monetary values related to specific areas.

Finally, one needs to be aware of the limitations of economic valuation and analysis. Ecosystem services and biodiversity are rather complex concepts. They can be associated with a wide range of benefits to human society, most of them still poorly understood. In general terms, the value of ecosystem services can be assessed in terms of its impact on the provision of inputs to production processes, on human welfare, and on the regulation of ecological functions. A complete understanding of these and their integration into multidisciplinary studies provides a great challenge for future research, in which economists, ecologists and others, including policy-makers, will have to work closely together. Only then can one expect to offer an insightfully policy. There is no doubt that the economics of ecosystem services and biodiversity will face many research and policy challenges in the years ahead and that is another way to ensure the growth and importance of this important transdisciplinary theme.

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