# The Economics of Ecosystems and Biodiversity

# The Ecological and Economic Foundation

## Chapter 7

## Key Messages and Linkages with National  and Local Policies



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One of the major objectives of this TEEB book is to assess current approaches for using ecological sciences and economics for informed choices and decision making. On the one hand TEEB intends to better inform conventional economic policy about its impacts on ecosystem health and biodiversity, on the other it suggests ways to mainstream the valuation of ecosystem services into national and local planning and policies as well as business assessments of their economic impacts and dependencies on biodiversity. The previous six chapters assess the state of art of our scientific understanding underlying economic analysis of ecosystem services and biodiversity. Chapter 1 in this volume identifies several challenges in integrating the disciplines of ecology and economics and organizes the complexities of the problem resulting from the differences in methodological frameworks in relation to variation in temporal and spatial scales. For example, the relevant time horizon for a cost–benefit analysis of afforestation or ecosystem restoration project is 10–20 years while the changes in biodiversity could occur on a time scale ranging from short – a fraction of a second (molecular level) to long – millions of years (biome level). Chapter 2 highlights that ecosystems typically produce multiple services that interact in complex ways. A resilient ecosystem maintains a flow of ecosystem services on a continuous basis, but ecosystems may or may not be resilient to anthropogenic disturbances. Chapter 3 suggests that biodiversity and ecosystems are amenable to economic analysis only if they can be quantified and several approaches for developing indicators are discussed. Chapters 4 and 5 together highlight the socio-cultural embeddedness of ecosystem service and biodiversity valuation, as well as its constraints and limitations . Chapter 4 outlines the role and importance of valuation as a human institution and places in context the role of *economic* valuation. Chapter 5 explains how, for a chosen set of ecosystem indicators and within a structured economic valuation framework, there could be reliable approaches for the economic valuation of ecosystem services.. Chapter 5 also highlights commonly practised methods of ecosystem service valuation, and discusses their constraints and limitations. Chapter 6 assesses the basis of choosing appropriate discount rates to be applied to a project with impacts on ecosystems and biodiversity.

In this chapter we attempt to summarize the key lessons learned from the assessments done in Chapters 1–6. The summary can be categorized under the following headings:

## 1 Framing of issues for economics of ecosystems and biodiversity

The study of the economics of ecosystem services and biodiversity strongly emphasizes the joint effort of ecology and economics. There is a growing need for collaboration between ecologists and economists to have a coherent perspective on the trade-offs reflected in individual and societal choice (Polasky and Segerson, 2009). Even if the outlooks of the two disciplines differ, the scale of the problem requires that solutions can only emerge in making the methodology more porous and fluid in order to embrace each other's take on the problem. We find that:

1. Linking biophysical aspects of ecosystems with human benefits through the notion of ecosystem services is essential to assess the trade-offs involved in the loss of ecosystems and biodiversity in a clear and consistent manner.

2. Economic assessment should be spatially and temporally explicit at scales meaningful for policy formation or interventions, inherently acknowledging that both ecological functioning and economic values are contextual, anthropocentric, individual-based and time specific.

3. Economic assessment should first aim to determine the service delivery in biophysical terms, to provide ecological underpinning to the economic valuation or measurement with alternative metrics.

4. Clearly dinstinguishing between functions, services and benefits is important to make ecosystem assessments more accessible to economic valuation, although no consensus has yet been reached on the classification.

5. Ecosystem assessments should be set within the context of contrasting scenarios – recognizing that both the values of ecosystem services and the costs of actions can be best measured as a function of changes between alternative options.

6. In assessing trade-offs between alternative uses of ecosystems, the total bundle of ecosystem services provided by different conversion and management states should be included.

7. Any valuation study should be fully aware of the 'cost' side of the equation, as focus on benefits only ignores important societal costs such as missed opportunities of alternative uses; this also allows for a more extensive range of societal values to be considered.

8. Economic assessments should integrate an analysis of risks and uncertainties, acknowledging the limitations of knowledge on the impacts of human actions on ecosystems and their services and on their importance to human well-being.

9. In order to improve incentive structures and institutions, the different stakeholders – that is, the beneficiaries of ecosystem services, those who are providing the services, those involved in or affected by the use, and the actors involved at different levels of decision making – should be clearly identified, and decision making processes need to be transparent.

10. Efforts aimed at changing behaviour of individuals and society towards their impact on ecosystems and biodiversity must take into account that ecosystems have always been dynamic, both internally and in response to changing environments.

11. The importance of using scenarios in ecosystem service assessments is beginning to be realized as early assessments presented a static picture in a rapidly changing world. The necessity of providing counter-factual evidence is now being demanded of conservation research (Ferraro and Pattanayak, 2006) and should become the norm in ecosystem service research as well.

12. The generation of scenarios is particularly important for monetary valuation, since scenarios enable analysis of changes in service delivery which are required to obtain marginal values. Making an analysis in incremental terms avoids (or at least reduces) the methodological difficulties which arise, depending on the relative magnitude of changes, especially when attempting to estimate total values given the non-constancy of marginal values associated with the complete loss of an ecosystem service.

13. In the TEEB context, comparing the outputs under several scenarios will inform decision makers of the welfare gains and losses of alternative possible futures and different associated policy packages.

14. *Indirect drivers* of ecosystem change include demographic shifts, technology innovations, economic development, legal and institutional frameworks, including policy instruments, the steady loss of traditional knowledge and cultural diversity and many other factors that influence our collective decisions.

15. All ecosystems are shaped by people, directly or indirectly and all people, rich or poor, rural or urban, depend directly or indirectly on the capacity of ecosystems to generate essential ecosystem services. In this sense, people and ecosystems are interdependent social-ecological

systems. It is not surprising that around 1.2 billion poor people are located in fragile and vulnerable ecosystems but it is not primarily the actions of the poor that affect those fragile ecosystems but rather the actions of 'rich' people who interfere with them and put in question the dependence of the poor (Barbier, 2008).

## 2 Linkages of ecosystem, ecosystem services and biodiversity

A clear understanding of the links between ecosystems and ecosystem services, and how variation in biodiversity affects ecosystem dynamics is needed to map the temporal and spatial flow of services. This will not only help in making robust valuations but would avoid double counting and provide necessary caveats while up-scaling the value from local to national and regional scale. We find that:

1. Variation in biological diversity relates to the function of ecosystems in at least three ways: (i) increase in diversity often leads to an increase in productivity due to complementary traits among species for resource use, and productivity itself underpins many ecosystem services; (ii) increased diversity leads to an increase in response diversity (range of traits related to how species within the same functional group respond to environmental drivers) resulting in less variability in functioning over time as environment changes; (iii) idiosyncratic effects due to keystone species properties and unique trait-combinations which may result in a disproportional effect of losing one particular species compared to the effect of losing individual species at random.

2. Ecosystems produce multiple services and these interact in complex ways, different services being interlinked, both negatively and positively. Delivery of many services will therefore vary in a correlated manner, but when an ecosystem is managed principally for the delivery of a single service (e.g. food production) other services are nearly always affected negatively.

3. Ecosystems vary in their ability to buffer and adapt to both natural and anthropogenic changes as well as recover after changes (i.e. resilience). When subjected to severe change, ecosystems may cross thresholds and move into different and often less desirable ecological states or trajectories. A major challenge is how to design ecosystem management in ways that maintain resilience and avoid the passing of undesirable thresholds.

4. There is clear evidence for a central role of biodiversity in the delivery of some – but not all – services, viewed individually. However, ecosystems need to be managed to deliver multiple services to sustain human well-being and also managed at the level of landscapes and seascapes in ways that avoid the passing of dangerous tipping-points. We can state with high certainty that maintaining functioning ecosystems capable of delivering multiple services requires a general approach to sustaining biodiversity, in the long term also when a single service is the focus.

5. When predicting the impact of biodiversity change on variability in the supply of ecosystem services, we need to measure the impact of biodiversity conservation over a range of environmental conditions. In the same way, we need to be able to identify the effect of biodiversity change on the capacity of social-ecological systems to absorb anthropogenic and environmental stresses and shocks without loss of value (Scheffer et al, 2001; Kinzig et al, 2006).

6. To understand and enhance the resilience of such complex, coupled systems, we need robust models of the linkages between biodiversity and ecosystem services, and between biodiversity change and human well-being (Perrings, 2007; Perrings et al, 2009).

## 3 Choice of indicators and value-articulating institutions

Economic analysis, especially the evaluation of changes in ecosystem services due to marginal change in intervention and policies, requires careful choice of indicators and measures. The social and cultural contexts in which value articulating institutions exist and reveal value must be known to those assigning economic values. Establishing these prerequisites would also provide greater credibility to the estimates that follow. We find that:

1. A lack of relevant information at different scales has hampered the ability to assess the economic consequences of the loss of ecosystems and biodiversity.

2. Most of the current measures and indicators of biodiversity and ecosystems were developed for purposes other than the economic assessment. They are therefore unable to show clear relationships between components of biodiversity and the services or benefits they provide to people.

3. A reliance on these existing measures will in all likelihood capture the value of only a few species and ecosystems relevant to food and fibre production, and will miss out the role of biodiversity and ecosystems in supporting the full range of benefits, as well as their resilience into the future.

4. A set of indicators is needed that is not only relevant and able to convey the message of the consequences of biodiversity loss, but must also be based on accepted methods that reflect the aspects of biodiversity involved and the service that is of interest, capture the often non-linear and multi-scale relationships between ecosystems and the benefits that they provide, and be convertible into economic terms.

5. While it is possible to obtain preliminary estimates of the consequences of biodiversity and ecosystem loss using existing data and measures, these must be complemented with active research and development into the measurement of biodiversity and ecosystem change, their links to benefit flows and the value of these flows so as to realize the full value of biodiversity and ecosystem management

6. The flow of ecosystem services from point of production to point of use is influenced by both biophysical (e.g. currents, migration) and anthropogenic (e.g. trade, access) processes which influence the scale of service flow from locally produced and used services (e.g. soil production) to globally distributed benefits (e.g. carbon sequestration for climate regulation).

7. In order to make a comprehensive and compelling economic case for the conservation of ecosystems and biodiversity it is essential to be able to understand, quantify and map the benefits received from ecosystems and biodiversity, and assign values to those benefits.

8. Biophysical measurements are important since biodiversity underpins the delivery of many ecosystem services and thus forms the underlying basis of value.

9. Valuation, including economic valuation, functions as a system of cultural projection which imposes a way of thinking and a form of relationship with the environment and reflects particular perceived realities, worldviews, mind sets and belief systems. However, it can also serve as a tool for self-reflection and feedback mechanism which helps people rethink their relations to the natural environment and increase knowledge about the consequences of consumption, choices and behaviour.

10. Due to multidimensional and socio-cultural embeddedness of value any exercise of valuation is relative to a given individual or group of people. In a multicultural and democratic context of biodiversity valuation, this makes the question of choosing a value-articulating institution more important than that of finding a correct value.

11. Economic valuation influences the notion of ownership and property applied to biodiversity and over the long term may change human relationship to the environment in significant ways.

12. Intrinsic values are culturally embedded. They can be taken into account by choosing the appropriate institutions which allow their articulation in addition to utilitarian values.

13. Valuation processes can be seen as a form of regulatory adaptation by serving as a mechanism to provide feedback in a an economic system where production and consumption, trade and exchange are so distant from the underlying ecosystem and so complex in their commercial structure that they may undermine perceptions of the impacts of human habits and behaviours on the natural environment.

14. Value change along the commodity chain has implications for the distribution of benefits, affects the level of incentives for conservation and represents an important methodological challenge for economic valuation.

15. Economic valuation may contribute to address our inability, reluctance or ideological intolerance to adjust institutions (also those which are value articulating) to our knowledge of ecosystems, biodiversity and the human being.

16. Economic valuation is a complex, spatial and institutional cross-scale problem. Many efforts focusing on particular parts of ecosystems or species, while effective at one level, lack the scope to control the pressure of commodity markets for land resources surrounding them. As such, and depending on their biophysical context, they may be limited to capturing the linkages and vertical interplay created by a growing functional interdependency of resource-use systems nested within larger ecosystems.

**4 Economic value, valuation methods, non-linear changes, resilience and uncertainty**

How to value ecosystem services, what are the tools available, and what are the assumptions necessary to arrive at credible and transparent estimates and finally come out with recommended methods to apply in a situation of non-linear changes remain the main mandate of TEEB. The literature on valuation is full of good suggestions (Freeman, 2003; Heal et al, 2005; Barbier, 2007; Hanley and Barbier, 2009; Barbier, 2009; Atkinson, 2010, Bateman et al, 2010). Yet valuation techniques face important challenges especially regarding uncertainty, irreversibility and resilience. They are typically found while valuing the regulating services of ecosystems (Kumar and Wood, 2010). Our assessment suggests that:

1. Estimating the value of the various services and benefits that ecosystems and biodiversity generate may be achieved with a variety of valuation approaches. Applying a combination of approaches may overcome disadvantages of relying solely on an individual method.

2. Valuation techniques in general and stated preference methods specifically are affected by uncertainty stemming from gaps in knowledge about ecosystem dynamics, human preferences and technical issues in the valuation process. There is a need to include uncertainty issues in valuation studies. However, when uncertainty is compounded by ignorance about ecosystem functioning or when there is even a small possibility of disastrous damages, such as complete ecological collapse of ecosystems, current valuation techniques used to estimate values to feed into extended cost–benefit analyses are insufficient.

3. Valuation results will be heavily dependent on social, cultural and economic contexts, the boundaries of which may not overlap with the delineation of the relevant ecological system. It is likely that better valuation can be achieved by identifying and involving relevant stakeholders.

4. Implementation of valuation approaches that may be suitable for some developed regions may be inadequate in developing countries, thus not being immediately transferable. Hence, standard valuations approaches need to be carefully adapted to account for particular challenges that arise in developing countries.

5. While benefits transfer methods may seem a practical, swift and cheaper way to get an estimate of the value of local ecosystems, particularly when the aim is to assess a large number of diverse ecosystems, due care should be exercised in their use especially when key features of 'sites', such as ecosystem dynamics, socio-economic and cultural contexts, largely differ one from another.

6. Benefit transfer methods can be divided into four categories in increasing order of complexity: (i) unit BT; (ii) adjusted unit BT; (iii) value function transfer; and (iv) meta-analytic function transfer. BT using any of these methods may result in estimates that differ from actual values, so-called transfer errors. The acceptable level of transfer error for decision making is context-specific, but if a highly precise value estimate is required it is recommended to commission a primary valuation study.

7. Economic valuation can provide useful information about changes to welfare that will result from ecosystem management actions, especially with regard to localized impacts that are fairly well known and far from ecological thresholds.

8. Valuation practitioners should acknowledge that valuation techniques face limitations that are as yet unresolved. They should present their results as such, and decision makers should interpret and use valuation data accordingly.

9. The limitations of monetary valuation are especially important as ecosystems approach critical thresholds and ecosystem change is irreversible, or reversible only at extreme cost. In this case and until more understanding of ecological dynamics and techniques to estimate the insurance value of biodiversity or the value of ecosystem resilience become available, under conditions of high uncertainty and existence of ecological thresholds, policy should be guided by the 'safe-minimum-standard' and 'precautionary approach' principles.

10. There are three sources of uncertainty pervading valuation of ecosystem services and biodiversity that have been taken into account: (i) uncertainty regarding the delivery or supply of ecosystem services and biodiversity; (ii) preference uncertainty; and (iii) technical uncertainty in the application of valuation methods. Some promising approaches are being developed to try to account for such types of uncertainty but generally valuation applications disregard the uncertainty factor.

11. The uncertainty regarding the delivery of ecosystem services makes stated preference methods complex. Stated preference methods have generally resorted to measuring respondents' risk perceptions. Other valuation approaches based on expected damage functions are based on risk analysis instead.

12. Preference uncertainty is inversely related to the level of knowledge and experience with the ecosystem service to be valued. This source of uncertainty has been relatively better acknowledged in stated preference approaches, for instance by requesting respondents to report a range of values rather than a specific value for the change in the provision of an ecosystem service.

13. Technical uncertainty pervades valuation studies especially with regard to the credibility of the estimates of non-use values through stated preference methods and the non conclusive issue of the large disparity between WTP and WTA value estimates. It has been suggested that combining valuation models and a preference calibration approach may be the way forward to minimize technical uncertainty.

14. The value of the resilience of an ecosystem is related to the expected benefits and costs that occur when the ecosystem shifts to another regime. An analogy can be drawn between the

valuation of ecosystem resilience and the valuation of a portfolio of assets in that the value of the asset mix – the ecosystem and its biodiversity – depends on the probability that a shift occurs as well as on the benefits and costs when it does.

15. Current knowledge about biodiversity and ecosystem dynamics at this point is insufficient to implement such portfolio assessment, and monetary analysis will be misleading when ecosystems are near critical thresholds. At the policy level, it is better to address this uncertainty and ignorance by employing a safe minimum standard approach and the precautionary principle.

16. Despite many limitations, valuation exercises can still provide information that is an indispensable component of environmental policy in general. But policy makers should interpret and utilize the valuable information provided by these techniques while acknowledging the limitations of this information.

17. It is likely that new techniques and combinations of different methodological approaches (e.g. monetary, deliberative and multicriteria methods) will be needed in order to properly face future challenges and provide more accurate values that would benefit decision making processes.

18. A closer collaboration between ecologists and economists may then contribute to develop valuation techniques that are better suited to dealing with the complex relationship between ecosystems and the services they provide to the local and global economies.

19. Future valuation practitioners of biodiversity and ecosystem services should make explicit the procedures and methods used in their studies as well as openly acknowledge any obstacles that they may have encountered.

## 5 Discounting as an ethical choice

Intertemporal distribution of costs and benefits poses a challenge for the decision makers in justifying resource allocation for a project and policies especially when they have competing demand for the resource available. The challenge becomes more severe if the project entails the impact on ecosystems in the long run. If the impacts of project through its costs and benefits accrue to poor and the rich disproportionately, it further complicates the analysis.

We find that an appropriate rate of discount can guide better choice of strategies and response policies for ecosystem management. We suggest:

1. There is a fundamental difference between the individual-at-a-point-in-time discount rate and the social discount rate.

2. In terms of the discounting equation, estimates of how well-off those in the future will be are the key factor as to how much we should leave the future.

3. A critical factor in discounting is the importance of environmental draw-down (destruction of natural capital) to estimates of the future growth rate of per capita consumption

4. In contrast to the recommendations of conventional economists, a variety of discount rates, including zero and negative rates, should be used depending on the time period involved, the degree of uncertainty, ethical responsibilities to the world's poorest, ethical responsibilities towards future generations, and the scope of project or policy being evaluated.

5. A low discount rate for the entire economy might favour more investment and growth and more environmental destruction. Macroeconomic consequences of a particular discount rate should be considered separately from microeconomic ones.

6. The rich and poor differ greatly in their direct dependence on biodiversity and the services of ecosystems.

7. There are no purely *economic* guidelines for choosing a discount rate. Responsibility to future generations is a matter of ethics, best guesses about the well-being of those in future and preserving life opportunities.

8. In general, a higher discount rate applied to specific cases will lead to the long-term degradation of biodiversity and ecosystems. A four per cent discount rate implies that biodiversity loss 50 years from now will be valued at only one-seventh of the same amount of biodiversity loss today.

9. A critical factor in discounting is the importance of environmental draw-down (destruction of natural capital) to estimates of g (as GDP growth). Is the current generation living on savings that should be passed to their descendents?

## 6 Identification of knowledge gaps and limitations and mapping into national policies: Challenges and options

The assessment of evidence on the relationship between ecosystem services and biodiversity helps not only in identifying the policy-relevant insights but also in filling the gaps in understanding the science which is critical for economic analysis. This can further be carried forward for research and must be remembered while designing policies for the national and global decision makers. Some of the emerging questions that are very relevant for economic analysis of change in ecosystems and biodiversity include:

**6.1 Links between biodiversity, ecosystems and resilience**

[nl]i What are the roles of species interactions and functional diversity for ecosystem resilience?

ii What are the drivers behind loss of resilience and how do they interact across scales?

iii What are the impacts of climate and related environmental changes on ecosystem functioning through effects on species (re)distribution, numbers and process rates?

**6.2 The dynamics of ecosystem services**

i How can we better quantify effects on regulating ecosystem services of an increase in non-sustainable use of provisioning services?

ii What tools can contribute to accurate mapping of land and seascape units in terms of functioning and service provision?

iii What specific tools could contribute to better assessment of spatial and temporal dynamics of service provision, especially in relation to defining who benefits, where and to what extent?

**6.3 Understanding the dynamics of governance and management of ecosystems and ecosystem services**

[nl]i If all ecosystem services are taken into account, what is the appropriate balance between 'more diverse landscapes generating bundles of ecosystems services' and more intensively managed ecosystems like monocultures for food production?

ii What are the trade-offs and complementarities involved in the provision of bundles of ecosystem services, and how do changes in the configuration of ecosystems affect their value?

iii What are the most effective mechanisms for the governance of non-marketed ecosystem services, and how can these be designed so as to exploit future improvements in our understanding of the relationships between biodiversity, ecosystem functioning and ecosystem services?

**6.4 Valuation and benefit transfer method**

i. Since marginal values are likely to vary with ecosystem characteristics, socio-economic characteristics of beneficiaries, and ecological context, care needs to be taken to adjust transferred values when there are important differences between study and policy sites.

ii It should be noted that the market size and rate of distance decay is likely to vary across different ecosystem services from the same ecosystem. It is also important to account for differences in site context in terms of the availability of substitute and complementary ecosystems and services.

iii In cases where a high quality primary valuation study is available for a study site with very similar characteristics to the policy site, the unit transfer method may produce the most precise value estimate. In cases where no value information for a closely similar study site is available, value function or meta-analytic function transfer provide a sound approach for controlling for site specific characteristics.

iv Aggregation of transferred unit values across the relevant population or ecosystem area needs to be undertaken carefully to avoid double counting values or misspecifying the market size for an ecosystem service.

v Future valuation practitioners of biodiversity and ecosystem services should make explicit the procedures and methods used in their studies as well as openly acknowledge any obstacles that they may have encountered.

## 6.5 Valuations and its context

Social and institutional analyses suggest that valuation is essentially a matter of choosing how to perceive the human being itself, how to perceive human's place in Nature and how to perceive Nature itself. This is because the way we perceive our natural environment determines the way we value and change it. One way of incorporating a multilayered understanding of human–environment relations, and understanding the value and motivational linkages between the two, is to address the large gap that exists between the language in which the preference of the people for ecosystem services is elicited and the language in which people feel more at home. The languages of research and policy show similar dissonance. The more the discourse moves away from the common lives and real-life concerns to abstruse quantification and reductionism, the more people are likely to give preferences that are fudged and confused as much as these are confusing, merely because the choices we offer are far from adequate (Kumar and Kumar, 2008, p814). Valuation approaches aiming at addressing complex socio-ecological systems require attention to the challenge of understanding problems of credibility, saliency and legitimacy at the intersection of different knowledge systems and access to information at different levels and by different groups (Cash et al, 2006). In this sense, valuation mechanisms should be seen as part of a broader range of diagnostic and assessment tools and political–institutional mechanisms that facilitate the understanding of complex socio-ecological systems (Ostrom, 2009), as well as coproduction, mediation, translation and negotiation of information and knowledge within and across levels (Cash et al, 2006; Brondizio et al, 2009). The main lesson that comes across when one reviews valuation literature is to avoid a 'one size fits all' approach, or as Ostrom (2007) puts it when proposing a framework for the analysis of complex social-ecological systems, we need to move beyond panaceas.

Regulating services provide value through their role in assuring the reliability of service supply over space or time; sometimes expressed in terms of the resilience of the system to environmental shocks. That is, they moderate the variability or uncertainty of the supply of provisioning and cultural services. While an increase in biodiversity may increase production, experimental data indicate that for given environmental conditions this effect is small. The productivity of some biologically diverse communities, for example, has been found to be about ten per cent higher than the productivity of monocultures, but the effect often saturates at fewer than ten species. If environmental conditions are not constant, however, the effect may increase with the number of species providing that they have different niches and hence different responses to disturbances or changes in environmental conditions. For instance, the regulation of pest and disease outbreaks is affected by food web complexity.

i) Since people care about the reliability (or variability) in the supply of these services (people are generally risk averse), anything that increases reliability (reduces variability) will be valued. The value of regulating services accordingly lies in their impact on the variability in the supply of the provisioning and cultural services. An important factor in this is the diversity of the functional groups responsible for the services involved. The greater the specialization or niche differentiation of the species within a functional group, the wider the range of environmental conditions that group is able to tolerate. In some cases greater diversity with a functional group both increases the mean level and reduces the variability of the services that group supports. Indeed, this portfolio effect turns out to be one of the strongest reasons for maintaining the diversity of functional groups.

ii) The general point here is that the value of ecosystem components, including the diversity of the biota, derives from the value of the goods and services they produce. For each of the ecosystem services described in this chapter we have identified its sensitivity to changes in biodiversity. If greater diversity enhances mean yields of valued services it is transparent that diversity will have value. However, it is also true that if greater diversity reduces the variance in the yield of valued services that will also be a source of value. Since people prefer reliability over unreliability, certainty over uncertainty, and stability over variability, they typically choose wider rather than narrower portfolios of assets. Biodiversity can be thought of as a portfolio of biotic resources, the value of which depends on its impact on both mean yields and the variance in yields.

iii) It follows that there is a close connection between the value of biodiversity in securing the regulating services, and its value in securing the resilience of ecosystems. Since resilience is a measure of the capacity of ecosystems to function over a range of environmental conditions, a system that is more resilient is also likely to deliver more effective regulating services.

### 6.6 From micro foundation to macro policy

One of the major criticisms of economic valuation of biodiversity and ecosystem services is that most valuation exercises do not allow for ecosystems and economies to impact each other simultaneously. Also, although not necessarily a criticism, the frame of reference for most economic analysis of ecosystems is at the firm, household or individual industry level. Setting the analysis at the firm, household or industry level masks potential spillovers associated with actions taken in one sector of an economy on other sectors, and the corresponding impacts on macroeconomic variables like gross domestic product (GDP), aggregate savings rates or trade patterns. Similarly, the structural changes accompanying economic growth (sectoral composition), trade and consumption patterns can have far reaching impacts on the health and condition of ecosystems. Two examples of such impacts are: (i) the intensification of agricultural production accompanying economic growth, and its impact on soil salinity and water logging, and on genetic diversity; and (ii) regional and national subsidies to fish harvesting and the corresponding impacts on fish stocks and marine biodiversity.

There are other relevant examples where a macroeconomic framework could provide useful insights into how to better manage an ecosystem. One current issue in the economics of coastal ecosystems is the impact of economic growth and the increased conversion of mangrove forests into agricultural or aquacultural uses, and the corresponding impact on the ability of coastal ecosystems to support fish populations. Another issue is the concern with delta ecosystem destruction due to decreased – sometimes non-existent – river flow. With terrestrial ecosystems, an issue that has received much attention, and will continue to do so in the near future, is carbon sequestration. A simplistic summary of the current discussion is Southern countries have potential to serve as carbon sinks, but deforestation in these countries provides them with a significant source of GDP. A natural question to ask is, if Northern countries want a Southern country to serve as a carbon sink how much income would that country forgo if it decreased its desired rate of deforestation, or stopped it altogether? The answer to this question likely sets the lower limit on the North’s offer price to the South country to steward its forest assets differently.

Thus far, the thrust of this TEEB book has been to summarize the dominant conceptual frameworks and related methodologies used to measure the economic costs and benefits of ecosystem management policies. Such policies range from taxes to eliminate externalities in an existing prevailing market (market failures) to policy-induced distortions implemented at regional, national and global levels (e.g. tariffs to protect import-competing sectors or taxes on factors used by sectors that damage ecosystem health). The maintained hypothesis, here, is policy design can be better informed by properly using economic valuation and accounting exercises (with the understanding that policy rankings can be influenced by the discount rate used in the analysis).

The methodologies discussed thus far, however, do not adequately accommodate the interdependencies among different economic subsectors and ecosystem services. The methodologies also are not designed to measure the potential impact of a policy on the entire economy and its underlying ecosystem. The dependence of conventional economic sectors on ecosystems arises not only through the use of tangible factors like timber, water and fish, but also the use of intangible services like waste minimization, climate regulations or the control of vector-borne diseases (MA, 2003, 2005). Each of these services adds value to human well-being, but the ability of ecosystems to provide such services can be influenced by human behaviour.

The economics of tropical mangrove forests illustrate this point. Marine scientists have established a link between mangrove area and the carrying capacity of fish stocks – loosely speaking, the larger the area planted to mangrove forests, the larger the stock of fish the coastal ecosystem can support (see Barbier, 2003, 2009; Hoanh et al, 2006). The simplest economic story embedded in the relationship between mangrove forest area and fish stock is: the smaller the mangrove forest, the more costly it should be to harvest fish. Ignoring the land-conversion process, a natural question to ask is how will net returns to the fishing industry change as mangrove area falls? In answering this question, one might rightfully ignore the rest of the economy – especially if the fishing area contributes little to the overall economy. Alternatively, consider an economy wherein harvested fish are sold to firms who employ capital and labour to process fresh fish, who in turn compete with manufacturing and service sector firms for capital and labour. In this case, a decrease in mangrove area leads to an increase in fish harvesting costs, which in turn decreases the supply of fresh fish to processors. This can lead to higher fresh fish prices, which can place downward pressure on the demand for capital and labour by fish processors. These interactions can have implications for regional wages and rates of return to capital and investment patterns. Empirical examples (non-fishery) in Roe et al (2009would suggest the economic impact of a declining mangrove forest on both the fishing fleet and processing sector will depend on how important capital is relative to labour in producing each sector's output.

The two mangrove examples illustrate that some problems in ecosystem economics are well suited to microeconomic analysis, while others are not. Other examples will reveal that some issues can be examined without explicitly accounting for biophysical/ecosystem dynamics, while others should not. Insights into the economics of some issues can be garnered using a simple, single-sector growth model integrated with a biophysical model (e.g. the Dynamic Integrated Climate Economy (DICE) model developed by Nordhaus and Yang, 1996). On the other hand, a careful investigation of the economics of the mangrove–fishery problem in the previous paragraph likely requires integrating fishery dynamics with a dynamic economic model having multiple sectors.

Another issue which must be addressed is the relationship between the relative scale of economic activities and the natural ecosystem to which the economic system is a subset. Accounting for scale effects is critical in understanding how to manage an ecosystem and economy in a sustainable fashion. This management challenge is directly related to the concept of *the carrying capacity of Nature* (Arrow et al,, 1995). Just as the micro units of the economy – e.g. individual households and firms – function as part of a macroeconomic system, the aggregate economy functions as part of a larger system which Daily (1991) refers to as the natural ecosystem.

In response to these omissions, developing a conceptual framework that captures the economics of interactions between large-scale ecosystems and regional or national economies would facilitate the design of regional and national ecosystem and biodiversity policy. Take for example, policy suggested in TEEB in national policy, chs 2, 4 and 6). The economic theory underlying such policy could benefit by having its roots in dynamic, general equilibrium models. Even more importantly, the model should be empirically implementable. A good starting point for such a model might be found by linking the multi-species, dynamic general equilibrium ecosystem model (GEEM) discussed in Tschirhart (2009), Eichner and Tschirhart (2007) and Finnoff and Tschirhart (2008) with the dynamic, multisector macroeconomic models presented in Roe et al (2009). Such a framework could serve as a nice point of departure for examining the relationship between ecosystem management and (i) economic growth, (ii) structural transformation and (iii) simple trade and balance of payment issues. The Roe et al approach, however, may not be of much value in understanding the relationship between monetary policy and ecosystems.

A multisector, general equilibrium is desirable for two reasons. First, a general equilibrium model provides us with a direct means of understanding the interdependencies among economic subsectors and between these sectors and an ecosystem. Second, we want two or more sectors because policy makers are typically interested in knowing (or having an idea of) the likely impact of a policy on different stakeholder groups, for example manufacturing and agricultural lobbies. The desired framework is dynamic because both ecosystems and economies are dynamic entities, and it is important to understand the short- and long-run impact of a policy on an economy and the ecosystem with which the economy is linked. Furthermore, a long-run view is essential when delving into questions of sustainability. Finally, another desired feature of a model linking economics and the ecosystem would be for the model to accommodate ecosystems defined by two or more natural assets (e.g. the stock of coral reef serving as habitat for a stock of fish). We feel this is important because ecosystems are typically viewed as the result of interplay between two or more species or, more generally, between abiotic factors and biotic organisms.

Several challenges emerge when introducing dynamics into an economics–ecosystem model. For instance, standard approaches to empirical economic dynamic modelling does not typically accommodate hyperbolic or other potentially more complex discounting concepts. In addition, one might need to entertain the possibility of ‘shallow-lake’ dynamics, which can lead to multiple steady state equilibria (see Mäler et al, 2003; Heijdra and Heijnen, 2009). The model might also need to accommodate transboundary problems, which to address properly in an empirical fashion is quite challenging.

6.6.1 *Ecosystem Accounting*

Two issues linked with natural assets are: (i) the role of natural assets in measuring social welfare and sustainability, and (ii) the role of natural assets in social accounting and input–output tables – often referred to as 'green accounting'. Welfare, its definitions and measurement is the topic of interest to a wide spectrum of disciplines (see Stiglitz et al, 2009). For the past few decades, per capita gross domestic product (GDP) and per capita gross national product (GNP) have been popular indices of welfare. GDP is the total value of all final goods and services produced in a region, and GNP is GDP plus income earned by domestic citizens abroad less income earned by foreign citizens in the region. While GNP is a reasonable measure of economic activity, when measuring welfare in a dynamic setting (e.g. an evolving economy) some economists prefer using wealth or net national product (NNP) as a measure of economic well-being or social welfare. Here, wealth is typically viewed as the real value of stocks, and NNP is equal to GNP less depreciation [see Weitzman (1976); Dasgupta and Mäler (2000); Heal and Kriström (2005); Dasgupta (2009)].

Note, however, that these income and wealth based measures of welfare have well known problems. One problem with per capita GDP is it glosses over issues of distribution, and implicitly assumes the marginal valuation of an additional unit of income is the same for an impoverished person as it is for a rich person. Another problem is that traditional measures of GDP (and NNP) do not account for the depreciation (i.e. degradation) of environmental assets, biodiversity or ecosystems. Creation of the Human Development Index – where GDP is combined with health status and education levels – is an improvement in welfare measurement, but is however silent on natural capital's and ecosystems' contribution to human welfare (Dasgupta, 2009). See Stiglitz et al (2009) for a discussion of economic welfare: definitions, measurement and statistical issues, and data needs. The importance to traditional agriculturalists and subsistence farmers of ecosystem services from forest biomes (eg : freshwater and soil nutrient cycling, provision of fuelwood and fodder, mitigation of flood and drought damage to crops and property, etc) has been evaluated by TEEB and found to be a very material component of their household incomes ( see "TEEB and Policy Making"). Traditional measures of economic performance are also insensitive to such equity and poverty implications of ecosystem services and of their ongoing losses.

The welfare discussion alluded to above is intimately related to the notion of sustainability. Although the issue of sustainability was taken up by Hicks and Lindahl beginning in the 1930s (Heal and Kriström, 2005), and discussed by Solow (1992 the potential long-run impact of environmental damages like global warming and concerns with the future availability of natural resources has more recently resurrected the sustainability discussion. Roughly speaking, an economy is on a sustainable trajectory if real wealth [Dasgupta and Mäler (2000)] or real income [Hicks (1939)], does not fall over time.

The national income account (NIA) is a fundamental macroeconomic indicator, which shows the level and performance of economic activities in the economy. The System of National Accounts (SNA) of the United Nations attempts to provide a benchmarked framework for measuring and summarizing national income data across all activities within an economy and to facilitate comparing such data across countries (SEEA 2003. A crucial component of the SNA is the estimation of GDP, where, at given market prices, the gross value of all the goods and services produced within an economy is estimated.

In measuring GDP, the contributions of ecosystem services such as bioremediation by wetlands, storm and flood protection by mangroves, and the prevention of soil erosion by forests are ignored. Hence, many ecosystem services which have a welfare-enhancing roles do not enter into macroeconomic value calculations. This is due to their relatively low perceived value as these resources and their contributions often fall outside the domain of the market, and hence remain un-priced and under-valued. Ultimately, this means that GDP underestimates the actual level of social welfare because it does not account for contributions from natural resources.

Economists are now in agreement that instead of measuring GDP or income – a flow concept – the more comprehensive measurement of the stock of wealth that includes the value of natural capital is a more meaningful and correct approach (Dasgupta and Mäler, 2000; Arrow et al, 2004; Dasgupta, 2009). The World Bank has attempted to implement the concept of ecosystem accounting, and created two reports in late 1990s – namely 'Monitoring Environmental Progress' (World Bank, 1995) and 'Expanding the Measure of Wealth' (World Bank, 1997). These reports are fundamentally based on Pearce and Atkinson's (1993) notion of wealth measurement and savings. Another important milestone in estimating natural wealth occurred in 2006, when the World Bank published 'Where Is the Wealth of Nations' a report that presents 'wealth accounts' of more than 100 countries (World Bank, 2006).

To date, there is a general consensus that natural assets are stocks that should enter a social accounting matrix (SAM) or input–output (IO) table as a factor account, and the provisioning and regulating services, if measurable, should enter as an intermediate input. Green accounts are a crucial ingredient in empirical general equilibrium modeling exercises because the SAM is the link between the macroeconomic theory and its empirical analogue. Although most countries have SAMs for one or more years, very few countries have SAM data that includes natural asset entries (Heal and Kriström, 2003).

Given the myriad of policy issues, it is useful to consider two broad categories of policy. One is related to the economic forces associated with the natural evolution of an economy (e.g. capital deepening and increased labour productivity), and how these forces impact (spill over onto) the exploitation of natural assets and ecosystems. In this category, policy instruments include taxes, subsidies, quotas, licences and property rights that are linked directly to natural assets and ecosystems. Similar instruments linked to other sectors can have indirect impacts on natural assets and ecosystems. The other set of policies are domestic macroeconomic policies (e.g. monetary policy) that cause major fiscal and trade imbalances, which in turn distort domestic product and factor markets. Similarly, foreign policies can have spillover effects on the home country.

Characteristics of a growing economy include capital deepening – here, broadly defined to include human capital – and typically an increase in the service sector's (housing, utilities, transportation, professional, banking and retail services) share of GDP, with most of the service goods not traded in international markets. Also, as economies grow (i) the share of the work force in agriculture falls as wages increase, which induces a substitution of capital for labour in production, and (ii) household expenditures on services and entertainment goods increase.

The possible impacts a successful economy can have on ecosystems and biodiversity 'works in reverse' for an unsuccessful, slow-growing economy. Often, poor economic performance is also associated with economic crises and volatility in factor incomes. Invariably, these conditions tend to slow the exodus of labour out of agriculture, slow the rate of capital deepening and dampen a country's incentives and political will to prevent the degradation of natural and environmental resources. Economic crises often result when countries pursue policies that lead to fiscal deficits or external debt that make their economies vulnerable to economic shocks. The needed within-country-adjustments – even with the assistance of international agencies and friendly governments – is invariably a decrease in government spending, an increase in transfers from households either directly through taxes and fees, and costs of adjustment as resources are reallocated from the production of home goods to the production of internationally traded goods. Until the imbalances are corrected and debt obligations met, household real disposable income is typically much less than before the shock, with wage income suffering the greatest decline. Ecosystem exploitation (e.g. harvesting timber for cooking and fuel) is exacerbated by an incentive to increase exploitation by those whose wages and employment have fallen, while at the same time, government budgets for the management of these resources is even more constrained.

**Finally,**

Through the TEEB series including in this book, in 'TEEB for Policy Makers' (TEEB in National Policy, 2011) and 'TEEB for Local Governments' (TEEB in Local Policy, 2011), we follow a tiered approach in analysing problems and suitable policy responses. We find that at times, it suffices just to *recognize* value - be it intrinsic, spiritual or social - to create a cost effective policy response for conservation or economically sustainable use of biodiversity and ecosystem services. At other times we may need to *demonstrate* economic value in order for policy makers to respond - such as a wetland conserved near Kampala (see TEEB in Local

Policy, 2011, Chapter 8) for its waste treatment function instead of reclaiming it for agriculture, or river flats maintained for their many ecosystem services instead of converting them for residential use near New Delhi (see TEEB in National Policy, 2011, Chapter 10, Box 10.6).

It is not a “risk-free” exercise to demonstrate value by deriving and propagating shadow prices. There is always the risk that misguided policy-makers or exploitative interests may want to use these prices for the wrong ends. Therefore, our proposition is that the act of valuing the flows and stocks of Nature is ethically valid so long as the purpose of that exercise is, first and foremost, to demonstrate value in order to instigate change of behaviour, and to pre-empt damaging trade-offs based on the implicit valuations that are involved in causing the loss of biodiversity and degradation of ecosystems.

TEEB has also focused considerably on changes which *capture* value by rewarding and supporting good conservation through a variety of means – Payments for Environmental Services (PES) , IPES, establishing new markets, EHS reforms, etc. (see TEEB in National Policy, 2011, Chapters 5 and 9, and TEEB in Local Policy, 2011, Chapter 8). These instruments offer a mechanism to translate external, non-market values of ecosystem services into real financial incentives for local actors to provide such services (Ferraro and Kiss, 2002). There is also a need to use existing knowledge and examples of success to develop more effective governance institutions, including property rights regimes and regulatory structures.

Recognizing that biodiversity underpins the foundations of economies, and of human well-being, is one thing. Translating that knowledge into concrete changes that will influence behaviour for the better is another, formidable challenge. It is one that must be met if the failures of the recent past are not to be repeated and compounded, with the potential for ever-increasing human and financial costs. This TEEB book and other forthcoming volumes ( especially TEEB in National Policy, 2011, and TEEB in Local Policy, 2011) make the case that greater economic and ecological rationality in addressing natural capital is not only necessary but possible, and indeed, that it is amply evidenced in many instances which deserve more attention, investment, and opportunity to replicate and to scale into wider use around the world.

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