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Introduction

Although natural ecosystems perform many services and are potentially very valuable, these values have often been ignored, with the result that degradation of ecosystems has occurred. The debate over what is the value of ecosystems, or of the environment and nature more generally, has highlighted the fact that the concept is complex and multidimensional. An economic perspective on ecosystems portrays them as natural assets providing a flow of goods and services, physical as well as aesthetic, intrinsic and moral. While it can be argued that biodiversity has intrinsic value in and of itself (either assigned by humans, or, more controversially, possessed regardless of human recognition), we do not accept as a consequence that allocation decisions involving environmental assets should be decided solely by non-economic means (O'Neil, 1997; Sagoff, 2004). Deliberative processes need not be seen as substitutes for economic cost–benefit analysis. The latter can better inform the former in a complementary relationship. We will set out what we call an Ecosystem Services Approach (ESApp) to the full appraisal of the role of ecosystem services in the economy and society.

The main problem when including the full range of ecosystem goods and services in economic choices is that many of these goods and services are not valued on markets. There is a gap between market valuation and the economic value of many ecosystem services. The non-marketed gaps must first be identified and then where possible monetized. In the case of many of the services, the identification of economically relevant services is of special importance, since over time those services not allocated by the market have continuously gained in significance as society has evolved.

The main objective of this book is to provide guidance on ESApp and the valuation of ecosystem services, using the case of multi-functional wetlands to illustrate and make recommendations regarding the methods and techniques that can be applied to appraise ecosystem management options. To this aim the book offers: a review of ESApp and ecosystem service valuation rationale, including their importance from both a policy and a project appraisal perspective; a useful reference when considering policy and appraisal of ecosystem management options; and ways in which legal obligations and other high-level management targets should be taken into account in valuation exercises, thus giving important policy context to the management options. Although concentrating on wetlands, the approaches suggested provide an assessment framework for other types of ecosystem assets.

The book is structured in the following way. Chapter 2 presents the relevant *conceptual background.* This covers the ecosystem services approach that provides the framework and linkages between ecosystems, their healthy functioning and the outcomes in terms of goods and services of benefit to human society. Chapter 3 then sets the valuation procedure within a range of possible policy contexts, and explores the correct procedures to adopt given the prevailing circumstances, that is, ecosystem conversion, ecosystem creation and ecosystem trade-offs. It also sets out the basis of socio-economic project, policy and programme appraisal and distinguishes between cost-effectiveness analysis, cost–benefit analysis and multi-criteria analysis. Chapters 4 and 5 provide guidelines on the *practical application* of the ecosystem services approach to the case of multi-functional wetlands. Chapter 6 describes a number of selective wetland case studies that outline the approach and the valuation techniques used in the previous sections. Finally we provide conclusions and an assessment of future prospects for the further deployment of the ecosystem services approach and its policy impact.

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The Ecosystem Services Approach to Natural Resource Management

Historically, conservation rationales have been centred on scientific and/or ethical grounds. The founding of the world's first legislated national park, Yellowstone, was a function of preserving the 'wonders within'. Likewise, international agreements such as the Convention on International Trade in Endangered Species (CITES) and the Convention on Biological Diversity (CBD) invoke ethical arguments for saving the 'last of', as well as biological variation. Biodiversity and ecosystem conservation has more recently incorporated utilitarian arguments, such as biodiversity as an insurance policy against undesirable changes in ecosystem services. Moving from purely scientific and ethical conservation motivations, a whole range of utilitarian arguments have sprung up under the concept of ecosystem services. A massive undertaking in this realm was the UN's Millennium Ecosystem Assessment (MEA, 2005). This was the product of over 1300 scientists' input and was explicitly structured around the concept of ecosystem services as an attempt to fully integrate ecological sustainability, conservation and human welfare. But how did we get to ecosystem services?

Humanity is completely reliant upon nature for our welfare and survival. The history of civilization is, at its most basic, a story of people trying to find places where natural resources are abundant and protection from the elements is available. Around 10,000 years ago when we began to domesticate nature the story changed a bit as we were now harnessing nature's services more directly through husbandry and agriculture. Humankind has always recognized the importance of what we now call ecosystem services. The ancient Greeks saw how important soil retention was when deforestation led to thinning soils resulting in their eventual reliance on olive trees for income since these can persist in poor soils. The classic example is of the society on Easter Island where cultural beliefs led to complete deforestation precluding soil retention, water regulation and raw material provision for sea vessels (see Ponting, 1993). Jared Diamond's *Collapse: How Societies Choose or Fail to Succeed* (2005) painstakingly documents the collapse of several societies throughout history, and points to loss of habitat and the services supplied by ecosystems (including fish stocking, soil retention, biomass production and water regulation) as the key factors in their demise.

In the 20th century, key issues like deforestation, ozone depletion, fisheries collapses and climate change have galvanized scientific investigation and political movements on the role that well-functioning ecosystems have in supplying or improving human welfare. Two such examples are the collapse of cod stocks in the North Atlantic Ocean in the early 1990s and stratospheric depletion of ozone. The marine ecosystems responsible for continually providing cod to the US and western Europe since the 10th century could no longer function at the level of extraction and completely collapsed less than two decades ago. We consider this a loss of ecosystem functioning. Since humanity derived welfare benefits from this ecological process (i.e. fish), the provision of fish stocks from this area is considered an ecosystem service. In the other example, the release of chlorofluorocarbons, which were at one time considered to be a wonderful invention for their benign effect on environmental systems, caused a breakdown in the ecosystem service we could call atmospheric regulation. One human *disservice* caused by the breakdown of functioning would be the rise in skin cancer incidents in the southern hemisphere.

This strong and positive relationship between well-functioning ecosystems and human welfare is unquestioned. The two endpoints are connected by what we are now calling ecosystem services. In this book we take a systematic look at

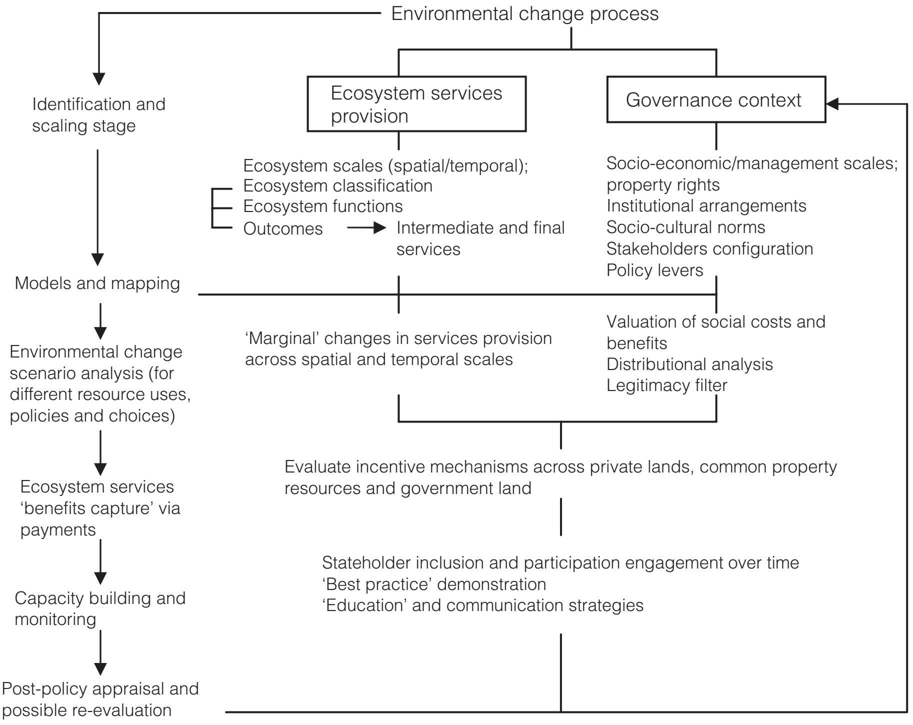

Figure 2.1 *Framework for an Ecosystem Services Approach (ESApp)*

what ecosystem services are; the roles of biodiversity and human agents in providing and appropriating them; how mapping can aid effective management decisions; and the importance of integrating policy-oriented science into a common methodology for ecosystem service evaluation. All these investigations can be integrated under a common approach that we are calling an Ecosystem Services Approach (ESApp). We argue that investigations of ecosystem services will require a systems approach from concept definition through compensation mechanisms to post-policy appraisal (Figure 2.1). A key aspect is a 'closed loop' structure, starting with biophysical research and closing with policy appraisal. Using Figure 2.1 as a guide, illustrating the ESApp is the purpose of this chapter.

ECOSYSTEM SERVICES DEFINED

Before we can talk about an ecosystem services approach we need to understand precisely what ecosystem services are. In the literature, there seems to be a consensus on a ***general*** meaning of ecosystem services. A few definitions in the literature are repeatedly cited (Costanza et al, 1997; Daily, 1997; MEA, 2005). The Millennium Assessment (MA) (MEA, 2005) defines ecosystem services as 'the benefits people obtain from ecosystems and divides ecosystem services into supporting, regulating, provisioning and cultural services'. This definition is general by design and, while it provides a context for discussion, it falls short as an operative definition. Despite the proliferation of interest in ecosystem services there have been relatively few attempts to define the concept clearly to make it operational (de Groot et al, 2002; Boyd and Banzhaf, 2007). Our position is that there is no single classification system for ecosystem services that is appropriate for use in all cases. In fact, a classification system should be informed by (1) the characteristics of the ecosystem or phenomena under investigation; and (2) the decision making context for which ecosystem services are being considered. We believe that there needs to be a clear and consistent definition of what ecosystem services are. This is because a functional definition, widely agreed upon, would allow for meaningful comparisons across different projects, policy contexts, time and space. Such a definition would also provide us with boundaries for the characteristics we are interested in. For example, if we use the MA definition, that is, benefits to humans, then the characteristics in focus include things outside ecological systems, such as imputed cultural and/or symbolic meanings. However, if ecosystem services are defined as ecological phenomena, as we propose in this book, then the characteristics we are interested in are characteristics of ecological systems only. Some of the identified characteristics, along with the decision context for mobilizing ecosystem services, will inform an appropriate classification system for use.

Drawing on Boyd and Banzhaf, we propose that *ecosystem services are the aspects of ecosystems consumed and/or utilized to produce human well-being*. Defined this way, ecosystem services include ecosystem organization (structure), operation (process) and outflows, as all are consumed or utilized by humanity either directly or indirectly.

The study of ecosystems has always demanded a systems approach or holistic view in order to truly understand operation and process (Allen and Starr, 1982). Investigating ecosystem services will require the same level of systemic insight, and whether they are consumed directly (raw materials) or indirectly (nutrient cycling) the key points of the definition (i.e. ecological components and connection to human welfare) are satisfied. Despite calling for this encompassing definition, it is also important to delineate between direct consumption and indirect utilization of ecosystem services. This will be important for valuation as well as for any natural capital accounting systems. In the ESApp we designate services to be either *intermediate* or *final* with human welfare benefits flowing from these final services. Figure 2.2 illustrates this delineation. For example, when considering the human benefit (i.e. product) of wild fruits, food provision is the final service and pollination an intermediate service.

This delineation is not strict as services are often a function of the beneficiary's perspective (Boyd, 2007). For example, water regulation services provided by vegetated landscape might be valued as a final service to someone interested in steady water supply, but valued as an intermediate service to someone interested in a final service of clean water for the benefit of drinking water. In this way the ESApp differs from the MA and its typology of supporting, regulating, provisioning and cultural services. While these categories undoubtedly offer strong heuristic value they can lead to confusion when trying to operationalize (either through accounting systems or for valuation purposes) ecosystem services. For example, nutrient cycling is a supporting service in the MA, water regulation is a regulating service, and recreation is a cultural service. However, all three could be referring to the same benefit that humans are concerned with, such as clean water. In accounting systems, valuation exercises

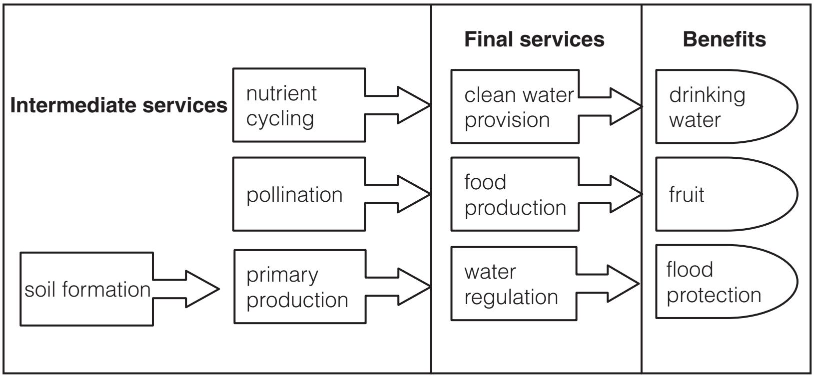

Figure 2.2 *Relationships among intermediate services, final services and benefits*

and policy decisions we are most often concerned with benefits, and therefore a more transparent method for evaluation is simply to consider the system in terms of intermediate services, final services and benefits. Given this schema we know only to add up, value or weigh the benefits for comparison.

Additionally, just as discrete ecosystems can deliver several ecosystem services, ecosystem processes can provide multiple benefits for human welfare. These are considered 'joint products'. Figure 2.3 is a simplified linear schematic of this situation. Water regulation is an ecosystem process (intermediate service) – simply an automatic operation of an ecosystem. As an ecosystem process, water regulation provides for final ecosystem services such as storm protection, improving water quality and extending water provision as a time delay, that is providing a regulated hydrologic flow. This third final service is similar to municipal water systems where the user pays for the water used, as well as a premium to guarantee that service continues reliably, where both are beneficial services.

As we argued earlier, the decision context for utilizing ecosystem service research is also crucial for mobilizing the ecosystem services concept. Our primary focus in this volume is the valuation of ecosystem services and our classification approach has been formulated with this context in mind. But other contexts may be the focus of attention and require other classification schemes.

One decision context for utilizing the concept of ecosystem services might be to promote understanding and to educate a larger public about the services and benefits that well-functioning ecosystems provide to humans. This was a major focus of the MA and its classification scheme was fit for purpose. The MA divided ecosystem services into a few very understandable categories – supporting services, regulating services, provisioning services and cultural services. This classification utilized the complexity characteristic of ecosystems and the public–private good dynamic to draw distinct boundaries of different ecosystem services. For example, by acknowledging the many interconnections among ecosystem components and processes, the MA classification placed supporting service as an underpinning to

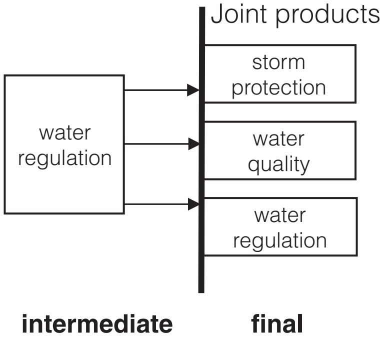

Figure 2.3 *An example of joint products stemming from a single ecosystem process*

the other service categories. This in turn makes their classification readily accessible as a heuristic – one of the key goals of the MA.

Another way to classify ecosystem services would be to use their spatial characteristics. This might be appropriate if the decision context was how to manage a given landscape for the provision of ecosystem services. In this case, it is important for the manager to know what services are provided on the landscape and how these services flow across that landscape. The European Union's Habitats and Water Framework Directive is taking such a tack by incorporating spatio-temporal characteristics of natural system into policy solutions. Utilizing the spatial characteristics a classification scheme might involve categories that describe relationships between service production and where the benefits are realized. Such a classification might include categories such as:

- *in situ* – where the services are provided and the benefits are realized in the same location;
- *omnidirectional* – where the services are provided in one location, but benefit the surrounding landscape without directional bias;
- *directional* – where the service provision benefits a specific location due to the flow direction.

A classification scheme as such could also use scale qualifiers, such as local omnidirectional (e.g. pollination), and regional direction (flood protection). Understanding the distribution of services and benefits as well as the landscape (or seascape) where the services are provided informs where management interventions should be concentrated. Classifying ecosystem services in this way recognizes such characteristics as the spatio-temporal dynamics of ecosystems and benefit dependence of services. This distributional classification can also highlight the possibility of cases where beneficiaries might have to compensate providers, such as in *payments for environmental services* schemes.

Through the economic concept of an externality – where the action of one agent brings about an inadvertent gain or loss to another without payment or compensation – economists have long been interested in the effects that changes in environmental quality can have on welfare. The work of Alfred Marshall and A.C. Pigou in the late 19th and early 20th centuries on externalities and common property problems laid early foundations for the future of environmental economics. With regard to ecosystem services, one person's harvesting of timber may preclude another person's benefit of bush meat due to declining habitat. The linked effect that the human economy has on the environment and that the environment has on the human economy is difficult to assess since the externalities reverberate throughout complex social and ecological systems (Crocker and Tschirhart, 1992). Dynamic modelling of complex systems can help to identify unintended consequences of these linked systems (Finnoff and Tschirhart, 2003).

In light of externalities and distribution issues, one possibly important classification scheme considers the decision context of how ecosystem services relate to equity in the provision of human welfare. This is important as it is now well accepted that failing environmental quality disproportionately affects people more marginalized by the market economy (Dasgupta, 2002). The decision context might be a government interested in measuring how the natural environment distributes and provides services and consequent benefits across their constituents. This is made complex by the fact that stakeholders at different spatial scales have different interests in ecosystem services (Hein et al, 2006). For example, the benefits people receive from existence values of biodiversity might conflict with benefits impoverished people receive from converting biologically diverse habitats, where poverty and species diversity have been shown to be highly correlated (Fisher and Christopher, 2007). In this decision context several characteristics are important for consideration – including the public–private goods aspect, spatio-temporal dynamic and how services are benefit-specific. Linking these characteristics to the decision context, that is fulfilling human needs and wants to a somewhat hierarchical classification, is found in Wallace (2007). Here an ecosystem service classification starts with basic needs – which Wallace labels adequate resources. Other categories include protection from predators, disease, parasites; benign physical and chemical environment; and socio-cultural fulfilment. Dividing services in this way across a landscape can provide decision makers with information about at what level people's needs are being met by ecosystems and their services.

THE ECOSYSTEM SERVICES APPROACH

Identification and scaling stage

Understanding the concept of ecosystem services, and how intermediate services, final services and benefits all interrelate, lays the building blocks for a systematic investigation of the link between ecosystems and human welfare. The ESApp requires a range of scientific experts, social scientists, stakeholders and decision-makers (Figure 2.1). In broad strokes the ESApp requires biophysical understanding of how and where services are generated; where and in what terms the benefits are realized; what level of value the services provide; how ecosystems are governed; what options there are for compensating providers of public goods and in what ways services flows and values are likely to change under different management and utilization scenarios. In addition to these aspects, the ESApp also inherently incorporates stakeholder involvement and capacity building. Policy recommendation and post-policy appraisal are further vital elements of the ESApp.

The first step in the ESApp is really a scoping stage. Researchers must identify the ecosystem services of interest and understand a range of characteristics about these services including:

- the spatial and temporal scales at which they operate;
- the different services of the ecosystem(s) in question;
- the outcomes in terms of intermediate and final services and benefits;
- the social and economic aspects involved in managing and governing the system;
- socio-cultural norms, stakeholder identities and existent policy mechanisms.

Once this 'identification and scaling stage' is complete then the ESApp necessitates an in-depth mapping and modelling phase.

Models and mapping

Despite our knowledge gaps on the functional roles of biodiversity, our ability to model ecosystem organization and operation is growing appreciably. This understanding provides the foundational insight for the ESApp. Basic scoping models can help to understand the patterns of ecosystem processes as well as identify the nesting and overlapping of systems and processes. Detailed data-driven process models yield quantitative insights into the functioning of the system and can highlight system drivers and sensitivities.

These biophysical characteristics determine the spatial distribution of ecosystem services. The location for services creation and where the benefits are received are not always identical. In fact there is a variety of ways in which provision units and benefit units vary in space. In some cases both the service provision and benefit occur at the same location (e.g. soil formation, provision of raw materials). Some services are provided omnidirectionally, that is the service provision unit provides benefits to the surrounding landscape (e.g. pollination, carbon sequestration). In some cases services are provided with a specific directional flow. For example, down slope areas benefit from services provided in uphill areas for services like water regulation services provided by forested slopes. Another example of this is the service provision of coastal wetlands providing storm and flood protection to the coastline and interior.

By mapping ecosystem services we can gain insight on where scarce funds can be used to optimize biodiversity or ecosystem service conservation or human welfare. Previous mapping exercises have demonstrated several insights such as where cost–benefit outcomes can be optimized (Balmford et al, 2003; Naidoo and Ricketts, 2006) where different taxa overlap; and correlations between alternative conservation assessments (Brooks et al, 2006). Also, by understanding the biophysical aspects of ecosystem service provision and how the benefits are realized we can use economic valuation techniques to apply an economic value to the services provided. Economic valuation techniques are discussed throughout this volume, and also in Appendix A. For conceptualizing the ESApp it is important to know that these values can be mapped across a landscape depending on where and how the benefits from ecosystem services are distributed and realized spatially.

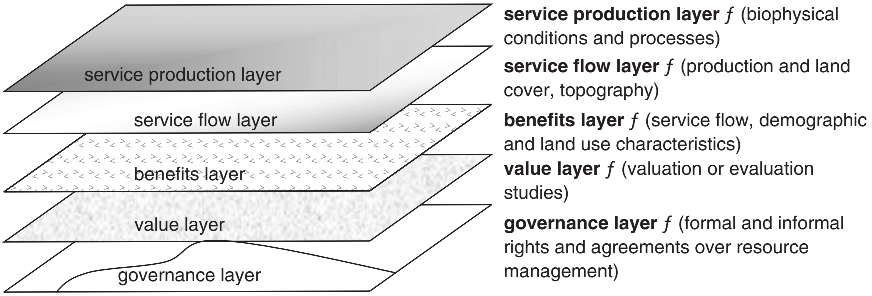

Figure 2.4 *Mapping layers integral to the ESApp*

In addition to the biophysical modelling, service mapping and valuation, governance systems must also be identified spatially. The various spatial and temporal scales at which governance operates means that understanding overlaps and gaps is crucial for successful ecosystem management. Governance represents both formal and informal systems of rights, regulations and arrangements. These can range from informal stakeholder agreements to international institutional arrangements. Additionally, a spatial understanding of governance and ecosystem service provision is an essential step for developing effective and fair compensation mechanisms (discussed below).

The governance dimension gives rise to several practical challenges. First of all there is typically a mismatch of the spatial and temporal scales at which ecosystems and political systems operate (Carpenter et al, 2006). The processes that are responsible for the provision of ecosystem services operate on scales from microscopic (nutrient exchange) to global (climate regulation). Picture any political boundary and you can imagine ecosystem services where either their provision or their use migrates over that boundary. Ecosystems such as the Amazon River Basin contribute services to not only the six countries that it encompasses, but globally. Governing for efficient and equitable allocation of these services would require an incredible amount of international cooperation and compensation. Temporally, governance systems vary from ancient community management norms to brief formal government terms lasting only a few years. The temporary nature of political tenure creates another hurdle to sustainable management.

Figure 2.4 shows how the mapping and modelling stage provides researchers with a series of maps that can be overlaid to get a holistic view of the system under investigation.

Environmental change scenario analysis

Once we understand how the system works in its current state we need to be able to identify changes in the system in terms of services, benefits and operation under different possible futures. By comparing the current system outcomes with alternative futures the ESApp can provide valuable input to policy decisions. This can be done using *scenario analysis*. Scenarios are plausible and consistent descriptions of the future that aid in forecasting and predictive analysis. Scenarios are not state predictions themselves, but rather they are typically qualitative storylines bolstered with some degree of quantitative data (Turner, 2005). The fundamental underpinning of scenarios is that the future is uncertain, so the goal is to develop plausible but distinct storylines of the future. By creating these storylines (*a priori*) it is possible to follow them logically through the system under investigation so that analyses of trade-offs among alternative futures and different policies are possible. Scenario analysis typically starts with broadscale or global drivers and suggests how these impact local drivers and the system state, and suggests policy responses. The scenarios of the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emissions Scenarios (SRES) and the MA's scenarios (Global Orchestration, Order from Strength, Adapting Mosaic, TechnoGarden) are two such examples.

Under the ESApp, scenario building would move from the qualitative storyline at the global scale and drive more quantitative regional and local situations. Depending on the scale of interest the scenarios provide information to test for a range of policy options. Figure 2.5 shows how scenario analysis is integrated into the ESApp, as the system of interest is analysed under the different scenarios. For each scenario (Future I and Future II) the landscape changes in regard to its service provision, flow, beneficiaries, valuation and perhaps its governance. For example, imagine that the current state of an agro-forestry landscape mosaic is represented by the series of maps labelled 'Current'. Imagine 'Future I' to be a scenario developed to look at how these maps change if we increase the amount of land under large-scale monocropping and 'Future II' to represent a sustainable forestry focused future. In these two scenarios the Current provision, distribution and value of ecosystem services will change in very different ways. Considering these changes can help decision makers formulate policies that suit the needs of their constituents.

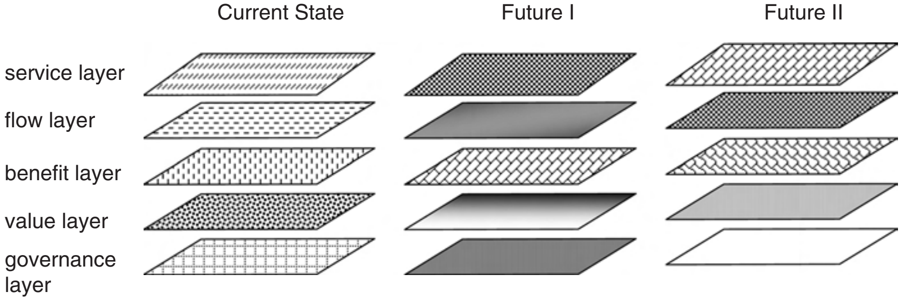

Figure 2.5 *The integration of mapping exercises and scenario analysis*

Ecosystem services 'benefits capture'

After the modelling and mapping stages, the valuation exercises and scenario analysis can provide additional spatially explicit layers to give further insight into which stakeholders gain or lose under different ecosystem states and forecasts. For fair allocation of benefits, 'users' will have to compensate 'providers' and because of the public goods aspect of ecosystem services this will have to be activated through some institutional (formal or informal) structure. This is where research on governance associated with ecosystems and natural resources becomes integral to the ESApp. When we understand the governance structures, or their absence, we can design successful compensation mechanisms to ensure sustainable ecosystem service provision and fair allocation of the benefits. This fair allocation of benefits – ecosystem services for users and compensation for providers – is what we consider *benefits capture*.

There are several currently operational mechanisms for benefits capture. Market-based mechanisms are becoming increasingly popular to achieve conservation goals and are already being used to compensate providers of ecosystem services. Instruments currently being used include taxes and user fees on undesirable behaviours, as well as payment and subsidies for desirable behaviours. Examples of the former include licensing for logging, fishing and hunting; harvesting taxes; and user fees on public lands.

A currently popular price-based instrument is the so-called *payments for ecosystem services* (PES). This approach has been recommended particularly for use in non-OECD countries, where regulatory and taxation systems are likely to be weak. In these schemes landowners are compensated for providing services that previously were uncompensated. The Mexican government has such a system to pay landowners for conserving forest in catchments important for hydrologic flows (Pagiola et al, 2005). The best-known payment scheme is Costa Rica's, which was established in 1995 and compensates landowners for carbon sequestration, water regulation services, biodiversity and scenic beauty provision. The measurement proxy is area of land forested and payments are around US$45/ha/yr.

The other general approach for compensating ecosystem service provision, or conservation in general, utilizes quantity-based instruments. These mechanisms are predicated upon an institution that sets a target quantity. Setting this quantity or scale creates a scarcity and therefore encourages more efficient allocation. Quantity-based instruments include marketable permits, such as tradable fishing quotas, and market credits, such as carbon credits and wetland banks. The quantity-based approach is quite a common policy prescription, from use in the United States to ensure no net loss of wetlands (Whigham, 1999) to fishing quotas in Canada and New Zealand (Dewees, 1998) to carbon markets considered in the Clean Development Mechanisms under Kyoto.

Despite the popularity and increasing theoretical and empirical investigation of compensation mechanisms for ecosystem service provision, a number of not so trivial obstacles exist for successful implementation. These include the difficulty of establishing property rights when necessary; being able to observe actual behaviour and measure and verify outcomes; linking payments directly to desired outcomes and not some proxy outcome; getting prices correct; overcoming cultural disjoints and equity concerns; mitigating externalizing behaviour and 'hotspots'; and financing the mechanisms. (See Box 2.1 for further description of these limitations.)

Another obstacle to implementing a benefits capture mechanism is the difficulty of moving from the current state (i.e. with extant welfare reducing behaviour) to the desired state envisioned as the goal of the mechanism. For example, how does the global community go from a world of high deforestation rates to a world without deforestation? We can imagine a payment system where the global community compensates tropical countries for reducing their deforestation rate. However, this penalizes countries who have had historically low deforestation rates, or encourages them to increase deforestation until the mechanism becomes operational, so that they can gain from future deforestation rate decreases. The example points to the mismatch between the mechanism incentives and the long-term goal. To satisfy some long-term goals we can imagine encountering incredible inertia in the present system, and therefore mechanisms will have to consider both short- and long-term components. Once again, stemming global deforestation rates will require a mechanism that allows incremental changes in behaviour (short-term) towards some more stringent long-term objective. In this way it should be practical, in the short term, for countries with historically high deforestation rates to be included in any such mechanism, and for countries with historically low deforestation rates, if they choose some moderate level of ecosystem conversion for national welfare improvements, to avoid penalization.

BOX 2.1 OBSTACLES TO MARKET-BASED CONSERVATION MECHANISMS

Property rights

The establishment of property or assignment rights over the good or service being provided is often necessary, but seldom easy. Designating who 'owns' resources such as wetlands, or who has the 'rights' to utilize the waste absorption capacity of the atmosphere is fraught with governance and equity issues. Without property rights, incentives to invest (divest) in sustainable (unsustainable) actions often do not exist, and free-riding is likely.

Measuring and monitoring

The ability to measure and monitor service provision is not straightforward with public or common pool resources. Individual behaviour might not be observable as it might take place in hinterlands, or the service might not lend itself to measuring, such as with pollination services.

Directly linking behaviour and compensation

In connection with the difficulties of measuring and monitoring ecosystem service provision direct links between service provision and compensation might not be possible and therefore allow defection. If we are interested in biodiversity provision, it might be impossible to measure and monitor the service directly and therefore we might use forested area as a proxy. In this case, we might easily achieve the proxy goal without the associated biodiversity goal (e.g. pressures from hunting could hinder the latter, but not affect the proxy).

Correct pricing

For price-based mechanisms, finding the correct price level to incentivize ecosystem service provision is not likely to be straightforward. For payment schemes, the payments would need to cover an agent's opportunity cost, but this is not always easy to elicit and the incentive exists for agents to overstate their opportunity cost. In Costa Rica the lands under payment contracts are more likely to be on steep slopes and inaccessible, suggesting that the buyer is overpaying. Information costs may be prohibitive.

Cultural hurdles

Price and quantity-based mechanisms assume to some degree that a market institutional set-up is common. In some places, assigning property rights to individuals or offering payments for expected behaviours may not be common practice or even acceptable (Adams et al, 2003). In several cases it has been shown that the price incentive is not always effective in changing behaviour (Gowdy and Erickson, 2005).

Externalizing

Conservation is often in danger of pushing deleterious activities to peripheries or at times to particular 'hot spots'. Additionally, the translocation of services, such as wetlands banking, is unlikely to guarantee the same quality of services (Salzman and Ruhl, 2006).

Monitoring, capacity building and post-policy appraisal

Effective, fair and sustainable ecosystem service provision will require scale-appropriate governance capacity and frequent monitoring. For some services local and regional knowledge of ecosystem processes will be high. In these cases the ability to design and implement solutions may already exist, such as with some pasture lands in Mongolia or Nepalese irrigation systems (Ostrom et al, 1999). However, in many cases education and capacity building from local to national and international scales will be necessary. Such is the current case with managing the climate regulation services of the earth's atmosphere. Cases like this will require coordination of science, policy, institutions and all concerned stakeholders. Several challenges exist including transboundary service provision and use, difficulty in measuring services, and difficulties in creating effective governance and compensation mechanisms (see Box 2.1). Any ESApp will recognize the importance of stakeholder inclusion, capacity building, and monitoring for outcomes throughout the research or project programme. These are not steps to be tacked on at the end, but must be integrated throughout for successful and sustainable outcomes. An example is the conservation of cloud forest for hydrologic flows in Loma Alta, Ecuador by incorporating stakeholder knowledge and concerns and providing scientific capacity (Becker, 2003).

Post-policy appraisal and re-evaluation

Finally, in addition to the challenges posed by monitoring, capacity building, and coordination, there is little guarantee that even well-informed and cooperative policy solutions will produce the desired outcomes. Post-policy and post-project appraisal is seldom undertaken in conservation spheres, and conservation initiatives have historically lacked robust quantitative evaluations of their performance despite their importance for informing future policy and funding decisions (Ferraro and Pattanayak, 2006). Information, institutional and market failures will all affect ecosystem service provision, and without post-policy appraisal we could follow costly prescriptions without the assumed associated benefits. The importance of monitoring and post-project appraisal deems that the policy role of the scientist (or integration to the policy process) is essential for an ESApp. In the next section we take a closer look at different policy contexts involving ecosystem services valuation and management.

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