The Economic, Social and Ecological Value of Ecosystem Services: *A Literature Review*

Final report

for the Department for Environment, Food and Rural Affairs

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Preface

This report presents the results of a broad review of the literature that has investigated the economic and other values of ecosystem goods and services. The review was commissioned by DEFRA (UK Department of Environment, Food and Rural Affairs) to examine the role of ecosystem goods and services in communicating the benefits of biodiversity.

The report considers the contribution of such goods and services from socio-economic and ecological perspectives drawing upon mostly international examples, and focusing on wetlands, forests and agro-ecosytems. Two case studies are presented in Annex 1 to demonstrate how ecosystem goods and services can be defined and their value quantified. Annex 2 contains a technical report that presents the scope of the study and further details on the issues discussed in the main report.

Executive Summary

Ecosystems and the biological diversity contained within them provide a stream of goods and services, the continued delivery of which remains essential to our economic prosperity and other aspects of our welfare. *Ecosystem goods* refer to the natural products harvested or used by humans such as wild fruit and nuts, forage, timber, game, natural fibres, medicines and so on. More importantly, *ecosystem services* support life by regulating essential processes such as purification of air and water, pollination of crops, nutrient cycling, decomposition of wastes, and generation and renewal of soils, as well as by moderating environmental conditions by stabilising climate, reducing the risk of extreme weather events, mitigating droughts and floods, and protecting soils from erosion. The benefits of these services manifest themselves at local, regional and global scales with often conflicting demands between stakeholders at these different levels.

One of the most pervasive impacts of current global change is the rapid decline in species and habitat diversity and its replacement with biologically poorer and more homogenous human-dominated landscapes. The loss of species is the most widely recognised consequence of such change, and as biodiversity underpins human life support systems, its loss implies significant consequences for humanity. The consequences of ecosystem degradation are experienced more severely in developing countries, the home of the vast majority of the world's natural capital and to the world's poor, who are heavily reliant on natural resources for their livelihood and income.

Driving forces behind ecosystem degradation are many and interlinked. Human society has for centuries taken for granted the services provided by natural systems partly because they are not formally traded and are therefore dissociated from pricing that reflects and warns of changes in supply or demand conditions. Just as markets fail to signal ecosystem degradation, economic policies frequently provide perverse incentives that encourage it. Absence of clearly defined and secure property rights, lack of clear environmental policy goals, poor enforcement of existing regulation, corruption, lack of political will and lack of institutional capacity are examples of failing governance that also leads to ecosystem degradation.

In addition, our limited capacity to deal with the potentially catastrophic consequences of ecosystem degradation is exacerbated by the lack of adequate information and knowledge about ecosystem functions and the benefits they generate for society. The main objective of this study is to showcase the current evidence base for the benefits of ecosystem goods and services. In achieving this objective, our focus has been on those goods and services about which there is no readily available data from markets. The report also provides a framework which links ecosystems to their goods and services and resulting benefits to society. This framework can enable better decision-making for ecosystem use, by demonstrating the full economic costs implicit in trade-offs between development and preservation of ecosystems.

Better information on its own will not bring about sustainable use of ecosystems, achievable only if this information is then used to address the drivers of ecosystem degradation. Examples of measures capable of 'capturing' demonstrated value include payments for provision of ecosystem services, creation of markets for ecosystem services where they do not already exist, improving the property rights system, enhancing the assets of the poor, improving the quality of economic growth, reforming international and industrial country policies and improving governance. This report and its annexes are only able to touch upon these measures, which are the subject of entire books.

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1 Overview

This section starts the report by posing the main questions of concern in defining and quantifying ecosystem goods and services, and sets a framework for incorporating this information into decision-making that is in line with the principles of sustainable development.

1.1 What are ecosystem goods and services?

Ecosystems and the biological diversity contained within them provide a stream of goods and services, the continued delivery of which remains essential to our economic prosperity and other aspects of our welfare. In a broad sense, ecosystem services refer to the range of conditions and processes through which natural ecosystems, and the species that they contain, help sustain and fulfil human life (Daily, 1997). These services regulate the production of *ecosystem goods*, the natural products harvested or used by humans such as wild fruit and nuts, forage, timber, game, natural fibres, medicines and so on. More importantly, particularly for those in less developed economies, *ecosystem services* support life by regulating essential processes, such as purification of air and water, pollination of crops, nutrient cycling, decomposition of wastes, and generation and renewal of soils, as well as by moderating environmental conditions by stabilising climate, reducing the risk of extreme weather events, mitigating droughts and floods, and protecting soils from erosion.

For the purposes of this report, ecosystem services have been grouped into six categories broadly based on both their ecological and economic function. These are:

- **Purification and Detoxification:** filtration, purification and detoxification of air, water and soils;
- **Cycling Processes**: nutrient cycling, nitrogen fixation, carbon sequestration, soil formation;
- **Regulation and Stabilisation**: pest and disease control, climate regulation, mitigation of storms and floods, erosion control, regulation of rainfall and water supply;
- **Habitat Provision**: refuge for animals and plants, storehouse for genetic material;
- **Regeneration and Production**: production of biomass providing raw materials and food, pollination and seed dispersal; and
- **Information/Life-fulfilling**: aesthetic, recreational, cultural and spiritual role, education and research.

Some further examples of these services are provided below.

Purification and detoxification services
Natural vegetation, especially woodlands and forests, acts as a filter removing particulate matter arising from the combustion of fossil fuels from the air. Soils, and particularly forest soils, also serve as effective filters that remove organic materials and chemicals from water, contributing to its purification before it reaches streams and rivers. Wetlands too perform an essential function of water purification by removing nitrogen and phosphorous from agricultural runoff, preventing eutrophication of streams and rivers. Wetlands also remove or transform toxins that would otherwise contaminate habitats.

Cycling processes
Vegetation plays an essential role in removing one of the main greenhouse gases, carbon dioxide, from the atmosphere. Carbon sequestration provides valuable economic services in terms of climate regulation. Nutrient cycling (through nitrogen fixation and the breakdown of soil organic content) and soil formation processes (the breakdown and release of minerals from rock and the accumulation of animal and plant organic matter) are particularly important in maintaining soil productivity, which provides an important economic input to agriculture.

Regulation and stabilisation services
Biologically rich ecosystems consist of numerous organisms that interact with each other in complex ways. The outcome of these complex interactions is that pests and diseases are naturally controlled, thereby minimising the risk of outbreaks. Natural pest control reduces dependence on chemical pesticides, which are costly and, if used repeatedly, can contaminate water and soils and encourage pests to develop resistance.

Mitigation of floods and erosion control are provided by vegetation, which intercepts rainfall and reduces the force with which it impacts the soil surface, binds the soil surface preventing its loss, and slows water flows into streams and rivers, thereby modulating the amplitude of water levels and reducing the likelihood of extreme flood events. Wetlands temporarily store excessive water flows, which moderate flood impacts on downstream environments. Coastal wetlands, particularly mangroves in the tropics and salt marshes in temperate latitudes, dissipate the forces of wind and wave action. Such habitats are also important as nurseries for commercially important fish and are rich breeding grounds for many bird species.

Habitat provision
Ecosystems provide habitats for wild plant and animal species, both resident and migratory. As such, ecosystems act as a refuge and storehouse for biodiversity, by maintaining the conditions which allow survival of the diverse array of species on the planet. Plant and animal species are a direct source of an immense number of goods and products that are harvested and used by humans for livelihood support, enrichment and welfare. Biodiversity also represents a genetic and biochemical library that underpins the flexibility and potential of much agricultural and pharmaceutical development.

Regeneration and production
This refers to the biotic productivity of natural ecosystems and the ability of these systems to regenerate through the conversion of light, energy and nutrients into biomass. Also included in this function are pollination and seed dispersal. The resulting broad diversity of carbohydrate structures provides many ecosystem goods including food, raw materials and energy resources. An immense number of bees, beetles, moths, birds, bats and other animals are the agents of pollen transfer from one plant to another, a crucial step in fertilisation and seed production. Pollination services represent enormous benefits for humans, as approximately one-third of the world's food crops rely on natural pollinator services (Chivian, 2003). Many plants are dependent for germination on seed dispersal by particular species of mammals, birds, insects or fish.

Information and life-fulfilling services
Natural landscapes provide humans with recreational and exercise opportunities, and along with the biodiversity they contain, feed into many cultural, intellectual and spiritual traditions which contribute to human well-being. Cultural and recreational activities in the environment are the source of much economic revenue through tourism and sport, and much intellectual development, both artistic and scientific, is influenced directly or indirectly by interaction with and inspiration from the natural environment.

1.2 Why are ecosystems being degraded?

One of the most pervasive impacts of current global change is the rapid decline in species and habitat diversity and its replacement with biologically poorer and more homogenous human-dominated landscapes. The loss of species, constituting in itself a mass extinction (Stork, 1999; Dirzo and Raven, 2003), is the most widely recognised consequence of such change, and as biodiversity underpins human life support systems, its loss implies significant consequences for humanity.

An estimated 40% of the global economy is based on biological products and processes (WEHAB, 2002) and yet these resources are being lost or severely damaged at an unprecedented rate, as exemplified in Box 1.1.

Box 1.1: Key indicators of global ecosystem degradation

- More than 50% of the world's wetlands have been drained, and populations of inland water and wetland species declined by 50% between 1970 and 1999. In the process, critical wildlife habitat has been lost, as have floodplains, which are safety valves for flood events and natural filters for flowing waters.
- Some 75% of the genetic diversity of domesticated crop plants has been lost in the past century.
- Approximately 20% of the world's freshwater fish species have become extinct, threatened or endangered in recent decades, and some 75% of the major marine fish stocks are either depleted, overexploited or being fished at their biological limit.
- During the period 1990 to 2000 an estimated 14.6 million hectares of forest were lost to deforestation per year.
- Roughly one-third of the world's coral reef systems have been destroyed or highly degraded.
- About 24% of mammals and 12% of bird species are currently considered to be globally threatened.

Source: WEHAB (2002)

Despite the essential functions of ecosystems and the consequences of their degradation, ecosystem services are mostly grossly undervalued by society, not least because of the lack of awareness of the link between natural ecosystems and the functioning of human support systems. Human society has for centuries taken for granted the services provided by natural systems, as they are not formally traded and are therefore dissociated from pricing that reflects and warns of changes in supply or demand conditions. With the continued degradation of ecosystems through a variety of human-led pressures, a better understanding of the extent of human dependence on ecosystem services, and hence the vulnerability of human welfare to ecosystem change, is essential for ensuring sustainable development.

Lack of this understanding and failure of markets in reflecting the value of ecosystems mean that information that conveyed to economic decision-makers at all levels is incomplete. Typically, the full social and environmental benefit of these goods and services and the full cost of their degradation are not translated in a way that will ensure optimal decisions for both the economy and the environment.

The causes of biodiversity loss and ecosystem function damage due to unsustainable production and consumption patterns are almost too numerous to mention. The drivers can be interdependent, driven by local, national or global factors and include:

- *Market and economic policy failures*, such as perverse subsidies, absence of markets for ecosystem goods and services, and inadequate or non-existent information about the value of goods and services;

- *Issues of governance*, such as absence of clearly defined and secure property rights, clear environmental policies and policy goals, poor enforcement of existing regulation, corruption, lack of political will, lack of capacity and inadequate information and knowledge; and

- *Global demographic and other factors*, such as human population growth, poverty, wars and unrest.

Action is required at both national and international levels to address these drivers and ensure that increased economic development does not threaten the continued provision of ecosystems goods and services.

1.3 What is the significance of ecosystem services to the world's poor?

With a significant share of the world's remaining natural capital, the economies of developing countries are heavily reliant on natural resources, and hence ecosystem services for their income, with major exports in agricultural commodities, fish, timber and minerals, as well as heavy reliance on tourism. The same holds at a local level, where a large proportion of the rural poor[1] depends on ecosystem services for survival (e.g.

[1] DFID et al (2002) define poverty as: "poverty is now widely viewed as encompassing both income and non-income dimensions of

through small-scale agriculture and the harvesting of products) and is most sensitive to changes in provision or quality of ecosystem services. Of the 1.2 billion people living in extreme poverty, approximately 900 million live in rural areas, where biodiversity and ecosystem services contribute to food security and nutrition, providing the raw materials that underpin health systems (both formal and informal) (Wetlands International, 2005).

There are a number of reasons why ecosystem services have particular relevance for the rural poor in developing countries. Firstly, the poor are dependent on agriculture (often subsistence agriculture), and have limited access to alternative sources of income. Agricultural activity means exposure to risks from pest outbreaks, flood and water scarcity. In addition, the rural poor are more likely to inhabit marginal, less agriculturally productive land, where harvest is more vulnerable to deterioration in soil or water quality. All of these risks can be reduced through appropriate ecosystem service management.

Secondly, studies measuring the contribution of harvested wild products show that income from these products has the greatest share in the total income of the poorest households, i.e. the poor are relatively more resource dependent. For example, Cavendish (1999), in a study in Zimbabwe, shows that the poorest are most dependent on environment income in relative terms: the lowest income quintile derives over 40% of their income from environmental sources compared to about 25% for the highest quintile.

Finally, poor farmers may be aware of the value of ecosystem services, but may be prevented from taking action to conserve them because of more immediate economic pressures, i.e. they have a high discount rate (Scherr, 1999), or because they do not own the titles to land they cultivate.

The sustainability of current use of biodiversity by the rural poor is a key issue, as is the extent to which the poor's dependence on goods and services from ecosystems is a consequence of poverty, rather than a way out of poverty. Cavendish (1999) also shows that, in Zimbabwe, those who are somewhat better off make more use of ecosystem goods and services in absolute terms (e.g. as income grows so does water consumption). This implies that economic growth alone may not be sufficient to reduce pressures on the environment.

The recognition of the market failings and their impacts on poverty has placed sustainable development at the forefront of the global agenda through the 1992 Earth Summit and the subsequent 2002 World Summit on Sustainable Development (WSSD). The outcome of the WSSD was a 'commitment' by the international community to a plan of implementation regarding sustainable development. Fundamental to this commitment are three main challenges: the eradication of poverty, changing patterns of consumption and production, and protection and management of the natural resource base for economic and social development (United Nations, 2002).

The United Nations Development Programme (UNDP, 2004a) clearly sets out the interlinkages between biodiversity, ecosystem services and the goal of meeting sustainable development through action on the Millennium Development Goals (MDG) adopted at the UN Millennium Summit in September 2000, as follows:

- Eradicating hunger (MDG 1) depends on sustainable and productive agriculture, which in turn relies on conserving and maintaining agricultural soils, water, genetic resources and ecological processes;
- The capacity of fisheries to supply hundreds of millions of the world's people with the bulk of their animal protein intake depends on the maintenance of ecosystems (such as wetland ecosystems such as mangroves and coral reefs) that provide fish with habitat and sustenance; and
- MDGs aimed at improving health and sanitation (MDGs 4, 5 and 6) require healthy, functioning freshwater ecosystems to provide adequate supplies of clean water; and genetic resources for both modern and traditional medicines.

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deprivation – including lack of income and other material means; lack of access to basic social services such as education, health, and safe water; lack of personal security; and lack of empowerment to participate in the political process and in decisions that influence someone's life." Extreme vulnerability to external shocks (including ecosystem degradation) is also seen as one of the major features of poverty (UNDP, 1997).

1.4 What are the key challenges?

Ideally ecosystems would be managed with sustainable development in mind such that decisions maximise social welfare over time. In practice, the drivers of ecosystem loss and degradation mentioned above ensure that ecosystem degradation continues unabated. This current lack of knowledge relates both to ecosystem functions and economic values.

Our limited understanding of ecosystem dynamics is reflected most forcefully in our inability to predict where thresholds separating two alternative, qualitatively different ecosystem states (well functioning and degraded) lie. The relationship between the condition of ecosystems and the services they provide is not a simple linear one, but rather more complex. Ecosystem services may show considerable resilience to stress, but also exhibit rapid, indeed catastrophic, change upon the transgression of certain, yet poorly identified, thresholds. It is therefore relatively easy to dismiss or ignore anthropogenic impacts on the environment when there is little apparent consequence to service provision, particularly when scientific advice is beset with uncertainty about ecosystem responses, and is for the most part unable to predict thresholds.

In addition to the ecological functions of ecosystems, we also lack information about the economic value of ecosystem functions, goods and services. The term 'economic value' is used here to describe the importance placed on ecosystems by individuals, which includes not only income generated from using ecosystem goods and services, but also other benefits they provide for human welfare that could alternatively be called social and ecological values. Quantitative evidence on economic value needs to be generated because many of these services are not traded in markets, and hence do not have prices, and thus are interpreted as having no value when it comes to making decisions about their use. In other words, markets fail to incorporate the full economic value of ecosystems in pricing and hence decision-making mechanisms. Armed with this additional information, many decisions about whether to convert or conserve ecosystems may be tipped on balance towards sustainable use and conservation. The remainder of this report focuses on the provision of decision-making frameworks and the demonstration of economic value from the literature that can inform policy decisions by providing measures of economic value where these are normally absent.

Information on the economic value of ecosystem services will not on its own provide a solution to ecosystem degradation. The real challenge is to use this information to redress market and policy failures. This can be done by removing perverse incentives such as subsidies that encourage degradation and creating positive incentives for achieving sustainable outcomes through payments for ecosystem services, creation of markets for services, or other incentives for sustainable resource management. This is the 'demonstration - capture' paradigm in environmental economics where demonstration of economic value should lead to their 'capture' through market or other mechanisms (where 'capture' infers turning at least some of the economic value into cash). While these capture mechanisms are not the subject of this report, a few examples are provided to stimulate discussion.

1.5 How do we measure the value of ecosystem services?

Key to understanding the importance of ecosystems and incorporating this in economic and other policy decision-making is to establish the link between a given ecosystem and its goods and services and how these are valued by individuals. Figure 1.1 demonstrates this link with a simplified model: ecosystems and their functions and processes provide outputs of goods and services, which generate benefits to human populations that can then be measured as increases in human well-being. Note that Figure 1.1 does not mention the creation / support of human life in the ecosystems – human wellbeing axis. The analysis here is not about the absolute value of human life and the role of ecosystems in its provision, but about the marginal value of ecosystem functions, goods and services and tradeoffs between the competing uses (including conservation) of these.

ECOSYSTEMS ⇒ ECOSYSTEM FUNCTIONS ⇒ ECOSYSTEM GOODS & SERVICES ⇒ CONTRIBUTION TO HUMAN WELBEING

Figure 1.1: Linking Ecosystems to Human Welfare

This is why a central concept of environmental economics is total economic value (TEV), which offers a useful framework for analysis. Primarily, TEV is composed of use values and non-use values.

Use value involves some interaction with the resource, either directly or indirectly:

Direct use value: involves human interaction with the ecosystem itself rather than via the services it provides. It may be consumptive or extractive use, such as fisheries or timber, or it may be non-consumptive, as with some recreational and educational activities.

Indirect use value: derives from services provided by the ecosystem. This might, for example, include the removal of nutrients, providing cleaner water to those downstream, the prevention of downstream flooding and diseases and provision of information.

Non-use value is associated with benefits derived simply from the knowledge that the ecosystem is maintained. By definition, it is not associated with any use of the resource or tangible benefit derived from it, although users of a resource might also attribute non-use value to it. It can be split into three basic components:

Existence value: derived simply from the satisfaction of knowing that ecosystems continue to exist, whether or not this might also benefit others (also associated with 'intrinsic value').

Bequest value: associated with the knowledge that ecosystems and their services will be passed on to descendants to maintain the opportunity for them to enjoy it in the future.

Altruistic value: derived from knowing that contemporaries can enjoy the goods and services ecosystems provide.

Finally, another category not immediately associated with the initial distinction between use values and non-use value includes:

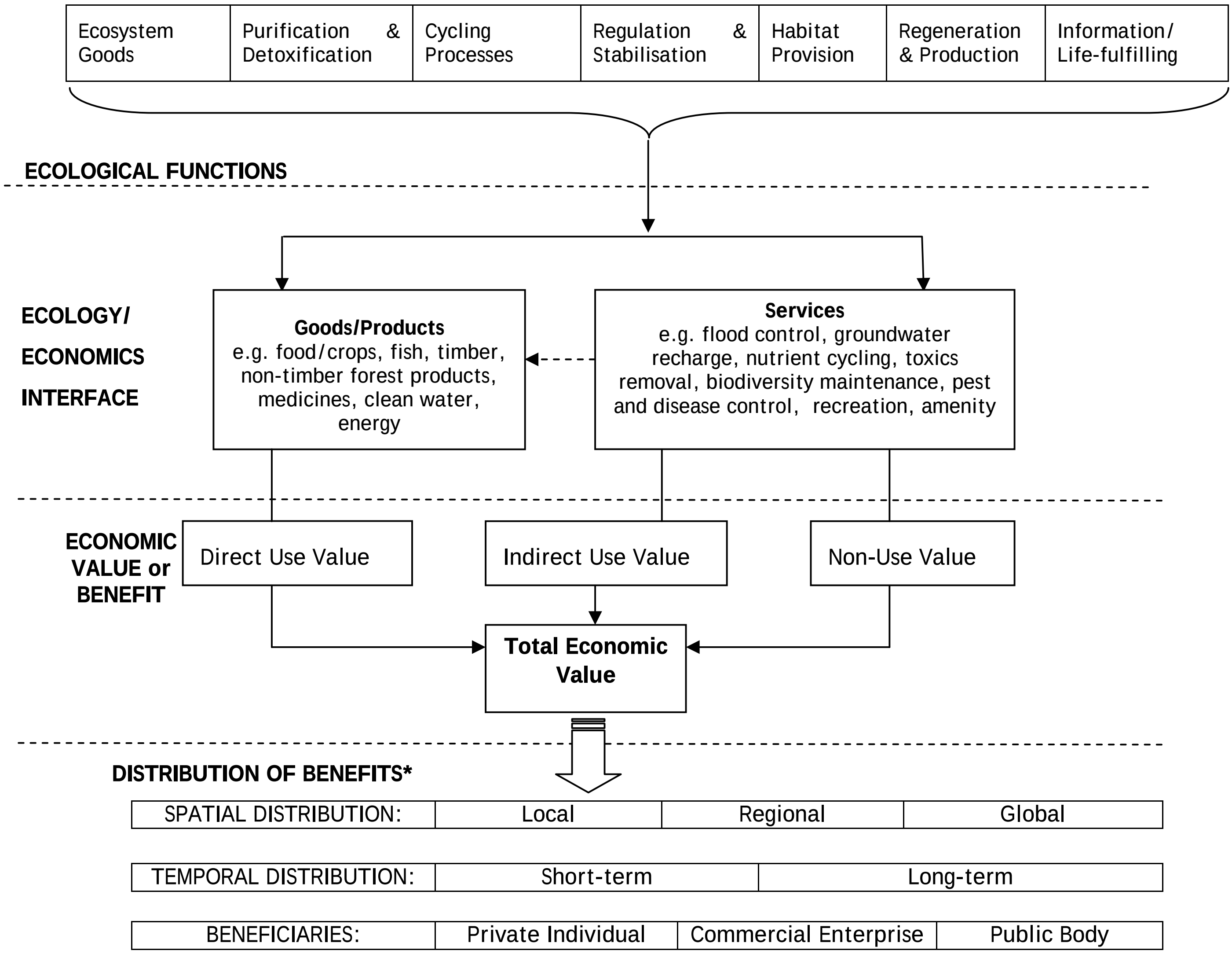
Option value: an individual derives benefit from ensuring that ecosystem services will be available for his or her own *use in the future*. In this sense it is a form of use value, although it can be regarded as a form of insurance to provide for possible future use (often associated with the potential of genetic information inherent in biodiversity to be used for research, e.g. pharmaceuticals).

TEV is measured by the preferences of individuals. When goods and services are provided in actual markets, individuals express their preferences via their purchasing behaviour. In other words, the price they pay in the market is at least a lower-bound indicator of how much they are willing to pay for the benefits they derive from consuming that good or service. For environmental resources which are not traded in actual markets, such behavioural and market price data are missing. In such cases, the methods of economic valuation (discussed in Annex 2) provide several tools that may be employed to estimate these 'non-market' or 'external' benefits. What these techniques have in common is that they express economic value in units of money. This has the advantage of allowing the non-market benefits of ecosystem goods and services to be compared with financial gains from their use. The economic literature using these techniques is vast, but relevant examples are presented throughout the report and its annexes. Regardless of whether all components of TEV can be expressed in monetary terms for a given ecosystem good or service, the concept is useful in gathering the necessary information for more sustainable decision-making.

1.6 Integrating the value of ecosystem services into decision-making

Figure 1.2 presents a framework for considering and measuring the value of ecosystem services for the purposes of decision-making at various levels, from local to regional and global. The framework in Figure 1.2 itself does not provide information and final decisions but simply constitutes a trail to follow when assessing the pros and cons of resource use decisions. The issues covered in the framework are discussed in the specific cases of wetlands, forests and agro-ecosystems in Section 2.

Figure 1.2: An Integrated Framework



*Note: costs (due to damage to ecosystems) equally apply here

The framework is geared towards addressing the question 'How can we incorporate the importance of ecosystem goods and services in economic decisions?'. There are four factors to take into account when answering this question:

- Understanding of ecological functions that produce ecosystem goods and services;
- Ecology and economics interface, which involves identifying which goods and services are directly supplied, indirectly provided or (positively or negatively) influenced by human activities;
- Defining and, if possible quantifying, the economic benefit of these goods and services, taking account of the components of the total economic value that applies in each case; and

- Distribution of benefits of ecosystem goods and services among different beneficiary groups (spatially defined at the very least) and time periods, or in other words, identifying different stakeholders, which is also useful in understanding the distribution of the costs involved when ecosystems are degraded.

Ecosystem dynamics – key considerations
As mentioned earlier on, our understanding of ecological functions and the provision of goods and services is limited. The framework here is a gross simplification, which necessitates a brief discussion of the complexities of the study of ecosystem function, and how ecosystems bring about goods and services to humankind. Any study of ecosystem dynamics and interactions with human systems needs to recognise the following characteristics of ecosystems:

- Thresholds are a typical feature of the relationship between human pressure on the environment and ecosystem function. In some cases humans can regulate the pressure imposed on systems to achieve optimal overall welfare benefits that combine economic and ecological values, whereas in others the response to stress is discontinuous and there is a sudden and catastrophic change in ecosystem conditions at some level of environmental stress. At this point the functioning of the ecosystem is shifted to an alternative stable state which is very often massively detrimental to human interests. Crucially, we currently lack sufficient understanding of ecosystem dynamics to identify thresholds *a priori*, and consequently it is difficult to implement informed policy. It is therefore particularly important to be able to identify thresholds where they exist within any model of ecosystem-economy interaction, in order to avoid unexpected catastrophic changes that could severely impinge upon human welfare;

- Declining species diversity simplifies ecosystems, which may in turn affect the stability of ecosystems in the face of disturbance, and thereby the capacity to deliver ecosystem functions that support human welfare. Species diversity, or at least the diversity of species comprising functional groups, provides ecological insurance, in that if some species are lost others are available to fill their functional roles. Declining biodiversity potentially erodes this ecological insurance until species 'redundancy' is reduced to a degree where continued species loss results in the catastrophic failure of ecosystem services. In rare cases some species may not have functional counterparts and their loss may contribute disproportionately to ecosystem failure. Loss of such 'keystone' species has been shown to have large impacts at local scales; and

- Ecosystem functionality interacts across habitats, ecosystems and scales. Landscapes consist of several functionally integrated ecosystems such that disturbances to one ecosystem have complex and indirect effects on other ecosystems within the landscape. These effects may be expressed through either physical or biological processes, and make it difficult to isolate any one ecosystem when studying ecosystem dynamics.

These complexities, which are discussed in detail in Annex 2, make it even more important for decisions to be taken with due account of their impacts on ecosystems in an integrated way from the start, as the ultimate consequences of not doing so are largely unknown but could be catastrophic.

Who benefits from ecosystem goods and services? – spatial and temporal considerations
The distribution of benefits of ecosystem goods and services among different beneficiary groups at different time periods is a crucial factor when considering the value of ecosystem goods and services. In terms of beneficiaries, we can think of individuals (the basic unit in estimating the total economic value), commercial entities and the public sector as forming broad categories. Table 1.2 identifies these beneficiaries across the local, regional/national and global scales. Often when decisions are made about resource use, the inclusion of the interests of the global community can tip the balance. This is especially the case when it comes to non-use and option values and even more so when mechanisms to capture these values for the local communities can be put in place.

Another scale at which the conflicts between users, or trade-offs between uses, become evident is that of temporal variation of ecosystem goods and services. Benefits and beneficiaries vary between short vs. long term, and this variation is clearest when exploitation of ecosystem goods in the short term leads to a decline in ecosystem services in the long term. One of the most striking examples of this is logging in the short term, which may lead to decline or loss of watershed and other services of forests.

Table 1.2: Beneficiaries of Ecosystem Services			
	Local	**National/Regional**	**Global**
Individual	Local users (e.g. hunter/gatherer, subsistence farmers and fishermen, recreation)	(e.g. tourists, consumers, education)	(e.g. tourists, consumers, education)
Commercial entity	Local industry (e.g. entrepreneurs, farmers, traders, artisans)	Economic sectors, national and regional GDP	International enterprise (e.g. fishery and forestry industry)
Public sector	Local Government (e.g. tax revenue)	National Government (e.g. tax revenue, foreign revenue from sale of concessions)	International Community

The distribution presented in Table 1.2 brings forth the issue of conflict of interest between the different beneficiaries or users of ecosystem goods and services. In other words, trade-offs between different uses become apparent.

Commercial interests tend to have a reputation for reaping the reward of harvesting natural resources at the expense of local users, even though blame is often shared with national governments who can provide incentives for this behaviour and can suffer either from corruption, lack of capacity or lack of political will to enforce better controls on resource extraction. The ability of national governments to collect tax and other foreign revenue related to resource rents, concessions and tourism, and redistribute this revenue to the benefit of the general public is also prey to these weaknesses. Addressing issues of governance and corporate social responsibility can help ensure the equitable distribution of the benefits of ecosystem exploitation.

2. Ecosystem Goods and Services – examples

Due to the vast literature on the value of ecosystem goods and services and the limited scope of any review, this Section focuses on three ecosystems: wetlands, forest and agro-ecosystems. Each sub-section corresponds to the factors covered in the integrated framework in Section 1. Thus, the overview of goods and services of each ecosystem covers the ecosystem functions, ecology-economy interface, economic value (or benefit) and distribution of benefits. In addition, threats to the ecosystem including the linkages with poverty and some policy recommendations are provided. Annex 1 applies the framework and quantifies the economic value for two wetlands and further details and examples can be found in Annex 2.

2.1 Wetlands

The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, 1971), defines wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres". Furthermore, wetlands "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands".

While in total wetlands cover 0.6% of the Earth’s surface, they provide a much larger proportion of the ecosystem services such as recreational amenities, flood control, storm buffering, biodiversity, climate regulation and socio-cultural values. They are vitally important and diverse fresh and marine water ecosystems which encourage biodiversity by contributing to primary productivity and providing habitat for a wide range of dependent species (including internationally recognised migratory wader birds). Thus, wetlands have a diverse fauna with a relatively large number of endemic species.

Table 2.1 uses the framework developed in Section 1 to present the goods and services of wetlands. While wetland *goods* are derived from the direct utilisation of wetland flora and fauna, wetland *services* result from ecosystem processes which support and protect human activities. Furthermore, these services will generally be associated with benefits that are derived off-site. For example, the nutrient cycling of a wetland will improve the water quality of the water body downstream, while the storage of flood water within a wetland will prevent flooding both upstream and downstream.

Table 2.1: Total Economic Value of wetland goods and services

	Goods and Services	Local	Regional	Global
Direct Use	Livestock/cultivation	x	x	
	Fisheries	x	x	
	Fibre for construction and handicraft production and fuel wood	x		
	Hunting for water fowl and other wildlife	x	x	
	Aesthetic value of wetlands, recreation	x	x	x
Indirect Use	Storm Buffering	x	x	
	Flood water storage & stream flow regulation	x	x	
	Water flow	x	x	
	Sediment & nutrient cycling – water quality improvements	x	x	
	Erosion control (wetland vegetation)	x	x	
	Carbon Sequestration – climate change and mitigation			x
Option*	Future direct and indirect uses of above goods and services	x	x	x
Non-Use*	Existence, bequest and altruistic value of wetland habitats and species; Traditional/cultural knowledge & traditions	x	x	x

*: These value components are not illustrated separately in what follows but are referred to under the ecosystem services as relevant.

The significance of a wetland will vary depending upon which particular good or service is being assessed. As the direct use values will generally involve some direct contact with the catchment itself, the beneficiaries are most likely to be local with the exception of visitors who may travel from far away. The indirect use benefits are likely to be of regional significance as these relate to the catchment in which the wetland is located. Due to the trans-boundary nature of river catchments, this may well extend across countries: for example the Nile passes through Tanzania, Kenya, Zaire, Burundi, Rwanda, Ethiopia, Uganda, and the Sudan before reaching the Mediterranean in Egypt. Further indirect benefits such as carbon sequestration take on a global scale, as do the non-use values, but the latter may be subject to 'distance decay' away from the site.

2.1.1 Goods and services provided by wetlands

Goods and services derived from wetlands can be of considerable value to society as demonstrated by the literature reviewed in the rest of this section and in Annex 2.

Livestock and cultivation

Wetland ecosystems provide an environment where particular plants (e.g. reeds) that are adapted to wet conditions tend to grow in abundance. Thus wetlands, especially those which are temporarily and seasonally waterlogged, can provide valuable grazing lands. They also provide fertile lands for a few crops that are adapted to the anaerobic conditions in wetlands. Rice, which forms the staple diet of 3 billion people or half the world's population (WWF, 2004), is one of these few crops.

Further agricultural gains are sought from wetlands by draining them. If wetlands are drained for short periods of time (see Case Study 2 in Annex 1), and re-flooded, they may be able to retain much of their function. However, if the wetlands are drained permanently, then these functions will be lost. Box 2.1

provides the example of the Hadejia-Nguru Wetlands of Nigeria by comparing the agricultural returns if the wetlands are drained to the use of other goods when they are not.

Box 2.1: Economic Values of harvested wetland goods in Nigeria (Eaton and Sarch, 1997)

A study of the Hadejia-Nguru Wetlands of Nigeria examined the value of wild resources used for food, raw materials and firewood. This showed that harvesting doum palm fronds and selling the dried bundles yields a return of about N200 (US$2.50) per day, and making mats from the fronds N10 (US$0.13) per day. The returns to labour from harvesting firewood and carrying it back to a local town for sale were estimated at approximately N40–60 (US$0.50–0.75) per day, while the returns to labour for women who collect and sell potash are estimated at N26–31 (US$0.33–0.39) per day.

The importance of wetland products relative to agriculture is shown by comparing these returns to the prevailing agricultural wage of between N50 and N70 (US$ 0.60–0.90) per day. Thus, the return to doum palm harvesting was three times greater than the relative agricultural return. Firewood also generates significant revenues for a range of individuals within wetlands communities.

Fisheries

Both freshwater and coastal wetlands fulfil the essential needs for maintaining fish populations, as they provide food, shelter, spawning and nursery areas, and clean water. Coral reefs and mangroves are sources of food and livelihoods for millions of people who live in coastal areas or on small islands in tropical countries. Reef-related fisheries constitute approximately 9–12% of the world's total fisheries consumption and up to 25% of fisheries production in tropical developing countries (Moberg and Folke, 1999).

Fibre for construction and handicraft production, and fuel wood

In addition to providing grazing for animals, wetland vegetation provides much valued material for products such as utensils, mats, trays, baskets and paper (produced from papyrus, which is a sedge), while the common reed (*Phragmites australis*) is used for construction purposes.

Hunting for water fowl and other wildlife

In a similar manner to fisheries, wetland vegetation provides the ideal conditions to support the breeding and feeding of waterfowl (including ducks and snipe) and other wildlife (such as reedbuck) which can be hunted either to provide a source of food or for recreational purposes. Whereas, provision of food is most relevant for the local population, recreational hunting could have a regional or even international significance.

Aesthetic value of wetlands

The wide diversity of vegetation, bird species, fish and other wildlife found within wetlands add to the diversity and beauty of the landscape. One way to capture this aesthetic value is to look at the contribution of the wetland ecosystem to tourism as exemplified in Box 2.2.

Box 2.2: Valuation of ecotourism

Moran (1994) estimated the current non-consumptive value of protected areas of wetland in Kenya by foreign visitors at some $450 million per year. This estimate is additional to current financial returns from tourism and makes no allowance for other direct and indirect benefits and potential returns from consumptive uses.

A valuation study of the coral reefs of the Phi Phi Islands, Thailand (Seenprachawong, 2001) showed the travel expenses (as an indicatory of the value of a trip) to be 8,216 million Baht (US$205 million) per year. In addition, visitors' willingness to pay to increase biodiversity at Phi Phi was estimated to be 287 Baht (about US$7) per visit.

Storm buffering, flood water storage and stream flow regulation

By storing water and slowing water movement, wetlands buffer surrounding areas from the worst effects of storms and floods. This service is of particular value to the poor, who lack the financial or other means to protect themselves against the impact of storms through reinforced buildings or protected food production systems, or to recover from storms quickly (FAO, 2001). The FAO report two case studies in the Mekong Delta and in Andra Pradesh, India, where in contrast to the wealthier households, the poor were unable to protect their houses or livelihoods in response to floods and cyclones. For example, the benefits of the urban flood control provided by the That Luang Marsh in Laos was estimated by examining damage costs avoided through flood prevention, giving an annual value of US$2.8 million per year, over 55% of the total economic value of the wetland (Gerard, 2004).

Water flow
By slowing down the movement of water and temporarily retaining it, wetlands act like sponges which reduce floods and also prolong stream-flow during low flow periods. If wetlands are flooded with river water where the water tables have been lowered considerably in dry periods, or where the regional water table is low; then water can percolate downwards into groundwater aquifers (*groundwater recharge*). These conditions occur in semi-arid or arid areas where the geology is made up of highly or moderately permeable deposits. Under specific hydrological conditions water can be discharged from these aquifers, emerging as springs or seepage zones (*groundwater discharge*).

Following the example of the Hadejia-Nguru wetlands in northern Nigeria, a study by Acharya (2000) estimates the value of replenishing and maintaining groundwater resources through the inundation of the wetlands during the wet season. The study suggests that the value of the recharge function is 1,147,000 Naira, or US$13,000, per day for the wetlands, and in terms of groundwater irrigated agricultural production, a value of at least 2,860 Naira or US$33 per farmer per dry season is attributable to the present rate of groundwater recharge.

Sediment & nutrient cycling – water quality improvements
Sediments and nutrients are deposited in and around wetlands, preventing the siltation of downstream waterways. In addition, high levels of nitrogen and phosphorous from agricultural runoff are removed by wetlands, preventing the eutrophication of streams and rivers and the contamination of groundwater supplies. Mangroves also act as buffers and catch excess sediment that would otherwise flow into the ocean, thereby protecting vital coral reefs and sea grass beds from damaging siltation.

Erosion control
Wetland vegetation controls erosion by reducing wave and current energy and by binding and stabilizing the soil. The mangrove system in particular has important indirect use value through its environmental function of controlling erosion and sedimentation, which protects agricultural production in relevant regions. In a study of the mangrove wetlands of Bintuni Bay, Irian Jaya, Indonesia, the benefits of erosion control were estimated to be around US$950 per household (Ruitenbeek, 1994), based on the value of the local agricultural production that this function provides.

Carbon Sequestration – climate change and mitigation
Wetlands are significant carbon sinks with peatlands and forested wetlands accounting for over 25% of the soil carbon pool. Conversion of wetlands to agriculture inevitably results in the release of large quantities of carbon dioxide.

Traditional/cultural knowledge & traditions
Cultural heritage includes the physical structures and artefacts of the past, traditional water and land-use management practices, and the religious significance of wetlands and their wildlife. While there are few studies of non-use values associated with wetlands, Barbier et al (1996) suggest that donations made through campaigns by European and North American environmental groups to raise funds to support tropical wetlands conservation hint at the magnitudes involved. For example, several years ago the UK's Royal Society for the Protection of Birds (RSPB) collected £500,000 from a one-off membership mailing campaign to help save the Hadejia-Nguru wetlands of Northern Nigeria in West Africa.

2.1.2 Challenges

Threats to wetlands
Fifty percent of wetlands worldwide have been lost since 1900 (Dugan, 1993 and OECD, 1996) and 58% of coral reefs are at moderate to high risk from human disturbance (Moser et al, 1996). Many other examples of the damage to wetlands are presented in Annex 2. A reasonable question to ask here would be why such damage is inflicted upon wetlands, which perform so many functions and are potentially so valuable. To some degree, the desirability of flat, fertile and easily accessible land has inevitably put them under pressure from other uses such as agriculture, industry and urbanisation. Therefore, the answer is likely to be in the way the decisions about alternative land uses are taken. In most such decisions, while the tangible, financial benefits of the conversion are measured and taken into account, the substantial value arising from wetland goods that are not traded in formal markets and services that do not generate direct cash returns are not. This market

failure is compounded by the separation between those who determine the use of the wetland and those who depend on the wetland's goods and services. Thus, the value of the goods and services are not captured by the decision-makers, while the costs of such decisions are borne by the local communities who can least afford them.

The resulting impact on the wetlands is one of declining ecosystem function, goods and services. This is well illustrated by coral reefs. Damaged or degraded coral reefs lose value because they are less productive, providing fewer goods and services than healthy reefs (Burke et al, 2002):

- A healthy coral reef might provide an average sustainable fisheries yield of 20 tonnes per year, the yield of a reef damaged by destructive fishing practices is likely to be much lower, under 5 tonnes per year.
- Fishers engaged in blast fishing may earn US$15,000 per km^2, but they generate losses to society over a 20-year period ranging from US$91,000 to US$700,000 per km^2. Total net losses from blast fishing are US$1.2 billion in the Philippines and US$570 million in Indonesia.
- In Indonesia, sustainable fishing can generate as much as US$63,000 per km^2 more over a 20-year period than overfishing on healthy reefs (the difference between a US$102,000 loss to society and a US$39,000 gain to the individual).
- Estimated loss from sedimentation in tourist areas are around US$100 million in Indonesia and US$114 million in Philippines.

Critical thresholds

The human impact-response relationship that is exemplified above by coral reefs is not a simple linear relationship. 'Thresholds' and the potential for irreversible change, whereby a change in the impacts on a wetland ecosystem has a disproportionate effect or causes an irreversible change, are known to exist. Thus, there may be a point beyond which a small increase in the exploitation of a wetland may be associated with relatively high economic costs.

One of the best studied examples of catastrophic change from one stable ecosystem state to another is that of lake systems that shift dramatically from clear water to a turbid state much reduced in biodiversity. Most relatively pristine shallow lakes have clear water that is rich in submerged vegetation and animal life. These appear little affected by increasing nutrient concentration until a critical threshold is passed, whereupon the lake shifts suddenly to the turbid state that is accompanied by a loss of the submerged vegetation and associated diversity. Reduction of nutrient input and concentration is often not sufficient to restore water clarity, and it is only when nutrient levels have been reduced to well below those at which the shift occurred is there a return to original conditions.

Wetlands and poverty

In order to understand the links between wetland goods and services and poverty, it is important to analyse who benefits from these goods and services. The framework introduced in Section 1 enables us to think in terms of local, regional (or national) and global beneficiaries. In some cases, the benefits to each of these groups are in conflict, and hence the actions of one group may reduce the benefits derived by other(s). Identifying the beneficiaries and potential conflicts at the start of a decision-making process (as this framework allows) increases the chances of avoiding wrong decisions.

Conflicts can also exist within a given beneficiary group. In developing countries, many wetlands resources are currently under common ownership. In Uganda, for example, this has led to problems over defining and enforcing ownership when increased population pressures reduced the effectiveness of the common ownership regimes (Emerton et al 1999; Maclean et al 2003a,b). A further conflict exists between the local users, who depend for their livelihoods on wetland goods and services, and the global community, which may demand the preservation of biodiversity supported by wetlands. Such conflicts are discussed in detail in the wetlands case study in Annex 1.

Resolving these conflicts is a challenge requiring investigation of and incentives for sustainable use of wetlands. Highlighting the benefits that wetland ecosystems provide in terms of goods and services, and the beneficiaries of those goods and services, would be a first step in enabling national and international decision-makers to face this challenge. Box 2.3 gives an example in which the long-term income and welfare of the local community (the poor within the local community in particular) are in conflict with the short-to-mediumterm financial gain of commercial entities.

Box 2.3: Including the wetland-poverty linkages in decision making: Ream National Park, Cambodia (Emerton, 2003)

High levels of local resource exploitation have impacted severely on the natural ecosystems of Cambodia's six coastal protected areas. Rural poverty is widespread on the coast of Cambodia, with more than half of the population classified as poor and lacking in basic amenities such as food, water and adequate housing. Should the mangroves be preserved for long-term but difficult to quantify benefits of the community, or harvested for immediate income, or converted for salt production and aquaculture?

This study showed that Ream National Park, in its current protected state, is an extremely important economic resource for adjacent communities and for the Sihanoukville Provincial economy. Household and village level surveys in the area found that almost all local residents depend on the park resources in some way for their basic subsistence and income. These resources are particularly important in this area, as the median family income is estimated at only $316 a year (a third of families earn less than $200) and where half of households can barely provide for their own subsistence. The net value of park resources is estimated to be around US$1.2 million a year, or an average of US$220 for every household living in and beside the National Park (livestock & crop production – US$520,000, forest products – US$191,000, and fisheries - $515,000). Ecosystem services such as storm protection and prevention of coastal erosion in areas surrounding the park contribute a further US$300,000 a year.

These values far exceed the benefits yielded by alternative uses: clear-cutting the mangroves could generate less than $630,000 a year and prawn farms can, under the best conditions, realise a net income of almost US$4,500 per hectare per year (but few actually do).

2.1.3 Key conclusions and recommendations

A number of conclusions and recommendations can be drawn from the literature review summarised here and in Annex 2.

The beneficiaries of wetland goods and services span the entire scale of those presented in Section 1: local, national / regional and global as well as individuals, commercial entities and public bodies. Determining the benefits accruing to these different parties is crucial in understanding the synergies and conflicts between the different uses (and non-use values) attributed to each party.

While in principle the concept of total economic value encompasses both use and non-use values of all wetland goods and services, the literature contains evidence mostly about the directly or indirectly traded goods and only some of the services. Notwithstanding the gaps in literature, existing information about economic value is rarely used in actual comparisons of the returns to wetland conversion or degradation and the returns to conservation. The multitude of wetland goods and services, the variety of different beneficiaries and lack of property rights which can guarantee returns to uses and conservation of wetlands – in short the threats mentioned in Section 1.2 – have lead to the current state of wetlands (a loss of half their size worldwide since 1900 (Dugan, 1993 and OECD, 1996) with associated economic welfare losses).

One measure against wetland degradation is to identify protected areas through national park systems. However, implementing such systems for the protection of services to a broad range of stakeholders at the regional and global level risks excluding direct use by the local community reliant on wetlands for their livelihood. The challenge is therefore in promoting sustainable use, for example through clear property rights regimes and potential payments to support sustainable livelihoods, or the provision of alternative means of income for local people.

The development of ecosystem services trading schemes which are currently being introduced in the UK, US, Australia and the EU offer the potential means with which more of the economic values can be captured. These schemes involve creating markets to ensure that the provision of ecosystem goods and services through sustainable management practices is rewarded. In theory, this process is undertaken by governments creating a market for the ecosystem services by defining property rights that are linked both to the ecosystem service and can be exchanged for financial reward.

3.2 Forests

The Food and Agricultural Organisation (FAO) defines forests as an area with (a) an existing or expected tree canopy of more than 10%; and (b) a total area of more 0.5 hectares where trees reach at least 5 metres in size (FAO, 2000). This definition extends to natural forests, forest plantations and land from which forest has been cleared but that will be reforested in the foreseeable future. However, stands of trees established primarily for agricultural production, such as fruit tree plantations are excluded from this definition (FAO, 2000). Defined as such, forests are among the world's most important biomes in terms of the area of land surface they cover (approximately 30% of all land - over 3.8 billion hectares (FAO, 2003)), the goods and services they provide, and the biodiversity they contain (approximately 90% of terrestrial biodiversity).

The World Bank (2001) highlights that more than 1 billion people depend on forests for their livelihoods to varying degrees. Sixty million indigenous people are almost wholly dependent on forests, while around 350 million people living within or adjacent to dense forests depend on them to a high degree for subsistence and income. In developing countries, agro-forestry farming schemes support 1.2 billion people and help sustain agricultural productivity and the generation of income. Forest industries provide employment for some 60 million people worldwide. The medical needs of approximately one billion people depend on drugs derived from forest plants, many of which have been long been used in traditional medicine

In recognition of the importance of forest ecosystems and the services provided, the proportion of forest cover to total land area (excluding inland waters) has been adopted as an indicator measure for monitoring progress towards achieving the Millennium Development Goals (MDGs) adopted by the member states of the United Nations under the 2000/2002 Millennium Declaration (United Nations, 2001). Forest cover is monitored in relation to the target of 'integrating the principles of sustainable development into country policies and programmes and reversing the loss of environmental resources' under the goal of 'ensuring environmental sustainability'. Monitoring forest cover reveals the relative importance of forest land within countries, while changes in forest cover reflect the demand for land from other competing uses (United Nations, 2003).

Table 2.2 provides an overview of ecosystem goods and services provided by forests on the basis of the total economic value classification presented in Section 1. Direct use values derived from forest ecosystems may be further distinguished between those which are consumptive or extractive, in terms of forest products (timber, fuelwood and charcoal and non-timber forest products) and those which are non-consumptive. Genetic information for traditional medicine and pharmaceutical purposes, recreation and tourism, research and education and cultural religious significance may all be classified as non-consumptive direct uses of forests. A number of significant indirect use values are also derived from forest ecosystems: regulation of regional rainfall, flood and water yield regulation, control of soil erosion, as well as carbon storage and sequestration.

The rest of this section presents key insights from recent ecological and economic literature that address the goods and services listed in Table 2.2. The review of literature is selective, highlighting issues such as the scale on which benefits are derived (subsistence for poor rural communities, global benefits from carbon storage and so on) as well as uncertainty that may surround the 'value' of ecosystem services. An understanding of these factors is useful when discussion turns to considerations of challenges and solutions in relation to forest ecosystems, as addressed at the end of the Section.

Table 2.2: Total Economic Value of forest goods and services				
	Goods and Services	**Local**	**Regional**	**Global**
Direct Use	Forest products - timber - fuelwood/charcoal - non-timber forest products	 x x x	 x	 x
	Genetic information - traditional medicine - pharmaceuticals - research	 x x x	 x x	 x x
	Recreation and tourism	x	x	x
Indirect Use	Regulation of regional rainfall		x	
	Flood and water yield regulation	x	x	
	Control of soil erosion	x	x	
	Carbon storage and sequestration			x
	Health	x		
Option*	Future direct and indirect uses of above goods and services	x	x	x
Non-use *	Traditional/cultural knowledge & traditions	x	x	x

*: These value components are not illustrated separately in what follows but are referred to under the ecosystem services as relevant.

2.2.1 Goods and services provided by forests

This section briefly reviews the forest goods and services that generate direct and indirect use values and non-use values. Further details are presented in Section 5 of Annex 2.

Timber

The use of timber may imply small scale exploitation by local communities for building material, or alternatively large scale commercial exploitation by national or international logging interests. Where timber is marketed, the economic value should be readily apparent. The annual turnover of roundwood, sawnwood, panels, pulp and paper exceeds US$200 billion, while the forest products sector in general is estimated to contribute about 1% of world gross domestic product and 3% of international merchandise trade (FAO www.fao.org/forestry/site/trade/en). Some of the rent captured by logging interests stays in the local area (via labour wages) and in the host country (via taxation and/or concession payments). This is unlikely to be sufficient, however, when over-exploitation of timber resources serves to remove important ecosystem functions.

Fuelwood

Biomass, and in particular fuelwood, is estimated to account for 11% of world energy consumption and 35% of energy consumption in developing countries (IEA, 1998). In terms of economic value, Shyamsundar and Kramer (1997) estimate that the value of fuelwood is US$39 per household per year for communities surrounding the Mantadia National Park in Madagascar. With mean annual household income estimated to be US$279, fuelwood collected from the forest amounts to almost 15% of household income. Fuelwood is also a commercial commodity especially in peri-urban areas. For example, in certain areas of Sub-Saharan Africa, tens of thousands of poor farmers and small traders supplement their incomes by selling fuelwood (Arnold et al, 2003).

Non-Timber Forest Products (NFTPs)

NTFPs include construction materials such as bamboo, rattan and palm leaves; wild food such as fruits, nuts and bushmeat; animal fodder; and medicinal plants. They are a feature of informal and/or subsistence economies and are widely used by mainly rural but also urban communities throughout the developing world.

Neumann and Hirsch (2000) note that there is overwhelming evidence indicating the poorest groups of households around the world are the populations principally engaged in NFTP extraction.

On the basis of 34 economic valuation studies, Pearce and Pearce (2001) suggest a clustering of net NTFP values in the range from US$5-$100 per hectare per year. The type and the importance of the product in supporting local communities and hence their economic value vary significantly with location. The authors also point out that the benefits of forest products are largely derived by local communities, and given the small size of the local population deriving these benefits, the total value per hectare may also be low if unit values are multiplied by a relatively small number of households. Case study 1 in Annex 1 further illustrates how the value of forest products can be assessed.

Genetic information: traditional medicine, pharmaceuticals and research

Traditional medicines derived from forest products typically confer significant direct use benefits to local forest communities. Although according to the World Health Organisation, around 80% of the population from developing countries rely on traditional medicines, mainly derived from plants, for their primary health care, the economic literature does not seem to cover these health benefits. One way in which the minimum value of traditional forest medicines could be estimated is through the cost of using pharmaceutical products to achieve the same level of protection. Notwithstanding the infeasibility of replacing all traditional medicine with manufactured drugs, the cost would be significant.

The historical economic value of the pharmaceutical use of genetic material, on the other hand, is easier to assess and at the very least is equal to the world markets in pharmaceutical products derived from genetic resources, which is around US$500-800 billion (ten Kate and Laird, 2000). However, the likely value of conserving individual species in current times for pharmaceutical research is estimated by some researchers to be lower than previously thought (Simpson, Sedjo and Reid, 1996). The essential reasons for this is that (a) biodiversity is abundant and hence one extra species has low economic value; and (b) there is extensive ‘redundancy’ in that, once a discovery is made, finding the compound again has no value. How valid these factors will be in the long-term remains to be seen.

In addition to pharmaceutical developments, biomedical research is also dependent on plants, animals and microbes. Chivian (2003) sites several cases where animal species native to forests offer potentially key insights to ongoing research (e.g. poison dart frogs in Central and South America relating to the study of the central nervous system).

Recreation and tourism

A further source of direct use value may be derived from forests in terms of recreational opportunities and the provision of amenity. Globally, it has been estimated that, depending on the region, 40 to 60% of international tourism can be labelled as eco-tourism, with wildlife tourism accounting for approximately 20 to 40% of international tourism (Ceballos-Lascuráin, 1996). Although a significant proportion of the economic value is potentially recoverable through entrance fees, tourism expenditure typically forms the basis of profits of tour operators, who may not necessarily be locally or even nationally based. In order to capture larger proportions of the economic value of ecotourism, the results of economic valuation studies have been used to set fees charged to visitors to national parks (IIED, 2003). Box 2.4 provides some examples of the economic value of ecotourism.

Regulation of regional rainfall

Forests contribute to climatic regulation, particularly rainfall and temperature, representing an important ecosystem service especially in tropical continental regions. Economic impacts resulting from forest regulation of regional rainfall typically arise in relation to the consequential effects on flood and water yield regulation which are discussed next.

Flood and water yield regulation

It is widely understood that deforestation disrupts the hydrological system by destroying the ‘sponge effect’ of forests, i.e., their ability to soak up moisture in periods of heavy rainfall and to release it gradually through groundwater discharge, thereby maintaining river flows even during dry periods. The sponge effect is destroyed following forest clearance, which has been shown to consistently and significantly increase stream-flow (see Box 2.5).

Box 2.4: Economic Value of Ecotourism

Mantandia National Park, Madagascar (Kramer et al. (1992; 1993; 1995)
The creation of the Mantadia National Park, Madagascar was expected to increase tourist visits to the area as a result of improved opportunities for accommodation and viewing wildlife. On the basis of the travel expenditures, estimated tourist benefits were US$24 per trip, assuming that the national park delivered a 10% increase in the quality – through improved facilities, educational materials and local guides.

Work by the authors in relation to the establishment of the National Park also includes estimates of indirect use value to downstream rice farmers, and non-use (existence) value of the forest to US residents. Although no formal cost-benefit analysis is undertaken, the research suggests there may be significant recreational benefits to foreign visitors from rainforest conservation. However the implicit trade-off could be the loss of welfare to poor local communities.

Monteverde Cloud Forest, Costa Rica (Menkaus and Lober, 1996 and Tobias and Mendelsohn, 1991)
Benefit of a visit to the Monteverde forest reserve was estimated to be US$1,150 per a US tourist per year. Another study estimated the same benefit to be US$35 per a Costa Rican tourist per visit. Per visit estimates are expected to be higher for foreign tourists due to higher income, higher travel expenditures already incurred and low (relative to income) entrance fees among other factors.

Box 2.5: Benefits of water provision and flood control: examples from Malaysia, Madagascar and Cameroon

In Malaysia, the protection of agricultural irrigation was valued at US$15 per hectare through the productivity of water in crop production by Kumari (1996). In the study this value was derived from the difference between crop production under current unsustainable logging practice and potential sustainable logging management.

The ability of the sponge effect to control flood events also has economic benefits in terms of avoided damage. For example, in Madagascar in years of normal weather, about 5% of the agricultural production is lost due to flooding annually. This damage figure is much higher in years of major storms (Kramer, Richter and Pattanayak 1995). In Cameroon, the benefit of flood protection provided by forests is estimated to be US$24 per hectare per year, valued in terms of avoidable crop and tree loses Yaron (2001).

Along coasts, mangrove forests provide protection against storm surges and coastal erosion. The clearance and destruction of these mangroves has led to salinisation and even inundation of coastal lands. The protective function of mangroves has been most dramatically and tragically demonstrated by the recent tsunami in the Indian Ocean where the destruction along the coast of Aceh province in Sumatra was far worse where protective mangrove forests had been cleared (Pearson, 2005).

Control of soil erosion

Forests protect soil surfaces from the direct impacts of rain by intercepting rainfall and by providing protective litter and humus layers. Like many other forest services, the value of soil erosion control is perhaps best understood when it declines and causes damage in the vicinity of the forest or downstream in the effected watershed. Siltation of reservoirs, irrigation systems and harbours in Java cost Indonesia U$58 million in 1987 alone (Myers, 1996). In addition, the increased loading of terrestrial sediments to aquatic environments is now widely recognised as a serious threat to coastal and estuarine habitats. In the 1980s logging on steep slopes in Bacuit Bay in the Philippines increased soil erosion 235 times above that of undisturbed forests, resulting in almost 50% loss of fishing revenue due to sedimentation-smothered coral reefs. From this the value of fisheries protection in terms of value per hectare of forest, was estimated to be US$264 per hectare per year (Hodgson and Dixon, 1988).

Carbon storage and sequestration

Forest ecosystems generate substantial global indirect use values through the storage and sequestration of carbon. The economic value of a tonne of carbon sequestered or stored is the same, i.e. the value of the avoided global warming damage had that tonne been released. In physical terms, though, the two functions are different (Pearce and Pearce, 2001). Carbon storage value may be thought of as the value that is lost if a forest is converted through logging or burning. Realisation of this value depends on what would prevail in the absence of protection or sustainable use of the forest. Carbon sequestration value refers to the net fixation of carbon which is aggregated over the rotation life of the forest.

Estimates of carbon storage values typically dominate all other forest benefits including those in relation to timber. In terms of an indicative value per hectare of forest, benefit estimates range from US$650 to US$3,500 per hectare in net present value terms (IIED, 2003). Tol et al (2000) suggest US$50 per tonne as the upper limit for the marginal value of a tonne of carbon, whilst Clarkson and Deyes (2002) arrive at a value of US$34 per tonne on the basis of a review of the existing literature[2]. These are significant estimates which are difficult to capture in practice. Mechanisms for such capture (e.g. carbon trading) are not widespread and the global and public good nature of this service suggests there is an incentive to 'free ride' on the efforts of others.

Health

This is another example where the value of the forest services is realised in their absence. Disturbances to forest ecosystems can affect the risk of directly acquiring infectious diseases, or indirectly through their effect on the biodiversity of infectious agents, reservoirs and vectors, which can result in significant impacts on human health (Chivian, 2003). For example, in the cases of leishmaniasis, yellow fever, trypanosomiasis (both African sleeping sickness and Chagas disease), and Kyasanur forest disease, deforestation can result in humans coming into closer contact with vectors at the edges between forests and human settlements. Logging can lead to changes in forest ecosystems that provide the perfect conditions for breeding of mosquitos, particularly the *Anopheles darlingi*, which is the most effective vector in Amazonia for malaria (Chivian, 2003).

In addition, decline in forest cover and related water yield regulation services has a negative impact on water supply and quality. Notably, clearance of forests upstream increases the variability in water flow resulting in erosion and flooding in wet seasons and water deficiencies in dry seasons. While this link cannot always be made quantitatively and may differ depending on other factors, insufficient supply of water has very real impacts on human health. Typhoid, cholera, amoebic infections, bacillary dysentery and diarrhoea, among related disease, case an estimated mortality of 15 million people each year, plus morbidity relating to as much as 80% of all sicknesses.

2.2.2 Challenges

Threats to forests

Unsustainable logging, pressures from agriculture and livestock rearing, or infrastructure development are resulting in the large-scale clearance of forested land, and undermining the provision of these services. Deforestation can give rise to classic externality outcomes, with the instigators of land clearance imposing costs on other groups, be they downstream users of water resources or those impacted upon by localised flooding, or global users who suffer indirectly from the reduced capacity of forests for sequestration and storage of carbon. Pearce and Pearce (2001) elaborate further by identifying the specific factors that contribute to land use decisions that threaten forests:

- Missing markets for forest goods and services result in a lack of price signals about their value;
- A typical absence of defined property rights provides no incentive for local communities to conserve open access resources such as forests;
- Activities such as slash and burn agriculture over agro-forestry suggest that not only are the net returns to the former are greater, but that local communities typically also have high discount rates. This reflects the subsistence nature of livelihoods with the need to provide food security in the present rather than in the future;
- Perverse incentives such as subsidies for agriculture, preferential logging concessions and reduced royalty fees encourage forest conversion;
- Population change is linked to rates of deforestation, although interactions between various factors are complex;

[2] This value is currently used by the UK Government in assessing the social cost of carbon emissions.

- Greater levels of international indebtedness are likely to mean that countries are more likely to pursue policies that threaten forest cover; and
- Developments such as road building for logging access may encourage migration to previously unexploited areas of forest and reductions in transportation costs will tend to influence rates of deforestation.

Kremen et al (2000) examine the opportunity costs of forest conservation, i.e. forgone benefits of forest use such as timber, finding that at the national level the financial benefits of logging are greater than conservation, but additional consideration of global benefits such carbon storage and sequestration and biodiversity leads to the conclusion that conservation benefits are greatest. Similarly Muriithi and Kenyon (2002) conclude that only when non-use and existence values, which are not realised by the local and national population, are included do forest conservation benefits exceed the opportunity costs. Therefore, overall, the challenge of forest conservation lies in creating the correct incentive framework to capture these values.

Forests and poverty

The dependence of the rural poor in developing countries on products derived from forest ecosystems means that poverty-environment linkages are fundamental to any discussion concerning the value of forest ecosystem services. From a poverty alleviation perspective, Cavendish (2003) underlines the three main purposes forest resources serve in rural livelihoods: (i) a safety net, overcoming unexpected shortfalls in cash income; (ii) support of current consumption, maintaining the existing level of income and preventing a decline into further poverty; and (iii) a route out of poverty, with forest products enabling sustainable increases in household income either through a 'stepping out' strategy or a 'stepping up' strategy. Stepping out refers to the accumulation of capital so as to move into other activities whilst stepping up refers to the intensification and specialisation in existing activities (Veldeld et al, 2004).

Furthermore, from the poverty perspective, the value of forest ecosystems to the rural poor in developing countries is typically expressed in terms of dependence of income on forest products. In the analysis undertaken by Vedeld et al (2004) around one fifth of total household income was found to be derived directly from forest products (see Box 2.6).

Box 2.6: Forest incomes and the rural poor (Vedeld et al, 2004)

This study, which was funded in part by the World Bank, carries out a meta-analysis of the results reported by 54 studies that investigate the extent to which rural households in developing countries (particularly African countries with an even mix of studies focussing on wet, semi wet and dry forests) depend on income from forest resources. In the analysis undertaken, the average household derived approximately US$678 per year (adjusted for purchasing power parity) in terms of forest income. Overall, total average household income was US$3043, implying that forest income is around 22% of total income. Vedeld et al also note that although agriculture and off-farm income generally display higher income shares, forest uses represent a significant source of income, being particularly important for households close to the survival line. Forest income is shown to be of particular significance with respect to 'gapfilling' and 'safety nets', providing an additional source of income in periods of both predicted and unpredicted shortfalls in other livelihood sources.

In order to reduce use and encourage conservation of forests, policy interventions try to increase the efficiency of returns to current uses or to provide alternative sources of income to the poor. Increasingly, however, there is the recognition that such efforts are failing to achieve the intended outcomes (Sayer 2000; Fisher, 2000; Conrad and Ferraro, 2002). Fundamental conceptual deficiencies include the likelihood that communities are more likely to view new activities as additional sources of income rather than substitutes. Furthermore, the more indirect approaches such as investments in ecotourism and NTFP marketing are likely to fail when the social, political, economic and technical conditions required for success are lacking in the target areas. Annex 2 provides further reasons why these interventions may not be successful.

2.2.3 Key conclusions and recommendations

A number of conclusions and recommendations can be drawn from the literature review summarised here and in Annex 2.

Demonstrating the value of forest ecosystem services can enable more sustainable land use decisions to be made. For most forest services, the economic value is demonstrated fully when the service is already threatened and the economic costs of their loss begin to be incurred.

Arguments for forest conservation over forest exploitation seem to be won only where it is possible to demonstrate the total economic value of conservation. Estimates of total economic value should address not only the use values enjoyed by local communities but also benefits enjoyed by the global community in the form of wildlife protection, carbon sequestration and option and non-use values.

While it is useful to demonstrate all components of the total economic value of forests and to use these in cost-benefit analysis of conservation, in practice this is not a sufficient incentive to change forest use behaviour. What is needed are mechanisms to capture the global benefits so that it may be realised by local populations and host country governments.

By explicitly defining property rights and establishing contracts for the provision of ecological services, ‘payments for environmental services’ are an overtly direct approach to the conservation of forest ecosystems and the preservation of biodiversity. The rationale is simple: conservation can be achieved by increasing the value of forest ecosystems to local communities. If local inhabitants are the principal agents of land conversion, then it must be their behaviour that must change to protect the ecosystem (Ferraro, 2001). This entails shifting revenue streams to change the comparative advantage of resource exploitation. Hence the revenue received from conservation must exceed the revenue from conversion of land.

Instances of carbon trading (even though sequestration credits are not yet tradable under the Kyoto Protocol) and examples of service payments in Mexico and Costa Rica (see details in Annex 2) provide examples of such thinking. These payments have the benefits of relative simplicity; addressing both short and long term concerns; achieving conservation objectives at ecosystem scale; direct provision of incentives to protect habitats; and mitigating political and social conflicts over resource allocation. Finally, successful forest conservation requires other broader policy interventions such as the removal of perverse subsidies.

2.3 Agro-ecosystems

Agro-ecosystems are estimated to cover between 28 and 37% of total land area, though this includes some overlap with forests and grasslands, given ecosystem fragmentation. About 69% are permanent pasture while the remainder are crops, of which 91% are annual and 9% perennial (WRI, 2001). These human dominated landscapes range from highly intensive and mechanised agricultural systems to more extensive subsistence systems.

Agriculture is a critical economic sector, especially in the developing world. It is most important to the economies of low-income countries, accounting for approximately 31% of GDP overall and 50% of GDP in Sub-Saharan Africa. In the middle and high income countries, by contrast, it accounts for 12% and 1-3% of GDP, respectively. Yet conventional measures of GDP greatly understate agriculture’s contribution to the economy, which should also include upstream and downstream manufacturing and services. Agriculture also provides many jobs, in the order of 56% to 65% of the total labour force in Asia and Sub-Saharan Africa (WRI, 2001).

The case of agriculture and ecosystem services is thus a particularly pertinent one, as agriculture is essentially a man-made ecosystem. At the same time as natural cycles (e.g. carbon and nutrient cycles) affect agriculture, they are altered by farming activities. Therefore, this section, in contrast to the previous two, highlights the role of biodiversity and ecosystem services in *providing for* agriculture, and examines the fragile relationship between certain farming practices and sustaining ecosystem services.

Table 2.3 provides an overview of ecosystem goods and services provided for and by agro-ecosystems.

Table 2.3: Total Economic Value of agro-ecosystem goods and services

	Goods and Services	Local	Regional	Global
Direct Use	Plants/food	x	x	x
	Livestock/Food	x	x	x
	Visual amenity of agricultural landscapes	x	x	
Indirect Use	Pest and disease control	x	x	
	Soil processes - soil nutrient cycling - maintenance of soil structure and porosity - maintenance of soil fertility	 x x x	 x x x	
	Pollination	x	x	
	Nutrient cycling	x		
	Water quality and quantity	x		
	Carbon Storage			x
	Genetic diversity	x	x	x
Option*	Future direct and indirect uses of above goods and services	x	x	x
Non-Use*	Traditional/cultural knowledge & traditions	x	x	x

*: These value components are not illustrated separately in what follows but are referred to under the ecosystem services as relevant.

2.3.1 Services provided by agro-ecosystems

This section focuses on the indirect use values of the agro-ecosystem services given the familiarity and abundance of data about the agro-ecosystem goods. The estimates of economic value reviewed concentrate on linking the ecosystem services as inputs to agricultural outputs which are not directly marketed (e.g. the effect on yield and income of soil stabilisation services provided by different plants). Further details are presented in Annex 2.

Pest and disease control

The loss of plant diversity that accompanies agricultural simplification of a landscape frequently results in less diverse but more abundant pest species (Andow, 1991 and Tonhasca and Byrne, 1994). The common solution to this problem is the application of pesticides, of which 2.5 million tonnes are applied annually to crops worldwide (Pimentel et al, 1993). In contrast, more diversified and less intensive agro-ecosystems retain natural pest control by supporting a greater number and diversity of predators and parasites that attack herbivorous pest species (Andow, 1991 and Russell, 1989).

While integrated pest management (IPM) has demonstrated the successful use of host plant resistance, natural biological control as well as reduced pesticide application to protect crops from pests (Naylor and Ehrlich, 1997), it has not been widely adopted because of subsidised pesticide costs and the knowledge-intensive management that is required by IPM.

Soil processes

The organic component of soils provides a critical service in maintaining soil structure, facilitating water storage and retention, reducing erosion and providing the organic matter from which nutrients are released. Conversion of tropical forests to agriculture can result in substantial losses of soil organic matter by as much as 50% within five years (Matson et al, 1997). Soil communities from agricultural systems have been shown to be substantially poorer in abundance and diversity than the soil communities of natural systems from which they are derived (Lavelle and Pshanasi, 1989). Degradation of the soil community occurs by removal and burning of the surface vegetation, tillage and substantial decrease in organic inputs into the soil among other factors.

Soil condition is a key measure of the long-term productive capacity of an agro-ecosystem. Both natural weathering and human management affect soil quality, and maintaining soil quality requires that soil-degrading and soil-conserving processes be balanced (WRI, 2001). (see Box 2.7)

Box 2.7: Extent of Soil Degradation Worldwide

Productivity losses due to soil degradation have been greatest in developing countries, since industrialised countries use high levels of farm inputs and tend to have deep soils that can better withstand soil degradation (Oldeman, 1998). Sub-regional studies have documented significant aggregate declines in crop yields due to degradation in parts of Asia, Africa and Central America. Economic losses due to soil degradation range from 1% to 9% of agricultural GDP in eight African countries (Bojo, 1996), from 3 to 13% in different parts of Mexico (McIntire, 1994) and 7% in South and Southeast Asia (Young, 1994). In terms of area, agricultural productivity is estimated to have declined significantly on 16% of agricultural land, notably in Africa (65%), Central America (74%) and Asia (38%) (Scherr, 1999). In terms of output, in Africa, production losses from soil erosion alone are estimated at 8%, while data from Asian and Middle Eastern countries suggest that productivity losses due to soil degradation may exceed 20% (Rattan, 1995).

Pollination

Pollination of crops is considered an ecosystem service of enormous economic value and pivotal importance, given that about one-third of foods we consume are insect-pollinated vegetables, pulses and fruits (Kevan and Phillips, 2001; Southwick and Southwick, 1992 and Nabhan and Buchmann, 1997). Reports of recent declines in both managed and wild bees, the most important pollinator group, have raised awareness of the need to conserve habitats that support these insects (Watanabe, 1994; Buchmann and Nabhan, 1996; Allen-Wardell et al, 1998). Forests and woodlands particularly have been noted to provide shelter, nest-sites, water, larval food plants and floral resources for an immense number of pollinators ranging from tiny insects to birds and bats, and decline in pollinators has been attributed to the spread of intensive farming in developed nations and the clearance of natural vegetation, particularly forests, in tropical countries.

Pollination by bees can raise the yields of coffee, one of the most valuable agricultural crops in terms of export from developing countries, by 15-50% (Free, 1993; Roubik, 2002; Klein et al, 2003a). For example, in Costa Rica flowers on coffee plants within 1km of forest received twice as many bee visits and twice as much pollen as flowers further away, and had 20% greater yields and 27% fewer deformed fruit (Ricketts et al, 2004). In this study pollination was calculated to contribute 7% of a farm's annual income.

Nutrient cycling

Nutrient supply in natural systems is largely derived from the turnover of soil organic matter which is mediated by soil nutrient cycling organisms. In agricultural settings this system is disrupted due to the substantial removal of nutrient when the crop is harvested, reduced nutrient release from organic matter, and large additions of readily available nitrogen as organic fertiliser, much of which is equally readily lost through leaching. The degradation of nutrient cycling services normally provided by an intact and diverse soil biota results in an estimated loss through leaching of 40 to 60% of nitrogen applied as inorganic fertiliser (Parton and Rasmussen, 1994 and Paustian et al, 1992) with severe downstream effects (see Section A4).

Water quality and quantity

Agriculture accounts for a large proportion of freshwater withdrawals, with about 70% used for irrigation alone. Eighty-two percent of world agro-ecosystems rely solely on rainfall, yet may nonetheless alter terrestrial water flows and water bodies. Moreover, sedimentation and leaching of agrochemicals or manure may threaten water quality. Agriculture may thus negatively impact both the quantity and quality of available water (WRI, 2001).

Mismanaged irrigation works lead to waterlogging or salinisation, which occurs on 10-15% of irrigated lands and costs farmers US$11 billion per year in reduced income, or 1% of world agricultural GDP (Postel, 1999). Rockstrom et al (2002) find a large scope for productivity gains, i.e., doubling of staple food yields, via improved irrigation and increased water retention in drought-prone areas of Africa. They also find that perceived risks associated with meteorological dry spells contribute to soil mining by making investments in fertilisation unattractive, implying that redressing water concerns could spur farmers to invest in land quality.

Carbon storage
Carbon in the form of soil organic matter (SOM) is of fundamental importance to the fertility of agro-ecosystems. SOM levels and their stability over time are key indicators of long-term soil quality and fertility, affecting water retention, cultivation, and the richness of soil biota and nutrients. When converted to agriculture, lands typically lose a significant proportion of their SOM. Carbon in soil and vegetation is also important to the global carbon cycle, accounting for 26-28% of carbon stored in terrestrial ecosystems. Land-use changes and land management practices emit an estimated 1.6 GtC to the atmosphere annually, or about 20% of human-induced greenhouse gas emissions (IPCC, 2000).

2.3.2 Challenges

Agro-ecosystems and poverty
Although modern agriculture has been relatively successful, with aggregate production rising steadily for years, continued increase in agricultural productivity is likely to mean further pressures on the environment.

For most people living in low-income, biodiversity rich countries, agriculture is also the principle livelihood. A large proportion of this agricultural activity takes place within or adjacent to biodiversity rich areas. Recent research (Cincotta and Engleman 2000; WFP, 2000) points to 1.1 billion people living within 'biodiversity hotspots', representing a fifth of all malnourished people. A total of 20% of land protected for biodiversity is land used for agriculture, while most of the remainder are 'islands within a sea of agriculture' (McNeely and Scherr, 2001).

Threats to other ecosystems
Concerns about the long-term sustainability and environmental costs of intensification include the detrimental impacts of simplified landscapes characterised by extensive monocultures and lost biodiversity, intensive pesticide and fertiliser use, and irrigation and mechanisation, all of which degrade the ecosystem services provided in less intensive forms of agricultural production. Negative environmental consequences of intensification are expressed at local scales, through erosion, reduced soil fertility and reduced biodiversity, at regional scales by the pollution of groundwater and eutrophication of lakes and rivers, and at global scales by affecting atmospheric composition and climate. Negative economic consequences include increased cost of agricultural production (due to increased man-made inputs and labour) and/or reduced income from agriculture and livestock activities.

2.3.3 Key conclusions and recommendations

A number of conclusions and recommendations can be drawn from the literature review summarised here and in Annex 2.

In order to maintain the valuable services provided to agriculture through agro-ecosystems, future agricultural management and economic policies should take into account the interaction between agriculture and the wider environment as well as the perverse pricing policies and subsidies that are still implemented in many countries.

In terms of policy measures, this requires removing the perverse subsidies that lead to overuse of pesticides and fertilisers and generally intensive agriculture. Reforms of the Common Agricultural Policy of the European Union are a step in the right direction.

In some developed countries, central governments provide subsidies to farmers for protecting habitats and biodiversity, i.e. fees for delivering ecosystem services. In developing countries, due to lack of sufficient central funds, other parties such as NGOs and international bodies will have to get involved in policy development. One such policy, the Equator Initiative (UNDP, 2004b), which aims to reduce poverty through conservation and sustainable use of biodiversity, calls for increased involvement by the food processing and producing sectors to encourage eco-agricultural practices such as reduced agrochemical use and increased use of integrated pest control service. The recommendations of the Initiative seem appropriate to repeat for the purposes of this report and include:

- A Global Programme for Eco-agriculture Research and Development should be set up to focus on collaborative projects between farmers and conservation organisations to develop operational systems, backed by socio-economic analysis and policy interventions;
- International and national policy research should determine cost-effective market, legislative and institutional interventions to promote eco-agriculture on a large scale;
- Basic research in biodiversity hotspots should focus on interactions between agricultural systems and landscape ecology; and
- Farmer education programmes should be developed, implemented and monitored.

3. Conclusions

All ecosystems deliver goods and services to humankind and therefore have economic value, where economic value is defined as all contributions to human welfare (financial, social, environmental and health). These ecosystem services include the purification of air and water, the pollination of crops, nutrient cycling and decomposition of wastes, the generation and renewal of soils, stabilisation of climate, mitigation of droughts and floods, and protecting soils from erosion. This review of the ecological and economic literature for a sub-set of ecosystems, namely, forests, wetlands and agro-ecosystems, describes the value of ecosystem goods and services from a multi-disciplinary perspective, and uses examples to demonstrate key issues.

Evidence from the ecological literature demonstrates the complexity of ecosystem functioning, and the unpredictability of ecosystem responses to the multitude of human pressures. In general, land management decisions tend to emphasise only a subset of these ecosystem consequences, and usually only at local scales, and the full range of ecosystem services is rarely recognised let alone explicitly considered. While ecological science has repeatedly highlighted the general pattern of ecosystem responses to human-imposed stress, including the existence of response discontinuities characterised by sudden and often catastrophic environmental change, quantifying these patterns and predicting the location of thresholds continue to elude us.

Evidence from the economic literature of the value of ecosystem services, differentiates between the value of goods which are used *directly* (e.g. timber, fish, etc) and those services which *indirectly* support and contribute to production systems and human welfare (e.g. watershed services and nutrient cycling). Ecosystem services are also valuable for reasons not related to their use (*non-use value*), for example because we believe they should exist for others now or in future and for their own sake. Use and non-use values combine to give the total economic value (TEV) of a resource. Through analysing the changes in the TEV, economics provides a framework that recognises the distribution of economic benefits between (or economic values held by) different stakeholders, there are gaps in the quantitative evidence base, which are discussed below.

Individual economic studies have generally been undertaken to inform a particular land-use decision at a local level, in most cases seeking to monetise the loss of total economic value due to degradation of ecosystem services. These studies have examined opportunity costs, replacement costs, contributions to local livelihoods (income), non-use values and so on. Evidence of large scale benefits from ecosystem services is demonstrated in this literature through high aggregate willingness to pay of affected populations for those services. Economic analysis also shows that maintaining ecosystems in an unused/undeveloped state is economically viable, i.e. generates higher welfare than use or development, generally only when all components of TEV are taken into account showing the importance of indirect use and non-use values.

In the face of this evidence why then does ecosystem conversion continue unabated? The answer lies in the drivers of ecosystem degradation:

- Perhaps most importantly, the willingness to pay for ecosystem services is generally not captured because of a lack of markets in these services. The relevance of economic values for ecosystem services is that they must generally be greater than the returns to ecosystem conversion and must be captured so that their maintenance can be financed and those who forgo benefits from conversion can be compensated. While there are some examples of instances where governments have created markets to capture ecosystem services, and a general evolution of markets in ecosystem services is evident (e.g. the nascent trade in carbon credits) these are isolated instances and unlikely to add up to enough to ensure an optimal provision of these services.

- The role of well-defined property rights in providing stewardship of ecosystems needs to be fully recognised. Most ecosystems are public goods associated with the classic problems of open access and overuse. International agreements (such as the Framework Convention on Climate Change) can create common property rights and partially limited open access, while for more locally defined ecosystems (like forests) private property rights may be more appropriate. Ownership should contribute to maximising economic gain together with maintenance of ecosystem services that contribute to long-term profits. In the absence of such property rights, sustainable harvest is sacrificed for short-term profit.

- The misguided policies of governments are responsible for distorting market signals, weighing the balance further in favour of ecosystem conversion, for example, through the use of subsidies and grants for tropical forest conversion, agricultural intensification and fisheries. Furthermore, many governments are also tainted with corruption, which contributes further towards land-use decisions that are made in the interests of the few, rather than the interests of the many.

- Increasing pressure on ecosystems through population growth, poverty and increasing personal or household consumption all contribute to the problem.

- The lack of ecological and economic information as well as the awareness of the value of ecosystem services at individual, commercial and public policy levels also contributes to the mismanagement of ecosystems. This report recommends wider recognition of these values, and the use of economic and ecologic frameworks for analysis.

- However, incorporating ecological and economic information into decision-making is not enough to ensure that ecosystems are used sustainably. As the Case Study 1 in Annex 1 concludes, the strong political power of the logging and plantation industries as well as the wide dispersion of the main beneficiaries of conservation prevent the most economically desirable outcome and also prevents the losers from deforestation from being compensated by those who gain.

Making decisions that reflect sustainability concerns requires taking into account the full range of costs and benefits to all stakeholders, and selecting outcomes that present a net benefit to society over the long term. They also require addressing the above factors contributing to unsustainable use of ecosystems and their eventual degradation and loss at local, regional or even global levels. Following the above analysis of drivers of ecosystem degradation, we can summarise the potential solutions using the same structure.

Addressing market failure
Where ecosystems are demonstrated to provide services that have higher value than under scenarios of ecosystem conversion, governments should intervene to correct the traditional market failures associated with externalities and information failure. The role of economic data on the value of ecosystem services is in informing the optimal provision of ecosystem services, where use of ecosystem services is balanced with preservation. Integral to establishing this level of use is improved understanding of ecosystem dynamics and integration of ecosystem and economic models.

There is a wide array of measures to tackle the undervaluation of ecosystem services. They include outright protection (which in some cases is appropriate, e.g. for genetic safeguarding), standard regulation, economic regulation in which polluters pay, and market creation. Table 3.1 presents an overview of measures used for conservation or sustainable use of biodiversity (or ecosystem services). The table, which summarises some of the discussion presented earlier in the report, illustrates these measures as lying along a scale from direct to indirect measures, where ‘direct’ entails a more direct payment for services. The potential discussion to be had here is lengthy and the subject of a number of books: this report has only been able to raise a few of the issues, and only briefly.

Table 3.1: Spectrum of Conservation Incentives

	Incentive Strategy	Example	Strengths/ Limitations
(Least direct) ↓	Exclusion and alternative income generation project	Protected areas with buffer zones – subsidies for agroforestry, agricultural intensification, industry in laternative locations	Few projects meet conservation and development objectives; limited options for expansion
	Use and marketing of extracted biological products	Non-Timber Forest Products	Good market demand but finite resources and often low market values; transportation difficulties; possibility of intensification
	Use and marketing of biodiversity with relatively intact ecosystems	Ecotourism, bioprospecting, apiculture, hunting	Limited prospects, successful in some areas; not always good for biodiversity
	Compensation (for foregone revenue) for reduced impact land and resource use	Direct subsidies, price subsidies	Targetting problems; expensive; addition instead of substitution
	Direct payment for environmental services	Watershed protection, carbon sequestration	Biodiversity as a side benefit, may or may not be protected
	Acquiring land (retirement) and biodiversity use rights	Easement, non-logging concessions, conservation leases	Success dependent on institutional environment; local issues
(Most direct)	Direct payment for conservation performance	Payment for actual successes - e.g. number of breeding birds, rare plant specimens	Specifies outcomes not just application of conservation techniques; dependent on monitoring and verification

Source: adapted from Ferraro and Kiss (2002)

Addressing the special links between ecosystems and poverty

Many policy opportunities present themselves to reduce poverty by protecting the ecosystems and generally improving environmental quality. Those that address market and governance failures also contribute to reduction of poverty. However, the following can also be considered with specific objective of poverty reduction in mind (DFID et al, 2002):

- Enhance the assets of the poor:
  - Strengthen resource rights of the poor
  - Enhance the poor's capacity to manage the environment
  - Expand access to environmentally-sound and locally-appropriate technology
  - Reduce the environmental vulnerability of the poor
- Improve the quality of growth:
  - Integrate poverty-environment issues into economic policy reforms
  - Encourage appropriate private sector involvement in pro-poor environmental management
  - Implement pro-poor environmental fiscal reforms
- Reform international and industrial country policies:
  - Reform international and industrial country trade policies
  - Make foreign direct investment more pro-poor and pro-environment
  - Enhance the contribution of multilateral environmental agreements to poverty reduction
  - Encourage sustainable consumption and production
  - Enhance the effectiveness of development cooperation and debt relief.

Addressing governance failure

Any of the measures listed in Table 3.1 require a consistent and comprehensive policy framework to be in place. Key areas for policy action that will contribute to the successful implementation of these measures and improve poverty-environment linkages (based on DFID et al, 2002):

- Integrate poverty-environmental issues into national development frameworks;
- Decentralise environmental management;
- Empower civil society, in particular poor and marginalised groups;
- Address gender dimensions of poverty-environment issues;
- Strengthen anti-corruption efforts to protect the environment and the poor;
- Reduce environment-related conflict;
- Improve poverty-environment monitoring and assessment; and
- Improve the property rights regimes.

Addressing the lack of information

Lack of sufficient information demonstrates itself in ecological research, economic literature and the effectiveness of economic and environmental policy measures.

In the face of the uncertainties about the impact of human activities on ecosystems, the greatest challenge for ecologists is to parameterise existing models of ecosystem response allowing for an informed and economically optimal decision making environment. Finally, ecological science provides a conceptual framework by which the responses of different ecosystem services may be recognised at appropriate scales. Assessing the outcome of land use decisions requires explicit recognition of several spatial and temporal scales of analysis. Integrating our knowledge of ecosystem properties and dynamics into economic assessments of land use is essential to determine the full costs of alternative land-use options.

Most of the economic studies reviewed for this report concentrate on a single use of a single good or service of a given ecosystem. This assessment of the literature is also made by Turner et al (2003). The difficulties in understanding the ecosystem dynamics and reflecting these in decision-making, however, lie in the interactions of multiple goods and services of ecosystems and how these affect the benefits received from these ecosystems. Therefore, future economic research in this area should consider a range of interdependent ecological functions, uses and economic benefits at a given site; or track changes in site values across different states of ecological disturbance. The information from this will not only help decision makers with the complex trade-offs between conservation, sustainable use and development but also trade-offs between local, national / regional and global beneficiaries.

The measures that can capture more of the economic value and increase the incentives for conservation are touched upon only briefly here due to the scope of the current study. Future research should investigate the necessary conditions for such measures and their relative merits. For example, the research could (i) examine the success of a particular incentive mechanism across locations (e.g. countries); (ii) consider the appropriateness of mechanisms for different ecosystems or types of ecosystem stress; or (iii) study the relative effectiveness of different mechanisms in a particular location. A starting point for this research would be a review of the literature on finance for ecosystem services, which is continually being updated.

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Glossary

Altruistic value: Person A's willingness to pay for the continued enjoyment of person B's use of environmental resources.

Avertive expenditures (or avoidance cost): Expenditures undertaken to avoid or mitigate the impacts of pollution.

Consumer surplus: The difference between the amount paid for a good or service and the maximum amount that an individual would be willing to pay.

Contingent valuation: A survey technique used to derive values for environmental change by estimating individuals' willingness to pay (or to accept compensation) for a specified change in the quality and quantity of a resource.

Cost-benefit analysis: A form of economic analysis in which costs and benefits over time, expressed in monetary units, are compared.

Discounting: Converts costs and benefits occurring at different points in future into comparable units of today (present value).

Ecological redundancy: the natural insurance capacity provided by diverse biological systems, see also *Functional insurance* and *Functional redundancy*.

Ecosystem function: all ecological processes that contribute to the maintenance of biological systems, regardless of whether they are beneficial to humans.

Ecosystem goods: products derived from natural systems that are harvested or used by people.

Ecosystem services: ecological processes that form the subset of ecosystem functions that benefit people.

Ecosystem: a community of organisms and their physical environment interacting as an ecological unit.

Existence values: Values that result from an individual's desire to ensure that an environmental asset is preserved for its own sake (a type of nonuse value).

Externalities: Changes that are not reflected in actual market prices; uncompensated impacts that affect third parties. Goods that remain unpriced and thus are external to the market (i.e., free goods such as those relating to the environment, with an example being clean air).

Financial analysis: Aimed at determining the financial gains and losses due to a policy or a project.

Functional insurance: an ecosystem property that contributes to ecosystem stability and is based on species that have similar functional roles but different responses to perturbation.

Functional redundancy: the degree to which species fulfil the same role in ecosystem processes and are therefore expendable with respect to ecosystem performance.

Hedonic pricing method: An implicit price for an environmental attribute is estimated from consideration of the actual markets, which are influenced by the quality and quantity of the environmental resource of concern (e.g., water quality improvements and property values).

Landscape: a mosaic of different ecosystems within a defined area.

Market price approach: In a perfectly competitive market, the market price of a good provides an appropriate estimate of its economic value (excluding nonuse values. In markets that are not perfectly competitive, economic value is calculated by removal of subsidies or other price distortions.

Net present value: The present value (i.e., in year 0) of the difference between the discounted stream of benefits and the discounted stream of costs.

Nonuse value: A value that is not related to direct or indirect use of the environment (e.g., existence, altruistic, and bequest values).

Opportunity cost: The value of a resource in its next best alternative use.

Option value: Value to a consumer of retaining the option to consume a good or service in the future.

Replacement costs: Impacts on environmental assets are measured in terms of the cost of replacing or re-creating the asset.

Resilience: the capacity and rate of ecosystem recovery to its original condition following perturbation.

Resistance: the degree to which an ecosystem is shifted from its original state by perturbation.

Total economic value: The sum of use values (direct use, indirect use, and option) plus nonuse values (altruistic, bequest, and existence).

Transfer payment: A payment for which no good or service is obtained in return (e.g., a tax or subsidy).

Travel cost method: The benefits arising from the recreational use of a site (or cost of collecting natural resources like firewood and water) are estimated in terms of the costs incurred in travel to the site.

Uncertainty: Stems from a lack of information or scientific knowledge and is characteristic of all predictive assessment.

Use value: A value related to the actual direct or indirect use of the environment (e.g., recreational value).

Willingness to accept compensation (WTA): The amount of money an individual would be willing to accept as compensation for forgoing a benefit or tolerating a cost.
Willingness to pay (WTP): The amount of money an individual would be willing to pay to secure a benefit or avoid a cost.