Chapter 3

Linking Ecosystem Services and Human Well-being

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Main Messages

Ecosystem services are indispensable to the well-being of all people in all places. Ecosystem services are the benefits that people obtain from ecosystems, including food, natural fibers, a steady supply of clean water, regulation of pests and diseases, medicinal substances, recreation, and protection from natural hazards such as floods. Human well-being consists of security, the basic materials for a viable livelihood (food, shelter, clothing, energy, etc., or the income necessary to purchase them), freedom and choice, good health, and good social-cultural relations. Links exist in both directions between the flow of ecosystem services and the level of human well-being. These linkages can be illustrated at all scales, from local to global; in all places in the world, from the least to the most developed; and for all peoples, from the poorest to the wealthiest and the rural to the urban and industrialized. There are important issues of equity involved: Who experiences the gains and losses in ecosystem services under conditions of ecosystem change? How are the services and well-being distributed across space and/or time? These issues can only be satisfactorily resolved by adopting a comprehensive approach to development that simultaneously considers ecological, social, and economic outcomes, balancing the interests of all affected groups, as well as the benefits in the present against the options that will be available to future generations.

Despite their obvious importance, ecosystem services are in decline in many places around the world (though some services are increasing in some areas, for example food production in managed ecosystems). In some cases, the loss may be too gradual to be noticed, or may be compensated by increases in other services or in some aspects of human well-being. In other cases, the loss of services is borne by people other than those causing the decline. A special case of the latter occurs when future generations bear the loss, while current generations reap the benefits.

Where the link between ecosystem services and human well-being is clear and immediate, affected people are more likely to develop regulatory institutions to ensure the continued supply of services. In some situations, though, the flow of services may be appropriated by more powerful groups. Also, if the link is obscured, ecosystem services may be undervalued and a severe loss of service can then result. Common reasons for the link not being apparent to all parties include: slow feedbacks (effects are felt long after the causes have taken place); displacement in space (effects are felt far from the cause); or displacement in social class (effects are principally felt by people without power).

The relationship between ecosystem services and human well-being can take on several different forms. Often, rising incomes are initially accompanied by declines in some ecosystem services. Once a sufficient level of wealth is achieved, societal priorities may emphasize the quality of the environment and the services it delivers. In other cases, there is no evidence for such a turn-around, and some services may decline continuously with increasing wealth. In yet other cases, a particular service may improve continuously in tandem with increasing wealth. Note that we do not equate human well-being with wealth; wealth is simply one important and frequently measured component of well-being.

In places where there are no other social safety nets, diminished human well-being tends to increase the immediate dependence on ecosystem services. The resultant additional pressure can damage the capacity of those local ecosystems to deliver services, and this capacity can decline to such a degree that the probability of disaster or conflict increases. The non-linear nature of both human and ecological systems and of the relationship between them means that there are some ecosystem damage thresholds that, if crossed, may prove to be irreversible. In this important respect, the future of the society-ecosystem relationship is rarely a simple linear extrapolation of recent trends or current conditions.

3.1 Introduction

This chapter interprets the MA conceptual framework (summarized in Chapter 1) in the context of local and regional assessments, with specific reference to ecosystem services and human well-being. The chapter illustrates, with examples from the sub-global assessments, different approaches to the measurement of human well-being; linkages between ecosystem services and well-being; and the challenges inherent in identifying and attributing those links. The chapter is not meant to be comprehensive in its treatment of these areas: the main findings of the sub-global assessments follow in the eight topic chapters and the final synthesis chapter of this volume. In addition, reports from each sub-global assessment have been, or will be, independently published.

History shows that human well-being, and indeed the persistence of civilizations, is strongly linked to the capacity of their environments to continue to deliver ecosystem services at the local to regional scale. (See Box 3.1.) The linkage works in both directions:

- human well-being depends, to a large measure, on the many services provided by nature; and
- the state of the environment is affected by the size and consumption patterns of human populations in ways that reduce or increase (at least temporarily) the supply of ecosystem services.

If the connection between ecosystem services and human well-being is so strong, why do people behave in an apparently irrational manner by undermining factors necessary for their own good? There are several possible reasons. Many ecosystem services, such as a benign climate, soil fertility, or the flow of water in rivers, are easily taken for granted, especially by urban people in industrial economies. Many people tend to think of the supply of these services as happening automatically and eternally, or they are unaware of their importance to them. In other cases, for instance, with respect to the maintenance of biodiversity, the causal connection with human well-being is not immediately and universally obvious. Who is disadvantaged if some obscure insect becomes extinct? In yet other cases, the loss of a service is a cost borne collectively, while the benefits arising from an action that lead to that loss are enjoyed by a smaller group, resulting in behavior that is rational for the individual but irrational for society as whole. In many instances, the feedback loop between declining ecosystem services and human well-being is slow, or operates at a distance, and this results in the warning signals being missed. Insensitivity to the impending collapse of ecosystem services appears to be a common and widespread phenomenon in historical examples.

3.2 What Are "Ecosystem Services"?

Ecosystem services are the benefits that people obtain from ecosystems (MA 2003). It is clear that the forest dwellers of Papua New Guinea, for example, gain a direct and immediate benefit from the subset of foods that they harvest from their rainforest ecosystem. Less obvious, but nonetheless as

BOX 3.1

Ecosystem Services and the Failure of Civilizations

There is thought-provoking, though sometimes controversial, evidence that failure to maintain an adequate supply of ecosystem services has been a major cause of societal collapse and attendant loss of human well-being in the past.

The best-established example is Easter Island in the southeast Pacific (Tainter 1988; Diamond 1997; Diamond 2005). Polynesian people settled the previously uninhabited island around 900 AD. They thrived initially, but eventually denuded the island of forest. The trees were needed as rollers for transporting massive stone statues, the poker-faced *moai,* to their ocean lookout posts. Massive soil erosion ensued, impairing the growth of crops. Wooden canoes for fishing could no longer be built. The seeds of native plants were eaten by introduced rats, and pollinating birds were lost. In consequence, from an estimated peak population of around 7,000 in the fifteenth century, numbers dwindled, conditions deteriorated, and warfare and cannibalism broke out. When Dutch explorers landed in 1722, there were fewer than 2,000 inhabitants—plus several hundred *moai.* By the nineteenth century, the survivors had dwindled to several hundred.

The civilizations in Mesopotamia, in the Tigris-Euphrates valley, were among the first examples of agrarian states. In earlier millennia within the surrounding Eastern Mediterranean region, between 7,000 and 11,000 years ago, several important crops and animals were probably domesticated. Writing, on clay tablets, appears to have been invented in Sumeria, the first major Mesopotamian civilization, around 5,000 years ago. Archaeological and historical evidence indicates that Sumeria suffered progressively from salinization of agricultural lands, following extensive deforestation and the use of irrigation (Jacobsen and Adams 1958; Ponting 1992). Between 4,000 and 5,000 years ago, wheat was gradually replaced by barley, a more salt-tolerant cereal. During the subsequent half millennium, Sumeria's agricultural productivity declined below the population's needs, causing the center of Mesopotamian civilization to move northwards, to Babylon.

The Mayan civilization is thought to have collapsed around a thousand years ago under the dual stress of an adverse regional climatic cycle extending over several centuries and excessive agricultural demand on fresh water supplies (Diamond 1997; Fagan 1999).

On the other hand, there is little evidence that ecosystem service constraints were behind the decline of the Greek, Roman, Inca, or Ming Chinese civilizations, to name but a few. In other cases, ecosystem service reduction may have been a contributory factor, but either its role is not fully established or its relationship to other factors is unclear (Tainter 1988, 1995). For example, the three main Egyptian dynastic periods and their intervening periods of collapse correspond closely with periods of above and below average flow of the Nile river (Bell 1971; Butzer 1984).

There are also historical examples of societies that have culturally evolved so as to live in balance with their natural resource base over a long period of time. (See Chapter 11 for an example from the highlands of Peru; see also examples in Diamond 2005.)

Failure of ecosystem services is thus implicated in many societal collapses in the past, but not all. As Diamond (2005) points out, the critical issue is how a given society chooses to respond to the signals of emerging problems.

real, is the benefit that urban people gain from both their local urban ecosystem (for instance, the amelioration of microclimate provided by plants in cities) or from the existence of food-producing and other ecosystems far from where they live. There are many types of ecosystem services, and several ways to classify them. The MA divides these into provisioning services, regulating services, supporting services, and cultural services, each of which has several sub-categories. (See Chapter 1.) Most MA sub-global assessments used these concepts but some, such as Vilcanota or Bajo Chirripó, adopted local concepts of "ecosystem services."

Biodiversity is a special case: in some respects it is an ecosystem service, and in other respects it is not. The distinction is subtle but important, and remains a source of much confusion, partly because the word "biodiversity" is often used outside the MA as a synonym for "life on Earth." Certainly, *all* ecosystem services require the existence of living organisms for their delivery, but in many cases it is not the *diversity* of the organisms that is important, but the presence of a viable population of at least one species representing a particular functional group. For example, a well-regulated hydrology requires plant cover, but there is no a priori reason to suspect that low-diversity vegetation would perform this function differently from high-diversity vegetation, if it had comparable leaf area, height, and stomatal conductance.

On the other hand, there are many cases where the *diversity* itself is essential to the service; such cases use the term biodiversity in its true sense—referring to the *variety* of genes, species, and ecosystems. For example, nature-based tourism sets out to appreciate diversity, not uniformity, and much other conventional tourism is enriched by the biodiversity encountered incidentally. The delivery of many ecosystem services requires a non-trivial amount of biodiversity, but not necessarily the maximum amount possible in that environment. For example, it is possible to produce food using a single crop cultivar growing in an abiotic nutrient solution, but in the long term, sustained productivity, adaptation capacity, pest resistance, and balanced nutrition depend on the existence of a diverse genetic pool in both the crop plant and the environment that supports it. Nevertheless, even an agro-ecosystem managed for high biodiversity typically has significantly less biodiversity than the native vegetation it replaces. Because of these complexities, the MA has chosen to treat biodiversity in general as an underlying condition that is required, in varying degrees, for the delivery of ecosystem services. Where biodiversity is clearly a service in its own right, it is identified as such.

There are some things related to natural ecosystems and the geophysical forces of Earth that do us harm rather than good. Examples are floods, landslides, and outbreaks of pests and diseases. We would not in normal language call them "services," but the MA does not treat them as a separate class, because the degree of their impact remains sensitive to ecosystem condition. For instance, all floods may be hazardous, but actions that are taken in the upper catchment can cause floods to be less frequent or less severe. This amelioration of an adverse impact is clearly a benefit to society. In some cases, one group of people sees the "service" as a benefit, while for others it is a disbenefit. For example, elephants are a boon to tourists, but a bane to small farmers. The MA conceptual framework treats all such examples as "services," even if in some cases the net impact on human populations is negative. This allows the net benefit, or change in benefit, to be assessed. The magnitude of a negative impact can often be altered by human action.

A major reason for conducting the MA simultaneously at several scales, and thus for having regional and local components, is that ecosystem services are scale-, time-, and location-dependent. The interplay between an ecological system and the human sub-systems embedded in it (both of which vary in time and space) means that ecosystem services tend to occupy particular space-time domains with somewhat fuzzy boundaries. At a local scale, a particular fruit may only be produced and consumed in a certain area, and only in certain seasons. At the other end of the space-and-time scale, climate change may occur over large regions and long periods of time.

The delineation of the domain and scope of individual MA sub-global assessments was left to the teams involved in their execution, in consultation with their stakeholders. This process generally involved a congruence of institutional factors (such as political governance boundaries) and biophysical factors (for example, the extent of a watershed). Having agreed on a domain, the user group at that scale then determined the most important ecosystem services to be assessed. Table 3.1 shows the range of the services addressed by a sample of MA sub-global assessments.

3.3 Human Well-being and Its Components

There is widespread recognition that human well-being includes the range of assets and experiences in Table 3.2, adapted from the MA conceptual framework (MA 2003; see also Chapter 1 of this volume). Human well-being has many components, including many aspects *not* based in ecosystem services. Moreover, the components of well-being are experienced and perceived differently across cultures and socioeconomic gradients. (See Chapter 11 for examples of different local perceptions of well-being.)

These components of well-being refer to personal and social functioning, and they express what a person values doing or being (Sen 1999). Well-being also needs to be understood at the supra-individual level, since some aspects of well-being are primarily a collective experience or the property of a community (for example, resilience to ecological shocks or stress). Indeed, the colloquial phrase "well-being of nations" reflects this perspective. Nevertheless, research—especially the *Voices of the Poor* study conducted in 23 countries (Narayan et al. 1999; Narayan et al. 2000)—has shown that poor people consistently stress that well-being depends primarily on having the "basic material minimum requirements for a good life," and they attach particular importance to secure and adequate livelihoods that enable them to provide for their children. The well-being of humans, as social beings, requires a society with a sufficient amount of social, human, and natural capital, as well as manufactured (that is, conventional economic) capital. Within ethnically and economically complex human cultures, trade-offs and exchanges occur among these types of capital. For example, the accumulation of manufactured capital is often achieved at the cost of natural capital, and sometimes at the cost of social capital. In the longer term, however, the stocks of all these forms of capital depend on the continuing flow of services from the natural world. In this sense, nature is the true "creator" to whose products human societies seek to add economic and cultural value, so as to suit the needs and purposes of society.

The management of shared natural resources poses particular institutional challenges that have been solved in different ways at various times and places. One common response is regulation to prevent abuse and free-riding; Hardin refers to "mutually agreed mutual coercion" (Hardin 1968). Another response is the process of enclosure and privatization. There is growing evidence that these are not the only effective approaches, and may not always work (Dietz et al. 2003). Since the early 1990s, there has been a worldwide proliferation of community-based groups seeking sustainable management of river basins, forests, irrigation systems, pests, wildlife, and fisheries (Pretty 2003). This indicates the potential for environmentally directed social capital to achieve a sustainable flow of ecosystem services.

The relationship of ecosystems and their services to human well-being is complex, and may change over time. Some ecosystem changes are planned, but many are the inadvertent result of other human activities—and these in particular may harm and impoverish people who are already disadvantaged. The sustainable well-being of a community at large depends on the continued flow of ecosystem services, and on the distribution of benefits and costs. Further, in an increasingly interconnected world, those gains and losses may be experienced at great distance in both space and time. Hence a further important criterion of well-being is the capacity to adapt in situations of change, and to do so without compromising the well-being of others, either now or in the future.

The MA used a range of methods and approaches to assess well-being. Some MA sub-global assessments used indices: for example, the assessment of Coastal British Columbia in Canada constructed an index of human well-being with 49 different indicators selected by experts and stakeholders (Coastal BC). Others used standalone indicators for each of the components of well-being, like the assessment of San Pedro de Atacama in Chile. Some used both indices and indicators, such as the Southern Africa Gariep Basin assessment (SAfMA Gariep), which used the Human Development Index developed by UNDP and socioeconomic indicators such as GDP per capita, unemployment rates, the Gini coefficient, primary school enrolment, life expectancy, and the age dependency ratio. Still others, in particular local level assessments, assessed well-being as perceived by the communities involved: Trinidad's Northern Range, the Bajo Chirripó in Costa Rica, and Sistelo in Portugal are examples of such assessments. Different criteria for well-being were identified by different communities; in

Table 3.1. Ecosystem Services in Selected MA Sub-global Assessments. This table reflects the individual sub-global assessment teams' own evaluations of how comprehensively they assessed services. The data were collected at the Knowledge Market session at the meeting of the Working Group in Alexandria, Egypt, in March 2004. (See Box 2.1 for a description of the "knowledge market" process.) Key: + + + = assessed comprehensively, + + = moderately assessed, + = slightly assessed. X = important to stakeholders, but not assessed.

Sub-global Assessment	Food, incl. Livestock and Fish	Water Supply	Fuel and Energy	Biodiversity-related	Carbon Sequestration	Fiber and Timber	Runoff Regulation	Cultural/ Spiritual Amenity	Other
San Pedro de Atacama	+	+ + +		+ +			+ +	+ + +	astronomical observation, minerals
Caribbean Sea	+ + +	+ +	+	+ + +				+ + +	shoreline stabilization, coastal water quality
Coastal BC	+ +			+ + +		+ + +	+	+ +	
Tropical Forest Margins	+ + +	+ + +		+ + +	+ + +	+ + +	+ +	+	nutrients, trace gases, grazing, pest control, air quality
India Local	+ +	+ + +	+ + +	+ + +		+ + +	+ +	+ + +	non-wood forest products (e.g., bidi leaves *Diospyros mespiliformis*)
PNG National	+ +	+ +	+	+ + +		+ +	+ +	+ + +	
PNG Local	+ + +	+ + +	+ +	+ +		X	+ + +	+ + +	gold
Laguna Lake Basin	+ + +	+ + +		+ + +	+ +			+	greenhouse gases
Portugal	+ + +	+ + +		+ + +	+ + +	+ + +	+ + +	+ +	primary production, erosion control
SAfMA	+ + +	+ + +	+ + +	+ + +				+ +	air quality, desertification
SAfMA Gariep	+ + +	+ + +	+ +	+ + +			+	+ +	minerals, air quality
SAfMA Livelihoods	+ + +	+ +	+ + +	+ + +		+ +	+ +	+ +	medicinal plants
SAfMA G–M	+ + +	+ + +	+ +	+ +		X	X	+	landscape importance
SAfMA Zambezi	+ + +	+ + +	+ +						
Sweden KW	+ + +	+ +		+ + +		+	+ + +	+ + +	filtering of nutrients, ecotourism
Sweden SU	+	+		+ + +	+ + +	+	+	+ + +	noise reduction, air quality, ecotourism
Northern Range	+ +	+ + +		+ +	X	+ +	+ + +	+ + +	land space for living
Mekong Wetlands	+ + +	+ + +	+	+ + +	+	+	+ + +	+	medicinal plants
Western China	+ + +	+ + +		+ + +	+ + +		+		desertification, soil erosion
Bajo Chirripó	+ +	+ + +		+ + +		+		+ + +	medicinal plants
Colombia	+ + +	+ + +		+ + +				+	
Eastern Himalayas	+	+ + +	+ +	+ +				+	
Sinai	+ + +	+ + +	+	+ + +			+ + +		medicinal plants, grazing
India Urban	+ +	+ + +	+ +	+ + +	+ +			+	human wildlife conflict, waste recycling
São Paulo	+ + +	+ + +		+ + +	+ +	+ + +	+ + +	+ + +	microclimate regulation, air pollution control, disease control, space
Altai-Sayan	+ +	+	+	+ + +		+ + +		+ + +	medicinal plants, habitat

Table 3.2. Components of Human Well-being. Well-being depends substantially, but not exclusively, on ecosystem services. The top-level categories are general, while the sub-elements relate specifically to the contribution by ecosystem services.

Security[a]

- a safe environment
- resilience to ecological shocks or stresses such as droughts, floods, and pests
- secure rights and access to ecosystem services

Basic material for a good life

- access to resources for a viable livelihood (including food and building materials) or the income to purchase them

Health

- adequate food and nutrition
- avoidance of disease
- clean and safe drinking water
- clean air
- energy for comfortable temperature control

Good social relations

- realization of aesthetic and recreational values
- ability to express cultural and spiritual values
- opportunity to observe and learn from nature
- development of social capital
- avoidance of tension and conflict over a declining resource base[a]

Freedom and choice

- the ability to influence decisions regarding ecosystem services and well-being

[a] Extreme breakdown of social relations can deteriorate into armed conflict, and thus in some cases could be considered an aspect of the security component of well-being.

BOX 3.2

Human Well-being as Perceived by Selected Communities Assessed

In the *Gariep Basin of Southern Africa,* different communities identified different criteria for well-being. For example "not being vulnerable" was an important criterion for people in Sehlabathebe, "self-determination" featured strongly as a criterion in the Richtersveld and the Great Fish River sites, and communities' sense of belonging was more important than cash in the Kat River Area. In each of the three communities, livestock ownership was a significant indicator of wealth (SAfMA Gariep).

In *Trinidad's Northern Range,* aspects of human well-being as perceived by the communities included income security (for example, an income that is based on regular and predictable employment), access to fresh water of good quality and quantity, security of land tenure, availability of affordable housing, recreational opportunities, personal security, and sense of place (Northern Range).

In *Sistelo, Portugal,* nearly forty different criteria for human well-being were identified using participatory approaches. The most cited criteria were: cash income, access to goods and services, assets (house, cattle, and fields), food quantity, health, leisure, age, capacity to work, not being alone, mutual help, conviviality, joy, security through retirement pensions, safe environment (air and water quality), and tranquility. Freedom from dependence on local provisioning services was considered a major improvement in the well-being of the community (Portugal).

Criteria for well-being in *Bajo Chirripó, Costa Rica,* were assessed in participatory workshops. Different groups in the same community identified different criteria. Elders identified species abundance, respect for their territory, preservation and development of the indigenous culture and adequate use of natural resources as main determinants of their well-being. Women identified seven needs: forest preservation, medicinal plant conservation, adequate use of natural resources, family respect, water conservation, employment and indigenous culture. Young men considered as important for well-being having their own house, employment, forest conservation, cultural respect, giving love and charity, water conservation and education (Bajo Chirripó).

Bajo Chirripó, elders, women, and young men all perceived well-being differently. (See Box 3.2.) Considering that well-being is context-dependent, it is not surprising that indicators and criteria vary across different situations.

All indicators used to measure human well-being have limitations. For instance, GDP data are normally readily available from national and international sources by sector on a historical basis, thus enabling measurement over time. But they often fail to include important non-marketed goods and services and neglect income distribution and natural capital depletion, which are also important for material well-being. For this reason, the MA assessments never used GDP per capita by itself as a proxy for material well-being, although many sub-global assessments used GDP data to assess the contribution of ecosystem services to the production of economic goods and services.

Equity—that is, a more equal distribution of well-being among people or "equality in the capability (or freedom) of different individuals to pursue a life of their choosing" (World Bank 2004)—is an important issue. Averages often hide large disparities in distribution. Some assessments tried to address this issue by using inequality measures, like the Gini coefficient (SAfMA Gariep) and the disaggregation of indicators by location (for example, urban versus rural, as in the Colombia assessment), or by gender or indigenous status (Coastal BC). Thus another reason why assessments of well-being at different scales are important—equity and inequity in access to services are often more evident at less-aggregated scales.

The selection of the indicators best suited to assess well-being in a specific context is crucial. Both the set of indicators used, and the way they are measured, influence the findings. Comprehensive assessments of well-being should address the multidimensional and specific nature of well-being, using multiple indicators and a combination of quantitative, qualitative, conventional, and participatory methods.

The aspects of human well-being assessed by a range of sub-global assessments are shown in Table 3.3. Although the assessments recognized the multidimensional character of human well-being, individual assessments did not exam-

Table 3.3. Components of Human Well-being in Selected MA Sub-global Assessments. This table reflects the individual sub-global assessment teams' own evaluation of how comprehensively they assessed the various components of human well-being. The data were collected at the Knowledge Market session at the meeting of the Working Group in Alexandria, Egypt, in March 2004. (See Box 2.1 for a description of the "knowledge market" process.) Key: + + + = comprehensively assessed, + + = moderately assessed; + = slightly assessed.

	Security			Health				
Sub-global Assessment	**Clean, Safe Environment**	**Resilience against Physical Hazards**	**Basic Material for a Good Life, incl. Income**	**Nutrition**	**Infectious Diseases**	**Other**	**Good Social, Cultural, and Spiritual Relations**	**Freedom and Choice**
San Pedro de Atacama	+ +		+ + +	+	+		+ + +	+
Caribbean Sea	+ +	+ +	+ + +	+	+ +		+	+
Coastal BC	+		+ + +				+ + +	+ + +
Tropical Forest Margins	+	+	+ + +	+ +	+		+	+ +
India Local	+ +	+ + +	+ + +			first aid	+ + +	+ + +
PNG National	+	+ +	+ + +	+ + +	+ +			+ +
PNG Local	+ + +	+ +	+ + +	+ + +	+ + +		+ + +	+ +
Laguna Lake Basin	+ +	+	+ +				+	+ +
Portugal	+ +		+ + +			respiratory disease	+ +	+ +
SAfMA Regional	+		+ + +	+ + +	+		+ +	+
SAfMA Gariep	+		+ + +	+ + +		AIDS		+
SAfMA Livelihoods	+ +	+	+ + +	+ +			+ +	
SAfMA G–M			+ + +	+ +				
SAfMA Zambezi			+ + +			+ +		
Sweden KW	+	+ + +	+ + +	+ +			+ + +	+ + +
Sweden SU	+					stress relief, exercise		
Northern Range	+	+ +	+ +		+		+ +	+
Mekong Wetlands	+ +	+	+ + +	+	+		+ +	+ + +
Western China		+	+ + +	+				+ + +
Bajo Chirripó	+ + +	earthquakes	+ + +	+ + +	+ + +	parasites	+ + +	+ + +
Colombia			+ + +	+ +	+ + +	+ +	+ +	
Eastern Himalayas			+ + +	+			+ + +	+ +
Sinai	+	+	+ +				+	
India Urban	+ +		+ +				+ +	+
São Paulo	+	+ + +	+ + +	+ +	+ +	+	+ +	+ +
Altai-Sayan	+ +		+ + +	+			+ + +	

ine all the dimensions of human well-being, and individual components of well-being were assessed to varying degrees of detail. Sub-global assessments tended to concentrate on those measures of well-being that are easier to quantify, particularly those associated with income.

There are several problems with assessing and attributing the links between ecosystem services and well-being. One is multiple causality: for example, human health depends on health services, education, *and* ecosystem services (and, often, several other factors as well). Thus an improvement in health, as measured by rising life expectancy, could occur in the face of a moderate decline in ecosystem services, if other factors were positive—including the efficiency of conversion of ecosystem "capital" to human "income." Sub-global assessments used indicators of well-being that frequently go beyond those linked directly and exclusively to ecosystem services: for example, average years of schooling and the literacy rate. Other indicators, such as under-five mortality, are more closely (but still not exclusively) linked to ecosystem services, in this case, clean water and adequate nutrition.

There are also issues of spatial and temporal scale. Whose well-being should be assessed? The well-being of people living in the place where a service is provided (the origin), or the well-being of those who benefit from this service? A related problem concerns intergenerational assessment, leading to "undemocratic democracy—the lack of democratic representation of future people" (Chambers and Conway 1991).

3.4 Links between Ecosystem Services and Human Well-being

Human well-being is affected by changes in the composition and functioning of ecosystems and the resultant flow of ecosystem services. Often-used terms such as "ecosystem health" or "ecosystem integrity" gain much more focus when defined in terms of the capacity of ecosystems to supply a particular basket of services to users of those services. Worldwide evidence of escalating human impacts on ecosystems raises questions about their capacity to continue to provide the services necessary for an acceptable level of human well-being. Human activity already impairs the flow of many ecosystem services. If current trends continue, humanity will markedly alter virtually all of Earth's remaining natural ecosystems within a few decades (Vitousek et al. 1997), in most cases in ways that increase the supply of one service (such as food or fiber) at the expense of others (for example, clean water and self-regulation of pests and diseases).

Human transformation of ecosystems and the choices about the ways in which their services are used can either amplify or reduce the benefits to society. For example, conversion of wetlands and forests to croplands helps to ensure stable food supplies, but it also causes pollution of waterways, disruption of hydrology, reduced fish yields, loss of biodiversity, and loss of scenic places. The value of the services lost to human society in the long term may exceed the short-term economic benefits that are gained from those transformative activities. Ecosystem transformation is undertaken, of course, because of real or anticipated benefits that will accrue at least in the short term. Indeed, our present societies are dependent on such transformation. Agriculture, forestry, and fishing provide one in every two jobs worldwide; and crops, timber, and fish contribute more to the global economy than do industrial goods (World Bank 1999). The key question is how to understand and quantify the current and future benefits, costs, and risks involved in all cases. There is much human well-being at stake, both now and in the future.

Mining in Papua New Guinea provides an example of the complex links between ecosystem services and human well-being. Mining involves the localized loss of agricultural land, plantations, and coral reefs, which are compensated for with cash handouts by the mining companies. In addition to replacing the lost services (perhaps not completely), the cash can also be used to obtain services not previously available, such as improved forms of housing, piped water supply systems, high-protein foods, western medicines, and other forms of health care, with dramatic increases in well-being. Nevertheless the loss of provisioning and regulating services usually tends to outlast the cash benefit. There are also important social impacts (for example, social disintegration and loss of spiritual values connected to a "sense of place") that decrease well-being in important ways. At Lihir, the spatial extent of the environmental impact of the mining operation is small, and the cash benefits are felt over a large area. As a result, there can be net increases in cash benefit (through employment and other spin-offs) in areas where there is no loss of ecosystem services (PNG).

Changes to ecosystems, and thus to human well-being, can occur at global, regional, sub-regional, national, and local scales, and often at several scales simultaneously. For example, fishing activities in the Caribbean Sea, which contribute a substantial portion of the region's GDP as well as providing jobs and protein to many people, can be analyzed at the fishing community scale, the national scale, the sub-regional scale, the regional scale, and the scale of the entire North Atlantic Ocean. Institutions exist for regulating the use of the service at all these scales, and failure of these institutions has impacts on the scales above and below it (Berkes 2004).

Indigenous peoples, that is, people who have lived within the context of a particular ecosystem for many generations, represent a special case of ecosystem service-well-being linkage. (See Chapter 11.) Not only does their "sense of place" figure overwhelmingly within their worldview, but when the ecosystem services they depend on decline, they may have few options to replace these with services from other sources. Furthermore, indigenous people are frequently politically marginalized and thus excluded from decisions that affect resources that they have used, and often protected, for centuries.

The set of linkages between ecosystem services and human well-being selected for study in particular sub-global assessments varied according to the different user needs in those assessments. Some local assessments, like those in the Vilcanota, Peru, assessment and in Sistelo in the Portugal assessment, also tried to assess how the communities perceive these links and which ecosystem services are most valued by them. In the Portugal assessment, a landscape with cultural and aesthetic value at the national scale—*socalcos* or cultivated terraces at successive heights on the mountain slopes—is seen by locals as having many disadvantages. In fact, most people agreed that a hypothetical scenario involving leveling the terrain would improve well-being (Portugal).

The examples in this volume (especially in Chapter 8) and elsewhere in the MA documentation illustrate the nature and extent of the connection between ecosystem services and human well-being, and the multiple scales at which the relationships exist. Clearly these links involve trade-offs (see the following sections). This section illustrates some of the links, mainly with examples from sub-global assessments; it is not meant to be exhaustive.

3.4.1 Provisioning Services

3.4.1.1 Fisheries as a Source of Food

Fisheries are an important source of food, employment, and income. Globally, marine fish and shellfish production has increased six-fold, from 17 million tons in 1950 to 105 million tons in 1997 (FAO 1999). This rapid growth has come in part from aquaculture, which in 2000 accounted for 27.3% of the total marine plus freshwater harvest (FAO 2002). Fish provide one sixth of the total animal protein and 6% of all protein consumed by humans (Laureti 1999). Fishing and aquaculture provided jobs for almost 35 million people worldwide in 2000 (FAO 2002), the vast majority of whom are in developing countries.

The Caribbean region, like other island systems, is particularly dependent on fishing. The number of people working in the fishing industry there increased from nearly 200,000 in the 1970s to over 500,000 in the 1990s, with half as many again employed in the secondary sectors (processing and marketing, boat building, net making, and other support industries). Moreover, it is estimated that each person working in the fisheries has five dependents; thus the total number of persons who are dependent on the Caribbean Sea for their living is approximately 1.5 million. Average per capita supply is 19 kg, which is well above the world average. Fish consumption in several of the small island states exceeds local production. In 2000, imports of fish and fishery products to the region were approximately 360,000 tons valued at $410 million, whereas exports was approximately 200,000 tons valued at $1.2 billion (Caribbean Sea; Agard and Cropper 2003).

In the Lihir Islands of Papua New Guinea, fish consumption represents about 10% of the recommended daily protein intake. Since the start of mining operations nearby, the consumption of fresh fish and marine invertebrates has increased slightly (Brewer et al. 2003, cited in PNG), but paradoxically, the pressure on local fish resources has not. Although the increasing availability and affordability of modern fishing gear due to the increase in cash income from mining would suggest increased local fishing activity, in practice more fish and other protein sources are now imported. The local fishery occasionally experiences a limited form of management because of the association of spiritual values with coral reefs and resultant restrictions on fishing activities

3.4.1.2 Fresh Water

The supply of usable fresh water will be a major challenge in the twenty-first century in many parts of the world. Globally, largely reflecting population growth, the amount of water available per person has decreased from 16,800 cubic meters per person per year in 1950, to 6,800 cubic meters per person per year in 2000 (Shiklomanov 1997; UNDP et al. 2000). More significant, one third of the world's population lives in countries experiencing moderate to high water stress, and this fraction is increasing as population and per capita water demand grow. The main consequences are negative impacts on food production, sanitation, and economic development (Hinrichsen et al. 1998), directly affecting material well-being and health.

Access to clean drinking water is a basic human need that, if not satisfied, can have several impacts on health. Lack of access to safe water supply and sanitation results in hundreds of millions of cases of water-related diseases and more than 5 million deaths every year (UNEP 2002). Water cleansing is an important service naturally provided by ecosystems. The Kristianstad Wetlands in Sweden provide ecosystem services related to fresh water, including retention and removal of dissolved substances, uptake of metals, bacterial removal, dilution of pollutants, soil wetting and fertilization, recharge and discharge of groundwater, reduced downstream damage, and avoidance costs of engineering structures (Sweden KW).

Water shortages can also have negative impacts on social relations and the security dimensions of well-being. The Salar de Atacama in Chile is a salty wetland within the driest desert in the world. Surface water is limited. The current major concern is over groundwater usage, and the extent to which its exploitation is sustainable. The economic activities in this region include mining, agriculture, and tourism, all of which depend on the quantity and quality of available water. The Salar de Atacama holds over 40% of world lithium reserves; mining provides 12% of the local employment and two thirds of the regional GDP. It also consumes 65% of the water used in the region. Tourism is the second largest source of employment and income, and needs fresh water for its facilities. Local communities rely on water for subsistence agriculture and raising livestock. Two thirds of subsistence farmers do not have enough resources to buy water rights when bidding against the mining companies. Hence the shortage of water is generating major conflicts over access and ownership rights among the competing users (San Pedro de Atacama).

Conflicts between local people and mining companies for water were potentially an issue for the people in the Lihir Island Group, Papua New Guinea. They depend for drinking water on creeks, springs, and rainwater collection and storage. In the northeast of Niolam, the gold mining company and its employees consume a significant amount of fresh water, but conflict has not arisen because the mines have new techniques for water extraction and storage (PNG).

Islands of the Caribbean Sea provide another example of how the introduction of new technology can alleviate an ecosystem service constraint. The available runoff in many islands in the region is inadequate to satisfy the demand for fresh water, so about 667,053 cubic meters per day is produced by desalinization of seawater. The cost of desalinization is about $317 million per year (Caribbean Sea; Agard and Cropper 2003).

3.4.1.3 Woodfuel and Charcoal

Woodfuel, one of the services supplied by forests and woodlands, is the main way in which the basic human needs for heating, cooking, and boiling water are satisfied in places where other sources of energy are unavailable or unaffordable. Even in highly industrial nations such as Sweden and the United States, wood supplies 17% and 3% of total energy consumption, respectively. Wood provides more than half the energy consumed in developing countries; in some African countries, such as Tanzania, Uganda, and Rwanda, it accounts for 80% (SAfMA Regional; Scholes and Biggs 2004). In the Kafue basin of Zambia, wood provides 96% of household energy consumed; in rural areas, 95% is consumed in the form of firewood, while in urban areas, 85% is in the form of charcoal. Shortage of woodfuel occurs in areas with high population density without access to alternative and affordable energy sources. In those provinces of Zambia where population densities exceed the national average of 13.7 persons per square kilometer, the demand for wood has already surpassed local supply. In such areas, people are vulnerable to illness and malnutrition because heating homes is too expensive, cooking food is not possible, and consumption of unboiled water facilitates the spread of waterborne diseases such as cholera. Women and children in poor rural communities are the most affected by woodfuel scarcity. They must walk long distances searching for firewood, and therefore have less time for tending crops, cooking meals, or attending school.

3.4.1.4 Biological Products

Billions of people around the world depend partly or fully on products collected from ecosystems for medicinal purposes. Some 75% of the world's population rely on traditional medicine for primary health care and 42% of the world's 25 top-selling drugs in 1997 were derived from natural sources (UNDP et al. 2000). Even when synthetic medicines (which themselves often originated from natural sources) are available, the need and demand for wild products persists. For example, although the development of a mining economy in the Lihir Island Group of Papua New Guinea has increased the availability of modern drugs and medical treatment, local people still widely use traditional medicines. Most medicinal plants used among these people are actively cultivated. Lime, which is made from coral, is a central ingredient in many traditional medicines. It is mixed with various medicinal plants to produce a paste that is usually applied as a topical remedy and is also used for alimentary diseases, colds, and pneumonia (Powell 1976; MacIntyre and Foale 2002, cited by PNG).

3.4.1.5 Coffee: An Example of a Natural Product–based Source of Employment and Income

Coffee production is a globally important economic sector especially for producer countries such as Brazil, Viet Nam, and Colombia, where it is a source of employment and income. The coffee-growing region of Colombia encompasses an area of more than 3.6 million hectares. Coffee is grown in 605 municipalities in the country (56% of the national total) and involves 420,000 households and more than half a million agricultural productive units or farms. Around 870,000 hectares are currently devoted to coffee production. This region makes an important and quite stable overall contribution to national gross domestic product (Colombia).

3.4.2 Regulating Services

3.4.2.1 Carbon Sequestration

Human activities are currently responsible for the emission of an estimated 7.9 billion tons of carbon to the atmosphere annually (IPCC 2001). Tropical deforestation currently accounts for approximately one fifth of the net increase in atmospheric carbon dioxide (IPCC 2001; see also MA *Current State and Trends,* Chapter 13.) In general, when forests are cleared, they are replaced by land uses that contain only 2–40% of the carbon originally stored in the forest (Palm et al. 2004). In Africa, clearing of forests accounts for 43% of carbon emissions (Gaston et al. 1998).

Increasing concentrations of carbon dioxide in the atmosphere contribute to climate change, which in turn are likely to affect human well-being through adverse impacts on the availability of fresh water, food production, and the distribution and seasonal transmission of vector-borne infectious diseases (UNEP 2002). Reducing anthropogenic carbon emission is one way to mitigate climate change; another way is to maintain or enhance the capacity of ecosystems to absorb carbon. Forests, while in their active growth phase, are the most effective terrestrial ecosystem for recapturing carbon dioxide, the greenhouse gas contributing most to global warming. Recuperation of degraded lands and soils through improved management or land use change—for example, from traditionally managed pastures to improved pastures or from degraded crop or grasslands to tree plantations and agroforestry—is particularly effective in sequestering carbon and still allowing the harvest of products to benefit the users of such land (Van Noordwijk et al. 2001). For example, the 353,004 hectares of undergrowth and 118,889 hectares of reforestation areas in the Green Belt of São Paulo city, Brazil, balances a large fraction of the carbon dioxide generated by the urban population, while providing other amenity services as well (São Paulo).

3.4.2.2. Water Flow Regulation

Forests provide several valuable services in relation to watershed protection. Tree roots pump water out of the soil, thereby reducing soil moisture and the likelihood of mudslides. Forests moderate the runoff from precipitation, reducing flows during flooding, increasing flows during drier times, and protecting soil from erosion (UNDP et al. 2000). Convincing evidence was found in a Southeast Asian study linking deforestation to increased local risks of flooding (that is, within small catchments) but there are several uncertainties about the basic relationships between rainfall, watershed functions, deforestation, reforestation, and other aspects of land use change in the humid tropics (Tropical Forest Margins; Tomich et al. in press). In Trinidad's Northern Range assessment, a strong link was also established between the services of runoff regulation and water retention and the environmental and economic security dimensions of well-being, based on expert and community opinions (Northern Range).

The Mekong is the world's twelfth longest river, stretching nearly five thousand kilometers from its source on the Tibetan plateau to its outlet on the coast of Viet Nam. All the states within the basin, which includes both the richest and poorest nations in Southeast Asia, are keen to promote economic development using the Mekong's water resources. For example, less than 5% of the hydroelectric power potential of 30,000–58,000 megawatts has so far been exploited (MRC 1997). By 2020, the demand for electricity in the Mekong region could be six times greater than in 1993 (MRC 1997). The attainment of this potential is dependent on maintaining the regulating and sediment control functions of the headwater catchments. Full development of this potential will inevitably have some adverse consequences on downstream services, such as the burgeoning fisheries of the Mekong delta.

3.4.2.3 Regulation of Infectious Disease in Humans and Domestic Plants and Animals

Ecosystem transformation may affect the spread of diseases with important impacts on human health. In the village of Koyyur in India, deforestation caused canopy gaps in the rainforest. This initiated growth of grasses and other fodder species, attracting cattle from the villages. These cattle carry ticks that transmit a monkey fever (Kyasanur Forest Disease), resulting in an increase in the disease in humans (India Local).

Decreased diversity in agroecosystems increases the risk of pest attack (Tropical Forest Margins; Landis et al. 2000), with adverse impacts on food production. Simplification of the ecosystem, for instance by the indiscriminate use of broad-spectrum pesticides, decreases the diversity of natural competitors and predators of the problem organism. Pesticides also have negative effects on non-target beneficial organisms, including pollinators and beneficial soil biota (Swift et al. in press). In many cases, an acceptable level of control of pests and diseases can be achieved with a reduced use of pesticides. In some cases, pesticides can be eliminated altogether by the use of natural parasites and predators (Tropical Forest Margins).

3.4.3 Cultural, Spiritual, and Recreational Services

Cultural services may be less tangible than material services, but they are nonetheless highly valued by people in all societies. People obtain diverse non-material benefits from ecosystems. These benefits include recreational facilities and tourism, aesthetic appreciation, inspiration, a sense of place, and educational value.

Many traditional cultural practices linked to ecosystem services have an important role in developing social capital and enhancing social well-being. In a participatory community assessment conducted in Sistelo, Portugal, people reported a worsening of some criteria of local social well-being such as joy, conviviality, and mutual help (Portugal; Pereira et al. 2004). This deterioration was in part linked to the abandonment of traditional agricultural practices such as gatherings of people to work in one another's fields and to accomplish some production activities such as *fiadas* (spinning wool) and *desfolhadas* (stripping of corn leaves). At the same time, this community also reported an improvement in criteria related to material well-being, mainly because of access to new income sources such as retirement pensions and remittances.

3.4.3.1 Nature-based Tourism and Recreation

Recreation and nature-based tourism are important sources of income and employment in many places around the world. The total value of international tourism exceeds $444 billion (World Bank 1999). Nature-based tourism (sometimes called environmental tourism or ecotourism, although strictly speaking, the latter is a subset of nature-based tourism and includes certain ethical considerations) may comprise 40–60% of this total. In Costa Rica, tourism generated $654 million in 1996, and in Kenya, $502 million in 1997. In both cases, most visitors are attracted to the natural assets of those countries. Prior to the outbreak of civil war in Rwanda, tourist visits provided $1.02 million, which enabled the government to protect mountain gorillas and their habitat in the Volcanoes National Park, creating employment for local residents (Gossling 1999). In southern Africa as a whole, nature-based tourism is estimated to generate $5 billion per year, growing at a rate several times higher than that of other natural resource–based activities (SAfMA Regional; Scholes and Biggs 2004).

The Caribbean is probably the most tourism-dependent region in the world. In 2003, the Caribbean travel and tourism economy directly and indirectly accounted for nearly 2 million jobs (one out of every eight jobs), 13.0% of GDP, and a sixth of the export earnings (World Tourism and Travel Council 2003, cited in Caribbean Sea).

The recreational benefit from nature also contributes to the health and social relations dimensions of well-being, as there is a correlation between green areas, good air quality, and human health. The National Urban Park in Stockholm, Sweden, for example, has an estimated 15 million visitors per year, most of whom visit the park for recreation purposes. More than 90% of the urban population in Stockholm visits the city's green area at least once a year, and about half of those visit at least weekly (Wiren 2002, cited by Sweden SU). Recreation in this park system promotes physical exercise and mental well-being. The green area allows humans to come into contact with nature and provides a resource for natural science teaching. The park has several teaching facilities specializing in nature-related subjects (Sweden SU).

3.4.4 Supporting Services

3.4.4.1 Soil Formation

Soil provides essential services such as nutrient cycling (the basis of soil fertility) and water retention. Deforestation and other land uses affect the physical, biological, and chemical properties of the soils, and thus their capacity to supply these services. There is evidence of disproportionate erosion rates on compacted surfaces such as roads, paths, tracks, and human settlements. Data from northern Thailand indicate that unpaved roads produce as much sediment as agriculture, even though these roads occupy less than one tenth of the area occupied by agriculture. Later stages of compaction may lead to runoff without much soil loss, but surface flows may pick up soil as soon as they pass over soil elsewhere with a higher propensity to erosion (Tropical Forest Margins).

3.4.4.2 Pollination

Pollinators contribute greatly to the production of food and other agricultural goods, and therefore to human material well-being and health. It is estimated that 90% of all flowering plants would not exist without animals and insects transporting pollen from one plant to another (UNDP et al. 2000). Pollinators also provide a recreational service by pollinating backyard gardens. Pollinator declines affect both total harvest and harvest quality (Allen-Wardell et al. 1998, cited by Sweden SU).

The Himalayan region, which extends from China to Afghanistan, is rich in honeybee diversity. It hosts five indigenous and one exotic bee species. Indigenous honeybees play a significant role in pollinating field crops and wild plants, thereby increasing productivity and sustaining ecosystem functions. People in the region recognize that bees help secure better livelihoods, both by increasing agricultural productivity and by generating direct income from selling honey and wax. Apples are a leading cash crop in the region, accounting for 60–80% of total household income. Annual production is estimated at more than 2.5 million tons, valued at about $450 million. In the early 1980s, market demand for particular types of apples altered traditional farming practices, causing farmers to uproot pollinator varieties and plant new, sterile cultivars. The pollinator populations were also negatively affected by excessive use of pesticides. The result was a reduction in overall apple productivity and local extinction of many natural pollinator species (Partap and Partap, 1997 and 2000).

3.4.4.3 Grazing: The Sustained Production of Forage

Grazing by domestic livestock and wild ungulates is the foundation of most human livelihoods in the arid and semiarid parts of the world, which together constitute about a quarter of the global land surface. Bedouins constitute the majority of people living in the Sinai Peninsula. Grazing supports a long list of services that contribute to the well-being of Bedouins; it permits their survival in this harsh desert environment. The services include meat and milk, meeting Bedouins' need for protein; transport, which is entirely dependent on camels; weed control by sheep in orchards; manure for fertilizing crops; animal skins for tents; and wool from camels, sheep, and goats for a variety of household and farming necessities. Wool is also the backbone of handicraft industries such as carpet weaving (Dames and Moore 1985).

3.5 Trade-offs and Congruence between Services

Typically, ecosystems deliver multiple benefits at the same time, from the same place. For example, the forests of Portugal simultaneously provide timber products (wood and cork), non-wood products (resins, honey, fruits, wild mushrooms, aromatic and medicinal plants, game, fodder, and acorn and woodland production), and other ecosystem services (recreational use, carbon sequestration, water resource protection, and environmental protection), approximately in the ratio of 3:2:1, in terms of economic value (Mendes 2004, cited by Portugal).

Some services can be delivered simultaneously from the same system or landscape without mutual interference, while others are partly or fully antagonistic. Services that have compatible landscape management needs can be referred to as "congruent." Decisions about the transformation and exploitation of ecosystems often pose difficult choices. There are typically trade-offs to consider between benefits and risks, gains now versus other types of gains in future, and gains to some persons accompanied by losses to others. Who should make such decisions, and how?

Consider, for example, the draining of swamps, which may reduce mosquito-borne infectious disease risks while at the same time destroying the wetland system and its flow of ecosystem services. Similarly, creating roads within forests facilitates contact with, and movement of, infectious diseases such as malaria and viral hemorrhagic fevers, while also providing remote communities with access to health care and to other facilities. Trade-offs can also occur over time. In Sri Lanka, for example, the clearing of tropical forest for agriculture initially reduced the habitat for forest-adapted anopheline mosquito vectors of malaria. However, in due course, other vector species occupied the changed habitat, thereby contributing to the resurgence of malaria (McMichael 2004).

An historical perspective may assist in understanding the interplay between a changing flow of ecosystem services, including trade-offs between them, and the resultant human consequences. (See Chapter 11.) This perspective takes account of slow biophysical (and often lagging) social processes. It emphasizes a dynamic rather than a static view of both development and the most-valued ecosystem services at various stages. The topic of trade-offs between ecosystem services is more comprehensively treated in Chapter 8.

3.6 Trade-offs between Ecosystem Services and Human Well-being

It does not necessarily follow that more ecosystem services mean more human well-being, or vice versa. It is, for instance, quite widely observed that general improvements in well-being often occur *despite,* or because of, decreases in ecosystem services, at least at the local scale. The Colombia assessment, for example, found high levels of biodiversity correlated significantly with high levels of unsatisfied basic needs and low levels of quality of life (Colombia; Rincon et al. 2004). The reasons for the complexity in the relationship are several.

First, human well-being has many contributory factors, only some of which are ecosystem-related. The concept of total capital may be helpful here (Dasgupta 2001). Total capital consists of natural capital, human capital, social capital, and manufactured capital. These forms of capital are partly substitutable for one another. Net human well-being improvement requires total capital to increase, which may be possible even if one or two components decrease, provided that the others increase sufficiently to balance the decline. The loss of a particular source of ecosystem service can be replaced with other sources, using the income derived either from the exploitation of natural or human capital or from the growth of manufactured capital. In this sense, development enhances freedom of choice (Sen 1999) and corresponds to an improvement in well-being. However, increases in net human well-being and total capital at scales greater than the single individual may well involve declines in well-being for particular individuals, because average measures of performance may not reflect regressive distributional impacts; this raises moral and practical problems involving who decides which trade-offs are acceptable. Furthermore, substitution may be a rational choice for humans, but there may be no substitutes for some ecosystem services. Can the complex interactions within and between ecosystems, especially those that produce regulating services, be ''substituted'' by human controls? Currently, the answer is certainly no.

Second, immediate improvements in well-being may occur at the expense of deferred environmental costs. An example is the accumulation of waste typically resulting from the rising consumption levels that follow increases in wealth. The waste products may not be an immediate problem, but may eventually exceed the limits of human tolerance or ecosystem absorptive capacity. The tolerable limit tends to be lower in population settings of poverty where, often, waste-absorbing environmental resources have already been overused.

Third, the widening geographical reach of communities that usually accompanies increases in well-being enables them to obtain the services they need from non-local sources. For example, in the broad sweep of history, urbanization is usually associated with improved well-being. At the same time, urban areas rapidly exceed the capacity of their immediate environment to supply their needs for food and water. They are nevertheless able to continue to grow, because the economic power of the city enables it to satisfy these needs from distant locations. The globalization of trade has progressively increased the disconnect between benefit and impact. The capacity to satisfy continuously growing local needs by unsustainable harvest from distant sources may now be reaching its limits, as the combined ''footprint'' of human settlements all around the world approaches and, in some cases, possibly exceeds the total area available for service delivery (Wackernagel and Rees 1996).

The issues of limits to substitution, thresholds of human tolerance or ecosystem absorptive capacity, and limits of ecosystem capacity to provide the needed services raise an important, but not yet answered, question: When does the relationship between ecosystem services and human well-being cease to be characterized by trade-offs, and instead is characterized by unambiguous net loss?

A conceptual framework for understanding the variable, and often apparently contradictory, relationship between ecosystem service level and human well-being is illustrated in Figure 3.1. There are plausible cases where an ecosystem service increases continuously as well-being increases, for

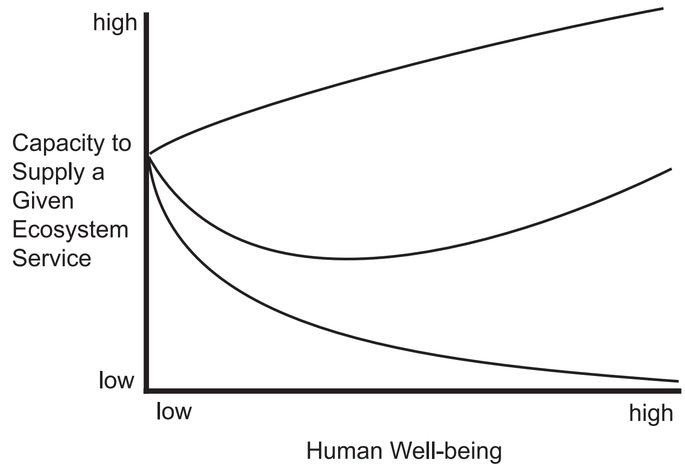

Figure 3.1. Examples of Some of the Possible Shapes of the Relationship between Human Well-being and Ecosystem Service Supply. The hypothesized relationships are for a single ecosystem service, from a particular location, followed over time as the human well-being in that location increases over time. In some cases, such as food provision, the capacity rises to an asymptote. In others, such as services related to biodiversity, it typically falls to an asymptote. Yet in others, such as water quality, it may initially fall, then recover somewhat.

instance as a result of the successful implementation of agricultural or sanitary technology. At a global scale, there is now greater food security than at any time in the history of the world. Most parts of the world have registered continuous improvement in yields per hectare and food supply per capita throughout their developmental history (Bruinsma 2003). There are some notable regional exceptions. As the scale of analysis becomes progressively more local, the issue of (in)equity of access becomes increasingly apparent, and the smoothly rising ''average'' curve may then take quite different forms.

There are plausible cases, such as the global climate regulating service, that may have been in continuous decline over the period of modern increases in well-being (IPCC 2001). The possibility that, for some services, the supply declines initially as well-being rises and then recovers at higher levels of well-being has been much speculated on (Rotmans and Rothman 2003); the resultant shape is sometimes known (albeit controversially) as the ''inverted environmental Kuznets curve.'' An example is riverine water quality in the developed world; the turnaround is usually interpreted as reflecting changing human priorities: once people are above a basic level of needs satisfaction, they have more resources to spare for environmental protection, and place a greater priority on issues such as a safe, clean, and attractive environment. A developing-world example of this pattern may be provided by tree cover in the eastern highlands of Africa. Initial deforestation has led to a gradually increasing use of trees-on-farms in some places, but it was not for environmental protection as much as for labor-sparing, high-yield investment. Figure 3.1 points out that no single form of the ecosystem services/ human well-being relationship holds in all cases.

The agencies responsible for promoting human well-being (for instance, national ministries of development or health) are typically different from those responsible for the protection of ecosystem services (for instance, environment ministries), and this can lead to tensions and non-optimal trade-offs. Even where both functions are within a single agency (for example, fisheries or forest ministries), they must deal with internal conflicts of purpose.

3.7 Issues of Equity and Access

There are important issues of both efficiency and equity of access to ecosystem services. The potential supply of an ecosystem service is not necessarily equal to what is actually used. The reasons for this include changes in demand in relation to the other options available to people, the technology available for the exploitation of ecosystem services, the level of knowledge of users, and restricted access to the service.

South Africa provides many examples of the ecosystem service consequences of inequities institutionalized by the apartheid system and persisting due to entrenched poverty after the formal abandonment of that system. Rural communities in the former tribal ''homelands'' had no rights of permanent residence outside those areas, but had few economic opportunities within them. As a result, they depended on the ecosystem resources that the areas offered, and in many cases overexploited them. Much of this degradation occurred in times of climatic drought or economic hardship (Eastern Cape local assessment, in SAfMA Gariep).

In places where there are no other social safety nets, diminished human well-being tends to increase immediate dependence on ecosystem services, and the resultant additional pressure can damage the capacity of those local ecosystems to deliver services. In Papua New Guinea, a ''destructive poverty syndrome'' was found in the central highlands and the coastal zone—especially on small islands. Destructive poverty is both the driver and the effect of environmental change. In this type of relationship between poverty and the environment, poor people sink further into poverty because their poverty drives them to participate in unsustainable resource management regimes. In contrast, conservative poverty, a form of the poverty–environment relationship in which environmental resources are not damaged or destroyed, was found in the PNG lowland interior and highland fringe.

The capacity to restrict access to a service is fundamental to all successful natural resource management institutions (Berkes 2004). The important question is: who experiences the gains and losses in access under conditions of ecosystem change? And how do the processes of economic and social change lead to displacement of those gains and losses across both space and time? For example, a transnational company may plant crops in a newly cleared area, transforming local ecosystems in ways that render them more productive in food-yield terms, but not necessarily in total ecosystem service terms, and not necessarily in the long term. The shareholders and employees of the company benefit, and presumably the consumers of the food do as well. The losers may include local farmers, harvesters and the people they supply, and those using the other services generated by the original landscape. The future impacts of losses of soil fertility, biodiversity, and ecosystem stability are seldom factored into this calculation, or if they are, they are so heavily time-discounted that they are overwhelmed by the immediate benefits. A useful tool to identify and discuss the benefits for different groups under different land uses is the alternatives to slash-and-burn matrix. (See Chapter 8.) The ASB matrix scores natural forest and various land-use systems that replace it against various criteria reflecting the different objectives of different interest groups (Tropical Forest Margins).

Secure rights to environmental resources (for example, land, water, trees) is an important dimension of well-being that reduces vulnerability. Environmental resources also have ''instrumental value'' (that is, they can be used to obtain something else of value), since they enhance a person's freedom to be and to do. Some assessments (for example, SAfMA Gariep and Coastal BC) addressed inequalities in access to natural resources; the literature highlights particularly the role of gender in determining access (Nunan et al. 2002), but inequality in access also has family, group, regional, and national dimensions and is closely related to power. Differential access to resources may also explain why some people living in environmental-resource-rich areas nevertheless have low human well-being.

Changes in the equity structure of societies can have impacts on ecosystem services. For example, economic liberalization in Viet Nam resulted in the development of a class of entrepreneurs with markedly greater access to capital. The poorer fishermen were unable to enter the capital- and technology-intensive shrimp fishery that developed. Furthermore, the ecological changes precipitated by the expansion of shrimp aquaculture reduced the capacity of the ecosystem to support traditional fish stocks, further exacerbating the inequity (KM–Downstream Mekong).

3.8 The Consequences of Ignoring the Link between Well-being and Ecosystem Condition

The capacity of human communities to form stable societies, to generate formal economies, and to plan for the future is underpinned by environmental stability (predictable fluctuations, such as seasonal changes, are a form of stability), reliable supplies of natural materials, and the adequate functioning of the cleansing and recycling processes of nature. Thus all people and their societies are fundamentally dependent on ecosystem services, although in some contexts the source or importance of particular services is more apparent than in others. In general, the visibility of these linkages tends to vary inversely with the degree of modernization and urbanization. The abundance of arctic mammals as a food source is of direct importance to the nutritional status and survival of the Inuit, and thus they pay close attention to it. On the other hand, the supply of red meat through butchers' shops in a modern city is much less critical to the well-being of metropolitan populations, given the many protein substitution possibilities.

The process of cultural evolution, occurring over centuries but substantially accelerated in the industrial era, has entailed a progressive dissociation of daily needs and activities from the services of the natural world, at least in the perceptions of most people. Subsistence communities have a much more immediate relationship with local ecosystems than do modern urban populations that live at several commercially mediated levels removed from nature. For that reason, both the awareness of human dependency on nature, and the rapidity and spatial immediacy with which ecosystem changes affect human well-being, vary hugely among contemporary human societies, spread across the spectrum from pre-agrarian to post-industrial.

With the global increase in the quantity of goods traded and the distances they travel, the possibility of dissociation of human well-being from local ecosystem conditions increases; the population of high-density Hong Kong, for example, draws on many imported rather than local ecosystem services. Several sub-global assessments highlight the issue of dissociation, including SAfMA Gariep, Portugal, and PNG. Food provisioning in Portugal is a good example; a stagnating or decreasing tendency at the national level of this fundamental service can be compensated for by imports (Portugal). Indeed, daily calorie intake per capita has increased by 4.8% from 1990 to 1997, but national supply of food is also increasingly dependent on imported food products (INE 1999, cited by Portugal).

As the magnitude and reach of human influence increases, so does the degree to which ecological processes that operate over large scales are affected. For instance, processes involving the atmosphere can be transported around the world within days in a west to east direction, and within a year or two in a north to south direction. Affluent populations driving large cars contribute disproportionately to the generation of greenhouse gases, but the environmental consequences both of oil extraction and refining and of global climate change impinge predominantly on groups other than those driving those large cars. While some developed countries may gain crop production potential with projected climate change, in about 40 poor developing countries—with a combined population of 2 billion, of whom 450 million are currently undernourished—production losses due to climate change may greatly increase the number of undernourished (Fischer et al. 2002).

There are also disconnects in terms of temporal sequence. For example, although the onset of critical deficiencies in ecosystem services can appear abrupt, they usually result from a long, unnoticed process of gradual decline. The decline may occur on a broad front, or it may be limited to one particular component or process. For instance, the "collapse" of fisheries hits the headlines when emergency measures are put in place to preserve the stocks, but the harvest pressures have usually been unsustainable (and known to be so) for years before that time. Substitution of one stock by another, and the use of progressively more sophisticated fishing techniques, can result in a disconnect between the mass of fish landed, which remains high, and the falling fish populations. Rwanda, with multiple ecosystem limitations, is an example. By the early 1990s, the accumulated pressures on agroecosystems of a large and growing population led to widespread rural shortages of food, clean water, and grazing land. This contributed to the escalation of ethnic tensions and to the ensuing civil conflict. The correspondence between areas of ecosystem service loss and social conflict is suggestive of a link between these two issues. The link could go in either or both directions: conflict creates conditions promoting ecosystem degradation, or environmental resource depletion could be a cause of conflict (SAfMA Regional; Scholes and Biggs 2004).

A decline in the supply of food, water, and materials is the most obvious consequence of adverse ecosystem change for human communities. Less acute or tangible consequences include:

- *the loss of genetic variation as strains of wild and cultivated plants disappear.* The robustness of traditional food supplies has long depended on this genetic diversity;
- *the invisible loss of biochemical diversity, as species go extinct.* Human societies have long depended on the many medicinal and other useful chemicals or materials from nature. It is certain that there are still many such products as yet undiscovered. They cannot contribute to our future well-being if they no longer exist;
- *the loss of recreational, aesthetic, and spiritual benefits* conferred by access to natural settings and the presence of plant and animal species;
- *the loss of environmental stabilization provided by natural vegetation.* This includes surface-water movement (flood control), soil stabilization, the uptake of atmospheric carbon dioxide by plants, and the provision of habitat for many animal species;
- *the loss of cleansing capacity for local water supplies,* provided by water movement through wetlands.
- *the loss of many different processes for the recycling of nutrients* via decomposition, transport, predator-prey transactions, and others.

3.9 Final Remarks

Human well-being has a two-way interaction with ecosystem condition, mediated in the one direction through the services that ecosystems provide to people, and in the other by the largely unintended impacts of human activities on ecosystem functioning. This feedback loop is self-regulating when people live in close and inescapable association with their local environment. If society fails to read the warning signs delivered by a decline in ecosystem services and does not adjust its activities accordingly, it ultimately fails (Diamond 2005). Thus most local communities that have been in one place for long periods of time have developed mechanisms for the protection of ecosystem services. As societies, via modernization and trade, have become less dependent for their well-being on the services provided by their local environments, the coupled human–environment system has become increasingly at risk of overexploitation. In the presence of trade-offs between services, and between ecosystem services and human well-being, overexploitation can lead to unambiguous net loss. People, everywhere and at all times, depend absolutely for their lives and livelihoods on the adequate functioning of Earth and its component ecosystems, whether local or distant, regardless of their level of awareness of this dependency.

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