Chapter 2
Rethinking watersheds

> Are watersheds appropriate management units? There is a need to rethink scale of intervention, upstream–downstream linkages, temporal and spatial processes, biophysical and socio-economic linkages, and political issues.
>
> Inter-Regional Conference, Group 3

The new concept for watersheds is based on current research and project experiences in hydrology and ecology, human ecology and environmental economics. This chapter summarizes a number of relevant issues for the next generation of watershed management programmes and projects.

NEW PERSPECTIVES ON WATERSHED HYDROLOGY AND BIOECOLOGY

Land use has an impact on the hydrological regime and quality of water downstream. The importance of this impact varies with the type of land use, the size of the watershed, climate, soil characteristics, topography, geology, etc. (Bosch and Hewlett, 1982; Bruijnzeel, 1990; Calder, 1999). In the past, neither the public nor decision-makers fully understood the relative importance of these factors and the need to consider the specific characteristics of each situation. This created misconceptions, particularly about the main causes of floods and droughts. The media, NGOs, government officials and some scientists have often convinced the public that deforestation is a main cause of changes in water regimes, because it leads to increased floods and reduced dry season flows in rivers. Many agencies have funded conservation and reforestation programmes in response to these concerns and perceptions about the causes and effects (Kaimowitz, 2004).

Forest, precipitation and water

Research on how forest cover affects rainfall remains inconclusive (Kaimowitz, 2004). The higher evaporation rate and greater aerodynamic roughness of forests compared with agricultural and pastureland increase atmospheric humidity and moisture convergence, but enhanced rainfall in forested areas cannot be attributed to forests themselves. Cloud forests may be exceptions, where cloud-water deposition may exceed interception losses (Calder, 2003). The effects of mountains and trees on the interception of rainfall may explain the observed differences. The discussion is complicated by the high variability of rainfall in space and time. The impact of forest cover on precipitation would probably be only marginal compared with other factors. Although the possibility that land-use change modifies rainfall patterns cannot be totally discarded, natural factors (and possibly climate change) have a far greater impact on rainfall than any change in land use would have (Box 5).

Worldwide, many watershed studies indicate that water yield increases when forests are harvested (Brooks, 2002). Research from the United Kingdom and elsewhere shows that water yields from forested catchments are generally lower than those from grassland or moorland landscapes because of higher interception losses (McKay and Nisbet, 2002). This research suggests that there "may be a 1.5 to 2.0 percent reduction of potential water yield for every 10 percent of a catchment under mature evergreen forest". Evaporation from deciduous woodland is generally less because of lower interception during the leafless period.

Forests use more water than other land uses

Forests use more water, through interception and complex evapotranspiration processes, than other land uses such as grassland or agriculture. Forests therefore reduce

BOX 5

Do forests really decrease runoff and regulate dry season flows?

Studies indicate that in wet conditions, interception losses are higher from forests than from shorter crops, primarily because the atmospheric transport of water vapour is increased by forests' aerodynamically rough surfaces. In dry conditions, transpiration from forests is likely to be higher because of the generally greater rooting depth of trees compared with shorter crops, which gives trees greater access to soil water. Consequently, contrary to widely accepted myths, runoff from forested areas will be less.

The few exceptions to this are cloud forests – where cloud water deposition may exceed interception losses – and very old forests. Reduced runoff following a bushfire in 200-year-old mountain ash (*Eucalyptus regnans)* forest in a water catchment for Melbourne, Australia is attributable to increased evaporation from forest regrowth, which has a much higher leaf area index than the old forest had.

General conclusions can be drawn about the impacts of forests on annual flow, but not about those on seasonal flow regimes. Site-specific, often competing processes operate, and the direction and magnitude of an impact may be difficult to predict for a particular site. It can be expected, however, that: (1) increased transpiration will reduce soil moisture and dry season flows; and (2) increased infiltration under natural forest will increase soil water recharge and dry season flows.

Drainage activities associated with plantation forestry in United Kingdom uplands increased dry season flows through initial dewatering and longer-term hydraulic changes to the drainage system. Pine afforestation of former grassland in South Africa reduced both annual and dry season stream flows. Similar results were found with eucalypt plantations in the Nilgiris region of south India. Bruijnzeel (1990) concludes that the infiltration properties of tropical forests are critical to how the available water is partitioned between runoff and recharge, leading to increased dry season flows.

Source: Calder, 2005.

total runoff: "most forests will evaporate significantly more water than shorter vegetation and reduce water for recharging aquifers or supplying rivers" (Calder, 2003). In the United Kingdom, coniferous afforestation in upland areas typically reduces annual stream flows in those areas by 20 percent. Compared with grassland, pine forests reduce recharge by about 75 percent and oak forests reduce it by 50 percent (Calder, 2003). The widely held view that "more trees equals more water from the catchment" is a misconception in many countries. The clarification of this issue is very important, especially where markets for environmental services are involved.

Hydrological regimes

In some cases, changes in land use have an impact on the hydrological regime of a river basin; for instance, forest clearing has a direct impact on the infiltration rate and recharge of aquifers. In many other cases, however, the relation between land use and the hydrological regime is not so clear. For example, the impact of wetland protection on flow regimes is still subject to debate; some research suggests that wetland protection increases peak flows and reduces base flows, while other research indicates increased water storage capacity, leading to reduced peak flow (Bullock, 1992).

Research shows that land use affects the infiltration of water into the soil, and any change in land use that compacts soil or diminishes its porosity will increase runoff and peak flow during rainfall events, and will possibly also increase flooding

(Kaimowitz, 2004). These findings hold for only small areas, however; at large scales the extent, intensity and distribution of storm events are likely to have much larger impacts on runoff than land-use changes have.

Extending or maintaining the duration of dry season base flows is important for irrigation, wildlife, riparian health and other ecological functions (Fleming, 2003). Research from the United Kingdom indicates that large areas of evergreen forest can result in significant declines in summer base flows in lowland areas (McKay and Nisbet, 2002). Forest design can help mitigate the impact of water use by trees, and the same research shows that water yields from young forests, felled areas and deciduous woodland are likely to be similar to those from grassland. This suggests that more diverse ecosystems should help to even out the effects of forestry at the larger watershed scale.

Hofer and Messerli (2006) found no statistical correlation between human activities in the Himalayas, e.g., deforestation, and large-scale floods in the lowlands, e.g., in Bangladesh. The authors concluded that deforestation in mountain areas should not be blamed for flood catastrophes in distant downstream areas. The many benefits of upstream watershed conservation should be considered at the scale of mountain communities and their smaller watershed environments (Box 6).

BOX 6

Forests and floods in Himalayan watersheds

Every year, during the monsoon season, the Himalayan region attracts worldwide attention because of disastrous flooding in the plains of the Ganges and the Brahmaputra. It is generally assumed that rapid forest removal in the mountains is responsible for these floods, based on the following chain of mechanisms: population growth in the mountains → increased demand for fuelwood, fodder and timber → increasing forest removal in ever-more marginal areas → intensified erosion and higher peak flows in rivers → severe flooding and siltation in densely populated and cultivated plains.

However, although in recent decades the Himalayas and their forelands have certainly undergone dynamic changes in land use owing to rapid population growth, the scientific community increasingly views the assumptions in the previous paragraph as too simplistic and misleading. Evidence from more than 20 years of research in the Himalayan region suggests that the impacts of mountain deforestation on hydrological systems depend more on scale.

Human-induced ecological changes in the Himalayas occur at the small-scale level, where forest clearance in a local highland watershed can lead to increased runoff and accelerated soil erosion in that watershed. At the large scale of the Ganges-Brahmaputra-Meghna system, however, there is no significant correlation between human activities in the mountains (forest removal) and catastrophes in the plains (floods). Human influences are dwarfed by the massive dimensions of natural processes. There is also no statistical evidence that flooding in Bangladesh has increased over the last 120 years, even though deforestation has increased constantly. Precipitation and runoff in the Himalayas do not seem to contribute significantly to the floods in distant Bangladesh because the flood flows and peaks of Himalayan tributaries are levelled into the base flow of the bigger rivers as they move downstream.

Mountain dwellers and their land-use practices should therefore not be blamed for floods in the plains far downstream, although mountain people do have a responsibility to use their environments sustainably. Mountain forests are crucial for the ecology of the entire Himalayas and for the people who depend on it; afforestation programmes should be regarded in this context, and not as a means of preventing flooding in the lowlands.

Source: Hofer, 2005.

TABLE 1
Potential impacts of land use on aspects of river regime

Observable impact of land use on:	Watershed size		
	Small (0.1–10 km²)	Medium (10–100 km²)	Large (at least 100 km²)
Average flow	X	-	-
Peak flow	X	-	-
Base flow	X	-	-
Groundwater recharge	X	-	-
Sediment load	X	-	-
Pathogens	X	-	-
Nutrients	X	X	X
Salinity	X	X	X
Pesticides	X	X	X

Source: Kiersch, 2000.

Sedimentation and erosion

Sedimentation can adversely affect reservoirs, waterways, irrigation systems and coastal zones, with negative implications for aquatic biology, fish production and biodiversity. The relationship between erosion rate and quantity of sediment transported by rivers is complex and depends on the geographical scale under consideration. Erosion and sedimentation vary widely according to geologic, climatic and other conditions. There is clear evidence that farm-level land-use practices can have a significant impact on the rate of erosion. Changes in land cover from forest to agriculture, for example, usually increase soil erosion, while good agricultural practices reduce it.

The impact of land-use practices on the overall sediment yield of river basins is very difficult to assess. Most of a river's sediment load originates from specific locations within the watershed and arrives in the river during extreme climatic events. The delivery of sediment to a river basin is relatively slow. Over the life span of a reservoir, very little sediment from the upper watershed travels more than 100 to 200 km. Thus, any impact that land-use practices have on the sedimentation rate of a large river will be felt only several decades later, when it is very difficult to distinguish between natural and human-induced sediment load.

Importance of scale

The impact of land use on river regime is a question of scale

Scale is one of the most important parameters in assessing the impact of land use on water. Table 1, which is based on numerous case studies, classifies the potential impact of land use on different aspects of water regime and quality, as a function of basin scale. Land use is likely to have a significant impact on water regime and water availability in only very small watersheds. As watersheds increase in size, the impact of land use on the hydrological regime becomes insignificant compared with that of natural factors, such as the intensity of extreme rainfall events. At larger scales, however, land use does have an impact on water quality, and the cumulative effects of pollution, for example, can be observed in large river basins.

Non-point-source pollution and deterioration of water quality

In regions of intensive agriculture, inappropriate application of fertilizers and pesticides may result in chemicals being washed out of the fields into rivers or aquifers, where they become concentrated and pollute the water sources of downstream users. Cattle feedlots, which are now recognized as a major cause of pollution, are also usually considered as non-point-source pollution, usually at a more localized scale.

Non-point-source pollution is relatively easy to assess because it makes radical changes to the chemical composition of the water. However, it is very difficult to quantify, mainly because of the complex degradation processes of some chemicals – particularly pesticides and toxic trace elements. Most non-point-source chemical and organic pollution of water resources occurs in industrialized countries, but it is increasing in several developing regions where intensive agriculture is practised.

As well as the quantity, the quality of water is also an important concern

Assessing and quantifying the impacts of land use on a river's water quality require a thorough analysis of the situation and a clear understanding of the physical processes concerned. When responding to watershed problems, the elements to be studied include the scale of the watershed, the distinction between natural and human-induced hazards, chemical processes, and the distinction between point-source and non-point-source pollution.

Eutrophication

Eutrophication is the process by which damaging quantities of nutrients accumulate in water bodies (Fleming, Hufschmidt and Hyman, 1982). Nutrients, mainly nitrogen and phosphorus, come from a variety of sources, including agricultural fertilizers, municipal sewage, grazing in riparian areas, and sediment from eroded watersheds. Although nutrients from natural sources are needed to keep the ecosystem productive, excess amounts from human activities can overload rivers and lakes, causing algal blooms and reduced water quality. High concentrations of algae consume the oxygen dissolved in water while they decompose, causing anoxic conditions that are toxic to aquatic life. Fish cannot survive in water with little or no dissolved oxygen, and many lakes, reservoirs, rivers and estuaries have lost valuable aquatic resources through eutrophication. Several species of algae are unfit for human and livestock consumption. Excessive algal growth has caused serious problems in the Lake of Zurich in Switzerland, Lake Erie in the United States, Phewa Lake in Nepal, the Nile Delta in Egypt, Negril Delta in Jamaica, Skaha Lake in Canada, Poza Honda Reservoir in Ecuador (Box 7), the Sea of Galilee in Israel, and Lake Garda in Italy.

BOX 7

Eutrophication in Ecuador

Poza Honda, Ecuador's first major reservoir, was constructed in 1970 in a small coastal watershed in Manabí province to supply water for domestic use and irrigation. Five years later, it was 25 percent full of sediment. Deforestation on steep slopes, unrestricted grazing and erosive agricultural practices had led to excessive nutrient loading, causing severe eutrophication and anoxic conditions throughout the reservoir, which had a mat of blue-green algae 20 cm deep. Water treatment filters required daily maintenance and irrigation canals were blocked by large-rooted plants.

A US$2 million watershed restoration plan was launched to protect the reservoir shoreline and conserve sub-watersheds. The plan included range management to control livestock grazing on steep slopes. After 13 years, the sedimentation rate had slowed from an annual 4 percent of reservoir volume to 2.5 percent, and 80 percent of the reservoir shoreline was protected from livestock grazing by a vegetative buffer zone. Nutrient influx was substantially reduced and algal growth controlled, making fishing a productive activity for watershed residents. Water quality was improved, with sufficient dissolved oxygen to support a healthy aquatic ecosystem while supplying water for domestic and agricultural uses.

Source: Fleming, 1995.

The nutrients causing eutrophication come from several locations scattered across a watershed; accordingly, projects aimed at reducing the movement of nutrients from the land should be carried out at the watershed level (Fleming, Hufschmidt and Hyman, 1982). Soil is the main carrier of nutrients, and erosion control is one of the most effective mitigation measures. While in small watersheds, upstream conservation (e.g., leading to reduced erosion) can have an immediate and substantive downstream impact (e.g., leading to reduced sedimentation and eutrophication in reservoirs and lakes), in large drainage basins, the relationship between upstream conservation and downstream impacts is more difficult to quantify.

Impacts of climate change and human activities

There is increasing evidence that the climate system is experiencing pronounced change, with an increase of 0.6 °C in the mean surface temperature of the planet since the end of the nineteenth century (IPCC, 2001). A substantial proportion of the warming over the last 50 years is attributed to human-induced greenhouse gasses. Changes to the hydrological cycle have also been detected, particularly in mountain areas; in temperate regions, mountain areas are experiencing increased intense precipitation events, while mountain rainfall in tropical regions has decreased and become more erratic, especially in areas affected by el Niño.

As most of the freshwater used by humans originates from precipitation in upper watersheds, the impacts of global climate change have become a major issue in mountain research. According to Uhlenbrook, Wenninger and Lorentz (2005), such impacts depend on rainfall changes and on land-use practices. For instance, a slight increase in event-precipitation is likely to have a much larger impact on runoff and flood discharge when inappropriate watershed management practices are applied.

Land-use changes are changing watershed landscape patterns, ecosystem function and climate dynamics; they affect biodiversity and hydrology and the transport of latent heat, carbon dioxide, nutrients and pollutants. Although global change is largely driven by nature, humans have become a significant environmental force with vast implications for watershed systems. Humans are not only subject to environmental change, but also constitute one of the main driving forces behind that change (Huber Bugmann and reasoner, 2005).

WATERSHED HUMAN ECOLOGY

Most watersheds are human-made environments

Most people live in watershed or river basin ecosystems that they have moulded to their needs throughout history; with the exception of a few residual and strictly protected areas, the ecology of most watersheds is in many ways human-made (Box 8). The relationship between human populations and watersheds has usually been adaptive, homeostatic and resilient. There are very few documented instances of human-made watershed collapses throughout the 5 000-year history of watershed management.

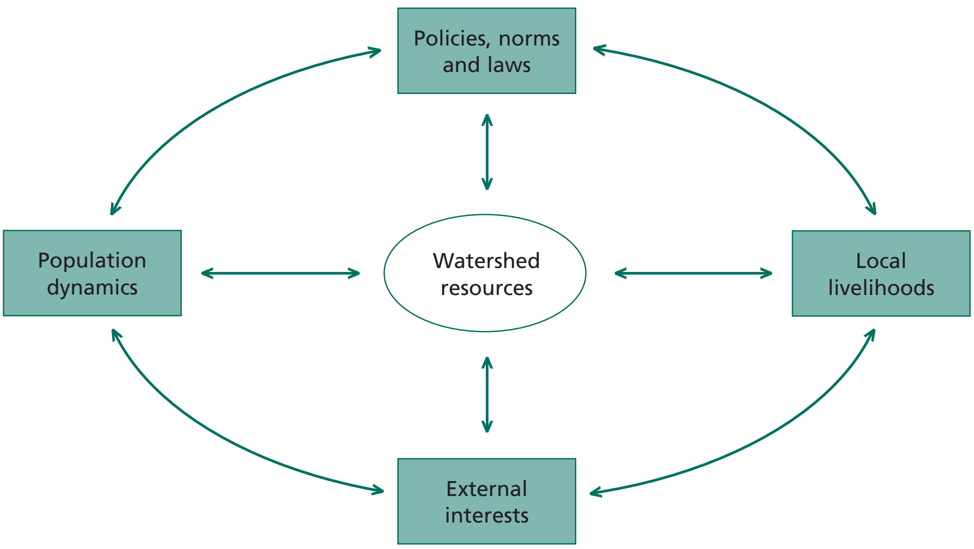
Factors in watershed human ecology fall under four main headings: local population dynamics, local livelihood systems, external interests, and policies, norms and laws (Figure 1). Interactions among these factors largely determine a watershed's environmental conditions at a given time.

Watersheds and human population dynamics

Population dynamics are changes in the number and socio-economic composition of the people living in a given area. They include changes to the balance between births and deaths ("natural growth"), and in- and out-migration.

Natural growth depends on the average number of successful pregnancies in a woman's reproductive life, mortality (particularly infant, child and maternal mortality) and life expectancy. It is influenced by genetic factors, the natural environment and a host of economic, social and cultural factors such as dietary patterns and contraception practices. Although unhealthy environments and non-adaptive behaviour can slow or stop natural growth, human populations tend to increase exponentially. During the

FIGURE 1
The human ecology of watersheds



BOX 8
Natural and humanly modified environments

Since the 1970s, human ecologists have focused on the ways in which human populations modify, shape and sometimes nurture the environment. In 1982, Roy Bennett summarized the findings of this research as follows:

> It is self-evident that human activities may alter natural environments, and geographical and ecological studies have shown in detail the mechanisms by which this has taken place, and the extent to which it has occurred. Here the term "natural" is being used to mean unmodified by *Homo sapiens*, but, of course, this does not mean that environments are not being constantly modified by other organisms. In fact, "pure nature" does not exist, and from an anthropological point of view, the environment must include humans and the result of their activities. The "natural regions" distinguished by biogeographers commonly correspond to regions transformed through human manipulation, and are only "natural" in a rather general sense… Thus environmental determinism cannot be simply represented as environment → society, but must be represented as environment ⇆ society. All environmental factors may be so modified. Populations of plant and animal species may be selectively husbanded, soils may be artificially enriched, climates altered through the removal of tracts of vegetation, and entire topographies transformed through the creation of irrigated rice terraces.

Source: Bennett, 1982.

last 100 years, this trend has been strengthened by the worldwide diffusion of modern sanitation, health care and formal education, which have decreased infant, child and maternal mortality and increased life expectancy. This is "demographic transition", which is intertwined with socio-economic development and cultural change (Box 9).

As a result of development and modernization, human populations are tending to grow beyond the carrying capacity of local environments and their resources. Local societies often seek to address this situation through migration. For instance, during the second half of the twentieth century, many upland populations migrated to find better opportunities in the lowlands or towns. More efficient agricultural technologies were also adopted to feed more people. Population pressure on downstream ecosystems and the demand for upstream ecosystem resources and services, such as water, power, timber and minerals, have increased. Upstream–downstream migration often worsens watershed environments (Box 10). Depopulation of mountain areas and urbanization have also caused major socio-political strains.

BOX 9

Agricultural frontier and demographic transition among the Shuar

The upper Morona and Santiago watershed in eastern Ecuador is the homeland of the Shuar, an indigenous group that adhered to traditional tropical forest hunting-horticulturist livelihood systems until the early twentieth century, when population density was about 1.2 inhabitants per square kilometre. In the 1960s, the Government of Ecuador started to colonize the Shuar territory and created a special institution to build the necessary infrastructure. Many Shuar abandoned the valley to escape abuse from the colonists. They migrated to the hills, where they started to combine indigenous slash-and-burn agriculture with cattle ranching.

In the mid-1960s, missionaries assisted the Shuar Federation to defend indigenous land rights, ensure that the Shuar shared in the benefits of development and preserve indigenous culture. The federation promoted the registration of Shuar settlements as legally acknowledged cooperatives; the procurement of agricultural land titles; credit and technical assistance for cattle ranching; and bilingual education, modern health care and transport services.

Over the next 20 years, the federation achieved its development objectives, but at a high price in terms of deforestation, the extinction of most hunting and gathering species and the degradation of fragile hillsides. This was mainly because it had adhered to the existing legal structure, which claimed all the Amazon as State property to be distributed to individuals or legally recognized groups according to their "exploitation capability". This policy made forest clearing for pastureland an inexpensive way of qualifying for huge land extensions, including those that the federation secured for many Shuar settlements. Cattle rearing provided Shuar people with income to pay for schools fees, health services and manufactured goods.

Modern health care reduced under-five mortality from 267 per thousand in 1976 to 99 per thousand in 1992. The population grew by about 4 percent a year; in the early 1990s, there were 5.2 people per square kilometre of entitled land, and this was expected to reach 10.6 people by 2006. The Shuar Federation was not sure that the land would be able to sustain all these people, so it made environmental sustainability a major objective, introducing agroforestry, new income-generating activities based on indigenous expertise, and the diversification of production. These initiatives may improve the human ecology of Morona Santiago watershed and prevent environmental catastrophe, but they cannot restore the ecological conditions and livelihood strategy that existed before the demographic transition.

Source: Borrini-Feyerabend and Pimbert, 2005.

BOX 10

The colonization of the Peruvian *montaña*

The eastern slopes of the Peruvian Andes are covered with tropical rain forest in a *montaña* landscape of steep mountains and deep valleys, dug out over the millennia by large rivers and their tributaries running towards the Amazon basin. These watersheds cover a total area of 270 000 km^2, and until the early twentieth century they were inhabited almost solely by a few thousand indigenous people.

Road construction across the mountains encouraged Quechua small farmers from the highlands and unemployed urban dwellers to migrate into the *montaña.* Large international companies established vast coffee, cocoa and ranching estates, offering jobs. The population increased from 240 000 in 1940 to 1.2 million by 1981. As natural growth accounts for only a twofold increase, most of this fivefold increase in 41 years was due to immigration.

One of the attraction factors of the large migration flow was a national policy to extend the agricultural frontier into the Amazonian uplands by constructing roads and infrastructure, facilitating land entitlements, assisting farmers and providing credit to small and medium-sized businesses. A side-effect was the development of a seasonal labour market, attracting thousands of landless highland farmers to the *montaña* watersheds. Among the expulsion factors were unequal land distribution in the Andes and the low productivity of mountain agriculture; a natural increase of the Andean population that was greater than the growth of on-site employment opportunities; and a national macroeconomic crisis, which led to increased unemployment in urban areas of Peru.

Governments and international agencies supported colonization of the *montaña* watersheds because it acted as a safety valve for Andean agricultural land tenure and productive structure. However, it also had severe environmental and social consequences. Deforestation, soil erosion, river pollution, conflicts with indigenous people, drug trafficking, civil war and poverty can all be attributed to this attempt to provide for the landless by expanding the agricultural frontier, without first resolving the inequities in access to natural resources and the unsustainable livelihoods systems that are prevalent in the Andean highlands.

Source: Barton *et al.,* 1997.

Local livelihood systems

Livelihoods link local people to watershed natural resources

Local livelihood systems are the most direct link between human population and the watershed natural environment. They comprise the assets, strategies, norms and institutions that allow households to make a living and reproduce within a particular natural and political environment. They include:

- access to and use of natural assets such as soil, water, forest, minerals and energy;
- norms and laws that regulate and protect such access and use;
- expertise, technology and infrastructure that utilize natural resources without overexploiting them;
- social institutions that mediate conflicting interests and promote cooperation regarding upstream ecosystem resources such as water, power, timber and minerals;
- values and beliefs that make sense of these features and support natural resource use.

Although types of livelihood system can be identified on a geo-ecological or historical basis, actual livelihood systems tend to be highly localized. Their geographic scope is generally limited to relatively small social groups living in self-contained territories, such as a sub-watershed, or a particular ecological floor or biotope (mountains, hills, lowlands, riverbanks, a valley, a swamp or a small town). Box 11 gives examples of local livelihoods in watershed ecosystems.

Local livelihood systems are cultural products. They develop slowly through trial and error, with experiences being transmitted from one generation to the next through behaviour, language, art, science and religion. Local livelihood systems should not be seen as solely traditional, however, as they are dynamic, evolutionary and open to innovation; they continuously *adapt* to environmental, demographic, economic, social and cultural changes. This process is not free from inefficiencies, waste and error, which may cause negative trends or shocks leading to watershed collapse. Box 12 gives an example of environmental degradation that is clearly related to the pressure of market economy, population growth and climate change on local livelihoods.

Most local livelihood systems manage natural resources relatively efficiently and sustainably: communal grazing has supported human livelihoods in inhospitable Alpine high-mountain environments for centuries, and water-sharing systems have sustained agricultural production in dry Near Eastern lowlands. In the Amazon, small-scale itinerant agriculture contributes to forest biodiversity through the diffusion of secondary forest species, which provide food for different species of mammals and birds, and by increasing sunlight infiltration in the surrounding dense rain forest areas. Box 13 gives another example from the West African savannah.

BOX 11

Local livelihoods in watershed ecosystems: examples from Nepal, the African lake region and central Italy

In Nepal's middle hills, the primary livelihood activity is agriculture on small terraces. Soil structure and fertility are maintained by compost, crop residues and leaf litter gathered from communally or State-owned forests. Manured livestock bedding is the main compost. Livestock are either kept in paddocks, or grazed on fallow land, common property forests and upland pastures. Richer households supplement farming with income from local businesses or employment. Poorer and landless households depend on non-land-based activities such as labouring, artisan work and non-timber forest production (Ellis and Allison, 2004).

On the shores of the African Great Lakes, the Sudd and Niger delta wetlands and shallow inland lakes, households practise agriculture, fisheries and livestock grazing on private land and common property resources. Crops, including paddy rice in wetland areas, are grown on land held under customary tenure, including that claimed during the seasonal retreat of lake water levels. Inundated areas that individual households have not claimed for crop agriculture are used for livestock grazing. Fisheries are State-controlled, but managed *de facto* as commons. Wealthier households own fishing-related assets and more land and livestock than other groups. Middle-income families own land, but cannot afford fishing-related assets. Lower-income households have access to land for subsistence cropping, but own fewer livestock and can fish only as crew labourers on other people's boats (Ellis and Allison, 2004).

In the Umbria region of Italy, traditional smallholder livelihoods are based on a mix of cereal and legume cropping, tree cropping, animal breeding and forestry. Cereal, leguminous and fodder crops are planted on rotation in small valley plots with abundant water throughout the year. Olive trees, nuts and vineyards are cultivated on slopes up to 700 m above sea level. Upland durmast and chestnut forests and rangeland prairies cover more than 70 percent of this rugged watershed area, and provide fodder, fuelwood, timber, chestnuts and other forest fruits. Although all farmers in this area have access to European Union Common Agriculture Policy subsidies, farming does not usually provide a living for all the family. Most watershed inhabitants complement their agricultural and forestry earnings with wage labour, trade and small agritourism enterprises (Warren, 2004).

BOX 12

Livelihoods and environmental degradation in the hills of eastern Guatemala

Jocotán municipality corresponds to the southern catchment of the Copán-Ch'orti' watershed in southeast Guatemala near the border with Honduras. Its very rugged, sloped territory of 148 km^2 ranges from 1 800 to 300 m above see level (asl). The total population is 37 000 people: 5 000 in the town and 32 000 in hamlets scattered throughout the countryside – about 215 people per square kilometre. In Jocotán there are too many people with too little land, in a very dynamic, fragile ecosystem.

When Spanish colonizers founded the town of Santiago de Jocotán in 1539, most of the Copán-Ch'orti' watershed was covered with subtropical rain forest in the valley, acacia forest on sloped hillsides and pinewoods in the highlands. Spanish settlers exploited the fertile alluvial valley intensively for cocoa, tobacco, sugar cane, salzaparilla, indigo and cattle. Ch'orti' *campesinos* who were not involved in colonial production were forced to grow subsistence maize on the sloping, stony, fragile and dry hillsides. This poor land had to be rotated every few years, leading to deforestation in the watershed.

Liberal reform in the nineteenth century transferred indigenous communal land titles to the municipality, enabling Jocotán's powerful Spanish entrepreneurs to increase their control over arable land and labour. By the end of the century, immigrants were moving to iron mines and coffee plantations in the uplands. The Ch'orti' retired towards less accessible and less productive areas, where they diversified their subsistence household economies with sales of small surpluses and handicrafts, sharecropping or wage labour.

By the 1920s, after two centuries of continued deforestation, there was insufficient land for crop rotation and the pressure on soil intensified. Rainfall was declining and in the 1950s, hillside *campesinos* started to sow drought-resistant sorghum as a security crop, along with traditional maize and beans. Men began to migrate seasonally to fruit plantations and big estates.

These strategies allowed *campesinos* to satisfy their immediate needs and maintain their families on farms. However, unfavourable terms of trade, population growth and subsequent increases in land fragmentation have caused continuous decline in households' natural, physical and financial assets over the last three or four decades. Shrinking land areas have led to overexploitation of soil and progressively decreasing yields, which chemical fertilizers have only partially amended. Lack of cash, labour and expertise prevent most *campesinos* from investing in soil conservation and water harvesting. In the meantime, surviving patches of pinewood on the mountain tops are being degraded by small-scale timber activities and daily fuelwood collection.

Vegetation cover is now inadequate to retain rainfall, humidity and soil. The rainy season often starts a month late and has longer and more frequent interruptions. Rainfall washes away huge amounts of fertile sediment, and landslides threaten infrastructure, crops, property and life. *Campesino* livelihoods in Jocotán are at increasing risk, and local people and institutions recognize the need to identify sustainable development alternatives.

Source: Warren, 2005.

BOX 13

Misreading an African landscape

Kissidoudou prefecture in the upper catchment of the Niger river has a striking landscape with patches of dense, verdant, semi-deciduous rainforest towering over expanses of grassy savannah. These forest islands, scattered over the gently rolling hills, are generally circular, of 1 or 2 km in diameter and usually contain one of the prefecture's 800 villages.

Since the French occupation in 1893, Guinea's administrators saw these forest patches as the last relics of a dense humid forest that once covered the landscape. They believed that local inhabitants had progressively converted the forests into savannah through shifting cultivation and fire setting, preserving only the narrow belts around villages. The European Union (EU)-funded Programme d'Aménagement des Bassin Versantes de l'Haute Niger assumed the same, 100 years later.

However, historical sources, interviews and satellite images show that these forest islands are not the relics of forest destruction. Instead, farmers grew them on what was originally savannah for subsistence, social and ritual purposes. The geographical distribution of the forest islands reflects the demographic dynamics of the last century, with Kuranko and Kissi villages splitting and new settlements being created, each with its own human-made forest. Aerial photographs and satellite images of five major villages show that between 1952 and 1992 forest islands increased in all locations.

The false assumptions about the Kissidoudou landscape reflected the power relations that colonial and post-colonial land policies supported. Because vegetation was considered degraded rather than natural, many traditional methods used by farmers to enrich their landscapes were obscured and marginalized. Policy-makers and environmental scientists assumed that people would improve forest and savannah habitats only through external programmes and projects and State-assisted village planning. Discussions presented inhabitants as incapable of managing resources sustainably, promoting the idea that external interventions were needed to improve the situation on their behalf.

Source: Fairhead and Leach, 1996.

Local livelihoods and external interests in watershed ecology

The case studies described in Boxes 9 to 13 highlight that local livelihood systems are best understood as part of broader economic, social and political systems. The nation State and decentralized governance units (departments, districts, municipalities, etc.) are the most prominent external actors in watershed human ecology, but global markets and international institutions have become increasingly important in determining access to and use of watershed natural resources over the last 50 years.

The socio-economic importance of watershed ecosystems goes far beyond local residents' interests. Food, timber and fuelwood produced in an upland valley may be needed in a downstream town. The inhabitants of a town and its rural hinterlands may wish to build a dam in a valley to prevent floods, irrigate fields and produce hydropower. A national or international corporation may wish to obtain a concession for extracting minerals or building a tourist resort. An environmental protection agency may decide to create a national park to protect mountain biodiversity. Sometimes these external interests are compatible with those of watershed inhabitants, but in other cases they pose a threat to local livelihoods. In all cases, watershed inhabitants have to share control over watershed resources with outsiders.

Policies, norms and laws

At the local level, watershed natural resources are held under a variety of tenure and access arrangements. These can be customary and rooted in local livelihoods and culture, or statutory and enforced by the State to harmonize on- and off-site interests and ensure that strategic environmental goods and services continue to be provided downstream. This situation has often led to complex and pluralistic tenure regimes in which private, social and State property coexist. As Box 14 illustrates, overlapping linkages and conflicting rules in pluralistic tenure regimes often have important implications for the environmental and socio-economic processes in watersheds.

BOX 14

Customary and statutory land rights in Kenya

The Nyando River basin covers 3 500 km^2 of western Kenya and has some of the country's most severe agricultural stagnation, environmental degradation and deepening poverty. The river is also a major contributor of sediment, nitrogen and phosphorus to Lake Victoria. About 750 000 people from two major language groups live here: the Luo in the lower and middle watershed, and the Kalenjin upstream. Resettlement of large farms in the "white highlands" led to the coexistence of Kalenjin with people of other ethnic groups, contributing to politically motivated "tribal clashes" in the 1990s.

The Kalenjin upper basin is comprised of gazetted forests, commercial tea plantations and small, steep-hillside agriculture plots on degazetted forest land. Mid-altitude areas contain smallholder farms (maize, beans and some coffee, bananas, sweet potatoes and dairy) and large-scale commercial farms, mostly sugar cane. The flood-prone Luo lakeshore area is mainly for subsistence production of maize, beans and sorghum, and commercial production of sugar cane and irrigated rice. Smallholder farmers and the National Irrigation Board own downstream, irrigated areas.

Land and water in the Nyando basin are held under a wide variety of both customary law and statutory property right arrangements, with three types of private tenure on former crown land – large agricultural leaseholds (former white-owned farms), subdivided agricultural leaseholds and non-agricultural leaseholds – and four types of private tenure on trust land: freehold land in adjudication areas, freehold land in settlement schemes, non-agricultural leaseholds and group ranches. Land degradation is most severe in subdivided agricultural leaseholds and freehold land in adjudication areas. In the former, problems are associated with poor land-use planning during the transition from large- to small-scale farming in the 1960s and early 1970s. The companies that purchased land on behalf of groups of shareholders failed to consider the land's productive capacity, the terrain or the need for public utilities. Land buying along ethnic lines led to clusters of different cultures living together on the same landscape, resulting in weakened traditional systems as people relied more on statutory law.

In Luo-designated areas, natural population growth led to the overuse of all land resources. In addition, some government and trust land areas have not been assigned to specific users, leaving them very vulnerable and subject to abuse because of their *de facto* open access. Many other areas, that are important for catchment management, spring heads, riparian areas, wetlands and water harvesting structures have been designated as private property.

This complex land tenure system creates many problems for watershed management. High erosion rates in the lower basin are associated with the overuse of uncultivated private areas for grazing and wood collection; in the upper basin, they are associated with the private allocation and farming of steep hillsides. Gully formation and low-quality water in mid-altitude areas are associated with the common use of springs on private land. Deforestation of riparian areas is associated with privatization and the ineffective enforcement of rules. Lack of public water management infrastructure is associated with lacking public or collective land for water storage structures.

Source: Swallow, Onyango and Meinzen-Dick, 2005.

States regulate access, tenure and use of watershed resources through policies, norms and laws. Regulation may have major implications on in- and out-migration dynamics and livelihood systems and often plays a crucial role in shaping the human ecology of the watershed (Boxes 9 and 10).

Once again, watershed scale is a crucial factor: the bigger the watershed area, the more complex the interplay between on- and off-site socio-economic interests, and the greater the need for regulation. Managing major river basins that are strategic assets for national economies is a public affair, while river system basins that are of concern for several countries, such as the Congo, the Rhine, the Amazon, the Tigris and Euphrates, and the Ganges, are subject to transboundary management agreements and interventions (Box 15). The same applies to some landlocked basins, such as the Mediterranean (Box 16), the Caspian Sea and Lake Victoria.

BOX 15

Transboundary watershed management and regional integration in West Africa

At 4 200 km, the Niger is the third longest river in Africa; its basin is the ninth largest in the world, with 2.2 million km^2 of surface. It is an important asset for nine West African countries – Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Guinea, Mali, the Niger, Nigeria and Chad – some of which are among the world's poorest countries.

The river crosses four climatic zones: humid tropical, dry tropical, semi-arid and arid. Its very variable rainfall ranges from 4 000 mm in the Guinea Gulf to 200 mm in the Sahel. Widespread environmental degradation and deteriorating natural resources in the basin are a result of unsustainable agricultural and ranching practices, bush fires and deforestation, pollution, water and wind erosion, silting of water courses, and proliferation of aquatic plants. Land degradation is a major threat for productivity and food production, particularly in the Sahelian area in the mid-watershed. An increasingly dry climate and decreasing sedimentation, associated with increasing demand for agricultural land, have contributed significantly to the destruction of vegetation cover. Stream flow, ecosystems and socio-economic activities are seriously threatened.

The Niger Transboundary Watershed Programme was set up to combat hydrological erosion. Its long-term objectives are protecting the basin's natural resources and conserving its hydrological potential in order to foster development, decrease food insecurity and poverty and preserve local ecosystems. It adopts a participatory, gender-sensitive approach, aimed at strengthening local stakeholders' responsibility and involving them in rehabilitation activities.

The programme includes a regional component aimed at strengthening the basin authority's capacity to intervene at the transboundary level. Three national components, designed as investment projects, focus on priority actions for environmental protection and the combating of siltation in Burkina Faso, Mali and the Niger. All three share common development objectives, but each has significant autonomy. National activities follow the participatory approach and aim to raise the awareness and commitment of local stakeholders at all stages of implementation.

Programme aims include stabilizing 3 000 to 5 000 ha of dunes, managing/protecting rangeland and catchments, rehabilitating 13 500 ha of degraded land through agroforestry, enhancing the watershed management capacity of local institutions and people, and strengthening the Niger Basin Authority. Other expected outputs include: a tool kit for identification, planning, coordination, monitoring and evaluation; a management plan for combating hydraulic erosion and siltation; enhanced food security and livelihoods for local people; income generation and diversification; rural employment; and women's empowerment through income-generating activities and literacy.

Source: Diallo, 2005.

Relationships between the human population and the watershed environment take place in a comprehensive framework that includes on- and off-site, upstream and downstream, micro and macro processes. This framework depends largely on the policies and laws through which the national society and international treaties regulate the use of watershed resources and services. The human ecology of watersheds is based on the micro- and macroeconomics of natural capital.

BOX 16

Freshwater in the Mediterranean basin

The Mediterranean region is bioclimatically characterized by strong summer droughts; over the last 20 years, most countries have experienced droughts lasting several years. Irregular precipitation and high water in the Mediterranean often cause flooding, and rain is a major cause of soil erosion. Major drainage and irrigation works in the nineteenth and twentieth centuries transformed numerous marshy plains into high-yielding land.

Today, the region's water demand is 300 billion m^3 – 100 percent more than a century ago and 60 percent more than 25 years ago. This demand is unevenly distributed among countries, ranging from 100 to more than 1 000 m^3/capita/year. Irrigation accounts for 82 percent of demand in the southern Mediterranean, but with the total urban population (in towns of more than 10 000 inhabitants) forecast to increase from 43 million in 1995 to 80 million in 2025, aqueducts and water treatment will need considerable investments in order to supply the necessary water and sanitation. As the world's most visited tourist destination, the summer demand for potable water increases greatly in coastal areas of the Mediterranean.

Water withdrawal already exceeds 50 percent of the renewable natural water in the Syrian Arab Republic, Tunisia and the Mediterranean watershed of Spain, and 90 percent in Egypt and Israel. Groundwater exploitation exceeds 400 percent in the Libyan Arab Jamahiriya. The Mediterranean's very unsustainable water consumption is caused by the overexploitation of groundwater and the increased use of fossil resources. Erosion and reservoir siltation also contribute, with annual losses of useful capacity reaching 2 to 3 percent in northern Africa; half of Morocco's useful capacity will be lost by 2050. The overexploitation of coastal aquifers has caused much seawater invasion, and up to 90 percent of wetlands in Mediterranean areas have disappeared, with a huge impact on ecosystems. Conflicts of use and interest between upstream and downstream areas, cities and farming, the short and the long terms are likely to worsen as the management costs for water protection, urban sanitation and pollution control grow.

In order to improve the balance between water supply and demand, stabilize pressure on the environment and address social and economic issues, there is a need to link resource management and water demand, particularly through reducing losses, increasing efficiency and arbitrating in resource allocation. This means defining environmental and social objectives, allocating roles between the public and private sectors, decentralizing management and increasing stakeholder participation, and applying technical and economic tools. Above all, agricultural and rural development policies in the Mediterranean region should consider environmental and social issues while they seek higher irrigation efficiency.

Source: Dassonville and Fé d'Ostiani, 2005.

WATERSHED ECONOMICS

Watersheds provide human societies with many goods and services, such as clean water, erosion control, carbon sequestration and conservation of biodiversity. Unlike timber, livestock products or minerals, however, the value of these goods and services is rarely expressed in monetary terms and there are no markets where they can be bought or sold. These goods and services are known as "public goods" or "positive externalities" (Cornes and Sandler, 1996).

The concept of public goods implies that one person's consumption of a good does not diminish another person's (*non-rivalry*) and does not bar anyone else from benefiting from the good (*non-exclusion*) (Table 2). Watershed-generated environmental public goods include regulation of water flow and quality, sediment delivery and the maintenance of landscape beauty.

An externality is a commodity's value that is not reflected in that commodity's market price. For example, the value of a forest in controlling stream-bank erosion and sediment load in a river is not reflected in the market price of the forest land, neither is the value of a highland swamp in recharging an aquifer reflected in water price. Farmers do not usually take externalities into account when they are deciding whether to conserve forest or clear trees, sell the timber and convert to other land uses.

Markets for non-rival and non-excludable goods and services generally fail because there are no incentives for beneficiaries to pay providers. As any payment to improve a good or service will benefit all beneficiaries, it is rational for each beneficiary to wait and see whether others will make an investment that improves access to the service. This is a "free-rider strategy"; if all beneficiaries adopt it, the good or service will not be supplied.

Society generally attaches a high value to the positive externalities of watershed landscapes and will take action to guarantee that they are provided for and conserved. This is the primary justification for the public funding of watershed management programmes. Many countries have laws regulating access to and use of watersheds, but these are often inefficient and difficult to implement; it is difficult to enforce laws aimed at protecting the landscapes that provide positive externalities.

Internalizing watershed externalities in market exchanges

Command and control approaches to protecting the flow of benefits from watershed landscapes have often failed, so efforts have recently been made to create markets for these externalities. Under such payment for environmental services (PES) mechanisms, the beneficiaries of externalities or services pay the providers. This transforms an externality into a tangible income for service providers. When providers and beneficiaries are located in the same watershed, most environmental services of interest are water-related, and depend on the type of water use, the hydrological regime and geological features of the watershed, and climatic factors. Table 3 summarizes the watershed-related environmental services identified in some Latin American studies. Watershed services also include carbon sequestration and the conservation of biodiversity.

TABLE 2
Characteristics of watershed goods and services

	High rivalry	Low rivalry
Low excludability	Public goods Most watershed environmental services, such as erosion control	Common pool resources, such as community woodland, fish in reservoirs and rivers
High excludability	Toll goods, such as access to national parks	Private goods, such as timber, minerals, agricultural produce

Source: Landell-Mills and Porras, 2002.

TABLE 3
Watershed environmental services and their users

Service	Users
Improvement or stabilization of annual water flow	Drinking-water suppliers Hydroelectric facilities with multi-annual storage Irrigation
Improvement or stabilization of dry season flows	Drinking-water suppliers Runoff river hydroelectric facilities Irrigation
Low concentrations of suspended sediments	Drinking-water suppliers Hydroelectric facilities with multi-annual storage Runoff river hydroelectric facilities
Low concentrations of sediment bed load	Hydroelectric facilities with multi-annual storage Irrigation
Low concentrations of fertilizer and pesticide residues	Drinking-water suppliers
Improvement of microbial quality	Drinking-water suppliers

Source: Kiersch, Hermans and Van Halsema, 2005.

The values of watershed environmental goods and services can be categorized according to the total economic value framework (Barbier, 1991; Pearce and Turner, 1990; Munasinghe, 1993). This framework divides the total value into use values and non-use values. Use values are those assigned to a resource that is needed for a current or future economic activity. They can be divided into: direct use values, reflecting a good's value as a direct input into an activity; indirect use values, reflecting a good's value in providing the environment for an activity; and option values, reflecting the value of guaranteed future access to a good. Non-use values are not associated with economic activities. Existence values apply to resources whose existence is very valuable to some people for religious or cultural reasons. Legacy values are those ascribed to the availability of a resource to future generations. Figure 2 illustrates the application of the total value framework to watershed water resources.

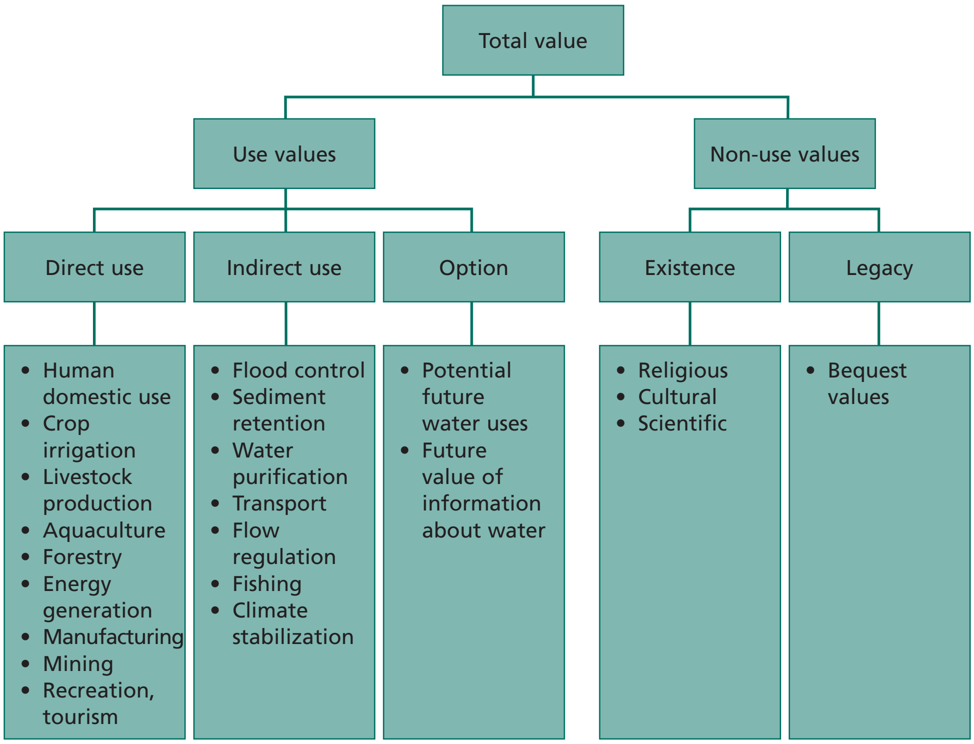
As Figure 2 shows, watershed environmental services typically have direct use or indirect use values, and may also have option, legacy and existence values, for example, from biodiversity conservation.

Assessing the economic value of watershed-generated services is not straightforward. First, the biophysical linkages between land use and water resources in the watershed must be well understood: there should be evidence that a specific land or water use upstream will benefit downstream water users. Second, the externality needs to be valued in economic terms. A PES mechanism can then be set up in which beneficiaries pay land users for providing the services.

Valuable and non-valuable watershed services

Although valuation methods for environmental services have been improved, there are limits to what they can achieve. Economic valuation makes costs and benefits transparent to decision-makers and the public, but it cannot assess moral or aesthetic considerations, such as the value of a resource that is needed for an ecosystem to function. Intergenerational equity is also difficult to assess. Discount rates and weighting approaches are used to account for resource stocks and flows over time (Pearce, 1983), but decisions about the proper weights for environmental, social and economic factors and for short-term versus long-term benefits are moral decisions that become political (Echavarría, 2000).

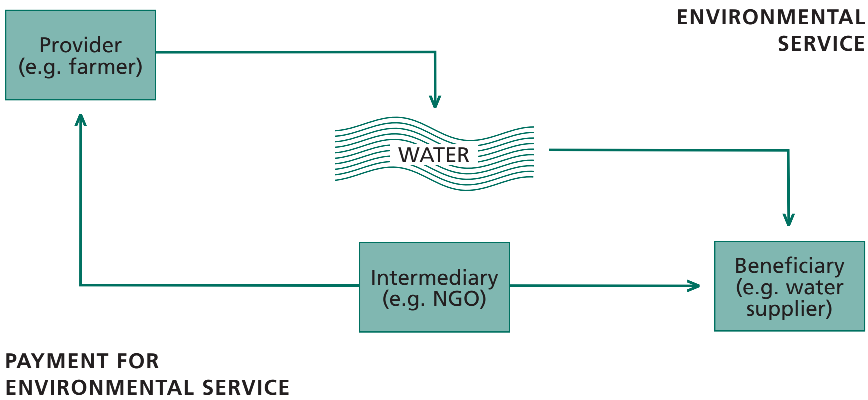
FIGURE 2
Total economic value framework as applied to watershed water resource



Source: Echavarría, 2000.

In spite of these concerns, the PES approach is a useful innovative concept for watershed management. Most PES schemes recognize that the environmental services provided by watershed systems will become increasingly scarce, depending on the willingness of beneficiaries to invest in their continued provision. Figure 3 illustrates a typical PES scheme for watersheds. Upstream *providers* supply a well-defined water-related environmental service to downstream *beneficiaries*, who *compensate* the providers through the payment scheme, either directly or through an *intermediary*.

FIGURE 3
Outline of PES scheme for watershed management



Watershed-based PES schemes can be divided into two main categories (Kiersch, Hermans and Van Halsema, 2005):

- *Local schemes* involve the service providers and beneficiaries of one watershed. Downstream beneficiaries may include municipal or private water supply, hydroelectric and other companies, such as beverage manufacturers. Providers may include individual landholders or groups of landholders, such as agricultural cooperatives (Boxes 17 and 18).
- *National-level programmes* finance incentives for land users through cross-sectoral subsidies such as taxes on fuel or energy production. The funds are channelled through government programmes, and there is not always a direct link between service providers and beneficiaries (Boxes 19 and 20).

BOX 17

A private agreement on compensatory payment for watershed management services in Costa Rica

In Costa Rica, several laws and regulations protect the ecosystems that regulate water resources by restricting land use in forested areas so as to preserve vegetation cover and avoid pollution. Since 1996, the government has also sponsored PES schemes to create economic incentives for conserving forest and to compensate those whose land or land uses generate environmental services. The Ministry of Environment is responsible for enforcing these laws and schemes, imposing fines and granting water concessions to La Esperanza Hydropower Project (LEHP).

Hydropower production requires regular water flows. About 98 percent of the LEHP watershed's 34 km^2 area is forested, and seasonal variations in river stream flow are a particular concern. In 1998, LEHP and the conservation NGO that owns the upstream watershed signed a private contract to reduce the risks associated with changes in land use. The main goal is to conserve forest cover in the upstream watershed in order to reduce fluctuations in stream flow and ensure regular downstream flow.

This was necessary because of a landownership dispute between LEHP and the NGO regarding the 1.5 ha site for the hydropower plant, which was on land that the NGO owned. The contract grants land-use rights to LEHP for 99 years; the NGO retains ownership and carries out activities to protect the forest cover of the watershed. LEHP compensates the NGO through payments that increase during the first five years and are then calculated on the basis of power production and inflation. The original value of the hydrological service was based on that used in similar government schemes. The payments contribute 10 to 25 percent of the NGO's annual budget, and increase the operation and maintenance costs of the power plant by 21 percent. In case of delayed payment, the NGO can revoke the right to use the land and all the infrastructure it contains.

Source: Rojas and Aylward, 2003.

BOX 18

A public–private PES scheme in rural Ecuador

Pimampiro municipality has about 20 000 inhabitants, 6 300 of whom are urban residents. It depends on water that originates in upstream forests and grassland. Between 1987 and 1997, an agricultural cooperative – the Asociación Nueva América (ANA) – acquired 638 ha of forest, upland prairie and agricultural land in the upstream watershed. Further encroachment on forests and upland prairie would put the town's water supply at risk.

In 2001, Pimampiro municipality and ANA signed a cooperation agreement with the twofold aim of preserving forest cover and upland prairie and protecting the water sources that supply urban Pimampiro with drinking-water. The municipality's Unit on Environment and Tourism (UMAT) makes contracts with cooperatives, based on their land management plans, and pays compensation for land uses that support water provision. The scheme was established with an international grant of US$15 000. Conserving primary forest and upland prairie attracts the highest payments, of US$1/ha/month, while secondary forest earns US$0.75/ha/month, and intervened primary forest or upland prairie US$0.50/ha/month. Agricultural land receives no payment. Payments are made after inspection by an UMAT technician every four months. In cases of repeated non-compliance, providers are excluded from the scheme.

The municipality has committed itself to directing 20 percent of residents' water fees into the fund. This amounts to less than US$4 000 a year, which is barely sufficient to pay the compensation on 638 ha and the administration, oversight and technical costs. To cover all the upstream area that provides water, a total of 4 285 ha would have to be included in the scheme, implying a sixfold increase in compensation payments, which is currently out of the municipality's reach.

Source: Ambrose, 2002.

BOX 19

Transfer of hydropower revenue to watershed management institutions in Colombia

With 47 468 m^3/capita/year, Colombia has abundant water resources. However, densely populated areas generally have less available water, triggering concerns about an impending water crisis in the medium term. Extreme climatic events such as el Niño have already caused considerable losses in the hydroelectric sector.

In response, the government is transferring 6 percent of the gross energy sales of hydroelectric projects to the municipalities and regional development organizations (RDOs). By law, 50 percent of these funds must be invested in improving watershed areas upstream of hydroelectric facilities, and RDOs must formulate and implement watershed management plans. Of 23 RDOs, 16 have hydroelectric projects in their areas, and between 1994 and 2000 they received a total of US$135 million from hydroelectric revenues.

This scheme is a powerful tool for investing in environmental services from upper watersheds, but payments are increasingly used to cover RDO administrative costs and other purposes. To rectify this, watershed management plans need to prioritize the areas of a watershed that provide the greatest hydrological impacts downstream. RDOs should define clear and verifiable indicators and a monitoring and evaluation system to assess the impacts generated.

In other PES schemes, such as in the Cauca valley, downstream water users transfer a share of their self-imposed water user fees to projects that conserve the upstream watershed (Echavarría, 2002b).

Source: Estrada and Quintero, 2004.

BOX 20

Costa Rica's National Forestry Financing Fund

Faced with diminishing forest resources caused by the advancement of the agricultural frontier, Costa Rica is at the forefront of PES development. The Forestry Law of 1996 established a national-level payment system that recognizes forested areas' provision of watershed protection, carbon sequestration, biodiversity conservation and preservation of scenic beauty. The National Forestry Financing Fund (FONAFIFO) administers payments under this programme, nearly two-thirds of which are funded from a fuel tax, with lesser shares provided from sales of carbon credits to international companies (18 percent), international donors, such as the Global Environment Facility (GEF), the World Bank and the German Bank for Reconstruction and Development (16 percent), and hydroelectric producers (5 percent). Since 2005, FONAFIFO has issued environmental service certificates to anyone interested in forest preservation.

The programme compensates forest preservation, reforestation and, since 2005, agroforestry and integrated plantation systems on the basis of the opportunity costs of converting forest to other productive uses. Between 1997 and 2004, more than 400 000 ha of land and more than 7 000 families benefited from the scheme; more than 80 percent of the contracts issued were for protecting existing forest and agroforestry. In some areas, however, the programme's payments have proved to be too small. In the peri-urban area around La Heredia, for example, the water supply company increased water tariffs in order to pay additional incentives to landholders in the watersheds that provide drinking-water. Contracts are signed for ten years for reforestation, five years for forest protection, and three years for agroforestry. Payments for forest protection are spread evenly over the contract period, while for reforestation and agroforestry about 50 percent is paid during the first year to aid landholders' initial investments.

The programme is very popular, with supply far outstripping demand. In 2005, FONAFIFO awarded contracts to only 12 percent (608 ha) of the projected reforestation area, 30 percent (132 000 ha) of the agroforestry area, and 57 percent (31 000 ha) of the forest protection area. Nevertheless, forest cover grew from 32 percent in 1990 to 45 percent in 2004. The FONAFIFO scheme has also encouraged similar private PES schemes, such as La Heredia and La Esperanza (Box 17), which take advantage of the national institutional set-up.

Source: Rojas and Aylward, 2003; FONAFIFO, 2005.