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Watershed protection: Capturing the benefits of nature's water supply services

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Abstract

Healthy watersheds provide valuable services to society, including the supply and purification of fresh water. Because these natural ecosystem services lie outside the traditional domain of commercial markets, they are undervalued and underprotected. With population and development pressures leading to the rapid modification of watershed lands, valuable hydrological services are being lost, which poses risks to the quality and cost of drinking water and the reliability of water supplies. Increasing the scale and scope of programmes to protect hydrological services requires policies that harmonize land uses in watersheds with the provision of these important natural services. This article summarizes key attributes of hydrological services and their economic benefits; presents a spectrum of institutional mechanisms for safeguarding those services; discusses programmes in Quito (Ecuador), Costa Rica and New York City; and offers some lessons learned and recommendations for achieving higher levels of watershed protection.

Keywords: Watersheds; Drinking water; Water quality; Ecosystem services; Natural capital; Land use; Rural landscapes; Soil and water conservation.

1. Introduction

A watershed is an area of land that drains into a common water source. Because watersheds connect and encompass terrestrial, freshwater, and coastal ecosystems, they perform a wide variety of valuable services, including the supply and purification of fresh water, the provision of habitat that safeguards fisheries and biological diversity, the sequestering of carbon that helps mitigate climatic change, and the support of recreation and tourism (see Table 1). In the parlance of ecological economics, watersheds are natural assets that deliver a stream of goods and services to society. Commercial markets, however, value these services only partially if at all.

The failure to adequately incorporate the value of natural services into decisions about the use and management of watershed lands is reducing the net benefits that societies derive from watersheds. Land-use changes — from forest to farmland, for example, and from farmland to urban settlements — diminish the ability of a watershed to perform its ecological work. In much of the world, the conversion and modification of watersheds has already progressed to a large extent. A global analysis of 106 primary watersheds found that in nearly one-third of them, more than half the land area had been converted to agriculture or urban–industrial use. In Europe, 13 watersheds have lost at least 90% of their original vegetative cover. China's Yangtze and Yellow River basins have lost 85% and 78% of their forest cover, respectively. In the Indus basin, more than 90% of forest lands have been converted to other uses, as have virtually all the forest lands of the Senegal and Lake Chad basins in sub-Saharan Africa (Revenga *et al.*, 1998).

The ability of healthy watersheds to moderate water flows and purify drinking water supplies is one of their most

Table 1. Ecosystem goods and services provided by healthy watersheds

- Water supplies for agricultural, industrial, and urban-domestic uses
- Water filtration/purification
- Flow regulation
- Flood control
- Erosion and sedimentation control
- Fisheries
- Timber and other forest products
- Recreation/tourism
- Habitat for biodiversity preservation
- Aesthetic enjoyment
- Climate stabilization
- Cultural, religious, inspirational values

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tangible and valuable services. The progressive loss of these services risks harm to human health through lowered drinking water quality, higher water costs that may burden poorer populations in particular, and lower crop productivity and hydroelectric output from reduced dry-season flows. As natural watersheds have been converted to alternative land uses, many industrial countries have turned to increasingly sophisticated technological treatment processes to remove pathogens and other contaminants from raw drinking water sources of diminished quality. In Denmark and Germany, for example, the average cost of drinking water is three times higher than in Australia and the United States, and four times higher than in South Africa (NUS Consulting Group, 2003). Although other factors play a part in these differences, the loss of natural watershed functions plays an important part. For societies facing the challenge of meeting the water supply needs of growing urban and rural populations, healthy watersheds are natural assets of increasing value.

Lack of information — both scientific and economic — on the links between land uses in a watershed and the corresponding hydrological services those watersheds provide complicates the task of designing appropriate institutional mechanisms for watershed protection (Aylward, 2002). Nonetheless, the mix of efforts now under way offers valuable ideas and lessons. This article presents a brief overview of the importance of natural water supply services, a typology of mechanisms for protecting those services, several cases where innovative mechanisms are under way to increase such protection, and recommendations for achieving higher and sustainable levels of protection.

2. The benefits of hydrological services from healthy watersheds

Of the many ecosystem services that watersheds provide, hydrological services constitute some of the most economically and socially valuable (Postel and Richter, 2003; Daily *et al.*, 2001; Landell-Mills and Porras, 2002). These services largely fall into four broad (and to some degree overlapping) categories: water filtration/purification; seasonal flow regulation; erosion and sediment control; and habitat preservation.

Watersheds with a high proportion of land covered by intact forests and wetlands are particularly effective at moderating runoff and purifying water supplies. The vegetation and soils of forests and wetlands have a remarkable capacity to filter out contaminants and trap sediment that would otherwise enter rivers, lakes, and streams. Bogotá, Colombia, for example, gets most of the drinking water for its 8 million citizens from a high-elevation wetland ecosystem called a *páramo*. The vegetation of the *páramo* absorbs, filters and releases clean water at a reliable rate of 28 m^3 per second with little seasonal variation and minimal need for treatment. This high reliability and quality translates into lower capital and treatment costs than would otherwise be the case. Indeed, the raw water delivered to the utility's treatment plant is so clean that the only treatment given is chlorine for disinfection; if turbidity increases significantly during heavy rains, the water is run through sand filters first — but this is rarely needed (Quintero, 2004). Bogotá's watershed lies within the Chingaza National Park and is protected by the public water utility, a level of protection that is critical because throughout much of the Colombian Andes, the area of *páramo* is dwindling rapidly due to population and agricultural pressures.

Table 2. Forest cover and predicted water treatment costs based on 27 US water supply systems[a]

Share of watershed forested	Treatment costs per 3,785 m^3	Average annual treatment costs	Cost increase over 60% forest cover
60%	$37	$297,110	–
50%	$46	$369,380	24%
40%	$58	$465,740	57%
30%	$73	$586,190	97%
20%	$93	$746,790	151%
10%	$115	$923,450	211%

Source: Adapted from Ernst (2004).
[a] Based on treatment of 22 million gallons (83,270 m^3) per day, the average daily production of the water suppliers surveyed.

Watershed protection has also reduced capital, operation and maintenance costs in industrial countries. An analysis of 27 US water suppliers revealed that treatment costs for drinking water deriving from watersheds covered at least 60% by forest were half of the cost of treating water from watersheds with 30% forest cover, and one-third of the cost of treating water from watersheds with 10% forest cover (see Table 2). Moreover, a number of US cities have avoided the need to construct expensive filtration plants by investing instead in watershed protection to maintain the purity of their drinking water (see Table 3). In cities such as Boston and Seattle, these cost-savings were possible largely because the municipal water authority owned and was able to protect the critical watershed lands. In the case of New York City, however, where about three quarters of the watershed is privately owned, achieving a level of protection sufficient to avoid construction of a filtration plant has required a multi-faceted agreement with watershed communities (see discussion below) that is now being implemented.

Watersheds without adequate protection inevitably deliver less clean, less reliable water to their downstream dependents. The conversion of natural watershed lands to agricultural, industrial, or urban uses adds to that watershed's pollution burden while simultaneously diminishing its ability to assimilate and process those pollutants. Deforestation, road construction, clear-cutting, and poor farming practices can send large influxes of eroded sediments into rivers and streams, markedly degrading the quality of water and of aquatic habitats (Calder, 2000; Newson, 1992). Runoff from livestock operations, where large quantities of

Table 3. Selected US cities that have avoided construction of filtration plants through watershed protection

Metropolitan area	Population	Avoided costs through watershed protection
	(thousands)	
New York City[a]	9,000	$1.5 billion spent on watershed protection over 10 years to avoid at least $6 billion in capital costs and $300 million in annual operating costs.
Boston, Massachusetts[b]	2,300	$180 million (gross) avoided cost.
Seattle, Washington[c]	1,300	$150–200 million (gross) avoided cost.
Portland, Oregon[d]	825	$920,000 spent annually to protect watershed is avoiding a $200 million capital cost.
Portland, Maine[d]	160	$729,000 spent annually to protect watershed has avoided $25 million in capital costs and $725,000 in operating costs.
Syracuse, New York[e]	150	$10 million watershed plan is avoiding $45–60 million in capital costs.
Auburn, Maine[f]	23	$570,000 spent to acquire watershed land is avoiding $30 million capital cost and $750,000 in annual operating costs.

Notes:
[a] The City is currently being required to construct a $687 million filtration plant for the more-developed Croton watershed, which supplies about 10% of the city's water. The filtration waiver applies to the Catskills/Delaware watershed, which supplies about 90% of the city's water (NRC, 2000).
[b] *US v. Massachusetts Water Resources Authority* (2000).
[c] Supply from Seattle's Cedar River watershed is unfiltered, but that from the Tolt watershed is now filtered (Flagor, 2003).
[d] Reid (2001).
[e] ECONorthwest (2004).
[f] Ernst (2004).

manure are concentrated, can add dangerous quantities of pathogens to watershed streams (US EPA, 2003). Fertilizers and pesticides applied to croplands, golf courses, and suburban lawns can enter surface and groundwater, where they pollute water bodies, degrade aquatic habitats, and contaminate drinking water sources. In the United States, the US Geological Survey (2001) has detected herbicides in 99% of urban stream samples and 50% of urban groundwater samples.

Cities and settlements dependent for their water supplies on relatively small watersheds with steep erosion-prone slopes are likely to experience the greatest effects of land-use changes on hydrological processes (Nelson and Chomitz, 2004). The capital city of Honduras, Tegucigalpa, is a case in point. The city gets 30% of its drinking water from the Guacerique watershed, which feeds the Los Laureles reservoir. The failure to formally recognize, protect, and manage the water purification and sediment control services provided by the watershed has led to the creeping deterioration of these hydrological services during a period of rapid population growth and rising land pressures. According to Lee (2000), agricultural and urban activities that are largely incompatible with the Guacerique watershed's function as a source of drinking water now occupy about one fifth of the watershed land. Nitrogen and phosphorus pollution from sewage and farmland runoff has led to algal blooms in the reservoir. High turbidity and fecal coliform (bacterial) levels in the reservoir's raw water have required greater use of treatment chemicals and increased expenses to maintain sand filters. Sedimentation resulting from high rates of hillside erosion in the watershed is estimated conservatively to be reducing the reservoir's storage volume by 2% annually — hastening the day when capital expenditures for a new supply will be needed.

The loss of hydrological services from the conversion of watershed lands typically happens incrementally and thus often goes unnoticed. In the extreme case of Mombasa, Kenya, however, the water supply system was abandoned after less than a decade because of the rise in treatment and maintenance costs resulting from rapid deterioration of its source water quality (Hirji and Ibrekk, 2001).

Although forests and wetlands are unambiguously good at cleansing water supplies, their ability to increase dry-season flows, reduce flood damage, and perform other water supply services varies with local conditions. For instance, young tree plantations often have high rates of evapotranspiration, so reforesting grassland may actually reduce seasonal water supplies: some water that would have infiltrated the soil and emerged downstream during the dry season is instead transpired back to the atmosphere by the rapidly growing trees. In Fiji, the large-scale planting of pine in watersheds that had previously been grassland resulted in 50–60% reductions in dry-season flow — reductions that put both drinking water supplies and the operation of a hydroelectric plant at risk (Dudley and Stolton, 2003). South Africa is actively working to reverse the negative water supply (and biodiversity) impacts from the spread of non-native eucalyptus, pine, black wattle, and other thirsty trees into the native *fynbos* (shrubland) watersheds of the Western Cape. The evapotranspiration requirements of these alien invasives greatly exceed that of the low-lying and drought-tolerant *fynbos* vegetation. Researchers have determined that a restored catchment would yield nearly 30% more water than one of equivalent size populated with thirsty alien trees — and generate new water supplies cost-effectively (van Wilgen *et al.*, 1996).

'Cloud forests' play a very important role in the water supply services of some mountain watersheds and deserve special protection. High-elevation 'cloud' or 'fog' forests usually increase local water supplies by raking moisture out of the fog-shrouded atmosphere that would otherwise remain in vapour form. In most cases, this increased water deposition in cloud-forest canopies exceeds the re-evaporation of water from those canopies, resulting in a net gain in water yield. Because their foliage is constantly wet, cloud forests also have lower evapotranspiration requirements, which means they pump less moisture from the soil back to the atmosphere. As a result, for a given level of rainfall, stream flows originating from cloud forests tend to be greater than those from grasslands or other types of land cover. According to Hamilton and Cassells (2003), this extra water supply is particularly noticeable and important in areas of low rainfall, where a low cloud deck touches the mountains. In such areas, the raking action of the cloud-forest canopy can double the amount of water made available by rainfall alone. In humid areas, the gain in yield may be closer to 15–20% — still a significant benefit to downstream communities in need of drinking water.

3. Institutional mechanisms for increasing protection of water-supply services

A rich variety of institutional mechanisms exists to encourage higher levels of protection of watershed hydrological services. There is no 'right' approach: successful arrangements will be contoured to the needs and characteristics of individual watersheds. Options that make sense for small watersheds may differ considerably from those suitable for very large ones. Similarly, measures appropriate for relatively pristine watersheds may not be applicable to watersheds in which substantial population and economic activity already exists.

The menu of options consists of four broad categories: governmental ownership and control of watershed lands; broad-based government incentive payments to encourage ecologically sound land-use choices; government regulations to protect watershed health (including market-based cap-and-trade schemes); and negotiated payments by the (usually downstream) beneficiaries of natural water supply services to the (usually upstream) providers of those services. Table 4 provides a sampling of these different types of watershed protection efforts now ongoing in various parts of the world. The cases described below illustrate in more detail the institutional features of several approaches. These have been selected from the group summarized in Table 4 not because they are the best, but because they offer useful lessons.

3.1. Watershed trust fund, Quito, Ecuador

The solution to watershed protection found by Quito, Ecuador, involves the establishment of a trust fund to finance payments to landowners in the watershed in return for their safeguarding the water supply for the city.

There is substantial overlap between lands legally protected for their conservation values (e.g., nature reserves, national parks, wilderness areas) and watersheds that cities depend upon for their drinking water. Of 105 populous cities in Africa, the Americas, Asia, and Europe, 33 obtain a significant portion of their water supplies from legally protected lands (Dudley and Stolton, 2003). In some cases, the safeguarding of water supplies was a primary reason for establishing the protected area. For example, the World Bank loaned Indonesia $1.2 million to establish the Dumoga-Bone National Park because of the water supply benefits the park would provide to a large irrigation project in the lowlands. Similarly, Honduras gave protected status to La Tigra National Park in part because its cloud forests helped generate 40% of the capital city's water supply at a cost equal to some 5% of the next best alternative source (Reid, 2001).

Land designated as protected, however, may in some cases be used by local inhabitants for farming, grazing, fuelwood collection, or other enterprises that potentially can compromise the provision of water supply services. In such cases, a sensible option may be to establish a mechanism through which the downstream beneficiaries of those services provide financial support for good watershed management practices to safeguard the quality and quantity of the water supply.

A case in point is Quito, the capital of Ecuador. Home to more than 1.5 million people, Quito derives about 80% of its drinking water from two protected areas — the Cayambe Coca Ecological Reserve and the Antisana Ecological Reserve. These reserves encompass 520,000 ha of high-altitude grasslands and cloud forests. Although formally protected as part of Ecuador's national park system, these reserve lands are also used for cattle, dairy, and timber production by the 27,000 people living within or around the reserves.

Concern about the impact of these activities on the quantity and quality of water supplied to Quito led to the establishment of a trust fund to finance watershed protection measures. Proposed in 1997 by *Fundación Antisana* (an environmental NGO based in Quito), and established in 2000 with support from The Nature Conservancy (a US-based conservation organization) and the US Agency for International Development (USAID), the trust fund (called *Fondo del Agua*, or FONAG) is designed to pool the demand for watershed protection among the various downstream beneficiaries. These include a municipal water supply agency (EMAAP-Q), irrigators, commercial flower plantations, and hydroelectric power stations. Quito's electricity supplier, *Empresa Eléctrica de Quito* (EEQ), generates about 22% of its hydropower in the watersheds surrounding the capital (Echavarria, 2002).

FONAG is a non-declining endowment fund that can receive money from both government agencies and private organizations. An independent financial manager invests the funds, and returns on these investments are to be used

Table 4. Institutional mechanisms for watershed protection: some examples

Case example	Motivation for watershed effort	Source of funds
Costa Rica: A national Payment for Environmental Services Programme	National law gives government authority to pay landowners for ecosystem services provided by their land	Tax on fossil fuels; World Bank loan; Global Environment Facility grant; sale of carbon credits
Paraná, Brazil: Ecological Value-Added Tax	State law earmarks 5% of value-added tax revenue to municipalities for critical watershed or conservation land	General tax on goods and services (value-added tax)
Colombia: Ecological Services Tax	National law establishing regional agencies responsible for watershed management	Property taxes; hydroelectric revenues; industrial water user fees
United States: Conservation Reserve Programme	National law gives government authority to compensate farmers for converting eligible cropland to more resource-conserving land uses	General taxpayer revenues
European Union: Agri-Environment Programmes	Regulation enacted by European Union	General EU budget for agricultural purposes
United States: Pollution Cap-and-Trade Schemes	National policy to reduce cost of achieving non-point pollution targets under Clean Water Act	Public and private polluting enterprises, some state and federal funding
New South Wales, Australia: Salinity Cap-and-Trade Scheme	State programme to reduce salinity of land and water cost-effectively	Salinity-emitting enterprises; Public and private investors in a state-run environmental services fund
Perrier Vittel: Direct payments by the company to farmers	Protect its source for high-priced bottled spring water, thereby increasing profits	Perrier Vittel
Quito, Ecuador: Watershed Trust Fund	Protect quality and supply of drinking water, as well as ancillary biodiversity and conservation benefits	Voluntary contributions from water supplier, electricity supplier, and NGOs; funding eventually to come from user fees
La Manguera SA: Costa Rican hydropower producer voluntarily pays a conservation organization to protect upper watershed	To ensure water flows for dry-season electricity production	Hydropower revenues
Cauca Valley Water-User Associations, Colombia	To ensure water flows for dry-season irrigation	Water-user fee, collected through the associations
New York City: A negotiated agreement with watershed communities	To avoid the cost of a filtration plant required under federal drinking water rules	Taxes on NYC water bills; municipal bond issues

for watershed protection measures, including acquisition of critical lands and improved agricultural practices. At this early stage, contributions to FONAG are voluntary. EMAAP-Q has committed itself to paying 1% of its water revenues into the fund, a payment expected to total about $14,000 per month. EEQ has agreed to pay a flat fee of $45,000 per year.

The voluntary nature of FONAG's funding and the heavy reliance on only two large contributors make long-term financial adequacy a challenge. Moreover, while an innovative financing tool, the endowment fund may not be the most efficient way to fund watershed protection — using the contributions immediately to pay for watershed protection measures may make more sense than first building an endowment from which to pay for those measures, especially because the longer-term goal is to establish a steady stream of user fees as the funding source. However, the lack of scientific information on the hydrological linkages of land use in the watershed and the corresponding lack of estimates as to the economic value of watershed services to the beneficiaries makes it difficult to establish credible user fees. In the interim, it is critical that EMAAP-Q and EEQ increase their contributions. At least one survey of water consumers in Quito suggested a willingness to pay higher fees for watershed protection (Echavarria, 2002).

Indeed, it is the willingness of beneficiaries to pay for watershed protection in the absence of good estimates of the value derived from that protection that has allowed FONAG to get off the ground. Strong political support for the fund helps as well, as do the important ancillary benefits of biodiversity preservation and poverty alleviation in the watershed. Yet the key is that EMAAP-Q and EEQ seem to accept that some minimum investment in protecting the local watershed is sensible even in the absence of a sound economic analysis. However, sustained financing and a broader base of contributors to FONAG may require the demonstration of more definite links between the watershed protection undertaken and the benefits downstream.

3.2. Costa Rica's forest protection

In Costa Rica, a solution to the problem of protecting sources of freshwater supply was found through making arrangements for forest protection, which secures four environmental services, joining hydrological services to other ecosystem values.

Additional support and financing for watershed protection can come from packaging a number of the goods and services jointly produced by the watershed. Ecosystem services that are potentially complementary to the natural water supply and purification services provided by watersheds include: soil conservation; sedimentation control; fisheries protection; carbon sequestration; biodiversity conservation; recreation; tourism; and cultural and aesthetic enhancements. The total value of such complementary benefits will often justify a greater degree of watershed preservation than would the hydrological services alone, as well as open up new financing opportunities. For example, Ecuador's National Biodiversity Policy recommends that beneficiaries pay for a variety of environmental services (including the provision of water) from public and private lands, with high priority given to *páramos*, mangroves, flood plains, and mountain forests (Echavarria *et al.*, 2004).

In 1996, Costa Rica adopted a forestry law (Law No. 7575) that explicitly recognizes four environmental services provided by forested lands — hydrological services; carbon fixation (which mitigates greenhouse gas emissions); biodiversity conservation; and provision of scenic beauty for recreation and tourism. The law gives the government authority to contract with landowners for the environmental services their lands provide. Funds for the *Pago por Servicios Ambientales* (or PSA, Payments for Environmental Services) programme are channeled through the National Forestry Fund (FONAFIFO). The PSA programme offers land owners different types of contracts, including forest conservation contracts under which owners agree to protect existing forests, and reforestation contracts. Payments are slightly above the opportunity cost of conversion to low-value land uses, such as pasture. The programme pays land owners about $40 ha/year under the forest conservation contracts and $538 per ha over five years under the reforestation contracts (Pagiola, 2002).

While authorizing payments for environmental services, the forestry law does not require that beneficiaries pay for those services. The primary funding source instead is the earmarking of revenues from a national sales tax on fossil fuels. A loan from the World Bank and a grant from the Global Environment Facility (GEF) (justified as a payment by the global community for Costa Rica's biodiversity conservation values) have provided substantial additional funds. The sale of carbon sequestration credits, which programme authorities had hoped would generate significant revenues for the programme, have yielded only $2 million from a single sale. Ultimately, the PSA programme aims to have all beneficiaries of hydrologic services paying for the services they receive.

On the surface, Costa Rica's programme seems quite successful. Between 1997 and 2002, more than 314,000 ha were incorporated into the programme and total payments amounted to more than $80 million (Rosa *et al.*, 2003). FONAFIFO has applications pending for more than 650,000 ha in addition to the land already enrolled (Pagiola, 2002). The forest conservation contracts have proven the most attractive, accounting for 82% of all contracts (see Table 5).

Table 5. Status of Costa Rica's Payments for Environmental Services Programme, 2002[a]

Contract type	Land area (ha)	Total payments (million US$)
Forest conservation	259,220	56.4
Forest management	32,012	11.2
Reforestation	22,613	12.8
Plantations	626	0.1
Totals	314,471	80.5

Source: Adapted from Rosa *et al.* (2003).
Note: [a] Based on data for 1997–2001 and areas planned and budgeted for 2002.

Despite these encouraging signs, analysts are concerned about both the equity and sustainability of Costa Rica's PSA programme. Contracts are made only with private landowners having title to their land, which excludes landholders and land users without property titles. This requirement, along with complicated bureaucratic procedures, high transaction costs, and other factors, has favoured medium- to large-scale private landowners over indigenous communities and small farmers. Only 3.2% of lands incorporated in the programme are indigenous territories, even though such territories comprise 20% of the natural forest outside of protected areas (Rosa *et al.*, 2003).

The programme will also need a firmer financial foundation. There is no guarantee that the transfer of revenue from the fuel tax to the programme will continue, nor that World Bank loans and GEF grants will be replenished. Therefore, the ability to increase payments by beneficiaries seems key to the programme's long-term success. Although total payments by beneficiaries have so far been disappointing, some important gains in this area have been made. To date, FONAFIFO has reached agreements with several hydroelectric power producers (HEP). Because they operate run-of-the-river plants, they have limited water storage capacity and thus depend on the watershed to provide adequate seasonal flows to sustain their electricity production.

Energia Global, for example, a private HEP, operates two small run-of-the-river facilities, one in the 2,404 ha Rio San Fernando watershed and the other in the 3,466 ha Rio Volcán watershed. *Energia Global* pays FONAFIFO for a portion of the payments the forestry fund is making to participating land users in those watersheds. Recently, the company's annual share was $10/ha, about a quarter of the standard PSA contract payment for forest conservation (Pagiola, 2002). *Energia Global's* rationale for investing in forest protection is based on the assumption that a degraded watershed would cause greater variability in seasonal stream flows, increasing the risk that the plant could not operate at maximum capacity. For *Energia Global*, each lost m^3 of water results in the loss of roughly 1 kWh of electricity output. The company is essentially betting that its investment in watershed protection will help secure at least an additional 460,000 m^3 of water per year for energy production compared with the water yield provided by a deforested or degraded watershed (Chomitz *et al.*, 1998).

Costa Rica's pioneering programme to compensate landowners for watershed services and thus to encourage forest conservation has created a useful model of ecosystem-service protection. The challenges, however, are to ensure that the programme does not exclude or disadvantage the poor, thereby worsening inequities, and to achieve sustainable financing.

3.3. New York City's agreement

Creating a unique link between ecosystem-service providers and beneficiaries, New York City has negotiated partnerships with upstream landowners and communities in the watershed where its drinking water originates, to ensure a pure and safe supply.

A critical attribute of most watersheds is that the costs and benefits of watershed protection will usually be separated spatially and borne by different parties. Put simply, land-holders upstream in the watershed typically provide most of the hydrological services while water suppliers, hydroelectric power producers, and other users downstream benefit from those services. Thus, linking beneficiaries with providers, directly or indirectly, is a key challenge in designing workable mechanisms for protecting hydrological services.

The driver for New York City's decision to invest in watershed protection was a requirement, under the US Safe Drinking Water Act, that water suppliers must filter their drinking water unless they can demonstrate that they are protecting their watershed sufficiently to satisfy water quality standards. New York City (NYC) is the largest city in the United States to choose watershed protection instead of a filtration plant. Faced with estimated capital costs of $6 billion and annual operation and maintenance costs of at least $300 million for the filtration plant, the City opted to seek a waiver of the filtration requirement by investing in a comprehensive watershed protection programme in the Catskill-Delaware watershed, which supplies 90% of the City's drinking water (NRC, 2000).

The hallmark of New York City's watershed protection programme is a memorandum of agreement (MOA) signed in 1997, after many years of negotiation, by a diverse set of interests, including state and federal officials, environmental organizations, and some 70 watershed towns and villages. The MOA commits the City to invest on the order of $1.5 billion over 10 years to restore and protect the watershed, as well as to financial and other measures that improve the local economies and quality of life of watershed residents.

More than three-quarters of the Catskill-Delaware watershed is covered by forest, an important asset for water quality protection. However, three-quarters of it is also in private ownership. Consequently, land acquisition is an important component of NYC's programme. Watershed lands have been divided into five different priority zones according to the land's importance for water quality protection. The City purchases land only from willing sellers — focusing on the highest-priority zones first — and pays full market price for it. In doing so, the City is choosing to incur additional costs, because under New York State's health codes it is legally entitled to take land in the watershed by eminent domain. However, as part of the agreement, NYC vowed not to do this. In addition, to prevent its land acquisition from eroding local town revenues, NYC is also paying property taxes on the watershed lands it owns now and will do the same on all new land and conservation easements it acquires.

Within the first five years of the programme, New York City solicited sales of about 104,700 ha and signed 477 purchase contracts for 13,940 ha — roughly doubling the area of protected buffer land surrounding the eight reservoirs in the Catskills/Delaware watershed. The purchase price of these lands totals some $94 million, an average of about $6,745 per ha. To provide additional benefits to watershed residents and towns, the City has opened more than 2,800 ha of its newly acquired watershed lands to public recreational uses that are deemed compatible with water quality protection, such as regulated fishing, hunting, and hiking. In addition, the City has either acquired or contracted for 960 ha of conservation easements: in exchange for the property owners' commitment to preserve the land, the City pays fair market value for the development rights as well as a portion of the property taxes in perpetuity (NYCDEP, 2002).

New York City actively works with partner organizations in the watershed to administer and implement various programme elements. In light of the diverse and numerous landowners in the watershed, these groups serve as important intermediaries for the programme's implementation. In addition to land acquisition, other key initiatives include:

i. A watershed agricultural programme to reduce polluted runoff from farming practices;
ii. A forestry programme, involving a partnership with landowners, loggers, and timber companies to better manage forests;
iii. A stream management programme, through which the City works with watershed communities and landowners to curb stream-bank erosion and riparian habitat degradation;
iv. Upgrades to wastewater infrastructure (treatment plants and septic systems) to reduce pollutants entering rivers and streams;
v. Construction of an ultraviolet disinfection plant to inactivate certain waterborne pathogens; and

vi. New regulation and enforcement mechanisms to ensure that the development and use of watershed lands is consistent with water quality protection.

As of early 2004, NYC had invested more than $1 billion in the watershed protection programme (Ward, 2004). Financing comes from additional taxes on residents' water bills and from bonds issued by the City. A review of the programme's first five years found sufficient progress in watershed protection to justify an extension of the Environmental Protection Agency's waiver of the filtration requirement. Sustaining this status will be increasingly difficult, however, as population and economic activities expand in the watershed region and as stricter federal drinking water standards are introduced in the coming years.

If successful, the New York City watershed programme should benefit both City residents and watershed land owners. City residents will enjoy high-quality water at a lower cost than would be the case with construction of the filtration plant. In return for providing water quality services to the City, landowners in the watershed will gain additional income, healthier streams and habitats, more recreational opportunities, and new economic investments, including a $60 million trust fund (financed by the City) that provides loans and grants for environmentally sustainable economic development projects in watershed communities.

The New York City programme is by far the largest scheme in the world putting into effect direct payments by a beneficiary of hydrological services to the providers of those services. It demonstrates that watershed protection can be a highly cost-effective alternative to technological treatment in meeting specific water quality standards. It also demonstrates that an inclusive negotiated partnership between upstream and downstream parties can result in expanded benefits for both from a working rural landscape.

4. Integrating rural development

Great opportunities lie in the potential integration of rural development with protection of watersheds and hydrological services.

Many countries, especially in the developing world, face the challenge of simultaneously having to reduce rural poverty and meet the growing water supply needs of expanding cities and industries. To date, most efforts to raise incomes in rural watersheds have justifiably aimed at local implementation of soil and water conservation measures that enhance land productivity. By focusing almost exclusively on the on-site benefits of watershed measures, however, this approach forfeits opportunities to expand the social and environmental benefits of watershed management, to link upper-watershed landowners providing hydrological services with the downstream beneficiaries of those services, and to establish compensation mechanisms that help finance watershed measures beyond project completion. Such missed opportunities are clearly evident, for example, in the World Bank's approach to watershed management.

Between 1990 and 2000, the World Bank allocated just over $1 billion to watershed management activities. Of 42 projects examined in an internal review of the Bank's watershed management portfolio, 38 projects (90% of them) focused narrowly on on-site measures to raise agricultural productivity. These projects tended to have disappointing rates of adoption of soil and water conservation technology after project termination: once subsidies were removed, implementation of measures dropped off significantly (Boerma, 2000). As a result, watershed investments that might have yielded positive net economic benefits downstream, were no longer made because they were not seen as profitable to the farmers themselves in the absence of subsidies.

Some of the Bank's own projects, however, illustrate the potential benefits of making the linkage between upstream and downstream beneficiaries in project design and implementation. For example, the Bank's micro-watershed project in the Brazilian state of Santa Catarina has proved highly successful by most measures. Improved land-management practices — including contour terracing, minimum tillage, and better storage systems for animal manure — were adopted by some 106,000 farmers on a total land area of 400,000 ha, spanning 534 micro-catchments (World Bank, 2000). Crop productivity on the farms rose by an average of 40% for wheat, 30% for maize, and 20% for soybean (Lituma *et al.*, 2003). Seeing the benefits, farmers outside the project area began spontaneously to upgrade their own practices, which added some 480,000 ha to the total land area improved in the state. Upon completion, the project's overall economic rate of return was estimated at 20% (World Bank, 2000).

Downstream hydrological benefits were not included in the project's design and assessment, in part due to lack of data. However, an independent study by Bassi (2002), investigated the effects of this World Bank project in the Lajeado São José micro-watershed, which supplies drinking water to the city of Chapecó. Bassi's analysis showed that there was a 69% reduction in suspended sediment concentration and a 61% reduction in turbidity of the raw water entering Chapecó's treatment plant. This substantial improvement in water quality permitted a corresponding reduction in the need for chemicals to treat the water, which in turn yielded cost-savings of $29,340 per year. These savings would be sufficient to pay back the entire cost of the Lajeado São José micro-watershed project in four years. Indeed, just one year of water treatment cost-savings exceeds the $25,000 paid to project farmers as subsidies to encourage them to adopt land-improvement measures.

Thus, in the Lajeado São José micro-watershed, and presumably in other micro-watersheds where there is a downstream municipality, an opportunity exists to strike a deal between the municipal water supplier and upstream farmers that would more equitably split the costs and benefits of the project. The water supplier should be willing to pay a portion of the funding to upstream farmers in return for the reduced water-treatment costs. Such a transaction would transform what is now a project subsidy of limited duration to participating farmers into an ongoing compensation payment for a valuable watershed service that these farmers can continue to provide — the protection of drinking water quality.

On a much larger scale, China's Loess Plateau project is cited by World Bank staff as a resounding success: it improved livelihoods for one million farm families, increased annual grain output by 64%, and produced a 3.5-fold increase in net per capita income. It also reduced the sediment load in the Yellow River system by 57 million tons, which in turn reduced the sedimentation of irrigation canals and reservoirs downstream and allowed expenditures on flood-protection embankments to be deferred. In a summary of the project's economic performance, the Bank reports an economic rate of return of 19% if only on-site benefits are considered, and 22% if the downstream benefits of reduced sedimentation are included (World Bank, 2003a). However, because downstream hydrological benefits were not incorporated into the project's design and financing, the construction of the larger erosion-control structures was reduced mid-way through the project; local farmers did not see sufficient benefits *to them* to justify the cost. A payment by or on behalf of the downstream beneficiaries would have allowed extra sedimentation-reduction benefits to be captured.

The Bank's new watershed management approach explicitly recognizes that the complementarity of upstream and downstream benefits will often make a watershed project economically justified, whereas a focus on either the upstream or downstream effects alone may not. It also acknowledges that "payments for environmental services by downstream users are seen as a promising option for distributing benefits and costs of watershed management between upstream and downstream stakeholders" (World Bank, 2001).

5. Lessons and recommendations

5.1. Act early to integrate watershed protection and management into the provision of safe drinking water

A fundamental lesson from those municipalities that have avoided expensive technological solutions to drinking water quality is the importance of acting early to protect critical watershed lands. The opportunity costs of watershed protection are rising over time as land values and the worth of foregone land uses increase; delaying action therefore often makes watershed protection more costly or even prohibitive. Where outright purchases of watershed lands are not feasible or equitable, regulations or payment schemes are necessary to ensure that the use of land within the watershed does not unduly compromise the watershed's purification and water-supply functions.

5.2. Designate watershed protection to be a responsibility of water suppliers and bridge institutional divisions that separate watershed decisions from the provision of safe drinking water

Many water suppliers consider watershed management to be the province of resource conservation districts, land management agencies, and other governmental entities. Many of these resource conservation agencies, however, do not consult actively or regularly with water suppliers. Water suppliers that own or control watershed lands also tend to separate water quality, which is typically overseen by engineers, from watershed protection, which is generally under the jurisdiction of biologists or other land-management experts. Although varying levels of coordination between the two groups occur, the separation of functions makes it more difficult to integrate a watershed's natural purification services with particular water quality goals.

Similarly, the World Bank's effort to invest more in watershed management needs better integration with its lending for urban drinking water services. The Bank's own water resources sector strategy underscores the importance of such integration (World Bank, 2003b). There are undoubtedly many ungrasped opportunities within the Bank's water project portfolio, including projects now in the pipeline, to lower water treatment costs, reduce public health risks, and secure drinking water sources by encouraging investments in watershed protection.

5.3. Acquire additional scientific and economic information on watershed services

Additional research is needed both on linkages between land use and hydrological effects within watersheds and on the valuation of ecosystem services — as well as on how to apply valuation techniques in real-world decision-making. While substantial progress has been made in these areas over the last decade (NRC, 2004), much remains to be done. Water suppliers and other beneficiaries of watershed services often do not know the degree to which the protection and management of any particular parcel of land will provide water service benefits, or whether the benefits of protecting the land are worth the costs. For example, the authors surveyed water retailers in California that supply surface water to 50,000 or more customers and found that water suppliers who had acquired or considered acquiring additional watershed land were aware of studies showing the water quality value of watershed protection, but were unable to determine the benefits of protecting specific areas of the watershed. Only one California water supplier, the City of Santa Cruz, had tried to place an economic value on watershed protection measures, and it was not confident that the value was accurate.

5.4. Establish equitable partnerships between the land-holders providing watershed services and those benefiting from the services

Improved land-use practices in rural watersheds can strengthen rural livelihoods while simultaneously safeguarding the provision of environmental services. New York City's watershed protection programme demonstrates the value of an inclusive negotiated agreement that lays out the responsibilities of all the parties; provides fair compensation to the service providers; uses an appropriate mix of financial incentives, regulations, land acquisitions, and other mechanisms; and makes improved livelihoods in the watershed an explicit goal along with water quality protection. Modified versions of this model may be especially important in watersheds of developing countries that are facing strong demographic pressures and are already supporting agricultural, forestry, and other economic activities. Unless watershed protection is undertaken with an explicit goal of equitably distributing the gains, there is a risk of benefiting urban-industrial enterprises at the expense of rural communities and the poor — and worsening social inequities.

5.5. Design water supply regulations that recognize the value of natural watershed services as cost-effective alternatives to technological treatment methods

Cities such as Bogotá, Boston, and New York City that have successfully safeguarded the natural water purification services of their watersheds and thereby avoided expensive treatment systems are saving their residents millions of dollars. Governments can expand these benefits by adopting regulations that not only allow but encourage water suppliers to meet drinking water quality standards through watershed protection. In particular, incentives to encourage early action to protect critical watershed lands and to institute water-user fees or water-rate structures that build the costs of watershed protection into urban water supply systems are critical to reaping a fuller portion of the benefits of natural watershed services. In much of the world, the affordability of future water supplies may depend on it.

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