

Managing forests for cleaner water for urban populations

S. Stolton and N. Dudley

Protecting forests helps ensure a supply of safe, clean water for the inhabitants of some of the world's largest cities.

Access to clean water is one of the most fundamental of human rights, but currently more than one billion city-dwelling people lack access to clean water. Generally it is not because water supplies are insufficient. Rather, this crisis is due to an inability to organize supply properly to meet demand. This failure is particularly frustrating in that nature contains the necessary mechanisms to provide clean, healthy water, including the filtering effect provided by healthy forests in watersheds. Yet in many parts of the world environmental mismanagement has led to a critical shortage of freshwater.

This article highlights how some of the largest cities in the world are able to supply sufficient freshwater to their inhabitants at least in part through the protection of forests. It identifies some key policy initiatives that could help reduce the vast number of people whose lives are dominated by the daily search for clean and safe water.

SUPPLY AND DEMAND

Water is, in theory, a quintessentially renewable resource. Water covers most of the world's surface, and over much of the world it falls unbidden from the skies. Yet because of the carelessness and profligacy with which water resources have been used, the speed of human population growth and the increasing demands for water, the provision of adequate, safe supplies of water is now a major source of concern, expense and even international tension.

The poorest members of society, unable to afford safe water, suffer the greatest impacts. One in five people in the developing world lives without a reliable

water supply. Lack of clean water has dire short- and long-term health impacts including increased infant mortality and impaired ability to work, which reduce industrial productivity and put pressure on already overstretched health services. On the other hand, access to clean water can have dramatic positive health impacts. For instance, it is estimated that when clean water is available the risk of early death is reduced by 23 percent in Uganda and 30 percent in Cameroon (UNDP, 2006).

Today, around half the world's population lives in towns and cities, and of these people one-third live without clean water or adequate sanitation (United Nations Human Settlement Programme, 2003). Municipal authorities have a variety of ways of supplying drinking-water, depending on where they are located, the resources available, social and political issues and the willingness of the population to conserve water. Most cities rely on the collection and diversion of existing surface and underground freshwater sources. Only minor amounts, on the global scale, are extracted directly from rainwater or from the seas. Until recently, the main focus of efforts to improve urban water supply has been within the cities themselves, including better distribution systems, treatment plants and sewage disposal. However, many authorities are now increasingly looking at land management systems that can help maintain pure water at the source.

WATER QUANTITY, QUALITY AND REGULARITY

People have settled historically in areas rich with natural resources, and today most of the world's population lives downstream of forested watersheds

Sue Stolton and **Nigel Dudley** are with Equilibrium Research, Bristol, United Kingdom.

(Reid, 2001). Societies have created strong cultural links with forests, and it is widely assumed that forests help to maintain a constant supply of good-quality water. Conversely, loss of forests has been blamed for problems ranging from flooding to aridity.

In fact, the hydrological role of forests remains a subject of debate. Some of the common assumptions about the benefits that forests bring are wrong in most situations; for example, most forests do not increase water flow in a catchment (in fact the reverse is often the case), nor do they necessarily control flooding. On the other hand, some positive benefits, including particularly their potential to supply relatively pure water, are frequently overlooked. Impacts of forests are influenced by many factors including the age and species of the trees, the amount of watershed under forest, soil, climate and forest management practices.

A meta-study conducted for the World Wide Fund for Nature (WWF) on the role of forest protection in drinking-water provision (Dudley and Stolton, 2003), including a survey of more than 100 of the world's most populous cities, revealed – as described below – a clear link between forests and the quality of water coming out of a catchment, a much more sporadic link between forests and the quantity of water available and a variable link between forests and the constancy of flow.

QUALITY

Forested watersheds generally offer higher-quality water than watersheds under alternative land uses, if only because virtually all the alternatives – agriculture, industry and settlement – are likely to increase the amounts of pollutants entering headwaters. Quality can also be higher because forests sometimes help to regulate soil erosion and reduce sediment load, although the extent and significance of this function will vary. Undisturbed forest with understorey, leaf litter and organically

enriched soil is the best watershed land cover for minimizing erosion by water. While forests are less able to control some contaminants (the human parasite *Giardia lamblia*, for example), in most cases the presence of forests can substantially reduce the need for treatment for drinking-water and thus radically reduce costs of supplying water.

Where municipalities have protected forests for their water resources, quality issues have generally been the primary motivation. In Tokyo, Japan, for example, the Metropolitan Government Bureau of Waterworks manages the forest in the upper reaches of the Tama River to increase the capacity to recharge water resources, to prevent reservoir sedimentation, to increase the forest's water purification capacity and to conserve the natural environment. In Sydney, Australia, the Catchment Authority manages about one-quarter of the catchment as a buffer zone to stop nutrients and other substances that could affect the quality of water from entering storage areas.

QUANTITY

The situation with regard to the flow of water from catchments is more complex. Despite years of catchment experiments, the precise interactions between different tree species and ages, different soil types and management regimes are still often poorly understood, making accurate predictions difficult. In contrast with popular assumptions, many studies suggest that in both very humid and very dry forests evaporation is likely to be greater from forests than from land covered with other types of vegetation; thus less water flows from forested catchments than, for example, from grassland or crops (Calder, 2000). The evidence seems to suggest, however, that cloud forests (Bruijnzeel, 1990) and some older natural forests (such as old *Eucalyptus* forests) can increase net water flow. Some cities factor management of these forests into plans for maintaining adequate water supplies.

REGULARITY

Constancy of flow is as important as total quantity, in terms of both maintenance of dry-season flow and absence of flooding during periods of heavy rain. Here opinion remains divided, as examples of very different responses can be found. In some cases dry-season flow is depressed by the presence of trees, while in other cases it is increased. Natural forests and plantations have different effects, but again these do not show a constant trend. In very general terms, forests often help to regulate relatively minor floods but are seldom able to prevent occasional, very major floods. Flooded forests – both lowland forests such as the Várzea forests of the Amazon and swamps in the uplands – have a more definite role in regulating water supply. However, the debate about the role of forests in maintaining constancy of water flow continues; a recently published study suggests that natural forests have a larger role in flood prevention than has generally been argued of late (Bradshaw *et al.*, 2007).

URBAN SUPPLY

The contributions of forests in providing clean water depend to a large extent on individual conditions, tree species and age, soil types, climate, management regimes and needs from the catchment. It is therefore perhaps not surprising that information on best practices for policy-makers remains scarce and models for predicting responses in individual catchments are at best approximate. Towns and cities are faced with a bewildering diversity of opinions on which to make hard financial and politically charged decisions about their water supply. Yet many of the world's biggest cities are choosing to rely at least in part on forested areas to help maintain water supplies.

The meta-study described above (Dudley and Stolton, 2003) indicated that about one-third (33 of 105) of the world's largest cities obtained a significant pro-

Gypsy Trail Lake, Croton watershed, New York State, United States (top): without the protection of surrounding forests, the watershed would no longer exist, and water would become scarce in New York City (bottom)

portion of their drinking-water directly from forested protected areas. At least five other cities in the review obtained water from sources originating in distant protected forested watersheds, and eight more obtained water from forests managed in a way that gave priority to their functions in providing water. In a number of cases there is also good evidence that forests help maintain water flow – for example in Melbourne, Australia and in some cities fed by cloud forests such as the Caribbean National Forest in Puerto Rico. However in some other cases where cities have been protecting forests specifically to maintain water supplies, there is little hard evidence that forest protection has this effect.

Many municipalities (although certainly not all) cite maintenance of a pure water supply as a reason for introducing forest protection or reforestation. In the United States, all states are required under federal law to have a Source Water Assessment, which promotes the idea that protecting drinking-water at the source is the most effective way of preventing drinking-water contamination (NRDC, 2003). The city of New York is famous for its use of protected forests to maintain its high-quality water supply. This approach was supported by popular vote in part because it was a cheaper option than building more treatment plants. Other cities in the United States also rely on forested catchments. Around 85 percent of San Francisco's drinking-water comes from the Hetch Hetchy watershed in Yosemite National Park. In Seattle, Washington, the primary sources of water are the Cedar River



© WFF-CANON/T. PETERSEN

© WFF-CANON/T. PETERSEN

watershed and the South Fork Tolt watershed, which together serve a population of 1.2 million people with unfiltered drinking-water.

Similar examples can be found in many tropical and subtropical regions. The Mount Makiling Forest Reserve south of Manila, the Philippines is a 4 244 ha area of forest administered and managed by the University of the Philippines. More than 50 percent of the reserve is forested, and its watershed ecosystem supplies five water districts and several water cooperatives serving domestic, institutional and commercial water users. In the

Dominican Republic, the Madre de las Aguas (Mother of the Waters) Conservation Area protects the headwaters of 17 rivers that provide energy, irrigation and drinkable water for more than 50 percent of the country's population. Examples of major cities drawing some or all of their drinking-water from protected areas include Mumbai, India; Jakarta, Indonesia; Karachi, Pakistan; Singapore; Bogotá, Colombia; Rio de Janeiro, Brazil; Quito, Ecuador; Caracas, Venezuela; Madrid, Spain; Sofia, Bulgaria; Abijan, Côte d'Ivoire; Cape Town, South Africa; and Harare, Zimbabwe.

MANAGING FORESTS FOR WATER

Forests offer a range of options for water provision, depending on their type, location and age and on what users need. Cities may choose a number of different forest management options, including protection, sustainable management and, where necessary, restoration.

Those responsible for water supply and forest management are faced with a number of questions: about whether forested watersheds offer real benefits for water supply; if they do, how much forest is required to gain these benefits; and how forests in watersheds can best be managed to protect water supplies. In most cases decisions will need to be taken in a context of competing demands on land, so that management for water will have to be balanced and traded off with other uses. The following questions all need to be answered before any decisions are made about forests managed for water.

- **What are the most pressing needs regarding water supply?** Are the pressures on water supply primarily driven by the need to get enough water, or a constant supply of water, or is the priority more to do with water quality? What quality issues are most important? For example, sediment will be most important for hydropower, whereas pollutants such as agrochemicals will also be of concern for drinking-water.
- **How is vegetation in the catchment likely to affect water quality and flow?** This needs specialist analysis, although some general points can be made. For example, cloud forests are likely to increase water, some old natural forests may also increase flow, and young forests and plantations are likely to decrease flow. Individual cases need to be assessed, depending on soil, climate, forest types and age, and management regime.
- **What is the land use?** Current status is important, but so are recent changes and likely future trends.

Answering these three questions will help to determine what natural vegetation (and perhaps other land uses) in the catchment offers in terms of water supply and whether future changes are likely to increase benefits or create problems. With this information, more strategic analysis can help to plan optimum management interventions:

- **What other demands are there on land in the catchment and how much might be available for water management?** Are other pressures on land likely to improve or degrade water? How much land is available, partially or completely, for water management? Can current land uses be improved from the perspective of the water from the catchment? What impacts would these changes have for local people and what are their needs and wishes? Can catchment areas also be used for other land uses, such as recreation or biodiversity conservation?
- **What are realistic management options?** Present and future management options should be analysed, including establishment and maintenance of protected areas, forest restoration and other forms of land use.

The analysis should tell whether the presence of forests can help supply the water required from the catchment and provide the information needed to make informed choices about a landscape mosaic that will fulfil both water needs and other needs from the watershed.

VALUING FORESTS

In many cases the economic case for managing ecosystem services can provide the impetus for sustainable forest management. A team of researchers from the United States, Argentina and the Netherlands put an average price tag of US\$33 trillion per year on global fundamental ecosystem services, which are usually taken for granted because they are free. Water regulation and supply was estimated to be worth US\$2.3 trillion

(Costanza *et al.*, 1997). At the national level, the economic value of the water storage function of China's forests is estimated as 7.5 trillion yuan (approximately US\$1 trillion), three times the value of the wood in those forests. Another study calculated that the presence of forest on Mount Kenya saved Kenya's economy more than US\$20 million by protecting the catchment for two of the country's main river systems, the Tana and the Ewaso Ng'iro (Emerton, 2001).

The issue for policy-makers is how to translate these values to help support particular types of land management. One reason why it has proved so difficult to halt and reverse global forest loss is that those who manage forests typically receive little or no compensation for the services that forests generate for others and hence have little incentive to manage them sustainably. Even when areas are protected, values such as water provi-

Forest on Mount Kenya protects the catchment for two of the country's main river systems, the Tana and the Ewaso Ng'iro (Mount Kenya National Park, Kenya)



© WALTER OCHIAI

sion are often not recognized by the users. Owing to the serious financial difficulties faced by protected areas in Venezuela, in 1999 the Instituto Nacional de Parques (INPARQUES), the State agency for protected areas, considered charging water companies for the direct services they obtain from these areas (including the three protected areas that are the source of water for the country's capital, Caracas). However, until now this initiative has not been further developed (Courau, 2003).

Recognition of this issue has encouraged the development of systems in which land users are paid for the environmental services that they generate through management. The central principle of the "payment for environmental services" (PES) approach is that those who provide environmental services should be compensated for doing so from those who receive the services. Projects using water resources as a springboard for PES schemes have mainly been developed in Latin America, but interest is quickening throughout the world. In Quito, Ecuador, for example, water companies are helping to pay for the management of protected areas that are the source for much of the capital's drinking-water.

CONCLUSIONS

One of the United Nations Millennium Development Goals is to halve by the year 2015 the portion of people who are unable to reach or afford safe drinking-water and who are without access to basic sanitation. Addressing this ambitious goal will clearly require a wide range of initiatives. The potential for forest protection and good forest management to contribute to provision of cheap, pure water deserves far greater attention than it has received until now. This recognition is becoming ever more urgent, as the Millennium Ecosystem Assessment (2005) estimates that approximately 60 percent of the world's ecosystem services are currently being degraded or used unsustainably. ♦



Quito, Ecuador is one of many major cities that draw some or all of their drinking-water from protected areas; water companies help pay for the management of these protected areas



Bibliography

- Bruijnzeel, L.A.** 1990. *Hydrology of moist tropical forests and effects of conversion: a state of knowledge review*. Paris, France, United Nations Educational, Scientific and Cultural Organization (UNESCO) International Hydrological Humid Tropics Programme.
- Bradshaw, C.J.A., Sodhi, N.S., Peh, K.S.-H. & Brook, B.W.** 2007. Global evidence that deforestation amplifies flood risk and severity in the developing world. *Global Change Biology*, 13(11): 2379–2395.
- Calder, I.R.** 2000. Forests and hydrological services: reconciling public and science perceptions. *Land Use and Water Resources Research*, 2: 1–12.
- Costanza, R., d'Arge, R., de Groot, R., Farberk, S., Grasso, M., Hannon, B., Limburg, K., Shahid Naem, I., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P. & van den Belt, M.** 1997. The value of the world's ecosystem services and natural capital. *Nature*, 387: 253–260.
- Courau, J.** 2003. Caracas, Venezuela. In N. Dudley & S. Stolton, eds. *Running pure: the importance of forest protected areas to drinking water*, pp. 90–92. Gland, Switzerland, World Wide Fund for Nature (WWF)/World Bank Alliance for Forest Conservation and Sustainable Use.
- Dudley, N. & Stolton, S., eds.** 2003. *Running pure: the importance of forest protected areas to drinking water*. Gland, Switzerland, WWF/World Bank Alliance for Forest Conservation and Sustainable Use.
- Emerton, L.** 2001. Why forest values are important to East Africa. *ACTS Innovation*, 8(2): 1–5.
- Millennium Ecosystem Assessment.** 2005. *Ecosystems and human well-being: synthesis*. Washington, DC, USA, Island Press.
- Natural Resources Defense Council (NRDC).** 2003. *What's on tap? Grading drinking water in U.S. cities*. New York, USA.
- Reid, W.V.** 2001. Capturing the value of ecosystem services to protect biodiversity. In G. Chichilenisky, G.C. Daily, P. Ehrlich, G. Heal & J.S. Miller, eds. *Managing human-dominated ecosystems*, pp. 197–225. Monographs in Systematic Botany Vol. 84. St Louis, USA, Missouri Botanical Garden Press.
- United Nations Development Programme (UNDP).** 2006. *Human Development Report*. New York, USA.
- United Nations Human Settlement Programme.** 2003. *Water and sanitation in the world's cities: local action for global goals*. London, UK, Earthscan. ♦