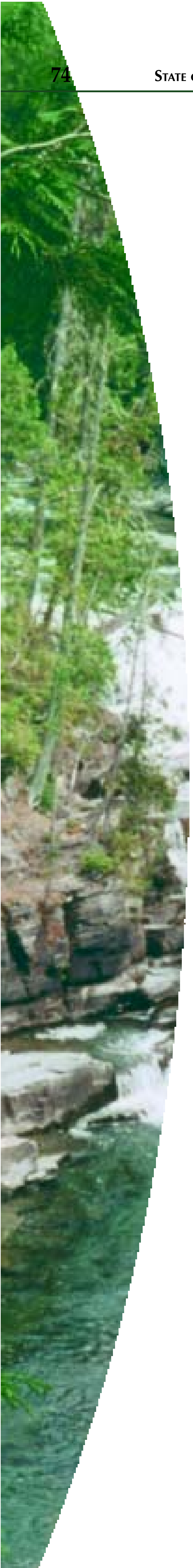


Sustainable use and management of freshwater resources: the role of forests

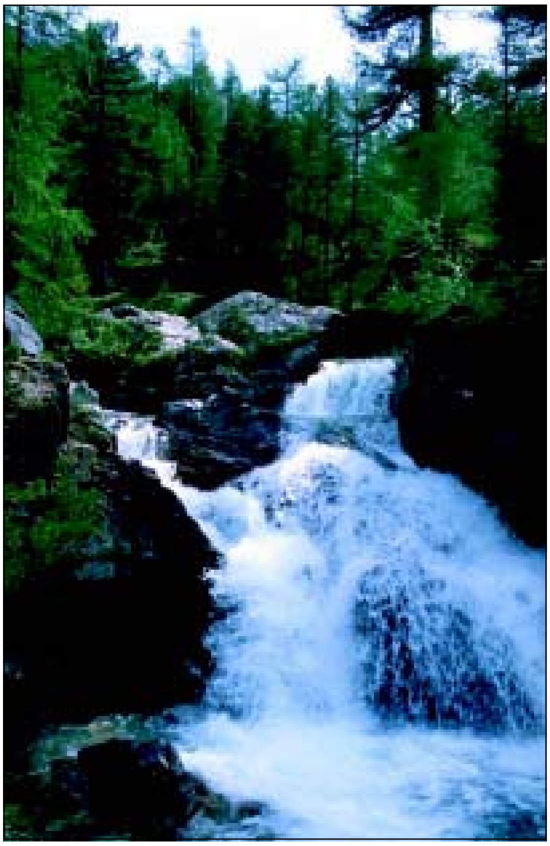
Dependable freshwater supplies and the ability to cope with the extremes of too little or too much water are requisites for sustainable human development. Warnings of freshwater scarcity issued at the end of the twentieth century (e.g. Falkenmark, 1989; Kundzewicz, 1997; Vorosmarty *et al*., 2000) are proving to be accurate, to the point that lack of water now threatens food security, livelihoods and human health (see UN, 1992; IFPRI, 2001). Worldwide, freshwater supports about 40 percent of all food-crop production via irrigation, supports 12 percent of all fish consumed by humans and generates 20 percent of all electric power (Johnson, Revenga and Echeverria, 2001). In addition to the direct impact of water scarcity, impaired quality of water reduces its usability.

More than 3 billion people worldwide do not have access to clean water, and the problem is particularly acute in developing countries, where 90 percent of wastewater is discharged into streams without treatment (Johnson, Revenga and Echeverria, 2001). Of the more than 3 million deaths that are attributed to polluted water and poor sanitation annually, more than 2 million are children in developing countries (van Damme, 2001). Furthermore, extensive loss of life and economic productivity result each year from rain-induced landslides, floods and torrents in developed and developing countries alike. Water and its management are therefore strategically important to economies and the well-being of people, and water management has become one of the major challenges of this century. Conflicts over water use will arise as water becomes increasingly scarce, making action on many fronts imperative.

Technologies exist to deal with water scarcity, and to some extent with the effects of hydrometeorological extremes (Brooks *et al*., 1997). If they are to be turned into solutions, several constraints must be overcome, including land scarcity and inadequate policies and institutions that hamper an effective response (Kundzewicz, 1997; Rosegrant, 1997; Scherr and Yadav, 1996). Although land use and freshwater are inextricably linked, they are rarely managed in concert. Upstream uses of land and water can affect downstream communities and their use of water. The converse is also true. Such linkages are readily seen with a watershed perspective, but are not always fully taken into account when responses are being developed at the local, national and international levels.

The International Year of Mountains – 2002 (Internet: www.mountains2002.org) focused worldwide attention on land and water use in mountainous watersheds. As the headwaters for all major rivers of the world, many of which are or were at one time forested, these watersheds are a key to freshwater management. The relationship between forests and freshwater, in both tropical and temperate regions, therefore needs to be understood if forests are to be better managed to sustain the productivity of uplands without affecting humans and the soil and water on which they depend. Enhancing the chances of achieving such objectives means taking a watershed management perspective in the planning, monitoring and implementation of forest, water resource, agricultural and urban development programmes.

Forested mountain watersheds are a key to dependable freshwater supplies (Switzerland)



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The loss of forest cover and conversion to other land uses can adversely affect freshwater supplies and compound human disasters resulting from hydrometeorological extremes. Watershed conditions can be improved and overall water resource management facilitated if forests are managed with hydrological objectives in mind. While not a panacea for resolving water issues, forests can provide tangible economic and environmental benefits. A watershed framework helps identify these benefits in both upstream and downstream areas.

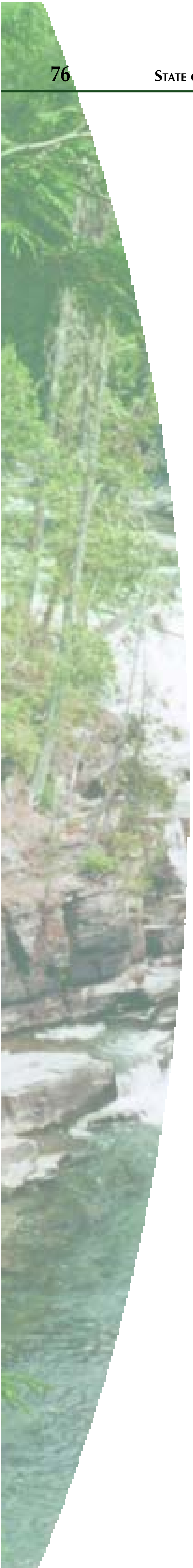
Forests are found where there are large quantities of water, normally where precipitation is abundant or in riparian areas where soil moisture is high. Perception of the influence of forests on water led to the establishment of the national forest system in the United States, as forest cover was considered necessary to sustain river flow (Lee, 1980). Most forests were subsequently found to use great amounts of water, contrary to early thinking. The present chapter summarizes the impact of forests on freshwater and suggests how forests and forest management can help achieve water resource management objectives.

Forested watersheds are exceptionally stable hydrological systems. In contrast to other land uses, healthy forests:

- strongly influence the quantity of water yielded from watersheds;
- discharge the highest quality of water;
- discharge lower storm flow peaks and volumes for a given input of rainfall;
- moderate variation in stream flow between the high and low flows during a year;
- provide the greatest soil stability and the lowest levels of soil mass movement, gully erosion and surface erosion;
- export the lowest levels of sediment downstream.

FORESTS, ATMOSPHERIC WATER AND WATER YIELD

The relationship among forests, atmospheric moisture and water yield has long been controversial. Lee (1980) noted that the natural coincidence of forest cover and higher precipitation is at least partly responsible for the popular notion that forests increase or attract rain, which leads to the assumption that their removal would significantly diminish precipitation. Globally, this is not the case; the removal of all forest cover would only reduce global precipitation by 1 to 2 percent at most (Lee, 1980). Calder (1999a) further suggested that deforestation has little effect on regional precipitation, although exceptions could occur in basins where rainfall largely depends on internally driven circulation patterns, such as the



Amazon basin. Even then, it has been estimated that complete deforestation and replacement with non-forest vegetation would reduce basin rainfall by less than 20 percent (Brooks *et al.*, 1997).

There are circumstances, however, in which forests intercept fog or low clouds (cloud forests), adding moisture to the site that would otherwise remain in the atmosphere. The relationship between forests and the yield of freshwater differs between cloud forest and non-cloud forest conditions.

Cloud forests and freshwater yield

Cloud forests occur along coastal areas in temperate climates and also in tropical montane regions where fog or low cloud conditions are common. Forests intercept atmospheric moisture (horizontal precipitation), which condenses on and drips from foliage, adding moisture to the soil. Rainfall is not increased, but forests add moisture that low-growing vegetation would not. The following are examples of freshwater augmentation by cloud forests.

- Coastal forests in the fog belt of western Oregon, the United States, augment water yield (Harr, 1982; Ingwersen, 1985). The removal of old-growth conifer forests from the municipal watershed of Portland, Oregon, reduced summer stream flow, but the regrowth of vegetation caused stream flow levels to return to normal within five to six years.
- Water augmentation by tropical montane cloud forests varies with altitude, location and season (Bruijnzeel and Proctor, 1993). The ratio of horizontal precipitation to annual rainfall was shown to vary between 4 and 85 percent, with higher values corresponding to dry seasons, while average horizontal precipitation varied between 0.2 and 4 mm per day. Annual stream flow from tropical montane cloud forest for a given rainfall was higher than from other tropical forests. The stream flow response to conversion of tropical montane cloud forest to other land uses has not been widely documented, although research is under way in Central America (Calder, 1999b, as reported by Kaimowitz, 2000).

Non-cloud forests and freshwater yield

Outside fog or tropical montane cloud forest regions, forests generally consume large quantities of water. More than 100 watershed experiments around the world have shown that forest removal increases stream flow, which varies in magnitude with climate and forest type and diminishes as forests regenerate (e.g. Bari *et al.*, 1996; Bosch and Hewlett, 1982; Lesch and Scott, 1997; Verry, Hornbeck and Todd, 2000; Whitehead and Robinson, 1993). When other land uses replace forests, flow increases are sustained. With few exceptions, results show the following.

- Removal of forest cover increases annual water yield by 60 to 650 mm. The size of the increase is generally proportional to the amount of biomass removed and is greater in wetter areas. Little effect has been reported in dryland areas where annual precipitation is less than 400 mm.
- Flow during dry seasons generally increases after forests are thinned or removed.
- Forests with high interception rates (e.g. conifers) or high transpiration rates (e.g. eucalypts) yield less water than those with lower interception and transpiration rates. Water yield would therefore be expected to increase when conifer forests are replaced by broadleaf forests and to decrease when broadleaf forests, shrubs or grasses are replaced by conifers (see Box opposite).

FORESTS, FLOODS AND DEBRIS FLOWS

Forests produce low levels of storm flow and greater soil stability than any other vegetation type because of their high infiltration rates, protective ground cover, high consumption of soil water and high tensile strength of roots. These attributes are particularly beneficial in mountainous terrain that is subject to torrential rainfall. Forest removal and road construction are problematic in such areas because they

A lesson from Fiji

Afforestation reduced water yield to a water supply reservoir in Fiji (Drysdale, 1981).

On the leeward side of two of the largest Fiji islands, 60 000 ha of *Pinus caribaea*, planted to develop a wood-based industry, replaced shrub vegetation. Six years after the forest was planted, dry season flows to a downstream water supply reservoir had decreased by 50 to 60 percent. The areas afforested were not in a cloud-forest environment. Had freshwater resources been considered in the afforestation plan, species with lower interception and transpiration rates would have been preferred over conifers.

The experience in Fiji convinced the Beijing Water Conservancy Bureau to reverse its plans to replace Chinese locust and shrubs with pine in the catchment area of the Miyun Reservoir, a key municipal water source for Beijing. Planners had mistakenly thought that conversion to pine would increase water yield to the reservoir, whereas the result would have been the opposite.

Tree removal (above) and road construction (below) in mountain areas can cause serious soil erosion and landslides (Nepal)

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increase the frequency and magnitude of landslides and debris flows (Sidle, 2000). However, there is a limit to the protection that forest cover provides, as was found in Taiwan Province of China (see Box on next page), where nearly all mountainous watersheds are forested and managed for slope stabilization and torrent control (Lu, Cheng and Brooks, 2001). As the amount of rainfall becomes extreme, the extent to which forests can help to prevent landslides, debris flows and flooding diminishes.

A frequently asked question is the extent to which forest cover affects flooding. In northern Minnesota, the United States, rainfall-generated peak flows up to the 25- to 30-year recurrence interval (RI) increased when 70 percent of the forest cover on a small watershed was clear-cut (Lu, 1994; Verry, 2000). Larger floods (RI > 100 years) were not affected by forest cover removal, supporting Hewlett's (1982) claim that changes

Typhoons, landslides and debris flows in Taiwan Province of China

Floods, landslides and debris flows, resulting from an average of three to four typhoons a year, cause extensive loss of life and property on the mountainous island of Taiwan Province of China. About 53 percent of the island has slopes steeper than 21°, and more than 100 peaks exceed 3 000 m above sea level (Lee, 1981). With shallow soils overlying weak, fractured and weathered geological formations, landslides load steep channels, which become primed for debris flows.

During the particularly destructive Typhoon Herb in 1996, rainfall at higher elevations exceeded 1 985 mm in 42 hours (Lu, Cheng and Brooks, 2001). Landslides and debris flows occurred throughout the island, many along roads and in drainage channels where native forest had been converted to grow tea, vegetable crops and betel nut palm, but many in forested areas as well. Given the amount and intensity of rainfall, debris flows and flooding occurred regardless of land use.

in forest cover have little effect on large floods in major streams. Importantly, the 1.5- to 2-year RI peak flows more than doubled when forest cover was removed.

Extreme hydrological events are the result of natural processes of erosion and sediment motion interacting with human systems (Davies, 1997). Where land scarcity concentrates people and their dwellings in hazardous areas, disasters will occur whether uplands are fully forested or not. This is the situation in Taiwan Province of China, with a population density approaching 600 inhabitants per square kilometre. People living on steep slopes, in the mouths of small drainage basins and in floodplains are bound to be vulnerable. A coordinated watershed management programme among government agencies has been suggested in order to address this threat for both upstream and downstream communities (Lu, Cheng and Brooks, 2001).

Hazardous areas must be identified, and policies and institutions established to provide incentives for people to avoid them. Terrain analysis based on Geographic Information Systems (GIS) offers the means to mark hazardous terrain in mountainous watersheds (Gupta and Joshi, 1990; Sidle, 2000), and methods to delineate floodplains and define zones according to the type and degree of risk are well known (Bedient and Huber, 1988). An example of an incentive to change people's behaviour is the Federal Flood Insurance Program in the United States, under which insurance rates in areas adjacent to rivers are linked to the degree of hazard.

FORESTS AND SEDIMENTATION

Because watersheds with healthy forests export the lowest levels of sediment of any cover type (Brooks *et al.*, 1997), it is not surprising that forests are often looked to as a means of reducing levels of downstream sediment in water supply reservoirs.

Larson and Albertin (1984) recommended reforestation to reverse a threefold increase in sedimentation in the Alhajuela Reservoir in Panama following the clearing of 18.2 percent of the watershed. Few such studies exist, and some people therefore suggest that the benefits from forest cover in reservoir protection have been overestimated (Kaimowitz, 2000). Reasons for such scepticism include:

- inadequate monitoring, and therefore limited empirical evidence linking forest changes to reservoir sedimentation levels;
- the fact that forest cover changes have occurred over such small areas of watersheds that little effect has been observed;
- the distance between upstream watershed projects and downstream reservoirs, which masks the effects;
- the recognition that other factors, such as non-forest land use, can increase stream flow peaks and affect sedimentation.

Downstream sediment delivery is affected both by changes in stream flow discharge from upland watersheds and by alterations in riparian areas along stream banks (Rosgen, 1994; Tabacchi *et al.*, 2000). Sediment levels of rivers are determined by both sediment availability

and stream flow discharge. The most effective discharge for transporting sediment over time is that associated with the bank-full stage (when the river channel is full but not overflowing), usually corresponding approximately to the average annual peak flow. When land use increases the size of these flows, the stream channel becomes unstable and sediment levels increase, regardless of whether erosion rates have been reduced. Healthy riparian forests can also reduce sediment levels by filtering out soil erosion inputs to channels and by maintaining stable stream banks. Degradation of both upland and riparian forests can therefore combine to increase sediment delivery to reservoirs.

FORESTS AND WATER QUALITY

Water pollution impairs water use by downstream users and seriously affects human health. The exceptionally high quality of water discharged from forested watersheds is the main reason that protected forests are preferred for municipal watersheds. Forests efficiently cycle nutrients and chemicals and decrease the sediment exported, thus reducing pollutants such as phosphorus and some heavy metals. The lower rate of rainfall runoff also reduces the load of all nutrients and pollutants entering water bodies.

In many developing countries, the food and resource needs of the rural poor, coupled with land scarcity and institutional limitations, constrain efforts to protect forested watersheds for municipal water supplies. However, the problems of polluted drinking-water and associated diseases significantly jeopardize the welfare of rural populations and urban communities alike. Water storage and transport facilities are sorely needed in many areas, along with improved sanitation and water treatment. Well-managed forested catchments above reservoirs can result in minimal requirements for water treatment. Echavarria and Lochman (1999) reported that US$1 billion spent on improved management of the New York City watersheds over ten years could save an outlay of US$4 billion to $6 billion for construction of new water treatment facilities.

Riparian forests

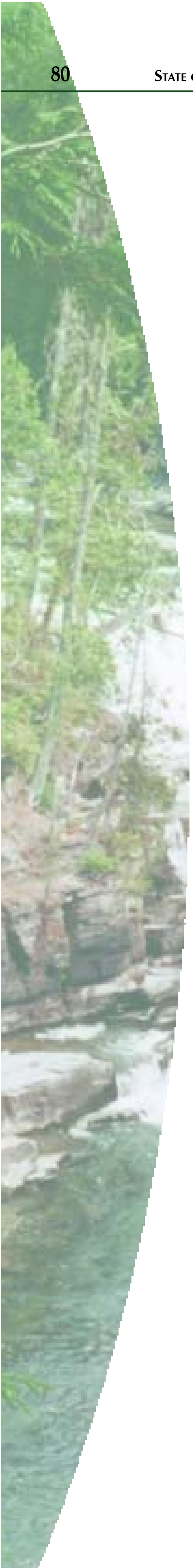
Forest buffers and agroforestry systems along water bodies further improve water quality. Long neglected and often exploited, riparian forests help to stabilize stream banks, reduce wastewater and chemical discharge into water bodies from upland areas and maintain cooler water temperatures, thus improving dissolved oxygen levels in water (Brooks *et al.*, 1997). The water quality can be enhanced for human consumption, leading to better health and productivity and greater diversity of aquatic ecosystems, including mangrove forests. As a result, healthy riparian forests increase fish production.

Riparian systems are heavily utilized because of their proximity to water and their high productivity for grazing and farming, and it is therefore unrealistic to protect them from all uses. With proper management, however, riparian forests and agroforestry systems along water bodies can mitigate the effects of nutrient, chemical and human waste discharge. At the same time, these systems can provide wood, forage and other products for the rural poor.

WATERSHEDS: RECOGNIZING UPSTREAM–DOWNSTREAM LINKAGES

Scale and cumulative effects

Freshwater benefits to downstream areas naturally accompany sound management of upland and riparian forests, but management can also be directed to specific freshwater objectives. In either case, benefits may be masked by spatial aspects, for example the location and diffuse nature of land-use practices and their effects; the scale of activities in proportion to watershed size; and the time needed for benefits to be realized. Changes on the land can have incremental effects that may not be individually apparent but can be considerable over the whole watershed and over time. This complexity has clouded the view of decision-makers in many parts of the world and weakened their commitment to watershed management. However, these cumulative effects must be recognized in environmental and economic assessments.



Cumulative effects of land use on downstream water flow, sediment loads and pollutants can best be observed on islands, over a few kilometres rather than hundreds. For example, deforestation and cropping practices on islands in the Caribbean and the Pacific have been linked to the degradation of estuaries, coral reefs and their dependent fisheries. In eastern Jamaica, the replacement of forests with upland coffee farming has increased soil erosion and the export of chemicals, which have contributed to the degradation of coral reefs (K. Eckman, personal communication, 2002). Such linkages are clear in river basins, but in larger systems the impact may take decades or longer to become evident, and may be masked by other land-use practices. An example of such an impact is the depletion of oxygen in the Gulf of Mexico, which has been traced in part to agricultural non-point pollution of the Mississippi River basin in the United States. Midwestern states in the United States are focusing on restoring riparian forests and wetlands and improving agricultural land use to reduce total maximum daily loads to the Mississippi River, in accordance with federal legislation calling on all states to improve impaired bodies of water. Urban and peri-urban forest and tree programmes are being developed and promoted to address poverty and food insecurity as well as to support protection and sustainable use of land resources.

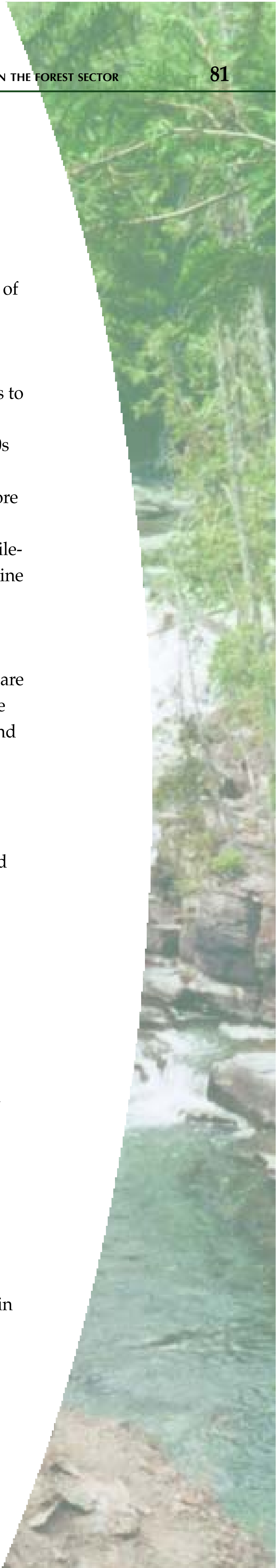
Economic considerations

Forest management and other watershed improvements to protect and manage freshwater require economic justification. A watershed perspective provides clarity in determining the economic value of forests for these purposes. Johnson, White and Perrot-Maître (2001) have emphasized the economic importance of the water-related ecosystem services provided by forests. However, no comprehensive economic analyses that consider the full range of these benefits have so far been made, because of a number of difficulties. These include inadequate monitoring and evaluation of watershed services from forestry projects; difficulties in placing an accurate value on many services, particularly those that are not traded in the marketplace; and water subsidies. In many parts of the world, water is heavily subsidized and often considered a free good. Its scarcity is now causing people to determine the value of freshwater more realistically. In contrast, the economic benefits of well-managed or protected forests have not been fully considered in terms of avoided losses from soil erosion, debris flows, sedimentation and floods, for example.

Improved watershed economics may thus be forthcoming as a result of water scarcity. What some are calling a new global water economy is emerging, in which freshwater is viewed more as an economic commodity than as a publicly managed resource (Anderson, 2002). For example, in southern California, the United States, farmers pay US\$8.11 per 1 000 m^3 of water in comparison with US\$1 622 paid by the city of Santa Barbara. Water there is more valuable than the crops being irrigated, with the result that some farmers sell their supplies to municipalities. In such instances, there may be sound economic justification for managing forested watersheds for water supplies.

The new water economy faces hurdles in developing countries, where water has often been treated as a free good because of longstanding practices and religious beliefs (Rosegrant and Cline, 2002). More efficient water allocation and innovative pricing policies can provide incentives to support forest management for water supply purposes. Policies that continue to treat water as a free good or that heavily subsidize it will continue to promote waste in developing and developed countries alike. Johnson, White and Perrot-Maître (2001) have suggested financial mechanisms that can enhance the restoration, maintenance and improvement of water-related services from forested watersheds.

In most cases, the methodology to perform the needed financial and economic analysis exists. Upstream and downstream data, sometimes sorely lacking, are transformed into benefits and costs that can be contrasted under "with" and "without" conditions (FAO, 1987). This approach has been used to assess watershed projects in



Morocco and China, encompassing, but not limited to, changes in forest cover and management (Brooks *et al.*, 1981; Shuhuai *et al.*, 2001). In both cases, watershed improvements, including forests and agroforestry, were found to be economically viable (with economic rates of return of 10 to 16 percent) when production and water resource benefits were combined.

Hydrological computer models can be used to examine human-induced effects on watersheds. Changes in water yield, flooding and sediment transport, for example, can be simulated and related to specific sites where economic benefits and costs are of interest. The cumulative effects of agricultural development, the loss of riparian forests in floodplains and wetland drainage were simulated for a watershed of the Minnesota River basin in the United States, using the Hydrocomp Simulation Program – Fortran (HSPF) model (Miller, 1999). These land-use changes increased annual stream flow and peak flow discharges, which can be related to "lost storage" in the basin. Hey (2001) determined that the downstream damage associated with a major recent flood could have been significantly reduced by restoring sufficient areas of riparian forest cover, floodplains and wetlands in the basin. He concluded that farmers could justifiably be compensated for such land conversion on the basis of reduced economic losses from future flooding. Such innovative approaches need to be expanded and considered for tropical watersheds and developing countries, with emphasis on developing computer simulation models.

Institutional and policy considerations

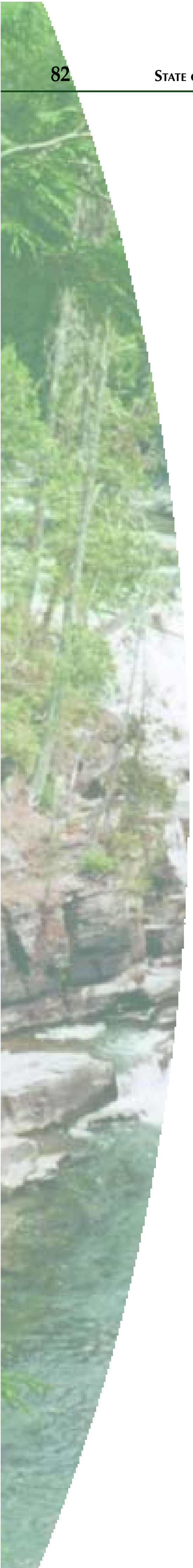
Better management of forests and water resources to improve human welfare requires more than just technical knowledge. While technical information provides a foundation for assessing upstream–downstream linkages and carrying out economic analyses, transforming such information into management practices requires the effective participation of stakeholders in order to develop a consensus and provide incentives for implementation (Eckman, Gregersen and Lundgren, 2000). A policy environment must be created that supports, rather than hinders, the integration of land and water management.

Since watershed and political boundaries rarely coincide, the coordination of land and water management depends on organizations to resolve transboundary issues and water-use disputes. In the United States during the 1990s the absence of effective watershed- or basin-level organizations led to the formation of more than 1 500 watershed districts to deal with upstream–downstream issues (Lant, 1999). Nile-basin countries established a partnership of nine riparian countries to resolve transboundary issues and to move towards more sustainable development (Baecher *et al.*, 2000). The inequities of water distribution in this region are amplified because more than 80 percent of the flow to the lower Nile, on which the Sudan and Egypt depend, originates in mountainous Ethiopia. Without cooperation and coordination, disputes over water use and development could clearly arise.

A better understanding of the processes and approaches required in large river basins is needed, and the International Year of Freshwater in 2003 is an opportunity for stakeholders to share experiences in order to identify possible paths for the future.

CONCLUSIONS AND RECOMMENDATIONS

The scarcity of freshwater is a global problem calling for more effective and efficient water management, from local watersheds to major river basins. The International Year of Freshwater in 2003 can help to focus global attention on issues and solutions and on the need for a comprehensive approach to cope with scarcity, on the one hand, and excess, on the other. Forests can have an important role in supplying freshwater, but their management must complement water management. Technology exists for the most part, but implementation requires policies and institutions to promote intersectoral dialogue and cooperation. The following are some



potential ways in which the management of forests and water can be mutually supportive.

First, mountainous forested watersheds require special attention as the highest freshwater-yielding areas in the world, but also as the source areas for landslides, torrents and floods. People inhabiting the headwater regions and those living in the downstream lowlands depend on freshwater from the uplands, and also feel the effects of hydrometeorological extremes. Action to prevent or mitigate disasters in mountainous terrain should include:

- maintenance of healthy forest cover on mountainous watersheds that are subject to torrential rainfall;
- development of programmes that combine forest protection with zoning, floodplain management and engineering structures to protect people from landslides, debris flows and floods.

Second, forests can be managed to enhance freshwater supplies, but as a component of comprehensive and multifaceted water management programmes. The economic value of water and its source areas must be recognized. By reducing water subsidies and treating water as a commodity rather than a free good, economic incentives can support better management in the following ways.

- The water yield of municipal watersheds in non-cloud forest conditions can be augmented when tree species with low consumptive use replace those with high consumptive use or when forest stands are periodically thinned and harvested.
- In cloud-forest conditions, mature and old-growth forests should be protected and managed to sustain stream flow during dry periods.
- Riparian forests should be managed to protect water quality, which can in turn enhance the productive capacity of aquatic ecosystems and improve the health and welfare of local human populations. In addition, full use should be made of agroforestry buffer systems that can achieve these goals and also provide food, fodder and wood products.
- Agroforestry systems need to be developed for upland watersheds in order to capture the hydrological benefits of forests, while enhancing food and natural resource production for the rural poor.

Third, the potential exists to mitigate the economic damage caused by floods and sediment delivery through forest management in uplands, riparian areas and floodplains. Although the largest and most damaging floods in major rivers are not affected by the extent of forest cover, moderate and localized floods can increase when forests are removed. Forest degradation brings with it many undesirable effects on water flow and quality. Healthy upland and riparian forests can maintain low levels of sediment delivery to rivers, lakes and reservoirs.

Fourth, a watershed perspective should be incorporated into the planning and management of forests, water, and urban and agricultural land use. This perspective is needed at the local level as well as the highest government levels in order to promote sustainable solutions.

Fifth, incentives and the means to achieve freshwater objectives must be provided through forest and other land-use management policies and institutions, from the local watershed level to the river basin level. Intersectoral dialogue and cooperation are necessary to achieve management objectives and to resolve inequities in terms of who pays for and who benefits from changes in upstream and downstream resource use. Expanded economic analysis is needed to understand these inequities better and to resolve them. The emerging water economy will facilitate the justification of land-use changes to enhance water supplies. Consideration should be given to compensating inhabitants who improve forests and other land uses that reduce downstream losses. The policy environment and institutional support may be enhanced through:

- improved understanding of the processes and required approaches for upstream–downstream management systems in the context of better water resource management and sustainable development;

- expanded educational and training programmes that are directed to local watershed inhabitants up to the highest-level policy-makers;
- better understanding and reconciliation of the role of forests in freshwater management, with emphasis on demonstration and extension programmes aimed at local users of land and water;
- expanded monitoring and evaluation of projects, as well as improved research on tropical forested watersheds in developing countries, given that many of the questions asked in the 1970s and 1980s about the hydrological role of tropical forests are still largely unanswered, or at least not well documented.

Socio-economic aspects as well as technical components need to be stressed so that the resulting information can provide the foundation for developing new technology and policies to enhance people's welfare through improved forest and freshwater management. ◆

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