

# Towards a new understanding of forests and water

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*An overview of the state of knowledge about forest and water interactions and salient issues in forest and water policy.*

The availability and quality of water in many regions of the world are more and more threatened by overuse, misuse and pollution, and it is increasingly recognized that both are strongly influenced by forests. Moreover, climate change is altering forest's role in regulating water flows and influencing the availability of water resources (Bergkamp, Orlando and Burton, 2003). Therefore, the relationship between forests and water is a critical issue that must be accorded high priority.

Forested catchments supply a high proportion of the water for domestic, agricultural, industrial and ecological needs in both upstream and downstream areas. A key challenge faced by land, forest and water managers is to maximize the wide range of multisectoral forest benefits without detriment to water resources and ecosystem function. To address this challenge, there is an urgent need for a better understanding of the interactions between forests/trees and water, for awareness raising and capacity building

in forest hydrology, and for embedding this knowledge and the research findings in policies. Similarly, there is a need to develop institutional mechanisms to enhance synergies in dealing with issues related to forests and water as well as to implement and enforce action programmes at the national and regional levels.

In the past, forest and water policies were often based on the assumption that under any hydrological and ecological circumstance, forest is the best land cover to maximize water yield, regulate seasonal flows and ensure high water quality. Following this assumption, conserving (or extending) forest cover in upstream watersheds was deemed the most effective measure to enhance water availability for agriculture, industrial and domestic uses, as well as for preventing floods in downstream areas.

Forest hydrology research conducted during the 1980s and 1990s (summarized by Bruijnzeel, 2004; Calder, 2005, 2007; Van Dijk and Keenan, 2007) suggests

## Key terms

**Discharge (or water flow):** volume of water passing through a given point at a given time

**Recharge:** refill of a groundwater aquifer

**River basin:** the complex system of watersheds and subwatersheds crossed by a major river and its tributaries while flowing from the source to the mouth

**Upstream/downstream linkages:** the environmental, socio-economic and cultural flows, synergies exchanges and conflicts between the upper and lower parts of a watershed

**Watershed (or catchment):** the geographical area drained by a watercourse – a concept applied to units ranging from a farm crossed by a creek (a microwatershed) to large river or lake basins

**Watershed management:** any human action aimed at ensuring a sustainable use of watershed resources

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a rather different picture. Although the important role of upstream forest cover in ensuring the delivery of high-quality water has been confirmed, earlier generalizations about the benefits of upstream forest cover on downstream annual and seasonal flows were generally fallacious and misleading. Studies have shown instead that, especially in arid or semi-arid ecosystems, forests are not the best land cover to increase downstream water yield. Moreover, solid evidence has shown that in tropical ecosystems the protective role of upstream forest cover against seasonal downstream floods has often been overestimated. This is especially true in connection with major events affecting large-scale watersheds or river basins (FAO and CIFOR, 2005).

The International Year of Freshwater 2003 and the third World Water Forum (Kyoto, Japan, 2003) helped drive the incorporation of this understanding of

biophysical interactions between forests and water into policies. The International Expert Meeting on Forests and Water, held in Shiga, Japan in November 2002 in preparation for these events, highlighted the need for more holistic consideration of interactions between water, forest, other land uses and socio-economic factors in complex watershed ecosystems. During the past five years, the Shiga Declaration has become a key reference for the development of a new generation of forest and water policies (see article by Zingari and Achouri, this issue).

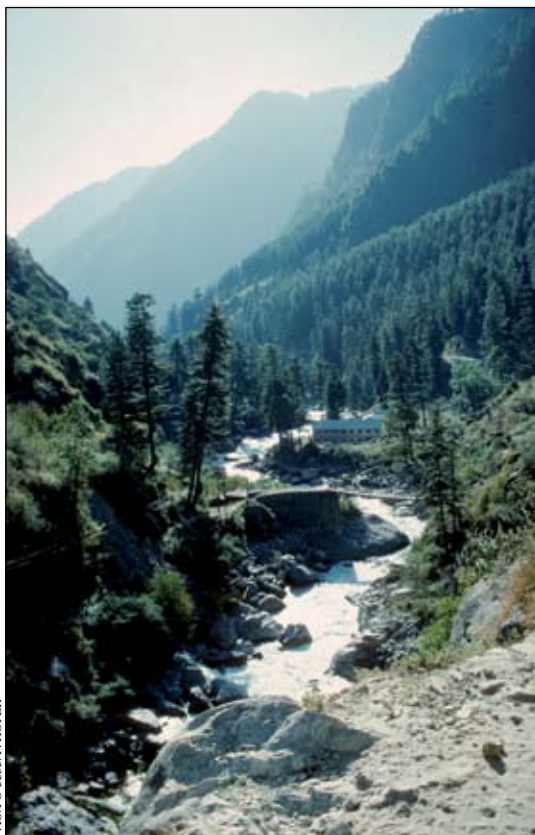
This article summarizes the state of current knowledge about forest and water interactions in watershed ecosystems. It summarizes some key issues that have emerged from discussion among forest hydrologists, other water-sector experts and policy-makers in the years since the Shiga Declaration, the third World Water Forum and the International Year of Freshwater.

#### STATE OF KNOWLEDGE ON FORESTS AND WATER

Recent forest hydrology has focused on three topics that are particularly relevant for policy-making: the comparative advantages and disadvantages of forest cover in maximizing downstream water yields; the role of upstream forests in maintaining water flows during the dry season; and water-quality preservation. This section summarizes findings in these three areas (based on Hamilton, 2005).

In the past, policy-making was often based on the assumption that the more trees, the more water. Current forest hydrology research challenges this assumption. The forest ecosystem is in fact a major user of water. Tree canopies reduce groundwater and stream flow, through interception of precipitation and evaporation and transpiration from the foliage. As both natural and human-established forests use more water than most replacement land cover (including agriculture and forage), there is no question that forest removal (even partial) increases downstream water yields.

Consequently, removal of heavy water-demanding forest cover has sometimes been suggested, especially in semi-arid areas, as a means of preventing or mitigating drought. However, such a policy should be weighed against the consequent loss of the many other services



*Upstream and downstream, there is a need for more holistic consideration of interactions between water, forest, other land uses and socio-economic factors (forested watershed in India, irrigation in the Syrian Arab Republic)*



and goods that forests supply, including erosion control, improved water quality, carbon fixation, recreation and aesthetic appeal, timber, fuelwood, other forest products and biodiversity. Such a practice should definitely be avoided in saline-prone areas, where forest removal would bring salts closer to the soil surface; and in mountain cloud forests, where tree foliage, epiphytic vegetative surfaces, twigs, branches, stems and shrubs provide a “net” to capture “horizontal precipitation” from fog or cloud.

It is also well established that partial or complete removal of tree cover may accelerate water discharge and increase flood risk during the rainy season and may reduce river flow or even cause river beds to dry out in the dry season. However, the importance of forest cover in regulating hydrological flows has often been overestimated. Impacts of forest cover removal are evident only at the micro level and in association with short-duration and low-intensity rainfall events (which are usually the most frequent). As rainfall duration or intensity increases, or as distance of the rainfall area from the watershed increases, the influence of tree cover on flow regulation decreases.

At the macro scale, natural processes in the upper watershed are more important than land management practices in the development of large floods. For instance, strong scientific evidence refutes the myth that deforestation in the Himalayas causes big floods in the lowlands of the Ganges and Brahmaputra; the large-scale floods result rather from a combination of simultaneous discharge peaks of the large rivers, high runoff from hills adjacent to the floodplains, heavy rainfall, high groundwater tables and spring tides, lateral river embankments and the disappearance of storage areas in the lowlands (Hofer and Messerli, 2006). Hence, although there are many good reasons for reforesting watersheds (e.g. reducing soil loss, keeping sediments out of streams, maintaining agricultural production, wildlife habitat and so forth), flood risk reduction or even

***Although forests can mitigate small, local floods, they do not appear to influence floods from extreme high-rainfall events like this one caused by a cyclone in Paznaun Valley, Austria in August 2005***



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control is not one of them. Reforestation to prevent or reduce floods is effective only at a local scale of a few hundred hectares. The complex relationships between forests and water in large river basins continue to be a matter of debate (see CIFOR, 2007), and it is clear that more work is needed for full understanding of these relationships.

It is in maintaining high water quality that forests make their most significant contribution to the hydrological characteristics of watershed ecosystems. This is achieved through minimization of soil erosion on site, reduction of sediment in water bodies (wetlands, ponds, lakes, streams, rivers) and trapping or filtering of other water pollutants in the forest litter, particularly through the following mechanisms.

- On sloping land, soil moves downhill mainly because of gravity and displacement by the splash action of

raindrops. Natural forest cover provides the most effective barrier to splash-induced soil erosion, largely because of the contribution of the lower canopy leaves and the ground litter in reducing the force of splashing. Forest removal and replacement with other land use systems leads in most cases to higher and accelerated erosion unless great care in soil conservation is practised.

- Erosion is generally associated with a higher sediment concentration in runoff and with siltation of watercourses. Good forest cover is more effective than any other kind of land cover in keeping the water as sediment free as possible. The surface cover, debris and tree roots trap sediments and stop their downslope movement. Moreover, deep tree roots stabilize slopes and help prevent shallow landslides.





**Forests maintain high water quality by minimizing soil erosion and reducing sediment; deforestation generally increases erosion, resulting in higher sediment concentration in runoff and siltation of watercourses (Pakistan)**

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- In addition to sediment, various types of pollution – depending on nearby land use and drainage to the watercourse – can also impair water quality. Potential pollutants include excessive concentrations of organic matter (leading to water eutrophication) and agricultural or industrial chemicals. Forest is certainly an appropriate ground cover for drinking-water-supply watersheds, because forestry activities (with the exception of intensively managed plantations) generally use no fertilizers or pesticides and avoid pollution from domestic sewage or industrial processes. In addition, non-point source pollution (i.e. pollution from many diffuse sources) from domestic, industrial and agricultural use can be greatly reduced or even eliminated by maintaining adequate riparian forest buffer zones along watercourses. Such zones, however, will not prevent groundwater contamination. Moreover, where atmospheric pollutants are captured by trees because of their height and aerodynamic resistance, watershed forests will not protect water quality. This problem is most prevalent in mountain forests in industrialized countries.

#### **ISSUES IN CURRENT FOREST AND WATER POLICIES**

Following the International Year of Freshwater 2003, discussion among forest hydrologists, other water sector experts and policy-makers has focused on three core issues: incorporation of forest hydrology knowledge in water policies; inclusion of forest-sector contributions in integrated water resource management policies; and payment for forest- and water-related environmental services.



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#### **Incorporation of forest hydrology knowledge in water policies**

Despite the significant advances in scientific understanding of forest and water interactions, the role of forests in relation to the sustainable management of water resources remains, as elaborated in the previous section, a contentious issue. Uncertainty, and in some cases confusion, persists because of difficulties in transferring research findings to different countries and regions, different watershed scales, different forest types and species and different forest management regimes.

Another difficulty is a gap between research and policy, which persists at least in part because of a general failure to communicate results of hydrological research effectively to policy-makers and to challenge conventional assumptions with scientific evidence. To address these issues, in 2006 the International Union of Forest Research Organizations (IUFRO) created a Task Force on Forests and Water Interactions. Its aim is to promote consensus in the forest hydrology

***Riparian forest buffer zones can greatly reduce or eliminate non-point source pollution from domestic, industrial and agricultural use (Suriname)***

community on the key issues concerning forest and water interactions, and to identify areas of scientific uncertainty on which to focus policy-relevant research. Seeking to generate and disseminate information that non-specialists can easily and safely use, the task force has produced a one-page fact sheet to convey key concepts in forest hydrology to policy-makers (summarized in the Box at right). FAO, similarly, has produced the booklet *Why invest in watershed management* to raise the awareness of policy- and decision-makers about the needs for and benefits of watershed management (see Box, next page).

For the linking of research and policy related to forest hydrology, education has an important role. Scientific and technical education is generally highly sectoral. Education across disciplines is necessary to improve knowledge of forest and water interactions, e.g. to improve capacity to assess effects of afforestation and reforestation programmes on water quality and quantity, flood control and soil protection.

#### **Inclusion of forestry in integrated water resource management**

Development of integrated water resource management plans at the watershed and/or river-basin level was one of the targets set by the World Summit on Sustainable Development in 2002. These multisectoral plans should be aimed at ensuring “water for people, food, nature, and industry and other uses” (Global Water Partnership TAC, 2000).

The need to include the “nature for water” dimension in these plans is increasingly recognized. The concept of nature for water takes into account the role of terrestrial ecosystems in enhancing water yields and water quality. For instance, the Lange Erlen forested area in Switzerland is flooded a dozen days a month with water from the Rhine to allow forest soil to filter the water to improve its quality and recharge the groundwater of the nearby city of Basel.

### **Forests and water: key messages for policy-makers**

#### **WATER USE BY FORESTS**

**Factors influencing water use by forests include climate, forest and soil type, among others. In general, forests use more water than shorter types of vegetation because of higher evaporation; they also have lower surface runoff, groundwater recharge and water yield. Forest management practices can have a marked impact on forest water use by influencing the mix of tree species and ages, the forest structure and the size of the area harvested and left open.**

#### **DRY-SEASON FLOWS**

**Forests reduce dry-season flows as much as or more than they reduce annual water yields. It is theoretically possible that in degraded agricultural catchments the extra infiltration associated with afforested land might outweigh the extra evaporation loss from forests, resulting in increased rather than reduced dry-season flows – but this has rarely been seen.**

#### **FLOOD FLOWS**

**Forests can mitigate small and local floods but do not appear to influence either extreme floods or those at the large catchment scale. One possible exception is reduction of downstream flooding by floodplain forest, where hydraulic roughness (the combination of all elements that may cause flow resistance, such as forest litter, dead wood, twigs and tree trunks) may slow down and desynchronize flood flows.**

#### **WATER QUALITY**

**Natural forests and well-managed plantations can protect drinking-water supplies. Managed forests usually have lower input of nutrients, pesticides and other chemicals than more intensive land uses such as agriculture. Forests planted in agricultural and urban areas can reduce pollutants, especially when located on runoff pathways or in riparian zones. However, trees exposed to high levels of air pollution capture sulphur and nitrogen and can increase water acidification.**

#### **EROSION**

**Forests protect soils and reduce erosion rates and sediment delivery to rivers. Forestry operations such as cultivation, drainage, road construction and timber harvesting may increase sediment losses, but best management practices can control this risk. Planting forest on erosion-prone soils and runoff pathways can reduce and intercept sediment.**

#### **CLIMATE CHANGE**

**Global climate models predict marked changes in seasonal snowfall, rainfall and evaporation in many parts of the world. In the context of these changes the influence of forests on water quantity and quality may be negative or positive. Where large-scale forest planting is contemplated for climate change mitigation, it is essential to ensure that it will not accentuate water shortages. Shade provided by riparian forests may help reduce thermal stress to aquatic life as climate warming intensifies.**

#### **ENERGY FORESTS**

**Fast-growing forest crops have potential for high water demand which can lead to reduced water yields. The local trade-off between energy generation opportunities and water impacts may be a key issue in regions where climate change threatens water resources.**

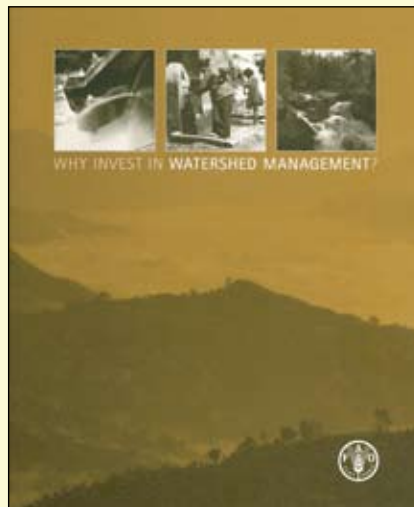
*Source: IUFRO, 2007.*

### *Why invest in watershed management?*

By providing high-quality freshwater, regulating discharge and runoff and hosting fertile arable land and immense forest resources, watershed areas have a pivotal role in the earth's ecology and contribute significantly to the wealth and welfare of human societies. In follow-up to the inter-regional watershed management review conducted in 2002–2003 (see Box, p. 22), FAO has recently produced the booklet *Why invest in watershed management* to raise the awareness of policy- and decision-makers about the environmental services provided by watersheds, the risks and threats currently affecting them, and related economics, management policies, governance institutions and programmes. Succinct and well illustrated, the publication addresses primarily those policy- and decision-makers responsible for finding a balance between socio-economic development and environmental conservation. The picture emerging from recent research supports the view that investing in watershed management can

significantly contribute to resolving these often diverging concerns.

*Why invest in watershed management* can be obtained free of charge by sending an e-mail to: [FO-publications@fao.org](mailto:FO-publications@fao.org). It can also be downloaded online at: [www.fao.org/forestry/site/37205](http://www.fao.org/forestry/site/37205)



As foresters are increasingly committed to the development of national forest programmes (NFPs) to implement sustainable forest management, there is scope for them to join forces with water experts to develop integrated water resource management plans and forestry programmes as part of a more comprehensive watershed/river-basin planning process. Similarly, management of transboundary watersheds and river basins should give greater consideration to the relationship between upstream forest cover and downstream water flows. For instance, the Program for the Sustainable Development of the Rhine (ICPR, 2001), a transboundary initiative, adopts afforestation and forest conservation measures to facilitate water retention and to prevent floods in nearby downstream areas. Protected forest area in the basin was

1 200 km<sup>2</sup> in 2005 and is expected to reach 3 500 km<sup>2</sup> by 2020.

Many countries have begun to develop integrated water resource management plans at the national and/or watershed level. Their implementation is complicated by the number and variety of stakeholders within and beyond a watershed and their different and sometimes contrasting interests, as well as by overlap of the administrative responsibilities of different regional authorities in many countries. A step-by-step planning process is advisable to ensure buy-in for effective implementation of the plan. For example, the Water Framework Directive of the European Union foresees the development of river-basin management plans from a consultative process which will take place in 2008 and be finalized by 2009. This gives time for European foresters to cooperate with their water-specialist colleagues.

### **Payments for environmental services**

In many countries, forest and water policies, plans and programmes are coming together through the increased popularity of payment for environmental services schemes (also called incentive-based cooperative agreements, stewardship payments, compensation schemes or performance payments) as financing mechanisms for watershed management, sustainable forest management and other sustainable development processes (see Box on Mexico). Payments do not necessarily involve money; often they take the form of services a community has been lacking, such as new or better roads, a school bus or weekly transport for farm produce.

Forest stewardship by upstream populations, for instance, can be compensated by downstream water users through direct payment for the provision of forest hydrological services such as discharge regulation or protection of water quality. In developing countries, the ensuing "hydrosolidarity" between upstream forest managers and downstream water users is often mediated by public agencies. For instance, since 1996 the Government of Costa Rica has sponsored schemes to create economic incentives for conserving forests and to compensate those whose land or land uses generate environmental services. More sophisticated mechanisms involving subsidies generated by income taxes and other public-sector sources are being put in place in industrialized countries (see Box on Switzerland). The United Nations Economic Commission for Europe (UNECE) Convention on the Protection and Use of Transboundary Watercourses and International Lakes (2007) recently endorsed the concept of payments for ecosystem services including the conservation and development of forest cover.

### **CONCLUSIONS**

During the five years since the Shiga Declaration, the third World Water Forum



### Payments for environmental hydrological services in Mexico

To counteract deforestation and water scarcity, Mexico created a programme of payments for hydrological environmental services in 2003. The programme provides economic incentives for avoiding deforestation in areas with severe water problems but where commercial forestry, in the short or medium term, could not match the opportunity cost of land-use conversion to agriculture or cattle ranching. The programme provides direct payments to land-owners with forest in excellent condition; it pays for watershed conservation and for management and restoration of temperate and tropical forests associated with water supply to communities. It is funded through a portion of water fees collected under the Federal Rights Law. The programme pays 400 pesos (US\$36.9) per hectare for cloud forest and 300 pesos (US\$27.7) for other types, and allows payments for up to 200 ha per beneficiary. In 2007, about 480 000 ha were covered under the programme through 879 contracts (Martínez, 2007).

and the International Year of Freshwater 2003, modern scientific understanding of forest and water interactions has been progressively permeating international and national environmental policies. This process has at last partially overcome what Hamilton (1985) termed the four “M”s (myths, misunderstandings, misinterpretations and misinformation) surrounding this topic in policy circles. New perspectives on water and forest interactions have enabled a clearer understanding of what forest can (and cannot) do to deal with the challenges the world will increasingly face in terms of the availability, quality and management of water resources.

On this basis, closer and more fruitful cooperation between water management experts and foresters has begun, as witnessed by the work on forests and water

done in the past five years by regional and global bodies such as the Ministerial Conference on the Protection of Forests in Europe (MCPFE), the International Network of Basin Organizations (INBO), the Latin American Network of Technical Cooperation in Watershed Management (REDLACH), the Mekong River Commission (MRC), the Convention on Biological Diversity (CBD), FAO’s Committee on Forestry (COFO), FAO’s Regional Forestry Commissions and the UNECE Timber Committee.

This cooperation needs to be further developed and strengthened at the national and regional levels, for instance through the exchange of technical expertise and experience across countries and regions. There is a need for more applied research on forests and water, as well as strengthened partnerships among research, educational, financial and political institutions. Sound comparative valuations are needed for forest services (hydrological and non), including their contribution to forest people’s livelihoods, production of biofuels, maintenance of biodiversity and aesthetic and recreational value. These needs are even more pressing with climate change adding to the complexity of the forest–water relationship and influencing forestry and water policies

in many regions of the world. New and innovative technical solutions for balancing the use of the many services provided by forests and needed by society – including those related to water – need to be developed and promoted to policy-makers, enabling informed decisions about integrated forest and water management in an era of global change.◆



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### Water supply and urban forest maintenance in Lausanne, Switzerland

The city of Lausanne, located on the shore of Lake Geneva in Switzerland, has 136 000 inhabitants. The city owns some 16 km<sup>2</sup> of forests which provide about 8 percent of its drinking-water. Funding from a combination of timber sales, subsidies and income tax does not fully cover the forest management expenses (about €15 per year per inhabitant), especially when particular emphasis is given to protection of water resources. Accordingly, a communal fund for sustainable development was established in 2001 with an initial contribution of roughly €3 million. Further funding comes from €0.009 per kilowatt-hour sold on the electricity network, €0.0003 per kilowatt-hour from gas sales and €0.01 per cubic metre of water, as well as 1 percent of the annual profits of the city’s industrial services, with no increase in expense to the consumers. Only part of the fund is used to promote and manage the forest, which allows flexibility, especially for multiyear projects. In addition, forest and water supply services work closely together.

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