

ISSN 0041-6436

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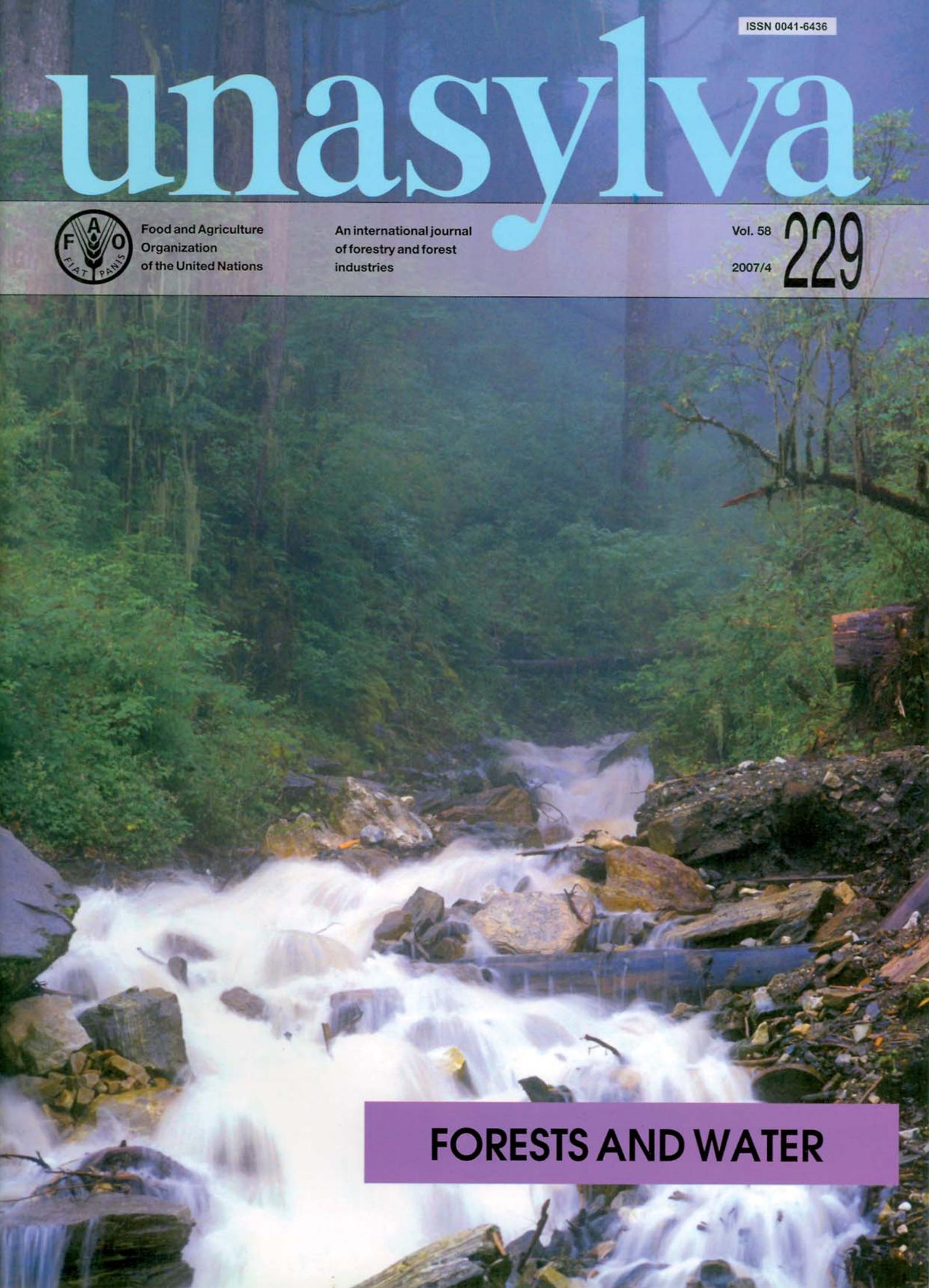
Food and Agriculture
Organization
of the United Nations

An international journal
of forestry and forest
industries

Vol. 58

2007/4

229

A photograph of a lush green forest with a river flowing through it, creating several small waterfalls and rapids over rocks. The water is white and frothy, contrasting with the deep green of the surrounding trees and foliage.

FORESTS AND WATER



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Cover photos:

FAO/M. Kashio (Bhutan)
Front, FO-6793; back, FO-6809

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Forests and water

Humans and other living things depend on water for life and health. Yet the World Health Organization reports that about 80 percent of the world's people live in places where the only available water is unsafe. Water-related problems such as overuse, scarcity, pollution, floods and drought are an increasingly important challenge to sustainable development – as the United Nations recognized in declaring 2005–2015 the “Water for Life” Decade.

Forested catchments supply a large proportion of all water used for domestic, agricultural and industrial needs. The availability and especially the quality of water are strongly influenced by forests and thus depend on proper forest management. The amount of water used by forests is also an issue of concern, particularly as the world increasingly looks to planted forests for carbon fixation, energy and wood supply and landscape rehabilitation.

To introduce this issue of *Unasylva*, I. Calder and co-authors appraise the state of knowledge of forest and water interactions and related policy issues. They emphasize the need to narrow the gap between research and policy-making and the importance of policy linkages between the forest and water sectors. They also stress the need for sound valuation of hydrological and other forest services.

Riparian vegetation has an important role in filtering sediment and pollutants. Bamboo is sometimes planted in tropical riparian areas to conserve soil and water. However, in a study in the Lao People's Democratic Republic, O. Vigiak *et al.* found that bamboo was less effective for this purpose than native grass; they recommend a grass strip alongside bamboo stands to enhance the trapping of sediments.

In Peninsular Malaysia, the criteria and indicators system used to certify tropical natural forests includes standards for protecting water. N.A. Chappell and H.C. Thang single out the most important of these standards – a 10 m buffer zone along streams and rivers where no forest operations are permitted – and consider its applicability to forest plantations and agroforestry systems.

The relation of forests and water in arid and semi-arid lands raises different problems. Availability of water is usually the main factor limiting natural distribution of trees in arid lands. M. Malagnoux, E.H. Sène and N. Atzmon examine strategies for reversing environmental degradation and desertification in drylands including afforestation, sand dune fixation, establishment of green belts and reserving areas for natural regeneration. They note that trees should only be planted where necessary and where the water balance allows.

The Tigris and Euphrates watershed is vital for the water balance of four countries in the Near East, where competition for water is increasingly a source of conflict. H.M. Kangarani and T. Shamekhi analyse the relations among forest, water and people to be considered in developing policies and collaboration for integrated conservation and management of forests and water in the region.

Mount Kulal, in northern Kenya, rises at the centre of one of the driest regions of East Africa. Capped with mist forest, it provides important hydrological services for the surrounding region. T.Y. Watkins and M. Imbuni examine the role of this unusual ecosystem as a source of water and natural resources which support local livelihoods. In Uganda, F. Kafeero postulates that the lowering of water levels in Lake Victoria has exacerbated deforestation, as reduced hydropower generation impels the population to rely on woodfuel for energy.

Forests also have a vital role in ensuring safe, clean water for urban populations. S. Stolton and N. Dudley note that more than one billion city-dwelling people lack access to clean water. Many of the largest cities in the world protect forests to help ensure a sufficient supply of freshwater for their inhabitants – in some cases through payments for environmental services.

Climate change adds to the complexity of the forest–water relationship. T. Stohlgren, C. Jarnevich and S. Kumar examine the many interacting factors that must be considered in trying to predict changes in water availability. Using examples from research in Colorado, United States, they trace the interrelatedness of mountain forest hydrology with climate change, previous land use histories, altered disturbance regimes (e.g. fire frequency, insect outbreaks, floods) and invasive species.

In South America, the loss of Andean cloud forests, particularly through conversion to agriculture, has upset the hydrological cycle and exacerbated landslide and flood damage related to El Niño. M. Fernández Barrena and co-authors analyse the viability of a system of payments for environmental services to mitigate the effects of El Niño through conservation of forests, soil and water in the Piura watershed of Peru, noting that such a system could also help improve the living conditions of peasant farmers in this mountain region.

Lastly, P.C. Zingari and M. Achouri look at progress in implementing policies, planning and management initiatives in the five years since an international expert meeting held in Shiga, Japan in 2002 brought forest and water interactions into the international spotlight. Examples show a clear trend towards stronger links in forest and water resource management at the global, regional and national levels.

Foresters and water management specialists are cooperating more closely than ever before, but their exchange of expertise could be developed further. Informed decisions about integrated forest and water management depend on applied research and its dissemination to policy-makers. With this issue of *Unasylva* we hope to enhance the flow of information, knowledge – and safe water.

Towards a new understanding of forests and water

I. Calder, T. Hofer, S. Vermont and P. Warren

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).

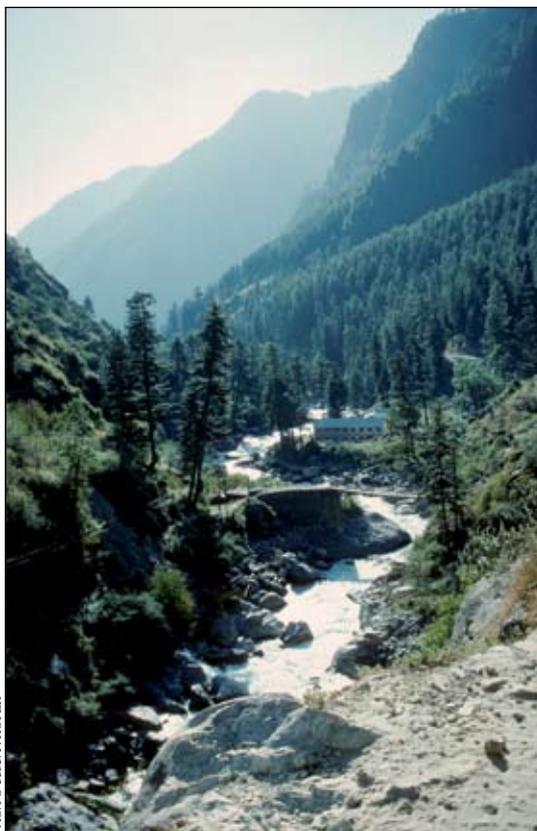
This article summarizes the state of current knowledge about forest and water interactions in watershed ecosystems. It summarizes some key issues that have emerged from discussion among forest hydrologists, other water-sector experts and policy-makers in the years since the Shiga Declaration, the third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



INSTITUT FÜR WASSERWIRTSCHAFT, HYDROLOGIE UND KONSTRUKTIVEN WASSERBAU

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.

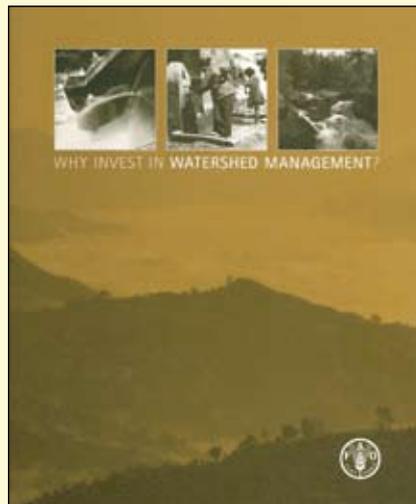
Source: IUFRO, 2007.

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. It can also be downloaded online at: 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 km² in 2005 and is expected to reach 3 500 km² 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 km² 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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Filtering of water pollutants by riparian vegetation: bamboo versus native grasses and rice in a Lao catchment

O. Vigiak, O. Ribolzi, A. Pierret, C. Valentin, O. Sengtaheuanghoung and A. Noble

Although bamboo is sometimes planted in riparian areas to conserve soil and water, a Southeast Asian study suggests that it may not be the best ground cover for this purpose.

Located at the interface of terrestrial and aquatic habitats, riparian zones have an important role in filtering and trapping of sediment and dissolved and sediment-borne pollutants. The effectiveness of riparian vegetation in filtering pollutants depends on several factors, including structure, composition and density of ground and canopy cover. In the humid tropics of Southeast Asia, the use of bamboo species – which provide important non-wood forest products (NWFPs) – has also been recommended for soil and water conservation. However, evidence of bamboo's effectiveness in this regard is limited.

This article reviews current knowledge on the water-related functions of vegetation in riparian areas. It then focuses on the results and main conclusions of research carried out in a headwater catchment in the north of the Lao People's Democratic Republic to compare fluxes

of water and sediment across riparian sites covered with bamboo and native grass (Vigiak *et al.*, 2008). The study also compared the filtering properties of natural riparian vegetation with those of cultivated upland rice.

SEDIMENTS AND POLLUTANTS

In Southeast Asia, increasing population pressure on the land is causing very rapid land-use changes: cultivation on sloping land is intensifying, while in most countries forest cover is shrinking. Shifting cultivators must recultivate the same land more frequently, which disrupts the cultivation-fallow cycle of their traditional farming system. The consequences are losses of soil fertility and crop yield, accelerated erosion on hillslopes and higher sediment deliv-

Bamboos are important non-wood forest products in Southeast Asia, for food (shoots) and for building material and handicrafts (stems)

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O. VIGIAK



In the traditional shifting cultivation system of mountainous Lao People's Democratic Republic, the landscape is a mosaic of cultivated fields, secondary vegetation and forest remnants; cultivation of annual crops on steep slopes is associated with high sediment yields

ery to streams (Roder, Phengchanh and Maniphone, 1997; Chaplot *et al.*, 2005). In forested catchments, compaction of soil on logging roads and skid trails may reduce water infiltration and augment surface erosion (Sidle, Tani and Ziegler, 2006). As sediments are carriers of nutrients and pollutants, the increase of sediment delivery to streams has negative impact on the livelihoods and health of downstream populations.

Provision of safe water is usually a main objective of natural resource management policy. Good water quality can be achieved by reducing emission of pollutants at the source, e.g. by proper management of agricultural or forestry activities, and/or by placing natural filters in the landscape to prevent pollutants from reaching the streams. Control of water pollutants is more effective near the pollution sources, i.e. in headwater catchments, where wetlands and riparian zones may be extremely effective pollutant filters.

RIPARIAN ZONE FUNCTIONS

A riparian zone, strictly defined, comprises only the vegetation in a stream channel and along the river banks; however, the term has recently been used more broadly to include the part of the landscape adjacent to a stream that exerts a direct influence on stream and lake margins and the water and aquatic ecosystems associated with them (Karssies and Prosser, 1999). In the

landscape, riparian habitats are corridors located at the interface of terrestrial and aquatic ecosystems. They act as conduits, filters or barriers controlling flows of water, sediments and nutrients. Ensuring riparian ecological functions such as filtering of polluted overland and subsurface flows, stabilization of stream banks and control of in-stream habitats is an important part of sound natural resource management (Mander and Hayakawa, 2005).

Many subsistence and income-generating activities that are integral parts of rural household economies are undertaken in riparian zones. In the Lao People's Democratic Republic, naturally occurring and cultivated bamboos found in riparian zones are important sources of food (shoots) and of raw materials for housing and handicrafts (de Beer

and McDermott, 1996). Forest remnants along the stream provide wildlife habitat and are popular sites for game hunting and fishing. Relatively flat topography and the availability of water for irrigation make riparian land attractive for cultivation. Bananas are often cultivated along headwater streams. Recently, the increasing demand for produce for the growing urban market has enticed farmers to convert riparian land into orchards. Vegetable gardening is mainly a dry-season activity; however, the upper reaches of headwater streams are also cultivated during the rainy season, either for vegetables or upland rice. The effects of these land-use changes on stream water quality are largely unknown.

RIPARIAN VEGETATION AS SEDIMENT FILTER

The effectiveness of riparian vegetation in filtering pollutants depends on the nature of the pollutant. Retention of sediments is usually higher than retention of sediment-bound pollutants, because most sediment-bound pollutants are usually attached to finer particles which are more difficult to retain; and dissolved contaminants are reduced the least (Karssies and Prosser, 1999). Riparian vegetation mainly filters sediments through the following mechanisms (Karssies and Prosser, 1999; Mander and Hayakawa, 2005):

- by enhancing infiltration (i.e. reducing runoff volume) and increasing

Growing demand from urban markets entices farmers to establish vegetable gardens on riparian land along the Mekong River (Luang Prabang, Lao People's Democratic Republic)



Bamboos have important riparian ecological functions, such as shading and control of water temperature and in-stream habitats (left); however, because of their scant ground cover, they do not appear to be very effective in trapping hillslope runoff water and sediments (right)



surface roughness (i.e. reducing runoff velocity), which favour sediment settling out – with effectiveness depending on many factors, such as rainfall characteristics and riparian topography;

- by protecting the stream banks and riparian soils from direct erosion;
- by filtering solid particles;
- by adsorbing pollutants;
- by taking up nutrients before they reach the watercourse.

Soil in riparian areas also adsorbs pollutants, and microbes in the soil take up nutrients.

Infiltration is by far the most important mechanism filtering incoming hillslope surface flows. However, when subsurface flows are sizeable, seepage and saturation flows can hinder infiltration (McKergow *et al.*, 2004).

The effectiveness of riparian vegetation in trapping sediments depends on many factors, such as incoming flow rates, sediment particle size, hydrologic and topographic settings of the riparian area, and vegetation cover and type (Karssies and Prosser, 1999).

EFFECTIVENESS OF DIFFERENT VEGETATION TYPES

Density, height and type are the most important characteristics affecting the capacity of vegetation to retain sediments in riparian land (Karssies and Prosser, 1999).

The density of the vegetation is important, particularly at ground surface, because the vegetation stems offer resistance to overland flow, thus reducing flow velocity and favouring particle settling. Vegetation should be uniformly dense; stoloniferous grasses (those spread by lateral stems, called stolons, which creep over the ground and give rise to new shoots along their length) and creeping grasses are the best, whereas tussocks may concentrate flow (Karssies and Prosser, 1999). A minimum of 45 percent ground cover is recommended for effective buffers. Vegetation height should be at least 10 to 15 cm; it must be high enough to avoid submergence from overland flow.

The effect of vegetation type is more controversial. Grass may be more effective than woody vegetation in reducing bank erosion and trapping sediments, but grass requires active management because succession processes tend to favour woody vegetation (Lyons, Trimble and Paine, 2000). Grass filters colonize new sediments quickly so they are not removed by subsequent runoff; grass filters should be perennial, resistant to flooding and drought, able to grow after partial inundation, and not invasive of other ecosystems (Karssies and Prosser, 1999).

Unless undergrowth is dense, forest is considered the least effective buffer because stems are dispersed and flow

often gets concentrated into rills, thus becoming more erosive. Litter works only as a temporary store: it traps sediments, but these are flushed out by subsequent runoff (Karssies and Prosser, 1999; McKergow *et al.*, 2004). However, trees and shrubs can provide other benefits to streams, such as shade and control of water temperature, which affect primary production and in-stream habitat (Lyons, Trimble and Paine, 2000). Forest should therefore be bordered by a grass strip to trap sediments from adjacent fields. For the southeastern United States, Sheridan, Lowrance and Bosch (1999) recommended forest riparian buffers composed of three zones: a grass filter strip adjacent to fields, whose main function is to spread surface runoff as sheet flow; a first forested zone where infiltration and sedimentation occurs; and a second forested zone to protect and stabilize stream banks.

Bamboo stands frequently occur near streams. Their bushy structure and close canopies ensure good shading of the stream, but the understorey vegetation may be sparse. In the southwestern and midwestern United States, the native bamboo species *Arundinaria gigantea* was found to be an effective filter for sediment, nitrogen and phosphorus (Blattel *et al.*, 2005; Schoonover *et al.*, 2006). Yet few other field studies have addressed the effectiveness of bamboo in filtering sediments.

BAMBOO VERSUS GRASS VERSUS RICE

To assess the efficiency of sediment trapping by naturally occurring or cultivated riparian vegetation, a field experiment was conducted in a small headwater catchment of northern Lao People's Democratic Republic (Houay Pano catchment, Luang Prabang Province). High sediment yields (more than 10 tonnes per hectare per year) have been associated with annual crops in this catchment (Chaplot *et al.*, 2005).

The headwater catchment receives an average of about 1 300 mm of rain per year, most of it during the monsoon season that lasts from mid-May to mid-October. The catchment is representative of the no-input slash and burn system of Southeast Asia. Over the past 30 years, the fallow period has been reduced from 10 to 15 years down to 2 to 5 years (Lestrelin and Giordano, 2006). Altitude ranges from 400 to more than 800 m. The main stream reach is a second-order perennial stream of irregular but steep topography. Riparian zones are mainly of convex or convex-concave shape, steep and narrow. Stream banks are high and steep.

More than 43 percent of the riparian areas along the Houay Pano stream are covered by a grass and shrub vegetation dominated by *Microstegium ciliatum* (referred to here as "native grass"). Bamboos, especially *Dendrocalamus* sp. and *Cephalostachium virgatum*, cover

TABLE 1. Average characteristics of riparian naturally occurring vegetation type, estimated from 3 m x 3 m plots during the 2005 rainy season (July–October 2005), Houay Pano ($n = 12$)

Vegetation type	Canopy cover (%)	Ground cover (%)	Density of grass stems (n/m^2)	Grass biomass (g/m^2)	Undergrowth height (m)
Native grass	85	88	355	435	0.75
Bamboo	70	39	64	45	0.27

TABLE 2. Characteristics of the riparian sites for monitoring of water and sediment fluxes, Houay Pano catchment, Lao People's Democratic Republic

Year/site	Vegetation type	Slope (%)	Width ^a (m)	Upslope land use
2005				
NG1	Native grass	16	11.6	3 years fallow
NG2	Native grass	58	10.4	Teak
BB1	Bamboo	20	8.8	2 years fallow
BB2	Bamboo	70	7.9	Banana
2006				
NG3	Native grass	75	5.1	2 years fallow
R_NG	Upland rice	65	7.0	2 years fallow
BB3	Bamboo	49	3.9	Banana
R_BB	Upland rice	48	5.2	Banana

^a Width is the horizontal distance of the monitored buffer zone.

19 percent of the riparian areas. Native grass and bamboo sites differ in ground and canopy cover (Table 1); therefore different performance in sediment filtering was expected. The remaining riparian areas in the catchment are covered with banana (15 percent), forest (15 percent), cassava (6 percent) and

napier grass (a cultivated fodder species, *Pennisetum purpureum*) (3 percent).

For two rainy seasons, volumes of surface water runoff and runoff sediment concentration entering and exiting bamboo and native grass riparian sites were measured by means of open troughs (Vigiak *et al.*, 2008). Two bamboo and two native grass sites were monitored in 2005, and one each in 2006. The sites differed in topographic settings, upslope conditions and buffer width. In 2006, vegetation adjacent to the riparian sites was cleared and upland rice was established for use as a reference and to assess the effect of clearance and cultivation in riparian land (Table 2).

Figure 1 shows the total runoff volumes and sediment load entering and exiting the native grass and bamboo riparian sites during the monitoring periods. Two native grass sites reduced the volume of water; these sites had less runoff exit-



In headwater mountain catchments of the northern Lao People's Democratic Republic, riparian areas are steep and narrow; clearance of this land for cultivation of rice or other annual crops may have serious negative impact on water quality

ing than entering. In the third, runoff out only slightly exceeded runoff in. All three bamboo sites had more water exiting than entering, which showed that infiltration of rainfall and incoming runoff was limited. Sediments were more concentrated in the runoff exiting the riparian sites than in that entering, particularly under bamboo vegetation. Bamboo sites were therefore sources of sediment to the stream, while native grass was generally a sediment sink.

Both vegetation types, however, were much better filters than upland rice. Figure 2 shows “box-and-whisker” plots of the ratio of sediment concentration in the outflow measured in adjacent plots between upland rice (sites R_BB and R_NG) and bamboo or native grass (BB3 and NG3, respectively) in 17 events during the 2006 monsoon season. The graph shows that runoff exiting upland rice always had higher concentration of sediments than the adjacent plots. Indeed, the sediment concentration in runoff exiting upland rice sites was, on average, three times higher than that in runoff exiting the adjacent bamboo site, and nine times higher than that in runoff from the native grass site.

MANAGEMENT IMPLICATIONS

Sediment retention measured in riparian sites in Houay Pano catchment was low. The natural setting of riparian land in this headwater catchment – steep, narrow and clayey – severely limits the possibility of trapping sediment and pollutants *in situ*. Seepage was frequently observed during the study, as is common in riparian zones in the humid and wet tropics (McKergow *et al.*, 2004; Sidle, Tani and Ziegler, 2006). Seepage inhibits infiltration and the resistance of soil to detachment and transport, while possibly triggering landslides and streambank collapse.

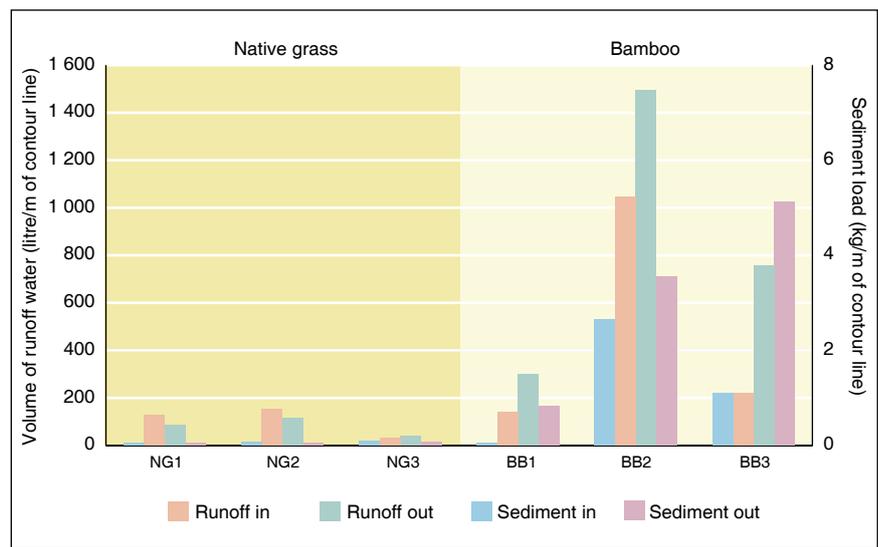
Cultivation of annual crops in this environment leads to high sediment yields (e.g. Chaplot *et al.*, 2005). Given the findings of this study, it is not appropriate to rely exclusively on the filtering capa-

city of riparian vegetation to enhance water quality. Proper management of riparian land cannot replace proper management of sloping land, but it is essential where cultivation of slopes is intensified.

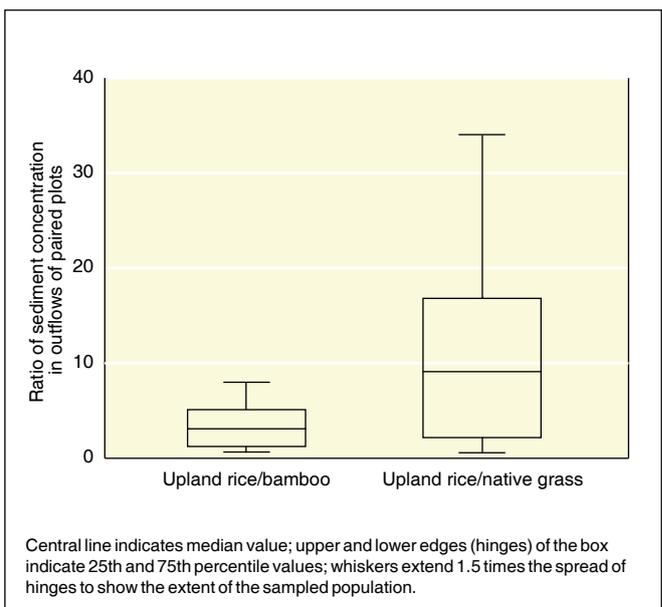
In northern Lao People’s Democratic Republic, riparian land offers important opportunities for income generation for the rural population. Relatively gentle slopes and the presence of water for irrigation make riparian land particularly appropriate for cultivation of vegetables,

which fetch increasing prices on the market. However, because of the proximity to streams, the use of riparian land affects water quality. The present study showed that cultivation of upland rice on riparian land led to increased sediment concentration in surface runoff flowing into the stream.

1
Volume of runoff water and sediment load entering and exiting native grass and bamboo sites, Houay Pano catchment, Lao People’s Democratic Republic, 2005 and 2006 monsoon seasons



2
“Box-and-whisker” plot of ratios of sediment concentration in outflow, Houay Pano catchment, 2006 (n = 17)



Native grass was the best vegetation cover for filtering surface water inflows and thus reducing sediment delivered to streams. Bamboo, although a source of valuable products for local communities, was not effective in reducing sediment pollution to streams, whether it was naturally occurring or planted. As these results contrast with those of Schoonover *et al.* (2006), further research is needed to confirm the effect of bamboo on soil and water conservation and water quality.

The study addressed only one aspect of the relationship between riparian vegetation and water quality. Bamboo effects on bank erosion protection and in-stream habitats are not well understood. It is therefore recommended, as advocated in the United States (Sheridan, Lowrance and Bosch, 1999), that the establishment or management of bamboo stands in riparian zones be coupled with the establishment or maintenance of a grass strip uphill from the watercourse to enhance the trapping of sediments. ♦



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Practical hydrological protection for tropical forests: the Malaysian experience

N.A. Chappell and H.C. Thang

Synergies between hydrological research and certification of natural forest management in the humid tropics give rise to water protection standards that are also partially applicable to forest plantations and agroforestry systems.

Stream-gauging structure within the buffer zone of the selectively logged Baru experimental watershed, East Malaysia



N.A. CHAPPELL

Water resources are essential for people, ecology and economic development in both forested and non-forested areas. As most tropical natural forests escape contamination by artificial chemicals such as those in urban landscapes or leached from intensive agriculture, the quality of their water is often the least hazardous to human health. Paradoxically because of the inherent quality of the natural forest environment, standards of environmental protection in selectively managed natural forests, including hydrological requirements, are often far tougher than those applied in non-forest lands.

Guidelines for hydrological protection during forestry operations are plentiful in the global forestry and hydrology literature (e.g. Megahan, 1977; Cassells, Gilmour and Bonell, 1984; FAO, 1996, 1999; Sabah Forestry Department, 1998; Hamilton, 2004; Thang and Chappell,

2004). They include measures to protect soil water and nutrient status, the recharge of major aquifers, microclimate and evaporation, and river resources. Some of the published guidelines, however, lack a credible scientific basis, some are contradictory, some are not viable economically, some are only directly applicable in temperate environments, some are so complex that they require a Ph.D. in hydrology to apply, and some even have negative impacts on certain aspects of the hydrological system.

This article reviews the hydrological basis of standards set within the system of Malaysian Criteria and Indicators for Forest Management Certification (MC&I), which has been used to certify forestry practices in 4.7 million hectares of permanent reserved forests in four states of Peninsular Malaysia: Selangor, Pahang, Terengganu and Negeri Sembilan. The inclusion of hydrologi-

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cal standards in the certification system ensures their universal application in all certified forest management units. The article identifies what the authors consider to be the single most important hydrological standard – the watercourse buffer zone – and considers its application outside certified natural forests, which is important because many tropical natural forests are being converted with no certified hydrological standards to agriculture, agroforestry and urban landscapes. The lessons learned in Malaysia’s relatively well-developed forestry sector, particularly those supported by primary hydrological research, may be useful for wider application in other tropical countries.

STANDARDS FOR HYDROLOGICAL PROTECTION

The Malaysian Criteria and Indicators for Forest Management Certification (Thang, 1996; MTCC, 2001, 2004) contain standards of performance or verifiers used to benefit the hydrological system through protection of the forest canopy and the ground (soil and water). Some of the standards are directly aimed at hydrological protection, while others, notably those related to minimizing collateral canopy damage, have an indirect impact on hydrological phenomena. For example, canopy disturbance caused by the opening of forest roads and subsequent selective harvesting can be minimized by reduced-impact logging (Pinard, Putz and Tay, 2000) to reduce damage to the remaining stand, especially the younger stems, and to biodiversity (Thang, 1987). This has the indirect hydrological benefit of reducing the change in the forest microclimate, minimizing declines in evapotranspiration (Nik and Harding, 1992; Chappell *et al.*, 2004b), while also reducing biomass loss and its impact on nutrient and carbon leakage (Yusop, 1989).

Quantitatively, river sediment load and turbidity are the hydrological features most affected by commercial harvesting in tropical natural forests, as shown by a recent review (Chappell *et al.*, 2004b).

Recent research, primarily in Malaysia, has shown that erosion, collapse of hollow-log culverts (along feeder roads and secondary haul roads) and landslides can increase river sediment loads 5- to 50-fold directly after selective harvesting (Chappell *et al.*, 2004a,b). The elevated sediment loads impair fish habitat, heighten flood risk downstream, increase the costs of treatment for potable water supplies and lead to the inundation of offshore coral beds.

Forestry measures that can reduce these changes and promote rapid recovery are consequently the most important standards for hydrological protection. In production forests of Malaysian permanent reserved forests, erosion, log-culvert collapse and landslides are primarily related to ground disturbance along skid trails (i.e. routes used by tracked skidders in log yarding) and haul roads (i.e. engineered roads used by timber lorries) by blade cutting, compaction, slope cutting and stream crossings. Canopy opening is only a secondary factor (Chappell *et al.*, 2004a). While the Malaysian criteria and indicators encourage minimization of the number of skid trails and haul roads, the relationship between the density of road or trail networks and river sediment inputs is complex, since much of the road and trail network is disconnected from permanent watercourses (streams and rivers) (Sidle *et al.*, 2004). However, where sediments reach permanent watercourses, sediment problems are easily transferred downstream over great distances.

The most hydrologically sensitive parts of the landscape are the watercourses with perennial flows and the road or trail crossing points (Chappell *et al.*, 2007). To comply with the criteria and indicators for Peninsular Malaysia, along all permanent watercourses it is necessary to demarcate a buffer zone 10 m wide (5 m either side of the channel) in which vehicle access and tree cutting are restricted only to stream or river crossings with bridges or culverts.

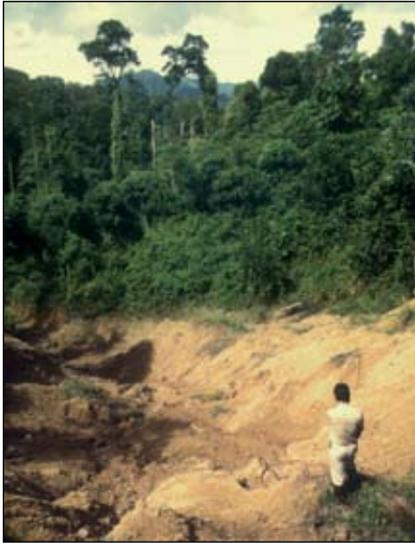
Other criteria and indicator systems differ in the recommended placement and dimensions of such buffer zones. Some foresters have suggested that ephemeral channels, which by definition flow only during storms, should be protected (FAO, 1999; Cassells and Bruijnzeel, 2004), while others suggest that protection is unnecessary for watercourses narrower than 5 m (Sist, Dykstra and Fimbel, 1998). In the humid tropics where drainage density (the length of watercourse with permanent flows per unit watershed area) is very high, if buffer zones were required for ephemeral channels they could take up 40 percent of the landscape (Thang and Chappell, 2004). Moreover, Chappell *et al.* (2004a) have shown that the greatest unit area input of sediments into channels is along first- to third-order channels (i.e. permanent streams to small rivers). This means that it is not critical to protect ephemeral channels, but it is important to buffer all permanent rivers and streams. This research thus endorses the hydrological standard universally applied within the forest reserves of the Malaysian states of Selangor, Pahang, Terengganu and Negeri Sembilan.

Road-initiated landslides in an experimental watershed of Ulu Segama Forest Reserve, East Malaysia, were observed to travel 150 and 500 m (Chappell *et al.*, 2004a). Although the haul roads in this area were located and built correctly, they were closer than this to permanent streams (see Table), indicating that sediment generated by major failures of cut-and-fill materials can reach permanent channels.

Mean distance from haul roads to permanent streams, Baru experimental watershed, Ulu Segama Forest Reserve, East Malaysia

Stream type	Distance (m)
First-order streams	87
Second-order streams	158
Third-order streams	255

Source: Chappell *et al.*, 2004a.



N.A. CHAPPELL

500 m landslide below a secondary haul road (Baru experimental watershed) shortly after failure

Thus, while the buffer zone may protect water by preventing skidders from using the watercourses as transport routes, it is not expected to trap sediments from upslope. Ziegler *et al.* (2006), working in agricultural landscapes in northern Viet Nam, have similarly questioned the effectiveness of buffer zones, even those up to 50 m wide, in trapping sediments. Bren (2000) and Chappell *et al.* (2006) have implied that prediction of the trap efficiency of buffer zones or the location of disturbance-sensitive streamside soils is currently too uncertain for practical application of variable-width buffer zones in forestry.

While skidders are prevented from using watercourses as routes within reduced-impact logging areas (e.g. Sabah Forestry Department, 1998), where skid trails cross permanent watercourses they have the potential to be significant points of input of sediments to streams and thence to rivers. The criteria and indicators for Peninsular Malaysia recommend various ways of crossing streams using either culverts or bridges. Hydrological research is needed to ensure that the allowed crossings, including the use of hollow logs

which may collapse after a few years, are both hydrologically sound and cost effective in the long term. Helicopter and skyline yarding, tested on steep terrain in East Malaysia (Mannan and Awang, 1997), has the potential to reduce significantly the number of tracks in the forest by eliminating skidder use from these areas (FAO, 1996). While reducing the number of stream crossings is expected to decrease river sediment loads, direct evidence of the watershed-scale impact of these different yarding methods in the tropics has yet to be measured. The main haul roads, with concrete stream culverts, engineered bridges and gravel surfaces, are designed in such a way that their impacts on sediments are unlikely to persist long after the construction phase (Forestry Department Peninsular Malaysia, 1999).

Certification within the forest reserves of the states of Selangor, Pahang, Terengganu and Negeri Sembilan has encouraged the use of improved logging practices supported by fundamental hydrological research (Thang and Chappell, 2004). Land managers should ask if the application of these findings could be of value also for hydrological protection during forest clearance or the establishment of tropical timber plantations or agroforestry systems.

PROTECTION IN UNCERTIFIED NATURAL FORESTS AND PLANTATIONS

As described above, for protection against the largest hydrological changes associated with tropical natural forestry, establishing a 10 m wide buffer zone along all permanent streams and rivers during forest harvesting operations is effective. In forests where it would be economically unaffordable to meet all the physical environmental standards required for certification by international assessors, this single standard, if followed strictly, would provide some assurance of water resources protection in natural forests.

In many areas where conversion from

natural forest to forest plantations, agroforestry or other land uses is planned, it may not be considered logistically feasible to prevent most tree cutting in all permanent streamside zones. However, research has shown that application of the buffer designation used within Peninsular Malaysia's MC&I would restrict forest cutting (except at "well managed" stream crossings) from only 7 percent of the landscape for watercourse protection (Thang and Chappell, 2004)—less than the area of forest reserves normally gazetted for protection of biological and physical resources. Moreover, such a buffer offers some protection for the most hydrologically sensitive small streams (i.e. less than 5 m channel width) which are the most numerous channels in the landscape but are the least protected in most tropical forestry systems (Thang and Chappell, 2004; Chappell *et al.*, 2007). If these "fingers" of natural forest cannot be kept, considerable hydrological benefits would still be obtained by minimizing skidder vehicle use within demarcated 10 m wide buffer zones alongside all permanent streams. Maintaining these ribbons of natural forest would also protect the aquatic habitat by reducing disturbances to stream-water temperature regimes associated with forest clearance (Davies and Nelson, 1994). Indeed, draft criteria and indicators for Malaysian forest plantations (MTCC, 2007) call for the 10 m buffer along all streams during conversion and after plantation establishment.

In agroforestry and intensive agricultural systems and in some forest plantation systems, the use of pesticides and artificial fertilizers greatly heightens the need to define and protect watercourses. In saturated streamside zones, where chemicals can reach streams quickly because they are generally carried more rapidly over land than through subsurface flow routes, prohibiting the use of chemicals is the best way to prevent their becoming a human health hazard; here streamside buffer zones with zero direct chemical applications may need to be wider than 5 m

to be effective (McKergow *et al.*, 2004). The presence of natural forest within these streamside zones also reduces the likelihood of overland flow by enhancing evaporation and infiltration, and enhances the utilization of nutrients leaching from upslope areas, thereby reducing losses of chemicals into channel watercourses (McDowell, 2001).

CONCLUSIONS

The two decades of research on forestry practices and hydrological processes in Malaysia's natural forests that underlie the certification of hydrologically sound forestry practices in forest reserves of the states of Selangor, Pahang, Terengganu and Negeri Sembilan offer findings pertinent to sustainable forest management in other countries in the humid tropics. Reduced-impact logging techniques within several Malaysian states help maintain the hydrological functioning of rivers in natural forests (e.g. Nik and Harding, 1992; Yusop, 1989; Chappell *et al.*, 2004b; Thang and Chappell, 2004). These rivers are of considerable importance for potable water supply because they are free from artificial chemical contamination. It is by influencing sediment load, however, that forestry practices have the largest impact on rivers in natural forests maintained for long-term timber production (Chappell *et al.*, 2004b). The MC&I hydrological standards of performance for Peninsular Malaysia contain

measures to mitigate impacts on sediment load (Thang and Chappell, 2004).

Despite the recent intensification of hydrological research within tropical natural forests (Bonell and Bruijnzeel, 2004), the impact of many forestry practices on tropical hydrological systems remains poorly quantified. Amounts and sources of river sediments in particular are extremely difficult to determine with accuracy because of the episodic nature of sediment delivery, the heterogeneity of the sediment sources and the high technological requirements for such measurements (Douglas *et al.*, 1999; Chappell *et al.*, 2004a). Despite these uncertainties, it is clear that small permanent streams – because they comprise the greatest length of perennial watercourse (Chappell *et al.*, 2007) and receive the greatest sediment inputs per unit watershed area (Chappell *et al.*, 2004a) – all need protection. Within certified forestry systems in Peninsular Malaysia, the placement of narrow buffer zones on small permanent streams:

- restricts skidder drivers from using small channels as routes, thereby reducing channel erosion;
- requires culverts or bridges to be placed at all road and trail crossings of permanent streams, reducing channel disturbance and disconnecting some slope sediment pathways from the channels;
- maintains canopy cover and hence microclimate along stream corridors.

These considerable benefits can be gained by limiting cutting and vehicle access from a relatively small area (less than 10 percent) of the landscape.

While few studies have addressed the hydrological impacts of forestry within tropical natural forests and associated mitigation strategies, almost none have addressed river turbidity for tropical plantations (Bonell and Bruijnzeel, 2004; Chappell, Tych and Bonell, 2007). There is an urgent need to extrapolate the findings of turbidity studies from tropical natural forests to watersheds with plantations, and to initiate new watershed-scale studies on river turbidity and water quality within timber or oil-palm plantations. Hydrological research is also needed to compare the value and economic impacts of buffer zones of different sizes within areas being converted to timber plantations and agroforestry systems. ♦



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FAO field projects in watershed management – some examples

Projects in the Democratic People's Republic of Korea and Tajikistan illustrate how FAO helps countries improve watershed management through capacity building, institutional development and fieldwork.

At the request of member countries, FAO implements many technical cooperation projects in watershed management. They generally include components of local and national capacity building, institutional development and pilot activities in the field directed towards reducing degradation of natural resources.

In the Democratic People's Republic of Korea, for example, two watersheds were selected for pilot activities. A comprehensive management plan was developed in a participatory manner for each. The project initiated afforestation, agroforestry and intercropping trials and sediment monitoring on sloping fields and in rivers. A national workshop attended by approximately 50 government officers from forestry, agriculture, meteorology and remote sensing, as well as scientists and field staff, focused on preparation of a medium- and long-term participatory integrated watershed management investment programme for the country.

As a result of awareness and skills developed through the project, the Academy of Forest Sciences is now developing a watershed management plan for the Taedong River, which flows through Pyongyang, the country's capital.

In Tajikistan, interventions in the pilot water-

shed included afforestation, agroforestry and gully rehabilitation, pasture management, drip irrigation technologies and farm pond construction. A modern greenhouse was erected for a tree nursery. Participants in training sessions and study tours to India and Nepal have already started to apply their newly acquired knowledge in the pilot project site.

Through the work of a pasture management interest group, controlled grazing has been introduced, vegetation has recovered and degradation has been significantly reduced. The water interest group introduced an irrigation calendar used to allocate irrigation water to each household on a specific date and in a specific quantity. Following the installation of pipes, households now get drinking-water directly from the spring. A women's group on income generation worked to establish a revolving fund which is now used for the implementation of small enterprise projects. A new watershed management unit has been created in the Soil Science Research Institute.

In both countries, watersheds selected for the pilot activities have evolved into attractive demonstration and training sites for modern approaches to participatory integrated watershed management.

The new generation of watershed management programmes and projects

In 2002, in the framework of preparations for the International Year of Freshwater 2003, FAO launched a global review of watershed management practice whose scope was explicit in its title: "Preparing for the next generation of watershed management programmes and projects".

The review involved about 80 institutions and 300 professionals from around the world through a survey and four regional workshops. It culminated in the interregional Conference on Water Resources for the Future, held in October 2003 in Sassari, Italy. Two national (Burundi and Nepal) and two regional (Latin America and the Mediterranean basin) case studies and five volumes of workshop and conference proceedings were published. The flagship output is FAO Forestry Paper No. 150, *The new generation of watershed management*

programmes and projects, a resource book for practitioners and local decision-makers which outlines the way forward in watershed management. Main features of the recommended approach include:

- longer-term programmes (at least ten years, in two or more phases), negotiated with local stakeholders and aimed at initiating a continuing watershed management process;
- local-level processes coordinated beyond the watershed level – i.e. at the river-basin or regional level – to take upstream/downstream linkages fully into account;
- implementation responsibility entrusted to relatively informal local institutions such as watershed management fora, with formal institutions such as government watershed authorities having a

more subsidiary, facilitating role than in the past;

- focus on natural resource management as part of local socio-economic development processes;
- multistakeholder collaboration linking social, technical and policy concerns in a pluralist learning and decision-making process;
- "fairly valid and cheap" monitoring and evaluation focused more on ecosystem changes than on managerial performance, based on uniting local and scientific knowledge and involving a variety of local stakeholders in data collection, analysis and interpretation.

The publications and documentation are available online at:

www.fao.org/forestry/site/forestsandwater



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An artist's visualization of the management plan of a pilot watershed in the Democratic People's Republic of Korea, positioned at the entrance to the watershed for awareness raising



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Intercropping experiment to reduce soil erosion, Democratic People's Republic of Korea



FAO/T. HOFER

Watershed management plan for pilot site in Tajikistan

Pilot watershed in Tajikistan before project interventions (left) and after one year of project implementation (right)



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Forests, trees and water in arid lands: a delicate balance

M. Malagnoux, E.H. Sène and N. Atzmon

In arid lands, where competition for water is acute, trees should be planted only when and where necessary and possible.

Arid lands are among the world's most fragile ecosystems, made more so by periodic droughts and increasing overexploitation of meagre resources. Arid and semi-arid lands cover around one-third of the world's land area and are inhabited by about one billion people, a large proportion of whom are among the poorest in the world.

Forests, trees and grasses are essential constituents of arid zone ecosystems and contribute to maintaining suitable conditions for agriculture, rangeland and human livelihoods. In providing goods (especially fuelwood and non-wood products) and environmental services to the rural poor and in contributing to the diversification of their household sources of income, forests and trees in arid zones boost poverty alleviation strategies and reduce food insecurity.

Roughly 6 percent of the world's forest area (about 230 million hectares) is located in arid lands (FAO, 2001).

Trees outside forests (scattered in the landscape, in arable lands, in grazing lands, in savannahs and steppes, in barren lands and in urban areas) have a vital role in arid lands, although it is difficult to assess their extent.

Availability of water – surface water, groundwater and air moisture – is usually the main factor limiting natural distribution of trees in arid lands, along with climate (rainfall, temperatures, wind) and soil quality. Each tree species is adapted to certain conditions and is located in its “niche”. When optimal conditions are widely distributed, forests or shrubs may cover large areas. More often, limited by water scarcity, vegetation is concentrated where runoff can accumulate or where groundwater is accessible. This leads to the uneven distribution of trees and bushes, for example in striped bush (fragmented bush stands), riparian forests, the deepest channels of valleys (thalwegs) and oases, and isolated in the landscape.

Water availability limits distribution of trees; some individuals are able to survive even in the desert far from any other vegetation (Mauritania)

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This article is adapted from Malagnoux, 2007.



FAO/CIFOR/UNEP/FAO/ITC

However, the natural distribution of vegetation has long been altered by human activities. Deforestation and degradation of tree and shrub formations (mainly through conversion to agricultural use) and overexploitation of forests and woodlands (through fuelwood collection and overgrazing) are among the major causes of soil degradation in arid areas. Furthermore, global warming is expected to result in rainfall decrease throughout most of the world's arid zones, which will lead to more severe water scarcity and increased desertification risks.

Many methods for reversing deforestation, degradation and desertification rely on tree planting. However, before trees are planted it is essential to consider the water balance.

A TREND OF DECREASING FOREST COVER

Deforestation

Conversion of forests for agricultural crops and pasture land is the main cause of the increasing deforestation in arid lands. In many places the prevailing shifting cultivation and crop/fallow systems are no longer possible and continuous cultivation of the same piece of land, often with no crop rotation, leads to exhaustion of soil fertility and the need for new lands. Degraded wooded lands which were formerly neglected are now actively deforested. Increased grazing pressure and unmanaged harvesting of fuelwood and other products also result in degradation and deforestation.

The remaining forests and wooded lands

are sometimes threatened by pest and disease outbreaks, although these are rare under extremely dry conditions. Forest fire is a constant threat in arid lands, although very large fires are rare compared with those occurring in other regions. Limited fuel accumulation due to high grazing pressure limits the extension of burned areas. However, fires cause considerable loss of forest, bush and tree cover, especially in the drier ecosystems, endangering ecological niches hosting relicts of forests of high biological diversity.

Desertification

The United Nations Conference on Environment and Development (UNCED, 1992) defined desertification as "land degradation in arid, semi-arid and dry

Acacia stands in the Sahel and their relationships with water

Water is a scarce and coveted resource in the Sahelian region. Competition for it is severe and when present it is rapidly used by humans, animals and plant species. *Acacia* spp. have a particularly sensitive interaction with water. In a year of abundant rainfall, they regenerate plentifully from seeds that may have been collecting for years, ready to germinate as soon as conditions are favourable. *Acacia* spp. also usually grow in abundance wherever topography, soil characteristics and local water economy facilitate their germination and growth, and this generates very marked landscapes.

Acacia nilotica stands prefer deep alluvial soils accumulated year after year by annual riverine floods. The seedlings survive these floods provided their tips are above the water. They regenerate profusely and grow quickly to become sturdy seedlings which can survive other floods. They then become strong even-aged clusters in regular stands. *Acacia nilotica* is valued for its wood, leaves and pods, and forms part of the livestock-rearing systems of river valleys, floodplains and lakes in the Sahel. It is among the most productive *Acacia* species in the region.

Acacia seyal is a tender wood species growing on heavy soils in extensive stands. These stands support animal husbandry and have also provided most of the fuelwood and charcoal supply for Sudano-Sahelian cities; as a result their extent has been considerably reduced. The land they formerly occupied in the Sudan now supports extensive industrial sorghum cultivation. *Acacia seyal* stands are linked to black soils usually occurring on large flat plains subjected to temporary flooding. Such floods, although short lived, favour the development of even-aged stands like those of *A. nilotica*. Along with *Acacia senegal* and *Combretum* spp., *A. seyal* produces large quantities of gums.

Acacia senegal is the main gum arabic producer in the Sahelian region. Especially in Chad, Mali, Mauritania, Senegal and the Sudan, this species produces the best quality gum arabic. The form and dispersion of its stands, often in extensive but localized patches, depend much on rainfall. Occasional favourable rainy seasons trigger explosive regeneration of *A. senegal*. This explains the occurrence of large even-aged stands on sandy soils with no apparent capacity to retain water. The species also grows in thick stands on alluvial soils in depressions that have collected fine alluvial material.

Natural woodland of *Acacia seyal* and *Acacia senegal*, the Sudan



FAO/FRONZSC, PALMBERG-LERCHÉ

sub-humid areas resulting from various factors, including climatic variations and human activities". Desertification is not an advance of existing deserts but is rather the effect of localized degradation of the land. It rapidly follows deforestation and soil exhaustion. Exposed to the sun, the wind and the rains, exhausted soils lose their organic matter and their structure while nutrients are leached away. Fine elements are blown into dust storms and sand grains become mobile and encroach on other lands through sheets and dunes. Overexploitation of forest, tree, bush, grazing land and soil resources has been increasing desertification.

Desertification is a worldwide problem directly affecting 250 million people, particularly in Africa where two-thirds of the continent is dry lands and deserts. However, more than 30 percent of the land in the United States is also affected by desertification. One quarter of Latin America and the Caribbean is deserts and dry lands. In Spain, one-fifth of the land is at risk of turning into deserts. In China, since the 1950s, sand drifts and degradation have taken a toll of nearly 700 000 ha of cultivated land, 2.35 million hectares of rangeland, 6.4 million hectares of forests, woodlands and shrub lands. Worldwide, some 70 percent of the 5.2 billion hectares of dry lands used for agriculture are degraded and threatened by desertification (FAO, 2007a).

Climate change effects on arid lands

Undisturbed forests are able to adapt to climatic and edaphic changes to a certain extent, but not over the long term: palaeobotanical records indicate that past climate change destroyed prevailing vegetation types and promoted new types to replace the former ones. According to most predictive models, global warming will affect arid lands through temperature increase and rainfall decrease all over the world (with the exception of southwestern Latin America, where more frequent El Niño–Southern Oscillations are expected

to lessen drought risks) (UCAR, 2005). The models predict increases of the frequency and/or intensity of droughts. Increased fire risks are also expected for the remaining forests and wooded lands. Increased temperatures lead to increased evaporation and more severe scarcity of water. All these trends lead to increased risks of desertification. In many places the vegetation already faces harsh conditions near the threshold of lethal temperatures. Any increase of these maximum temperatures will directly lead to irremediable vegetation loss.

The main consequences of climate change in arid lands will be a decrease of agriculture, rangeland and forest productivity, biodiversity, soil organic matter and fertility. This will worsen poverty and food insecurity. Populations will be forced to migrate. It is predicted that 135 million environmental refugees will leave their land by 2020 because of desertification, of which 60 million will be displaced in sub-Saharan Africa (FAO, 2007b). Already facing the lost productivity of natural rangelands, nomadic and transhumant herders may be forced to settle. Concentration of herds around their new homes has already led to the disappearance of most of the vegetation cover around many settlements and around wells and other water sources that provide drinkable water for humans and animals year round. Policies to support settling of nomadic herders are weak in many countries.

Another problem is related to the ageing of the tree population as a result of overgrazing of young seedlings, which impedes the natural regeneration of trees. Overmature trees progressively lose their resilience to climatic stress, so that a single climatic event can destroy a whole area of forest. For example, most of the *Acacia nilotica* forests of the Senegal River Valley died in the early 1970s after a severe drought.

Restoring vegetative cover of arid-zone lands can help mitigate climate change by increasing carbon uptake and storage,

even if only a small amount of carbon per unit area will be sequestered. The area of arid lands to be restored is so huge that it constitutes a good potential sink for carbon. The economics of related schemes should, however, be carefully considered and documented.

REVERSING THE DEGRADATION TREND

Removing the causes

To start with, the human-induced causes of desertification should be tackled. Poor people are obliged to exploit whatever resource they may have access to for their survival. Overexploitation should be avoided through assistance to meet their basic needs with income generation opportunities. Poverty mitigation measures can include planting trees (for their products and services) in major afforestation schemes, woodlots, linear plantations, windbreaks and hedgerows and as isolated trees in agricultural and other landscapes.

Natural regeneration through land protection

The most evident way to restore vegetative cover is to protect it from the causes of degradation: mostly exploitation (harvesting and grazing) and fires. Vegetation can spread naturally, even on bare lands, but the process is often slow. Protection is not always easy as it has to be maintained carefully over a long period. Planting trees, bushes and grass will speed up the process. Then, the restored lands need to be sustainably managed.

The Abéché protected area in Chad is a noteworthy example. In 1961, 305 barren hectares with a few *Acacia* trees (*A. rad-diana*, *A. senegal* and *A. mellifera*) were fenced off with barbed wire and carefully watched over to protect the watershed. Within ten years, without any planting, total land cover had been obtained. After 45 years of almost continuous protection, the protected area is now clearly differentiated from its surroundings in satellite images.



On formerly barren land at Abéché, Chad, protective measures initiated in the 1960s have resulted in restoration of land cover

Afforestation, sand dune fixation and green belts

Afforestation through tree plantation can be a good tool for environmental restoration. During the second half of the twentieth century many forest plantations were established in arid lands all over the world, mostly for protection or for fuelwood production, and the pace of plantation programmes has been speeding up (FAO, 2006a,b). Plantation programmes have used many species (often exotics) and techniques, from low investment (rainfed) to high investment (rainfed with land shaping or irrigated from the water table, deep aquifers or wastewater). The varied successes and failures of such plantations now constitute good sources of information for future activities.

Many countries around the world (e.g. Chile, China, Denmark, France, the Islamic Republic of Iran, Mauritania, the Niger, Senegal and Viet Nam) have developed tree plantation techniques for fixation of shifting sands. In arid zones, both local and large national or international schemes apply such techniques to protect productive lands, infrastructures and settlements. Many of the plantations also produce wood and non-wood products.

Many arid zone towns and cities have planted local green belts to protect their population and infrastructures against dust storms and encroaching sands and

to influence the microclimate. Arable lands, irrigation schemes, railways, roads, canals and coastal dunes are also being protected through dedicated schemes.

Larger-scale afforestation schemes for land reclamation have a long history; they were implemented in France and Germany in the eighteenth and nineteenth centuries and in the United States after the 1935 Dust Bowl. In Algeria, FAO and the World Food Programme (WFP) started the tree planting programme “Chantiers populaires de reboisement” in 1966. In 1971, Algeria initiated the “Barrage vert”, a planted 20 km-wide belt on the fringe of the Sahara desert intended to stretch 1 500 km from the western to the eastern borders of the country, to comprise 3 million hectares. By 2003 only 100 000 ha had been planted, however, mainly with *Pinus halepensis* (Belaaz, 2003). Following this national initiative, North African countries (Morocco, Algeria, Tunisia and the Libyan Arab Jamahiriya) started a regional programme, the Arab Magreb Union (UMA) green belt for the north of the Sahara, but since the 1990s there has been little evidence of its activities.

In 1978, China initiated the “Great Green Wall” project which afforested 9 million hectares in its first ten years. In the current phase of the project, now called “the New Great Wall”, an additional 5 million hectares are to be planted

by 2010 (Ratliff, 2003). Dust storms still trouble Beijing as yet, but airborne dust is carried such distances that the effects of such greening efforts may require several decades to become evident.

The African Union launched a “Green Wall for the Sahara” project in Abuja, Nigeria in December 2006 to contribute to halting and reversing desertification at the southern and northern fringes of the Sahara. The project will work hand in hand with all concerned countries and other organizations and programmes such as the New Partnership for Africa’s Development (NEPAD), the Global Environment Facility (GEF) Operational Program on Sustainable Land Management (OP 15), the United Nations Convention to Combat Desertification (UNCCD) and the TerrAfrica Initiative. Rather than merely establishing a few lines of trees, the project will address sustainable and integrated resource management and restoration activities (through tree planting, rangeland restoration and agriculture, implemented only where feasible and sustainable) in a land belt as wide as possible. It will be a task for several generations.

The results obtained from green belt experiences have varied greatly depending on the scale of the afforestation schemes, the quality of the methods applied, their adaptation to local conditions and the quality of the plantation management. An in-depth study of the climate, soil, water, land use and socio-economic conditions is always required. Local water availability and water demand must always be considered (see below). Green belt initiatives must also take into account previous land uses and ownership and the causes for deforestation and desertification, including peoples’ needs for forest products, pasture and croplands, offering alternative solutions to cover these needs. Local people should be involved all through the process, from conception to the management of the new resources. Large monospecific tree stands should be avoided and a patchwork of different types of plant cover (including agricultural crops and grazing) preferred

whenever possible. Local species should be preferred; several projects have clearly shown the problems related to exotic species, which may become invasive in their new environment.

IMPROVING THE WATER BALANCE

Natural forests and tree plantations improve the water cycle in diminishing runoff and improving the replenishment of the water table. Tree planting has often been proposed as a way to increase rainfall. It has been estimated that 60 percent of rainfall over the moist evergreen Amazon forest comes from the forest itself through evapotranspiration (TheAmazon.org, 2007). However, planting trees will produce tangible results in increasing rainfall on neighbouring areas only when very large areas are converted to forest (Avisar and Otte, 2007).

However, trees also consume water. The more the aerial system of trees is developed, the more water they transpire. The desirability of tree planting in arid lands is debated because trees may consume more water than they provide to the water cycle. Some countries, such as South Africa, have

imposed a tax on the water consumed by forests. In certain circumstances where trees consume all the rainwater, it may be judged better to harvest this water through a bare watershed, store it in a reservoir and use it to irrigate high-value agricultural crops. For example, in Yatir, Israel, where average precipitation is only 270 mm per year, more than 3 000 ha of rainfed *Pinus halepensis* were planted in the early 1960s under a large-scale afforestation project. Although the forest provides carbon sequestration benefits and contributes to the livelihoods of nearby communities (particularly through fuelwood and non-wood forest products such as resins, fodder and medicinal and aromatic plants), it uses all the precipitation water. Furthermore, the forest has altered the biodiversity of the region, as new predation dynamics threaten endemic species. Rueff and Schwartz (2007) reported that the water that the watershed would have provided if it had not been afforested would have alleviated poverty better if it had been used for agriculture. They suggested that afforestation on a smaller scale, such as on farmers' plots, may yield similar benefits with fewer drawbacks, as combining tree planting and agriculture is less disturbing to the environment, improves agricultural yields, conserves water and soils and provides fuelwood for farmers.

Local populations have implemented different methods of water harvesting to benefit their crops and their trees. One technique was adapted from the natural example of the striped bush at the transition between continuous bush stands and grass steppe (Malagnoux, 2008). Where rainfall does not provide enough water to maintain a continuous vegetative cover, fragmented vegetative cover is separated by land strips of varying width. Runoff from the bare land strips provides the vegetation with the water it needs; the strips thus constitute small watersheds. Agronomists have improved on these traditional techniques, and foresters have also adapted them to the size and needs of their trees. Mechanized technologies have been developed to increase the scale of land restoration dramatically through quicker and cheaper land processing, while deepening the strips to increase water-holding capacity.

In tree planting for desertification control, the present and future water balance of the stand should be systematically estimated for each phase of its evolution. Appropriate silvicultural measures should be promoted to maintain the yearly water consumption below the yearly water inflow – including species choice, surface to be planted, planting density, thinning, pruning, coppicing, pollarding and also, when necessary, conversion to more sustainable vegetative cover, for instance from a dense stand to a parkland or grassland. Every desertification control programme or greening activity should be considered at the landscape level. Trees should be planted only when really needed and where possible.

In addition to rain, other water sources such as recycled water and deep aquifers have to be considered. Many arid lands and deserts have deep aquifer resources that could be tapped. While some restoration activities could rely for a short period on fossil aquifers, these activities will be sustainable only when water recharge exceeds or equals water withdrawal. With urbanization accelerating in arid lands,

Water drawn from a shallow well is used to irrigate trees planted as part of sand dune stabilization efforts, the Niger; once the roots reach the water table, the trees will no longer need to be watered



urban forestry and other urban greening programmes using vegetation that consumes less water than trees (e.g. bushes and grasses) are of increasing importance. More recycled water is being used in such programmes, including sewage water in some countries, and this practice will progressively grow in the future.

CONSERVATION AND SOUND MANAGEMENT

The sound and sustainable management of land, vegetative cover, water resources and biodiversity means that only that part which is renewable, i.e. their effective production, is used, ensuring maintenance of the capital and its productive capacity. Sustainable land management includes:

- conservation agriculture (minimum soil disturbance, maximum return of organic matter to the soil, permanent soil cover and crop rotation);
- sound management of grazing lands (adjusting grazing pressure to carrying capacity);
- multipurpose forest management planning.

Of prime importance is the participation of the local people and communities, capitalizing on their traditional knowledge and practices. Clear land-use rights are essential to sound land management. Reinforcing people's control over resources and guaranteeing them secure and fair access ensures their long-term commitment to resource conservation. Desertification control programmes must be mainstreamed into national development plans and strategies in particular to alleviate poverty, eliminate institutional, legislative or infrastructure constraints and facilitate co-management of development projects.

CONCLUSIONS

Arid-land forests and trees have an important role in land stabilization, desertification control, watershed protection and other functions as well as providing wood (especially woodfuel) and non-wood products including fodder for domestic animals. They provide subsistence

for local populations and are integrated in the fabric of rural societies. Yet the productive and protective functions and vitality of forests and trees in arid lands are often jeopardized by human-caused stresses and natural hazards. Despite their importance for local economies and for the people, arid land forests and forest products are still largely neglected in natural resource management policy and decision-making processes.

When tree planting is considered, the water balance should be assessed and its evolution should be estimated for each period of the whole life of the planted stand. Every desertification control programme or greening activity should be considered at landscape level. More than "plant a tree", the motto for combating desertification should be "manage land and resources wisely: plant a tree only where and when it is sustainable". ♦



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Policy proposals for integrating forest, water and people in the Tigris and Euphrates watershed

H.M. Kangarani and T. Shamekhi

Integrated forest and watershed management, especially across borders, needs to centre on people.

The waters of the Tigris and Euphrates watershed have supported civilization for more than 6 000 years. Covering 76.6 million hectares, the watershed is of great importance for the water balance in Iraq, the Syrian Arab Republic and Turkey and also extends into the Islamic Republic of Iran.

More than 90 percent of the watershed is classified as arid land. Forests cover 1.2 percent of the total land area (918 800 ha), while agricultural crops cover 25.4 percent and grasslands 47.7 percent (FAO, 2005, 2007; UN ESCWA, 2002) (see Map). Forests were once more dense and widespread, but centuries of exploitation – aggravated by environmental and economic conditions and a history of conflict – have decreased their extent and affected their composition. Fifty endemic tree species are under threat of extinction.

The water resources in the watershed are often overused, wasted and polluted. Overirrigation and flooding of fields have raised water tables and contaminated soils with saline water, which can cause crop failure and reach the rivers.

Heavy dependence on agriculture, especially using irrigation, fertilizers and chemicals, combined with largely sandy and gypsiferous soils, has resulted in massive leaching of chemicals into the groundwater. Subsequent overpumping of wells has exacerbated the problem.

Deforestation is also having an impact on the quality of water flowing through the watershed or stored in the water table.

Population pressure in the watershed is relatively high, with an average of 57 people per square kilometre. The area is challenged not only by rapid population growth, but also high poverty levels, increased rural-to-urban migration within the watershed, political instability, high unemployment and low economic growth, rapid industrialization without sufficient attention to the environment (resulting in water, air and soil pollution) and poor land-use planning.

The combination of increasing population and fixed water supply in the watershed has resulted in decreasing water availability per capita. The countries of the Tigris and Euphrates watershed are relatively water rich for the Near East region,

Heavy dependence on irrigated agriculture and overpumping of wells exacerbate the region's water problem (Syrian Arab Republic)



FAO/19100R.FAIDUTTI

Deforestation and overgrazing have an impact on the quality of water flowing through the watershed or stored in the water table (Iraq)



FAO/2146R.MESSOR

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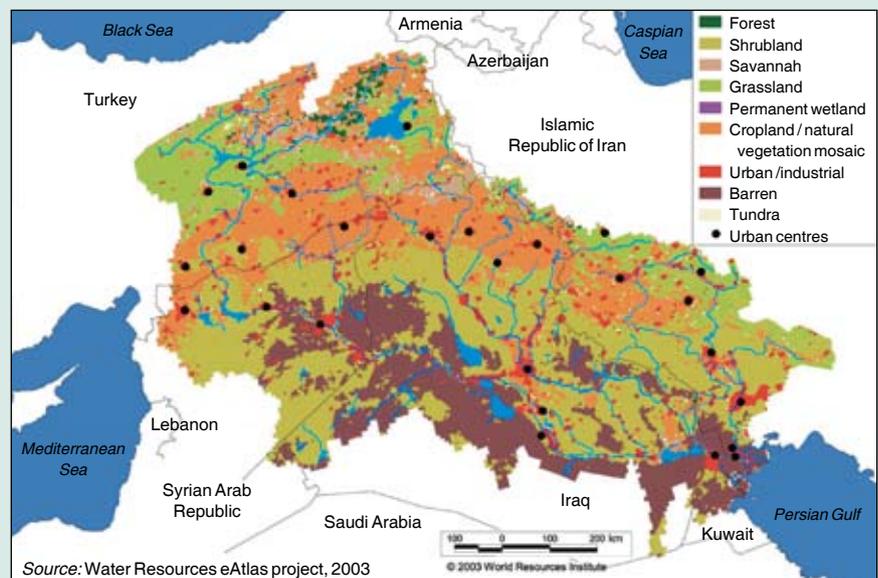
where water is scarce in most countries. However, unequal distribution of water, insufficiently planned dam construction and high rates of water withdrawal, especially for agriculture, are sources of conflict and impediments to economic development. With demand for water greater than the total volume of water in the two rivers, countries in the watershed have repeatedly wrangled – for example, when an intervention in one country has been perceived to reduce water availability in another. Many of the populations in the watershed depend on rivers that traverse an international boundary before reaching them. Some have no access to rivers and depend on diminishing wells or expensive desalinated water from the sea. With the cost of relocating water supplies and building new dams measuring tens of millions of dollars, the very future of some towns and their associated industries may be in question.

In order to propose appropriate policies for conservation and management of the forests and water, it is essential to address the ways in which forest, water and people relate to each other.

Recommendations

Forest and people issues. Since forest influences water quantity and especially quality, managing the forest for water conservation is an appropriate goal. Forestry decision-makers need to promote the incorporation of forest management in national and regional strategies, plans and programmes related to river, watershed and groundwater management; and to work with international and national organizations and institutions to increase understanding of hydrological and environmental services of forests.

Priority should be given to preventing forest degradation – including by limiting grazing in forest lands – and promoting afforestation and reforestation (including trees outside forests) for environmental protection and local wood supply, especially fuelwood. Because of the critical condition of the forest and some people's dependence on it for their livelihoods, other economic functions of forest besides wood production need to be highlighted; non-wood forest products (NWFPs) and ecotourism should be promoted through appropriate policies. Devolving forest management responsibilities to the local level can give



Land use in the Tigris and Euphrates watershed

communities the rights and incentive to manage and use forest resources sustainably.

Countries should prepare source protection plans based on catchment reforestation, including measures to control potential sources of contamination such as septic systems and fuel tanks and identifying alternative drinking-water sources in the event of contamination. This would entail mapping of the recharge area of the water sources and identification of appropriate fast-growing species.

Although some of the remaining natural forests of the Tigris and Euphrates watershed are reserved in national parks, these have not been reserved, to date, for their water production values. Currently only 0.4 percent of the total area of the watershed is protected area. Conservation of the forests will be increasingly important to ensure water supply from this watershed as both resident populations and tourist numbers increase, and some parts of the forest should be set aside as protected areas where no exploitation is permitted. It would be economically prudent to “buy” these forests from the sawmill industry or pastoralists with money generated by selling water to domestic and other users. This would encourage the industry to shift its attention to younger forests, plantation timber and higher value-added sawn timber products.

Information on the effects of forests on water resources is inadequate (see Box, p. 32). Additional study is needed to establish the economic

value of managing the forests to protect soil and water quality and quantity, to take full advantage of the watershed's ability to store water temporarily and prevent downstream flood damage, and to map future water supply and demand.

Water and people issues. With water shortage threatening to surpass oil as a main source of conflict in the region, an arrangement is needed to ensure that the waters of the Tigris and Euphrates watershed are used in a rational, equitable and sustainable way. Improved cooperation in water planning, beyond strictly national concerns, could help the countries involved in the watershed adapt to the rapid demographic changes and their impact on water availability.

For more permanent drinking-water protection, purchase of the source protection area is a viable but costly approach. The establishment of a drinking-water revolving fund as adopted in the United States (US EPA, 2007) might be a way to reduce the cost. The United States programme provides loans on good terms to public water systems for infrastructure improvement. Source protection funds could provide low-interest loans to help municipalities that have already developed a source protection plan purchase land or development rights.

Countries in the watershed would benefit from collaborative formulation and implemen-

tation of a plan for the basin as a whole, aimed at harmonizing seemingly conflicting demands. Such a plan might address water transfers between rivers and reservoirs, as well as interconnected water and energy systems. Joint regional research institutes, training centres and pilot farms would enable countries to exchange expertise not only of engineers and technicians but also of farmers. The Turkish experience (supported by the World Bank) of water user associations provides an interesting model for increasing water use efficiency and water revenue collection and saving water (Beaumont, 1998; Dudley and Stolton, 2003).

Water supply-enhancing techniques (e.g. water harvesting, joint use of surface and groundwater sources, water reuse and, if necessary, cloud seeding) and demand-management technologies must be part of a comprehensive solution in the Tigris and Euphrates watershed. Potential strategies include improvement of electricity distribution infrastructure to reduce losses, and construc-

tion of wind or photovoltaic power plants. The overall objective of water agreement in this watershed would be to promote sustainable utilization of the region's land and water resources for the welfare of its people.

Conclusions

Integrated watershed management planning needs to take people, forest and water into account – in fact people need to be the central pivot. Sustainable management of forest and water must go hand in hand with vigorous pursuit of population policies, improved social conditions, poverty alleviation strategies and broad-based economic growth.

All forest policies should be close to nature and multipurpose. To change the previous forest policies of this watershed, appropriate infrastructure needs to be introduced; but because of the high poverty and social instability in the watershed, changes must be made slowly and step by step.

Nature never follows the policy of any government, never listens to the politician, never recog-

nizes political borders and never changes its way because of any religious or political belief. To protect nature we should adapt to nature.



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Information needs for better management of forests and water

In addition to the need for political will, lack of reliable information is one of the main challenges to effective management of the Tigris and Euphrates watershed. Thus the first step is collecting useful and practical information in the following areas:

- **Forest:** current situation, carrying capacity of forested land (in terms of all economic and environmental benefits), capacity for reforestation with native or introduced species, endemic species characteristics, land with potential for afforestation, main forest threats;
- **Water resources:** changes among seasons and years in each country, major floods in the past 100 years and the main factors involved, relation between these floods and land use changes, effects of forest on water quality and quantity;
- **Forest-dependent people and rural poverty:** primary needs, poverty levels, work opportunities, extent of dependence on forest, relations with forest, current involvement in forest management;
- **Demand:** for forest products (including wood, fuelwood, non-wood forest products and forest services) and for water, by urban, rural and forest-dependent people, agriculture, etc.;
- **Institutional arrangements:** national, regional and local institutions and administrations; governmental, private and non-governmental organizations; national and regional development plans; policies and legislation related to forests, people and water; local and traditional structures related to natural resource management;
- **Public opinion:** about forests and forest benefits, ecotourism, importance of forest conservation, substitution of wood products with other materials.

Forests of Mount Kulal, Kenya: source of water and support to local livelihoods

T.Y. Watkins and M. Imbumi

Mist-capped Mount Kulal, rising in the middle of one of the driest regions of East Africa, provides vital hydrological services for the entire region.

Mount Kulal is an eroded volcanic peak covered with mist forest at its summit and varying vegetation types below. It is among the highest peaks in northern Kenya and represents a unique ecosystem surrounded by arid and semi-arid lands on all sides. The mountain ecosystem captures moisture in the forms of mist and rain and provides important hydrological services for the entire region.

Mount Kulal is the centrepiece of the Man and the Biosphere (MAB) reserve of the same name, which is one of six MAB reserves in Kenya. The United Nations Educational, Scientific and Cultural Organization (UNESCO) designated it as a MAB reserve in 1979. Located in northern Kenya in the

Marsabit District, the reserve covers about 7 000 km² extending from the eastern side of Lake Turkana through ragged lava flows to the top of Mount Kulal, where the core zone measuring 11 km² is located. In the eastern and northeastern part of the core zone, the reserve drops down through semi-desert ecosystems to the hot lowlands of the Chalbi Desert (see Map).

The Turkana, Samburu, Rendille, El Molo and Gabbra people who inhabit this varied landscape rely on the environment for their herding, fishing and farming livelihoods while in turn having an undeniable impact on it. These primarily pastoralist cultures have adapted their subsistence practices to incorporate and increasingly rely on both montane forests

Mount Kulal biosphere reserve



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and semi-arid vegetation for many forest products and services, including fuel-wood, raw material for charcoal, timber for construction, food, medicines and socio-cultural and spiritual services. A few individuals on Mount Kulal and along Lake Turkana have begun businesses or cooperatives capitalizing on ecotourism interest in the region.

The Integrated Project in Arid Lands (IPAL), a collaborative effort of the United Nations Environment Programme (UNEP) and the MAB Programme of UNESCO, carried out research in this region from the mid-1970s to the mid-1980s and deepened understanding of the biotic systems supported by the mountain in the midst of arid lands. The Government of Kenya gazetted the forests during this period. The Kenya Forestry Research Institute (KEFRI) assumed programme management from UNESCO, but it has not had active programmes for over a decade. Since cessation of these programmes, conservation and management activities in Mount Kulal forests as well as the entire reserve have come to a halt. The forests may be at risk of severe degradation.

According to Kenyan law, the forests and other areas not occupied by homesteads belong to the government, but according to local traditions the land is held collectively by the community. Landownership has not yet been put to the test legally at Mount Kulal, nor elsewhere in northern Kenya (except at the Samburu Game Reserve, where conservation measures barred nomadic pastoralists from their traditional pastures). The uncertain land tenure situation represents a challenge for conservation management planning and for sustainable forest management.

This article is based on the work of IPAL and the findings of a UNESCO-Kenya multidisciplinary working group that visited the Mount Kulal reserve in December 2006 to explore the current status of the reserve and its inhabitants.

GEOLGY, TOPOGRAPHY AND HYDROLOGY

As Mount Kulal is of volcanic origin, lava fields define the landscape in the surrounding area (Herlocker, 1979) and the mountain's sides are steep and often slashed by deep canyons, especially on the eastern and western flanks. To the west, Lake Turkana lies at 410 m elevation while the floor of the Chalbi Desert to the north is between 435 and 500 m. The highest point of Mount Kulal is 2 335 m. This peak is one wall of the remains of a volcanic crater located at the centre of the mountain ridge, but the eastern rim has been eroded over millennia to form the magnificent El Kajarta Gorge, which splits Kulal into two parts (Herlocker, 1979). The lower slopes give way to alluvial plains at 500 to 700 m. To the south, these plains are bounded by the even higher mountain ranges of the Ndotos and Nyiru (2 752 m).

The location of a peak as high as Mount Kulal in the middle of one of the driest regions of East Africa not only makes it unique topographically, but also contributes to the particular ecosystem services the mountain and its forests provide to the region. The climate of the region is driven by the northeast and southeast monsoon systems. The northeast monsoon provides hot, dry air masses that bring high winds from the north or northeast and a short rainy season in October and November. The southeast monsoon, originating in the Indian Ocean, is more favourable for rainfall. The long rainy season is highly variable but usually peaks during April. The topography of Mount Kulal creates what is known as orographic lifting: air masses are forced from lower to higher elevation, where they cool down and thus can no longer hold as much moisture, so that clouds and precipitation form. This phenomenon, along with the convergence of the conflicting monsoon systems, results in cooling and rainfall (Herlocker, 1979). Mist forests at the core zone of the MAB reserve aid

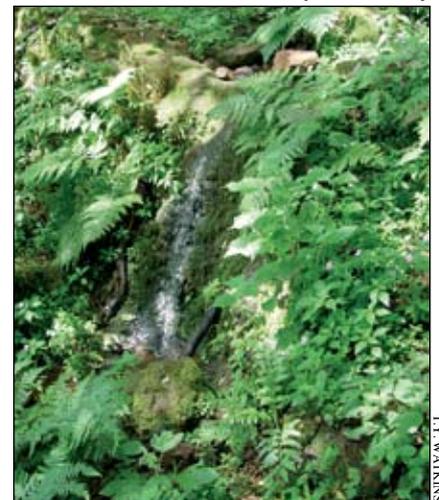
in trapping moisture derived from the evapotranspiration occurring in the lowlands, and may increase local rainfall, although this has not been adequately studied.

ECOSYSTEM SERVICES

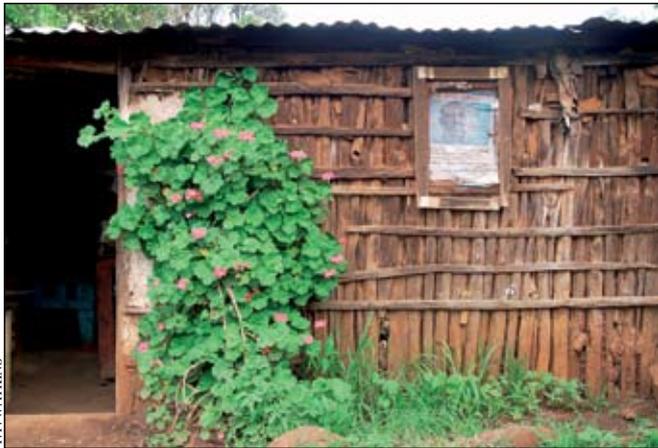
The Mount Kulal forests aid in holding water and delivering it to the villages on and around the mountain. Water is delivered by springs in the forest and on the shoulders of the mountain, as well as by seasonal and constant springs at the base of the mountain. Up to a dozen springs and water holes are known on the mountain alone (Synott, 1979). Intact forests at all levels, from the mist and cloud forests at the summit, through the villages of Gatab, Oltorop, Larashi and Arabal, to the *Acacia* forests on the shoulders of the mountain, aid in retention and absorption of the often short and intense rains and in preventing rapid runoff. Rapid runoff can cause not only soil erosion and loss of vegetative cover, but also loss of livestock and human life through serious flooding downstream.

The rich volcanic soils that are increasingly used for agriculture to complement traditional herding practices are not the only important geological feature of

Springs on Mount Kulal currently flow year round and maintain stream ecologies rich in plant diversity



T. WATKINS



Construction of houses from wood is the most common use of forest products in the villages of Mount Kulal

Mount Kulal. The ancient lava flows filter and conduct water to springs throughout the region. Loyangalani Spring provides year-round freshwater on the eastern shore of the salty Lake Turkana and has become the key to the largest settlement in the region (Fuchs *et al.*, 1935). Loyangalani was originally established as a trading and administrative centre based on proximity to the spring and remains reliant on it for all its freshwater (Fratkin and Roth, 2005). It now serves as a base for the small amount of ecotourism in the reserve. The Oasis Lodge, outside the centre of Loyangalani but close to the origin of Loyangalani Spring, was the first business established purely for tourism in the region and has first access to water from the springs. Although there are now many camps and lodges in the region, the Oasis Lodge remains the premier ecotourism lodge. In addition, numerous other seasonal springs rise near lava-strewn streambeds or in the middle of lava fields. These are important watering holes for humans and for the animals on which they depend for their livelihoods.

FORESTS AND LIVELIHOODS

Mount Kulal forest provides many resources to communities living on the mountain as well as those living at lower altitudes. The forest is the main source of building material, fuelwood and medicine for local inhabitants. The deep gorges are used by *morans*, young

Samburu warriors, as training and hiding grounds. Samburu villagers report the historical use of numerous caves, gorges and even cavernous fig-tree trunks as refuges during raids and prolonged battles with neighbouring pastoralists.

The forest products used most often are poles for construction of local houses. Samburu houses in the villages of Mount Kulal take one of two forms. Mud and pole structures built with tree trunks can last decades, especially with regular maintenance of mud walls and metal roofs. More traditional homes use smaller branches that are buried in the ground and bent into a dome to form the main structure of the house. This structure is then thatched with grass and brush and now preferably roofed with plastic. These homes may last only a few years and it is not unusual for a compound to have several

constructions of varying ages. Smaller twigs (e.g. of *Lippia* sp. and *Lantana* sp.) for reinforcing the mud walls may be obtained from bushland near the village rather than from the forest.

Probably used at an equal rate is deadwood for fuelwood. Local administrative officials attempt to enforce conservation laws established during more active management of the reserve, which limit cutting of living trees for fuelwood in the forests on the mountain. However, cutting of brush or trees in the forested areas outside the core zone and the lowlands of the reserve seems to be unregulated. Fuelwood here is vital most of the year because of the cool climate and high humidity. Woodfuel (fuelwood and charcoal) is the main energy source, but charcoal is made on a small scale, mainly for local consumption. According to one resident of Gatab, some households collect as much as 40 to 50 kg of fuelwood daily, although this is probably an extreme upper limit.

On a smaller scale, minerals are quite important to Samburu culture. Local people collect red ochre from *lorian lolkaria* or “a place of red ochre” in the forest. The ochre is mixed with sheep-tail fat and smeared on the hair to make it beautiful and grow long. It is mainly used by *morans*, although young women may also use small amounts. Harvesters sell the ochre at 10 shillings (US\$0.15) per tablespoon in local villages.

On Mount Kulal fuelwood is vital most of year because of the cool climate and high humidity



T.Y. WATKINS

Most surveyed residents verified that the forest is a rich source of local and traditional medicines, although it is difficult to quantify the amounts collected. As this information was received from non-specialists, it is safe to assume that many if not most households collect these products periodically. Since they are available to all in the nearby forest, they are not actively traded or exchanged in markets. Some plants are used in soup, mainly by *moran*, to prevent diseases, while women add certain plants to the milk given to children to fortify them. Both *Clerodendrum myricoides* and *Boerhavia coccinea* are planted in homesteads for their medicinal value.

During prolonged droughts people bring their animals into the forests to

forage. Branches, usually of olive trees (*Olea europaea* ssp. *cuspidata* and *Olea capensis* ssp. *macrocarpa*), are cut to feed the animals. During extreme droughts, animals also browse most other plants in the forest. The extent and effect of grazing in the forest is not yet known. Signs of cut branches and occasionally small trees are visible in the forest. Selective use of preferred species may warrant study to determine the effect of decreased biodiversity of forest species. Formerly, IPAL projects employed a guard to limit grazing inside the forest (Lewis, 1977), but this has since been replaced by the community's own surveillance team. In times of extreme drought when forest resources become more important to livestock, elders allow unsupervised grazing in the forest.

Provision of water is the most important service provided by the forest for local villages. A number of springs now have impoundments to collect water for piping by gravity flow to holding tanks that serve local communities. Current construction, expansion and maintenance of this system are provided through the African Inland Church mission in Gatab. The water committee, a part of the local village council, is responsible for the management of the water system and any possible extension of it in the villages. Tampering with the water sources invites a fine of 1 000 shillings (about US\$15) and other disciplinary measures by the local administration. In lowland areas three dams have been constructed and have proved useful to pastoral groups who mainly use them to water their livestock.

RECOMMENDATIONS FOR IMPROVED CONSERVATION

Mount Kulal's topography works in combination with regional weather patterns to trap condensation which gives rise to mist forests. The often lush highland forest cover holds rich volcanic soil in place during the seasonal rainfall. By slowing down runoff, forest cover not only prevents soil erosion that is evident in cleared areas, but also helps direct rainwater to the porous lava beds, in turn directing spring water to the edges of the Chalbi Desert and the rocky shores of Lake Turkana.

Diverse forest biological resources provide shelter, food, medicine and cultural and historical value to local people. Traditional pastoralist Samburu families are diversifying livelihoods and increasingly relying on agriculture for subsistence and trade. The newly established agriculture depends on water and soil, which both rely on the natural resources of Mount Kulal. People living inside the MAB reserve need to use and manage the resources sustainably so as not to endanger the very environment that supports them.



An impoundment constructed about 30 years ago collects Mount Kulal spring water which is then piped to holding tanks that serve local communities



Trees anchor the unstable volcanic soils of Mount Kulal; slip erosion is common in areas that have been cleared near many springs in the forest

T.Y. WATKINS

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The UNESCO working group for the Mount Kulal biosphere reserve has grouped recommendations for the reserve's future into three broad categories: capacity building, conservation and development.

The Samburu communities living on Mount Kulal have a few usually species-specific traditional conservation practices. For example, *Ficus thonningii* is associated with rituals and is sacred to the Samburu people. *Juniperus procera*, although not ritually significant, is also protected. The cultural importance of some trees to the Samburu may explain why they have maintained some of the conservation practices aimed at forests introduced by UNESCO despite their limited financial resources. This strong foundation needs to be built upon and reinforced. Community administrators and leaders need to network and continue to build capacity for conservation and development.

In spite of individual awareness regarding conservation issues and community policing of blatant forest destruction, people living within the reserve tend to encroach on the forests of Mount Kulal. The continued selection of some trees for use and others for conservation will affect the biodiversity of the forests and have unknown consequences. In addition, several cultural groups live inside the reserve, not only the Samburu. Conservation efforts need to focus on the importance of maintaining ecosystem services for all inhabitants of the reserve and the region. Education in forest management and resource conservation that links livelihoods explicitly with ecosystem services will clarify the need to conserve biodiversity and manage forests in a sustainable way. Continuing participatory research will lead to better understanding of human/environment interactions and guide conservation with a focus on continuing access to forest products for sustainable livelihoods.

Trade and regional integration of communities and individuals may provide

opportunities to improve livelihoods, food security and health. Villagers are already expanding herd diversity and introducing horticulture and market exchange into their livelihood portfolios. This can be done in a sustainable fashion, although it is not always done so now. Current and future development schemes must incorporate maintenance of biodiversity and conservation as necessary components. ♦



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The impact of water shortage on forest resources – the case of Uganda

F. Kafeero

In Uganda, the reduction of water resources due to climate change has weakened hydropower generation, leading people to turn to woodfuels for energy – and fueling deforestation.

In recent years the effects of climate change have been observed in Uganda in increased frequency of extreme weather events such as prolonged droughts and heavy rainstorms resulting in floods and landslides. After the extreme and prolonged drought of 2004/05, the water level of Lake Victoria dropped by one whole metre in 2006. This dramatic fall was attributed to high evaporation from the lake surface, low rainfall in the headwaters of the rivers draining into the lake, and the excessive removal of water for power generation from Owen Falls dam to meet the growing demand for electricity in the country.

With reduced water availability for power generation in Lake Victoria (the only source of water for the Owen Falls dam), the country experienced unprecedented power rationing which affected the industrial and domestic sectors. The shortage of power caused the interruption of economic activities and had an overall negative impact on the country's economy and the livelihoods of its people. To meet the demand for electricity, the government resorted to using expensive thermal power, which escalated electricity tariffs from 216 to 426 shillings (US\$0.13 to \$0.25) per unit of domestic consumption.

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One result of higher electricity prices has been increased pressure on forest resources. Almost all households (95 percent) in the country use woodfuel (fuelwood or charcoal) to meet some part of their energy needs. With the exorbitant power tariffs, dependence on tree and forest products for fuel was heightened even further. Urban populations that generally used electricity for cooking reverted to use of woodfuel. The demand for woodfuel then surpassed the supply, causing the prices of charcoal and fuelwood to skyrocket.

An offshoot of this dynamic has been increased deforestation in unsustainably managed forests, especially private natural forests, as woodfuel suppliers seek to meet the increased demand and take advantage of the price boom. Many rural households have resorted to cutting their trees, including fruit-trees, to get fuelwood as forests become more and more depleted. The heavy cutting of the forest, coupled with unsustainable slash-and-burn practices, has contributed to land and

soil degradation, which in turn is responsible for poor food-crop yields, further threatening food security.

As the country has experienced abnormally high rains in 2007, with almost no recognizable dry season during the period July to September, the lake levels have slowly risen. However electricity generation levels have not recovered, and hydropower is still being supplemented by thermal generators. Thus power tariffs have remained excessively high for the poor and middle-class Ugandans that make up the largest part of the population. Tree cutting and deforestation thus continue unabated in response to the increasing scarcity of woodfuel. The heavy rains further wash away the bare soils into the lake and rivers, increasing the problem of siltation. It is feared that if and when the extreme dry conditions set in, the vicious cycle will be further exacerbated, posing a threat to human life in Uganda in the present generation and that to come.

Recent lowering of the water level of Lake Victoria has reduced water supply to the Nalubaale power station (Owen Falls dam), resulting in power shortage



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Along the shore of Lake Victoria in Uganda, fishermen bag charcoal for smoking fish; fuelwood and charcoal are widely used in the country, and unsustainable woodfuel production, especially from private natural forests, is a cause of deforestation



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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

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(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



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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)



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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. ♦



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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



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Forest legacies, climate change, altered disturbance regimes, invasive species and water

T. Stohlgren, C. Jarnevich and S. Kumar

Climate change is one of many drivers affecting forest hydrology.

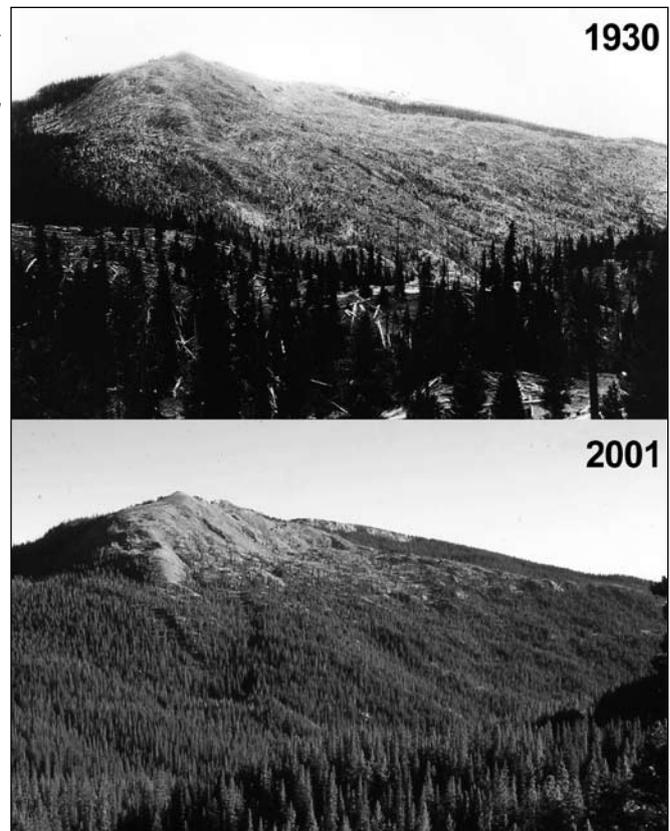
Climate is a major driver of forest species distributions and the growth rate and structure of forests. Thus, climate change can potentially have significant effects on mountain forest hydrology, particularly the amount of water available downstream. However, many other factors influence forest biomass and mountain hydrology, and climate change effects cannot be viewed in isolation from previous land use histories (i.e. forest legacies), altered disturbance regimes (e.g. fire frequency, insect outbreaks, floods) and invasive species. Based on research from Colorado, United States,

this article examines the many factors that must be considered in seeking to predict changes in water availability.

FOREST LEGACIES

Few current landscapes in the United States have escaped human influence, for example through logging, mining, agriculture, grazing by domestic livestock, elimination of large carnivores, human-caused wildfire and/or pollution. Many landscapes continue to undergo changes caused by human use, while others are reverting to their natural state (Figure 1). The quality and amount of water available

1
Repeat photography
of a subalpine
watershed in
Colorado, United
States



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downstream is likely to be affected by changes in the composition, structure, canopy cover and biomass of the forest as it responds to past human land use and other disturbances, e.g. from forest fire. For example, many watersheds in the Rocky Mountains of Colorado were affected by logging, mining and increased human-caused fires between 1850 and 1900 (Veblen and Lorenz, 1991). Stream flow probably increased following those disturbances, remaining high while forests were recovering. Current stream flow might logically be expected to be less owing to increased interception of snow by maturing forest canopy and increased water use by the forest. Climate change in the late twentieth century must be measured against the backdrop of forest and landscape legacies.

CLIMATE CHANGE AND STREAM FLOW

Climate change is not new to montane watersheds (Pielou, 1991). For example, in the upper Colorado River Basin in the United States, mean annual temperature has increased significantly since the end of the Little Ice Age (around 1850). As shown in Figure 2 (top) average temperature has increased by 1°C since systematic measurements began in 1895. In recent years the warming has been greater still; accelerated by human activities, change rates have become extremely rapid in some areas. At watershed weather stations in the western third of Colorado, precipitation has declined slightly but not significantly over the same period, decreasing on average by less than 3 percent (Figure 2, middle). Annual variation in temperature and precipitation has been significant (Figure 2, bottom), fluctuating sporadically from warm-dry years to cool-wet years, or from warm-wet years to cool-dry years, with many years in each quadrant. (The long-term average is at the centre of the diagram.) Forest plant and animal species in the watershed have been subjected to fluctuations in mean temperature of

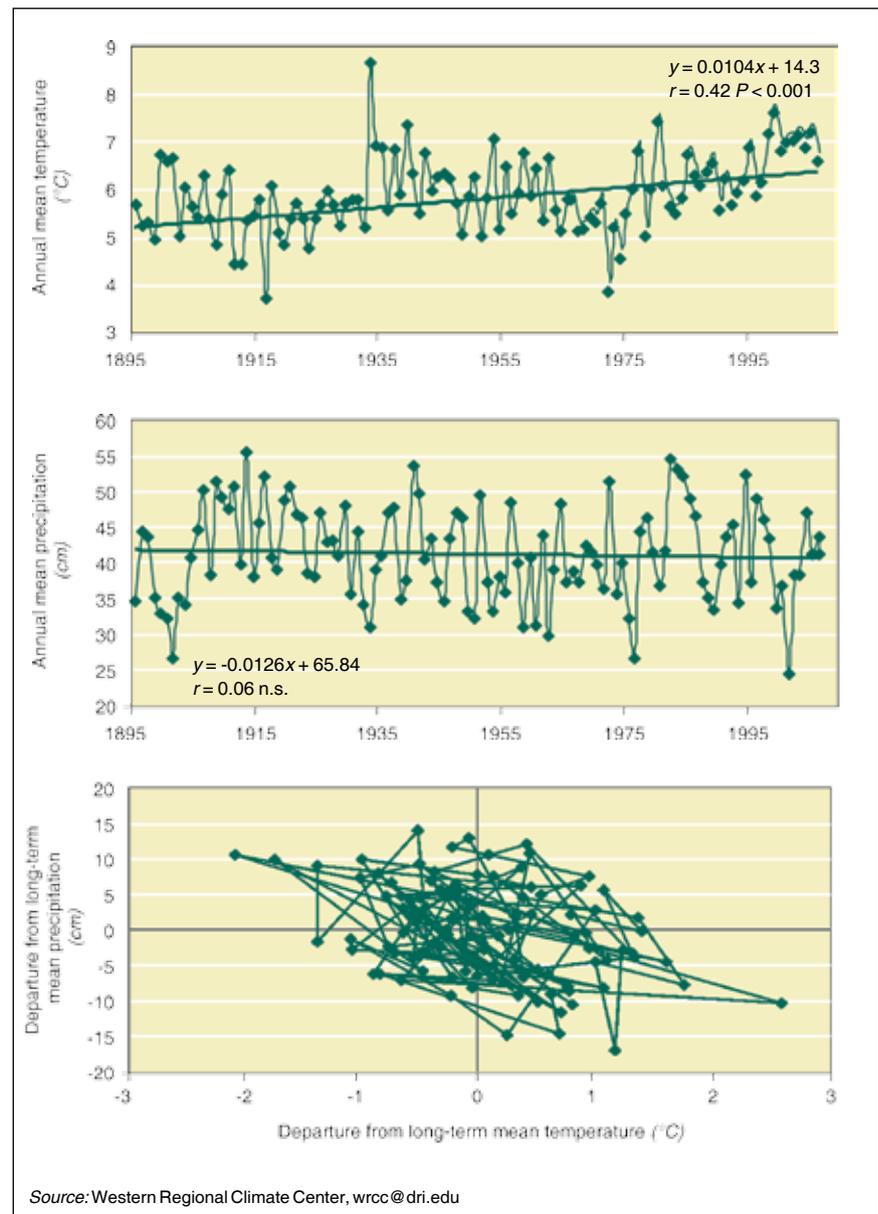
almost 5°C and a 30 percent range in annual precipitation since the beginning of the climate record.

Many long-lived forest plant and animal species have persisted despite these annual fluctuations in climate; indeed the fluctuations may have heightened their adaptability to long-term climate shifts. Still, annual fluctuations may have lesser effects on forest structure than extreme events such as droughts lasting several years or repeated years of warmer-than-

average winters, which exacerbate major outbreaks of forest insects. Thus, rare climate scenarios may have long-lasting effects on forest structure and biomass and later downstream flows.

Stream flow affects the timing and delivery of water downstream for agricultural and domestic uses. An analysis

2
Long-term temperature (top),
precipitation (middle) and annual
fluctuation (bottom) for the
Colorado River Basin



of three upper-elevation watersheds in Colorado showed no significant trends in stream flow but high annual variation (Figure 3). Other investigators have shown tendencies for earlier snowmelt and peak stream flows of several watersheds in the western United States under current and projected climatic conditions

(Leung *et al.*, 2003; Stewart, Cayan and Dettinger, 2004, 2005). Storm runoff and rain added to snow events may be more common in a warming climate. However, multi-year droughts may be even more detrimental. It is likely that many water supply systems that developed under historically wetter conditions may be inadequate during exceptional droughts. Mega-droughts, such as a drought in the lower Colorado River in the mid-1100s

believed to have lasted 60 years or more (Meko *et al.*, 2007), should capture the attention of today's water planners.

Stream flow depends heavily on the amount, timing and form of precipitation. Generally, snow remains in the watershed longer than rain. Groundwater storage, loss and recharge also have an influence on stream flow. Other important factors include the periodicity and sequencing of wet and dry years relative to groundwater recharge and water supply systems (e.g. irrigation systems, canals, dams) which buffer the effects of drought.

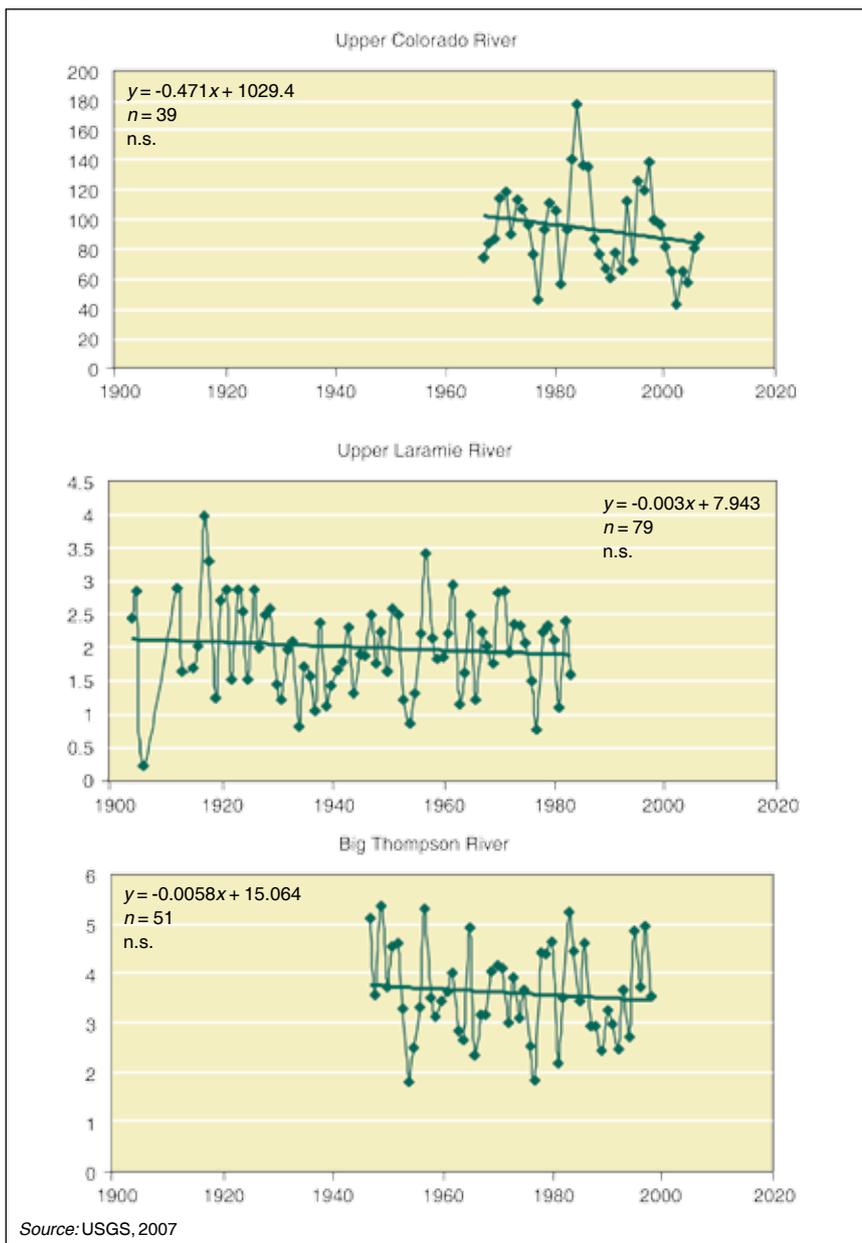
There is little doubt that future climate change will affect water supplies – fluctuations in climate have always done so. However, this influence is interlinked with forest and landscape legacies, altered disturbance regimes and invasive plants, insects and pathogens.

ALTERED DISTURBANCE REGIMES

Humans have caused changes in many natural systems by altering historic disturbance regimes such as the frequency, intensity and pattern of wildfires and insect outbreaks. Likewise, flood control with dams, reservoirs and canals has an obvious effect on flow patterns in many watersheds. Fire suppression has greatly reduced the number of wildfires each year in the United States (Figure 4, top), while the area of each fire appears to be on the increase (Figure 4, bottom). Extensive logging and very large fires in the first half of the twentieth century altered many forested watersheds in the Colorado Rocky Mountains, as evidenced by hundreds of repeat photographs (Veblen and Lorenz, 1991). Subsequent even-aged and dense forest regrowth undoubtedly added to forest homogeneity and the amount of fuels available for wildfires today in some areas.

Native insect and pathogen outbreaks are periodic and can be locally devastating to forest structure and biomass, which in turn affect water supplies. Large bark beetle outbreaks have affected several million hectares of United States

3
Annual stream flow data for three upper-elevation watersheds in Colorado (discharge, m³ per second)



forests in recent years. Defoliated forests may behave similarly to forests that have been burned, but the effect of defoliation may not be as extensive or continuous in many areas. While the co-evolution of native forest species with native insects and pathogens provides some ecosystem resilience, native forests are now additionally bombarded with non-native invasive pests for which natural defences are limited.

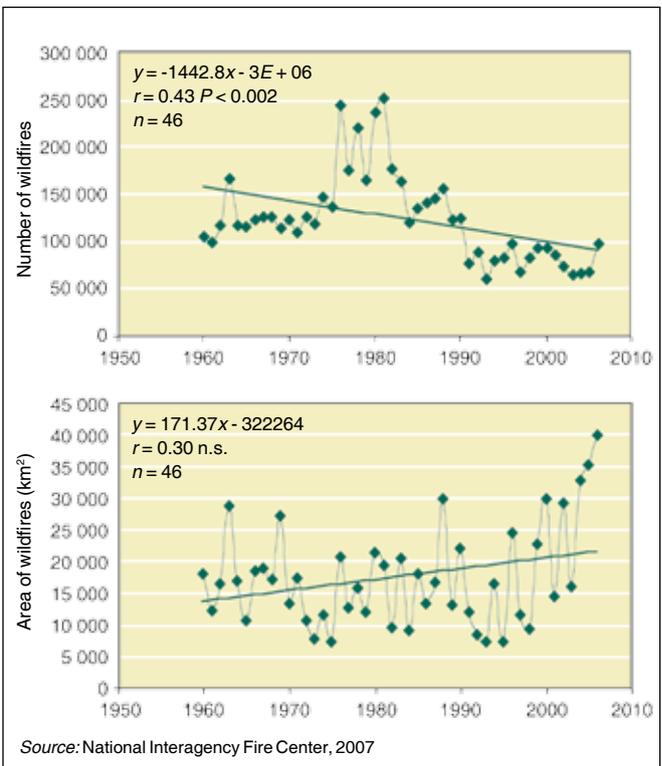
INVASIVE SPECIES

Non-native invasive forest pests and pathogens add significant stress to watersheds, with the ability to decimate large expanses of intact forest. Notorious examples in the United States, some introduced recently, include fungal and fungal-like diseases such as sudden oak death (caused by *Phytophthora ramorum*) (Figure 5), chestnut blight (caused by *Cryphonectria parasitica*), Dutch elm disease (caused by *Ophiostoma* spp. and spread by the elm bark beetle, *Scolytus multistriatus*) and white pine blister rust (caused by *Cronartium ribicola*); and insect pests such as gypsy moth (*Lymantria dispar*) and emerald ash borer (*Agilus planipennis*). White pine blister rust, for example, has caused over 90 percent mortality to some subalpine forest stands in Glacier National Park, Montana. Because native forest species have not co-evolved with the pests, their natural defences may be limited.

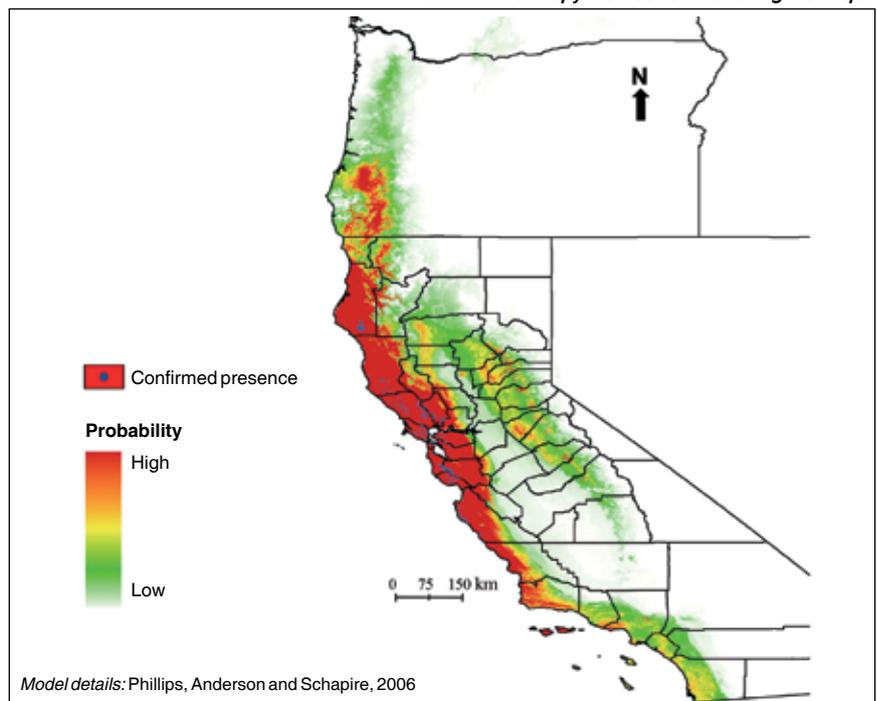
Other harmful invasive non-native species may indirectly affect forest structure. Invasive earthworms in the United States are changing soil structure and nutrient cycling. Non-native grasses and shrubs, often dispersed by birds spreading the seeds, can alter the fuel loads in forests and thus the natural fire regimes.

Some invasive species directly or indirectly affect stream water quality and quantity. For example, Japanese knotweed (*Fallopia japonica*), which has more shallow roots than native riparian species, can affect water quality

4
United States wildfire statistics, 1960–2006



5
Potential habitat suitability map for distribution of *Phytophthora ramorum*, the pathogen causing sudden oak death, in the western United States, prepared using maximum entropy distribution modelling technique





Typical forest affected by sudden oak death, California, United States

by increasing the suspended sediment loads and turbidity (Talmage and Kiviat, 2002). A freshwater diatom, *Didymosphenia geminata*, is changing physical and biological conditions in streams and may indirectly affect stream water quality by forming masses or blooms that degrade fish habitat, smother submerged plants and invertebrates and restrict water flow while depleting dissolved oxygen (Spaulding and Elwell, 2007).

The cumulative effects of non-native invasive plants, insects and pathogens may affect forest structure and biomass and downstream water availability. Increased trade, transportation, and long-range transport may exacerbate the problem. Pest inspectors intercept additional forest pests every year.

AN INTEGRATED APPROACH

An integrated approach is needed to quantify and understand the effects of multiple factors on the quantity, timing and quality of downstream water from montane watersheds. Some investigators have tried to isolate the effects of recent climate change on disturbance regimes (e.g. Westerling *et al.*, 2006), but a more comprehensive, integrated and long-term view may be warranted. The landscape legacy can directly affect wildfire frequency and size and the occurrence of invasive pathogens that

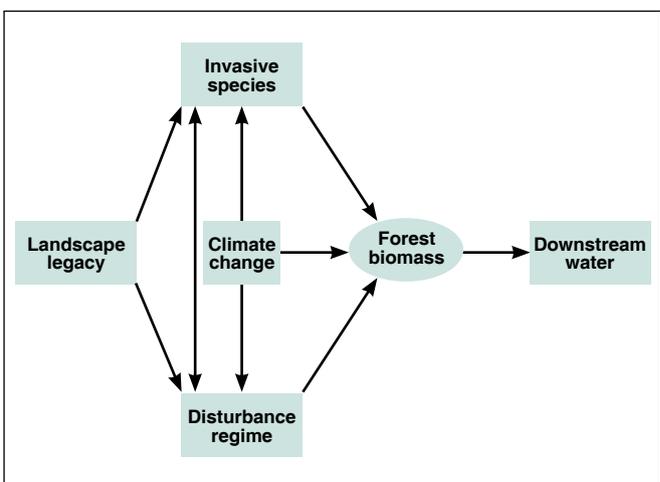
add to the problem (Figure 6). Invasive forest plants, insects and pathogens can, in turn, directly affect the disturbance regime (e.g. invasive grasses altering the frequency of fire, white pine blister rust directly killing trees). Climate change and fluctuation can directly affect precipitation (timing, amount and form) and water storage, or it can indirectly affect water availability by influencing species composition and the occurrence of native and non-native pathogens and pests or the disturbance regime (the frequency or intensity of fires or native insect outbreaks). Continued land-use change and resource use add to the ever-changing landscape legacy (Stohlgren *et al.*, 1998). An integrated approach and

careful monitoring of many interacting factors may be the only way to quantify and predict the complex of changes facing many mountain watersheds.

To develop a predictive science, water managers have a long way to go. Despite the general trends discussed above, site-specific predictions and models of stream flow have eluded scientists. For example, in 2002 precipitation in Denver, Colorado was below average, and newspapers at the time predicted continued drought and low runoff for the city's water supply. However, subsequent years (through 2007) had much higher and even above-average runoff despite the regional trends of warmer temperatures (Denver Water, 2007). Unfortunately, scientists have yet to create accurate predictions of stream flow months to seasons in advance.

An integrated approach, which quantifies the current condition and past trends, can be combined with spatial and temporal modelling to develop likely scenarios of future change in forest structure and water supply. A strong "ecosystem forecasting" capability is the key: combining geographic information system (GIS) technologies with climate and land-use scenarios, while preventing and minimizing the effects of harmful invasive species. ♦

6
Multiple factors affecting the quantity, timing and quality of downstream water in mountain watersheds





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Can the effects of El Niño be mitigated through a system of payments for environmental services?

A study of the Piura River watershed, Peru

M. Fernández Barrena, N. Grados, M.S. Dunin-Borkowski, P. Martínez de Anguita and P. Flores Velásquez

To predict the viability of a system of payments for protection against floods and hydrological cycle disturbances, the estimated costs of modifying land use practices were compared with the amounts that users would be willing to pay.

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This article is adapted from a study published in the Revista Electrónica de la Red Latinoamericana de Cooperación Técnica en Manejo de Cuenas Hidrográficas (REDLACH), Number 1, Year 4 (2007).

Andean cloud forests are vanishing with the ongoing advance of the agricultural frontier. The environmental degradation caused by inappropriate farming practices is destabilizing the hydrological cycle, increasing the seasonal fluctuations in river flows and disturbances such as landslides and floods. In the northern region of Piura, Peru, these problems are increasing vulnerability to the El Niño phenomenon – an oscillation of the ocean-atmosphere system in the tropical Pacific which has important consequences for weather around the globe (INRENA, 2005).

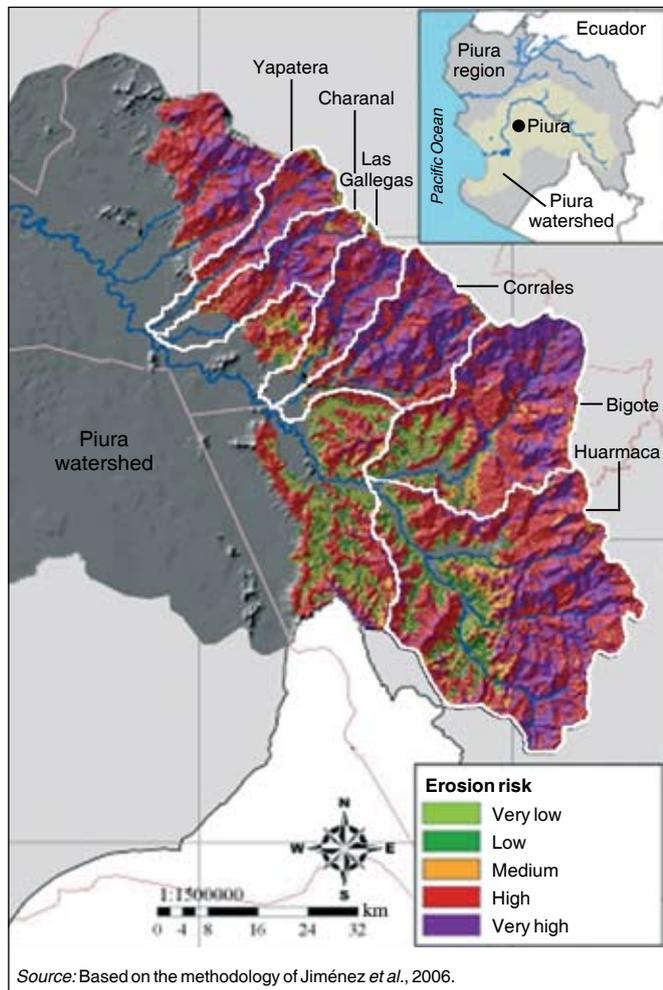
In recent decades El Niño disturbances have resulted in costly damage in the

watershed of the Piura River by causing landslides in steep areas and severe floods downstream. In 1998, the losses were valued at more than US\$100 million (CTAR, 1998). Rainfall in a 1983 event was even higher, but because of the high deforestation rate the damage was greater in 1998.

A study of the Piura watershed indicated that in view of such catastrophes inhabitants would be willing to pay for environmental services such as flood protection and control of the hydrological cycle (improvement in the quantity and quality of water and reduction in seasonal flow fluctuations). The study examined the feasibility of a system of payments for environmental services (PES) for the



In the Piura River watershed, Peru, loss of forest cover has increased erosion; the hydrological system could be improved by compensating small upland farmers for reforestation, forest conservation and adoption of agroforestry, sustainable farming and silvopasture techniques that protect soil



1
Erosion risk in the main subwatershed areas of the Piura watershed, Peru

The downstream population includes some 300 000 potential buyers of the services, with average annual income of more than US\$2 400.

The watershed has six main subwatersheds where improvements could contribute to regulating the hydrological cycle. All of the banks of the Piura River from the outlets of its main tributaries to its arrival at the Pacific Ocean are vulnerable to sudden rises. Practically the whole zone, including most upland farmland, has a high to very high erosion risk (Figure 1). Geographic information system (GIS) analysis showed that erosion risk is influenced more by forest cover than by soil type. The solutions to the problem are clear: conservation of the remaining forests, recovery of lost areas, reforestation of stands, a shift to agroforestry and other systems that protect soil from erosion, and development of silvipasture (López Cadenas de Llano, 1990; Braud *et al.*, 2001).

The flow in the Piura River undergoes wide seasonal fluctuation, ranging from 5.72 m³ per second for about ten months of the year to 200 m³ per second in the rainy season. It also varies considerably from year to year; for example, in El Niño years it reaches peak flows of 1 600 m³ per second, while in La Niña years flow is much lower.

The Yapatera and Charanal subwatersheds were identified as those that could benefit most from intervention, as they have particularly serious erosion (Figure 2). Although they are the smallest subwatershed basins, occupying only 15.4 percent of the total area, together they account for 38 percent of the sediment and 23 percent of the water supplied by the six subwatersheds of the Piura River.

A survey of almost 200 potential purchasers in the city of Piura, together with other studies, indicated that the inhabitants of the watershed are willing to pay for environmental services (Table 1). More than 80 percent of the city residents who responded to the

watershed whose proceeds could be used to conserve forests and develop sustainable farming and livestock techniques (Martínez de Anguita *et al.*, 2006). Finance would come from downstream inhabitants who suffer from the effects of El Niño. The payments would be used to compensate small farmers for their labour on forest and river-channel conservation, to create incentives for the adoption of soil protection techniques in the farming systems used, and also to help improve the living conditions of peasant farmers in this mountain region.

The study included a socio-economic analysis of the watershed area to identify potential service providers; a survey of potential users of the environmental services and their willingness to pay for

them; and mapping and hydrological study of the watershed area to identify the most important areas for maintenance of environmental services. By comparing the costs of the measures needed to conserve water resources and the amounts that service users and other investors could be expected to contribute, it was possible to analyse the viability of several alternative options for a PES system.

MODEL PES SCHEME

The high watershed of the Piura River has a population of about 70 000 potential providers of environmental services; they share similar farming systems and socio-economic conditions, with average annual income of about US\$400.

survey acknowledged their readiness to pay. Some 66 percent of those surveyed would prefer to make payments to an independent institution set up for the purpose. Another 19 percent would prefer to make payments together with water bills for the sake of convenience. The choices of the remaining 15 percent were divided among city or regional government or unspecified others.

As some socio-economic groups would be willing to pay more than others, a scheme of differentiated payments by socio-economic group would maximize income from the PES system. By multiplying the amount that each group would be willing to pay by the number of households in that group (Table 2), it was calculated that annual income from the system would total more than

10 million nuevos soles (S./), equivalent to US\$3.2 million.

The providers identified were landowners in the upper part of the River Piura watershed who could maintain or improve the quality of water with good practices or a change in land use. Payments would compensate them in various cases for reforestation and management of reforested areas, for conserving forests or for adopting agroforestry practices. A physical planning model was created using the methodology proposed by Jiménez *et al.* (2006), dividing the providers' area into zones (Figure 3):

- **maximum environmental service protection zone:** areas on steep slopes and thus having a greater risk of erosion, divided into two subzones:
 - **maximum protection zone 1:** slope greater than 60 percent (40 728 ha);
 - **maximum protection zone 2:** slope between 40 and 60 percent (63 070 ha);
- **hydrological protection zone:** land located 150 m from water channels and springs and covered by vegetation that protects the channels, while also providing habitat and conservation corridors for diverse plant and animal species (35 333 ha).
- **environmental service conservation zone:** natural or primary forest areas, whose protection is vital for the quality of watershed environmental services as well as for conservation of biodiversity (16 091 ha);
- **sustainable farming zone:** land used for agriculture and animal husbandry (71 696 ha).

With a view to maximizing the area to be protected with limited funding, various types of contract are proposed for providers in the various zones to be included in the PES system (see Box). Incentives are designed to encourage adoption of best practices for each zone, with a view to conserving and improving the environmental service and improving

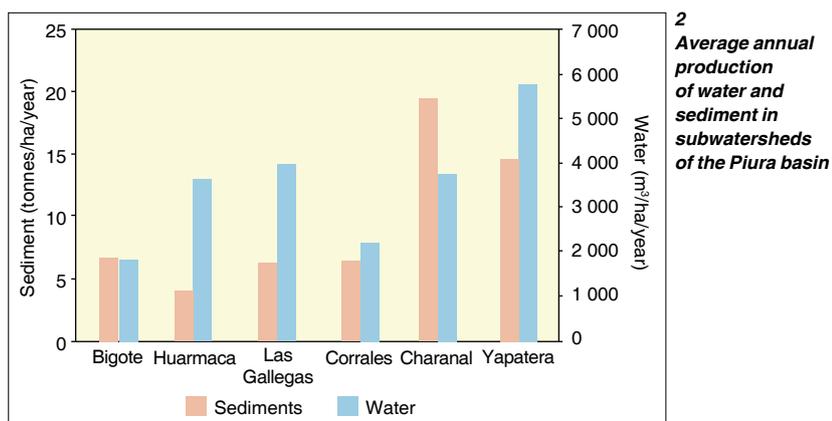


TABLE 1. Potential purchasers of environmental services identified in the Piura River watershed area

Identified purchaser	Environmental service demanded	Motive for purchasing the service
Piura regional government, inhabitants of the city of Piura and other smaller cities (Tambo Grande, Morropón, Chulucanas)	Mitigation of flood risks	Catastrophes caused by the 1983 and 1998 El Niño phenomena, with losses totalling more than US\$100 million (CTAR, 1998)
Farmers in the lower areas of the mountains	Quality and quantity of water and reduction in seasonal fluctuations	Improvement in crops for domestic and international markets
Enosa Electric Company	Quantity of water and reduction in seasonal fluctuations	Reduced electricity production by mini-hydroelectric plants
Enterprises or industries	Some service or improvement in social image	Improvement or reduction of risks

TABLE 2. Population structure of Piura city according to socio-economic groups and their willingness to pay for the service

Monthly expenditure (S./)	Average willing to pay per month (S./)	Households		Inhabitants	
		No.	% of total	No.	% of total
>920	29.9	7 000	9.7	39 000	10.8
636–920	17.8	20 400	28.1	97 700	27
457–636	9.4	28 000	38.6	128 100	35.4
<457	n.a.	17 100	23.6	96 900	26.8

Note: S./ = US\$0.3194 (3/8/2007).

Sources: Personal survey; APOYO Opinión y Mercado, 2003; INEI, 2005.

3 Plan of the providers' area

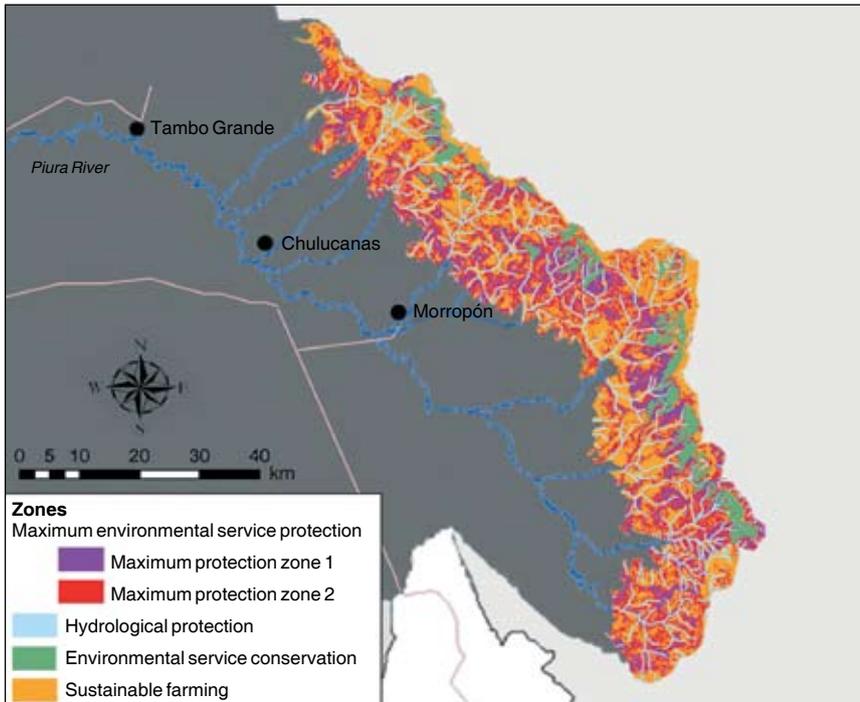


TABLE 3. Alternative options

Option	Areas covered under the scheme	Total area (ha)	Average compensation (soles/ha/year)
1	The whole area, for the best possible environmental service and benefit to the greatest number of inhabitants	195 945	51.2
2	The whole area except the Huarmaca subwatershed, which was given a lower priority in the hydrological model because of its lower degree of degradation	130 846	76.7
3	All subwatershed areas except Huarmaca	115 419	86.9
4	Priority hydrological response units of upland crops with the greatest sediment production per hectare, and zones requiring no initial outlay (forests and hydrological protection zones)	82 579	121.5

the quality of life of families in mountain areas by increasing their income.

On the basis of the income of the purchasers living in the city of Piura, and supposing that all the properties in the watershed subscribed to the PES system, the average amount that could be paid per hectare as opportunity cost was calculated. Four alternative options were drawn up, encompassing decreasing portions of the watershed area (Table 3).

The average sum to be paid per hectare would be adjusted according to the various contracts to which the owners might subscribe, depending on the type of land owned and their specific interests.

Under Option 1, it was estimated that an initial investment of US\$28.7 million would be needed (Table 4), and Options 2 and 3 would require a similar outlay. This sum would be used to supply the materials needed to meet the providers'

Proposed contract types

TYPE I: FOREST OWNERS

- *Primary forest.* The sum received per unit area should be greater than or equal to what a farmer would receive under the PES system. Some activities are restricted.
- *Secondary or reforested forest.* The sum received should be lower than that received by owners of primary forest, but higher than that of the other categories.

In each of these cases, an extra incentive is included if the area owned lies within any of the protection zones defined in the physical plan.

TYPE II: OWNERS OF RIVERBANKS WITHOUT NATURAL VEGETATION

Owners of land located 150 m from rivers and water sources (hydrological protection zone) will receive payment similar to that under a Type I contract, to compensate them for the opportunity cost of maintaining these areas with natural plant cover.

TYPE III: OWNERS OF AGRICULTURAL LAND

The sum received must be adjusted so that, when it is combined with profits from production, the owner will draw greater profit from subscribing to the contract than from eliminating the forest.

TYPE IV: OWNERS OF PASTURELAND

The sum offered must be attractive enough to encourage the owner to subscribe to the system. Payment would be received after the proposed silvipastoral model is achieved.

TYPE V: COMMUNAL FORESTS AND LANDS

Previous contracts should be adjusted depending on whether the land is forested or can be reforested. Payment will go to the city council, which must use it for the conservation and management of these forests.

TABLE 4. Estimated initial cost of Option 1 with local government contribution for labour

Zone	Area (ha)	Initial cost		Labour cost	
		(S/. per ha)	(S/.)	(S/. per ha)	(S/.)
Maximum protection 1	28 931	792	22 913 252	173.5	5 019 507
Maximum protection 2	49 954	792	39 563 873	173.5	8 667 086
Conservation of the service	16 091	0	0	0	0
Hydrographical protection	35 333	0	0	0	0
Sustainable farming	71 696	382.5	27 421 710	283.5	20 325 757.3
Total			89 898 835		34 012 350
			US\$28 714 387		US\$10 863 787

Source: Elaborated on the basis of farming models and costs proposed by Piura University for the Programa de Desarrollo Sostenible de Ecosistemas de Montaña del Perú.

TABLE 5. Cost of implementing the PES system, divided into stages, focusing on priority areas in order to achieve the ideal proposed in the physical plan

Zone	Area (ha)	Initial cost		Labour cost	
		(S/. per ha)	(S/.)	(S/. per ha)	(S/.)
Year 0: Option 4 (49% of environmental services)					
Maximum protection 1	3 446	792.0	2 729 559	173.5	597 953
Maximum protection 2	9 651	792.0	7 643 727	173.5	1 674 478.0
Hydrological protection	35 333	0	0	0	0
Conservation	16 091	0	0	0	0
Sustainable farming	18 058	382.5	6 906 792	283.5	5 119 512
Total			17 280 078		7 391 943
			US\$5 514 855		US\$2 361 042
Year 2: Option 3 (68% of environmental services)					
Maximum protection 1	14 004	792.0	11 091 133	173.5	2 429 686
Maximum protection 2	18 235	792.0	14 441 802	173.5	3 163 703
Hydrological protection	0	0	0	0	0
Conservation	0	0	0	0	0
Sustainable farming	26 265	382.5	10 045 716	283.5	7 446 173
Total			35 578 651		13 039 562
			US\$11 354 757		US\$4 164 934
Year 4: Option 2 (75% of environmental services)					
Maximum protection 1	2 045.9	792.0	1 620 376	173.5	354 968.6
Maximum protection 2	4 818.6	792.0	3 816 363	173.5	836 034.1
Hydrological protection	0	0	0	0	0
Conservation	0	0	0	0	0
Sustainable farming	5 337.7	382.5	2 041 509.0	283.5	1 513 225.0
Total			7 478 248		2 704 228
			US\$2 386 647		US\$863 751
Year 5: Option 1 (100% of environmental services)					
Maximum protection 1	10 227	792.0	8 099 665	173.5	1 774 358
Maximum protection 2	17 696	792.0	14 015 443	173.5	3 070 302
Hydrological protection	0	0	0	0	0
Conservation	0	0	0	0	0
Sustainable farming	21 350	382.5	8 165 962	283.5	6 052 845
Total			30 281 070		10 897 506
			US\$9 664 060		US\$3 480 745
TOTAL			US\$28 920 319		US\$10 870 471

requirements without their having to invest any initial capital; the providers would furnish the labour required to make the changes in land use. With local government able to contribute US\$10.9 million (calculating the cost of labour at the market rate) and Piura city purchasers US\$3.2 million per year, funding would be insufficient to make this proposal viable. This cost would also be very high for attracting international aid or a loan.

More feasible options, however, would be Option 4, focusing on priority hydrological response units (identified by their soil type, plant cover and meteorological conditions) or a staged approach starting with the zones of highest priority (Table 5) or focusing on Options 2 and 3. Option 2 would be the most efficient, providing 75 percent of the environmental services at a cost of US\$19.2 million.

CONCLUSIONS

A PES system focusing on mitigating damage caused by the El Niño phenomenon could be viable. Although high initial costs would preclude implementation of an optimal conservation scheme, less complete options could be practicable with contributions from the government or international donors in addition to payments by the users of environmental services. Although they would contribute less than inhabitants of the city of Piura, other potential purchasers, especially farmers in the lower area who could pay for the regular supply of a sufficient quantity of good-quality water, would add to the total. The differentiation of payments on the basis of the purchasers' ability to pay would increase income under the PES system and contribute to social equity. Particularly in the Andean countries, where social inequalities are a common problem, the relation of buyers and providers could help to level social differences.

The method described here, although specific to the Piura River watershed, could also be extrapolated to other situations.

Although assistance from the government or, failing this, international assistance would be necessary for such a scheme, such assistance would be justifiable. It is enough to remember that the 1998 El Niño event caused infrastructure damage of over US\$100 million in the Piura region, which is much more than the cost of implementing the proposed plan. ♦

Martínez de Anguita, P., Rivera, S., Beneitez, J.M. & Cruz, F. 2006. Establecimiento de un mecanismo de pago por servicios ambientales sobre un soporte GIS en la cuenca del río Calan, Honduras. *Geofocus*, 6: 152–181. ♦



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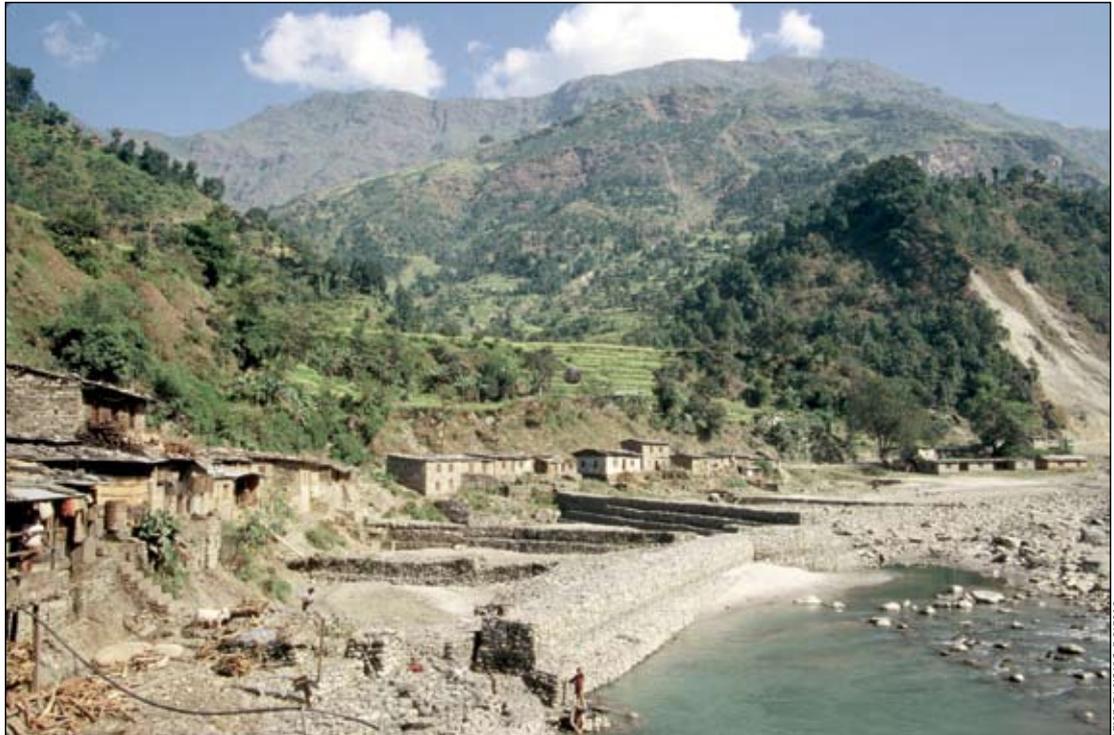
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Five years after Shiga: recent developments in forest and water policy and implementation

P.C. Zingari and M. Achouri

Progress since the milestone International Expert Meeting on Forests and Water held in Shiga, Japan in 2002.

Climate change, water scarcity, environmental degradation, food insecurity and livelihood and human health challenges all urgently require policy attention to interrelationships between forest and water (riverside settlement, Nepal)



FAO/IFB-SG/SHIGA-DIRSI

The recurrence of extreme weather events, climate change and the need for adaptation strategies are focusing national and international attention on water, water-related ecosystems and watersheds. In addition, growing problems of water scarcity, environmental degradation, food insecurity and poor livelihood conditions and human health all require urgent policy and management measures, pointing attention to interrelationships between forest and water.

A number of forest-related cooperation mechanisms such as regional criteria and indicators processes to monitor sustainable forest management, and the global legally binding

environmental conventions on biological diversity, desertification and climate change, have been considering water and watershed issues. At the same time, the growing number of water-related initiatives worldwide, such as the International Network of Basin Organizations (INBO, see www.inbo-news.org) or the World Water Council (WWC, see www.worldwatercouncil.org), are progressively taking into account the role of trees, forests, riparian ecosystems and their management in achieving targets of freshwater quality, quantity, timing and hazard prevention. The Global Water Partnership, as another example among many, has developed a compendium of good practices that identifies field

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examples of forests providing benefits to water resources and to balanced management of watersheds (GWP, 2007).

In many countries, forest and water policies, legislation and administration have long been shaping forest rehabilitation programmes; this has been the case in European countries such as France, Italy and Switzerland since the eighteenth century. Only in the past few decades, however, has the emphasis on theory and practice of hydrology been replaced by a more comprehensive approach embracing environmental issues, land use and watersheds. More recent efforts have sought further to integrate varied sectors and the participation of stakeholders within a wider approach to environmental protection with a solid basis in forest science.

The International Expert Meeting on Forests and Water in Shiga, Japan, held in November 2002 in the framework of the Third World Water Forum in Kyoto, Japan, can be considered a major step towards improved understanding and effective implementation of policies, planning and management initiatives worldwide related to forests and water. Convened jointly by FAO, the International Tropical Timber Organization (ITTO), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Forestry Agency of Japan, the expert meeting focused on new challenges and perspectives concerning forest and water interactions, such as the need for better understanding of the hydrological and environmental services provided by forest ecosystems, more effective management tools integrating forest and water resources, and clearer national strategies and policies to guide stakeholders in the field (Forestry Agency of Japan, 2002). The meeting also raised questions on the role and services of forests in the global freshwater crisis which threatens livelihoods – including health and food security – and biodiversity conservation. These were grouped as follows:

- what are the exact nature, possibilities and limits of the contribution of forests to the water crisis under different climatic conditions and overall climate change?
- how can forest services be incorporated into larger watershed management approaches, including payment for environmental services?
- to what extent and on what basis should each stakeholder be involved for effective and equitable action?

This article reviews some of the progress made during the past five years (2002 to 2007) on the main issues raised, providing some practical evidence and examples from around the world. It addresses four broad areas considered at Shiga:

- integrated, participatory and cross-sectoral approaches to planning and management;
- understanding of biophysical processes;
- economics of watershed services;
- effective collaborative arrangements and partnerships among stakeholders.

INTEGRATED PLANNING AND MANAGEMENT

The need for cross-sectoral approaches and practices in forestry is widely recognized, and the implementation of national integrated water resources management and water efficiency plans was requested at the World Summit for Sustainable Development in 2002 (WSSD, 2003). Institutions and individuals should take concrete steps to integrate water considerations and water resources management into the many sectors affecting and influencing it, including forestry. The main recommendation of the Shiga meeting on this point was that policies and institutional arrangements should be defined to facilitate collaboration among decision-makers and between the decision-makers and resource users.

One example of a policy instrument that integrates forestry and water is the “social accounting” established by the

forest administration of the Autonomous Province of Trento, Italy (2006). This tool aims to establish the value of the social, economic and environmental benefits of the watershed management fieldwork implemented annually in terms of water quality, quantity control, sustainability and monitoring. The accounting covers 5 600 km of torrents and rivers over a land area of 6 400 km², a forest area of 3 500 km² (55 percent of the land area), the work of 333 employees and over €34 million budget in 2005.

The Mekong River Commission (MRC) (see www.mrcmekong.org; www.mekonginfo.org) in Southeast Asia is one of the largest-scale and most complex examples of integrated trans-boundary forest and water management programmes. It deals with 795 000 km² in six riparian countries and over 60 million people. Ninety percent of the area’s population lives in rural areas where they supplement food crops with fish from forests and wetlands, including large areas of flooded forests. One of the three main goals of the current strategic plan for 2006 to 2010 is the implementation of an integrated approach to watershed management in which forest conservation plays a pivotal role in relation to biodiversity; water quality, availability, timing, use and monitoring; and individual and institutional capacity building. MRC is part of the above-mentioned International Network of Basin Organizations (INBO), which brings together watershed management authorities worldwide.

The implementation process of the European Union Water Framework Directive (EU-WFD) applies the overarching principle of “restoring the good ecological status of waters through an integrated approach to, and a long-term planning of, the watershed” (European Communities, 2000). Implementation of EU-WFD is based on:

- surveys of each basin situation (by 2004) and setting of standard monitoring networks (by 2006);



The Mekong River Commission in Southeast Asia is one of the largest-scale and most complex examples of integrated transboundary forest and water management programmes (the River Ou, a Mekong tributary, in the Lao People's Democratic Republic)

- participatory large-scale watershed management master plans and specific operational action plans (by 2009);
- review and report of achievements and development of a second action plan (by 2015).

This regional legally binding instrument is also attracting interest outside the European Union and may be an interesting model for other regions. A survey on watershed issues and priorities in 31 countries carried out in 2003 by FAO in collaboration with the European Observatory of Mountain Forests (FAO, 2006a) indicated that national forest institutions consider EU-WFD a balanced combination of planning, administrative, financial, methodological and practical measures that is helping to achieve concrete goals.

The Motueka River/Tasman Bay Community provides a good example of participatory and integrated watershed management (ICM Motueka Research Programme, 2007). The overall basin is about 2 200 km² and is located in the northwestern part of the South Island of New Zealand. Two-thirds of its area is steeplands covered by native southern beech (*Nothofagus* spp.), podocarps (*Podocarpus* spp.) and commercial radiata pine (*Pinus radiata*) and Douglas

fir (*Pseudotsuga menziesii*) plantations. The river rises in elevation from sea level to 1 600 m in alpine headwaters and delivers 95 percent of the freshwater to Tasman Bay, a productive and shallow coastal body of high cultural, economic and ecological significance. Consideration of upstream–downstream interactions in the planning and implementation of water management activities ensures and reinforces the practice of participatory and integrated approaches.

UNDERSTANDING OF BIOPHYSICAL PROCESSES

Forested watersheds are exceptionally stable hydrological systems (FAO, 2003). In comparison with other land uses, healthy forests:

- strongly influence the quantity and quality of water yielded from watersheds;
- discharge lower storm flow peaks and volumes for a given input of rainfall;
- moderate variation in stream flow during the year;
- stabilize soil and prevent gully and surface erosion;
- export the lowest levels of sediment downstream.

Forested watersheds are exceptionally stable hydrological systems (Canada)



The Shiga Meeting underlined that although much was known about hydrological processes in forests on the small scale, many biophysical aspects of the relation of forest and water on a larger scale were still to be clarified within the different climatic areas of the world. Moreover, it noted that despite basic knowledge on biophysical processes (see Bonell and Bruijnzeel, 2005), there were discrepancies between the views of policy-makers, the public at large and the scientific community, for example on the effects of reforestation on streamflow. The Shiga debate on these scientific aspects was very rich, raising stimulating questions for further work.

The “Forest Management and Water Cycle” (FORMAN) initiative, which started in 2007 under the intergovernmental European Cooperation in the field of Scientific and Technical Research (COST) network (see www.cost.esf.org/index.php?id=142), is addressing some of these questions. The main objective of this COST Action is to enhance knowledge on forest–water interactions and to elaborate science-based guidelines for improving the management of forests predominantly designated for the production, storage and provision of water. It is currently reviewing temperate forest and water issues. The five priority areas of research are:

- influences of different forest types, species and management practices on water;
- importance of scale on forest management–water relations;
- overall effects of forests on water status (quality, quantity, ground-water);
- protective function of forests (low and peak flow, flood mitigation, erosion);
- effects of climate change on forests and water.

Addressing similar issues, an international workshop on “Water Management through Forest Management”, held in November 2007 in Beijing, China [ed.

note: see p. 68, this issue], examined advances over the past century in the scientific understanding of forest hydrological processes and impacts at the scale of forest stands and small watersheds.

ECONOMICS OF WATERSHED SERVICES

One of the main recommendations of the Shiga meeting was to assess the full economic value of forest and water resources in order to put in place appropriate incentives to support natural resource management for the sustainable provision of services – which also depends on secure resource and land tenure rights. Economic valuation will allow awareness-raising on the importance of environmental services and equitable sharing of costs and benefits between resource users and providers. The Shiga meeting discussed partnerships built on upstream–downstream interactions, as management or mismanagement of upland and riparian forests affects all those living downstream. Payment for environmental services (PES) is one form of such partnerships.

Since the Shiga meeting, considerable work has been done to develop the concept and practices related to PES, defined by UNECE (2006) as a

“contractual transaction between a buyer and a seller for an ecosystem service or a land use/management practice likely to secure that service”. Case studies and guidelines collected in the framework of the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes document methods, payment schemes and accompanying measures (many of them forest related) from successful experiences around the world (UNECE, 2006; Working Group on Integrated Water Resources Management, 2006). Forest- and water-related PES schemes have been implemented in many countries, especially in Latin America. Schemes range from local initiatives with or without external funding to national programmes financed through cross-sectoral subsidies.

Along the same line, the Organisation for Economic Co-operation and Development (OECD) has recently reiterated its support for forest and water policy that rewards the provision of services instead of subsidies to the forest sector (Bonnis, 2007).

COLLABORATIVE AND PARTICIPATORY ARRANGEMENTS

The Shiga meeting, in line with the WSSD Plan of Implementation (WSSD,

The need to assess the full economic value of forest and water resources is increasingly recognized (in Mexico, local spring water is bottled by rural communities for sale in nearby cities – a non-wood forest product of growing importance)



ITIOS ANTA-FONSECA

2003), recommended the promotion of effective and equitable collaborative arrangements and partnerships among all stakeholders and at all levels for better and more coordinated management of water resources.

Collaborative arrangements among national and international organizations include the World Water Council (see www.worldwatercouncil.org) and the Collaborative Partnership on Forests (see www.fao.org/forestry/cpf). Linking forests and water, FAO collaborated with countries and institutional partners to shape a new generation of watershed management programmes and projects. The resultant resource book for practitioners and local decision-makers (FAO, 2006b) assembles the input of more than 80 institutions, gathered through a global survey and four regional workshops [ed. note: see Box p. 22].

Other alliances on the global level are exchange and twinning initiatives. Examples include the Brahmatwinn Project (2007), a collaboration between the Upper Brahmaputra River Basin in South Asia (Tibet, Bhutan and the state of Assam in northeastern India) and the Upper Danube River Basin in Europe, and the Twinbasin Initiative (2007) which promotes twinning of river basins worldwide for the development of integrated water resource management practices.

Many forested watersheds around the world are brought together within the Hydrology for the Environment, Life and Policy (HELP) Programme of UNESCO and the World Meteorological Organization (WMO) (see www.unesco.org/water/ihp/help). This initiative supports integrated watershed management through frameworks enabling experts, managers and scientists to work together on water-related problems. A global network of watersheds (measuring up to 106 km²) facilitates exchange of field experiences. The Motueka River/Tasman Bay Community described above is one of the basins in the HELP network.

CONCLUSIONS

The Shiga meeting offered an international platform for building consensus and identifying the way forward on forest and water conservation and management. After only five years it is early to evaluate the implementation of its recommendations; yet there have been significant achievements at the international and national levels. The International Year of Freshwater 2003, together with the International Decade for Action “Water for Life” 2005–2015 (see www.un.org/waterforlifedecade), further contributed to the recognition of the interrelations of water and terrestrial ecosystems and the need for urgent action to protect them both for sustainable provision of environmental services. Policy discussions show clear trends towards stronger links between forest and water resource management.

There is no doubt that these links will have to be further reinforced in practice. Further efforts are required on interdisciplinary research, on the improvement of data quality and availability, and on a wider use of equitable PES schemes. Growing problems of water scarcity and increasing environmental degradation and their impacts on food security make water supply and demand a pressing issue and a potential source of conflict, calling for greater attention to the development of appropriate approaches and comprehensive policies to achieve successful integrated water resources management.

Based on the main achievements and on the needs identified since the Shiga meeting, local and national decision-makers should further enhance forest and water policies and practices by thoroughly considering, adapting and adopting the following actions:

- specific cross-sectoral laws, plans, measures and institutional reorientations;
- programmes for effective awareness-raising, linking of science and policies, and capacity building for var-

ied target groups ranging from local watershed inhabitants to high-level policy-makers;

- initiatives to improve scientific understanding of forest–water interactions, local knowledge and monitoring to support evidence-based interventions;
- harmonized micro- and macro-level linkage of experiences, initiatives and mechanisms in the context of sustainable forest and water management;
- expanded evaluation of projects based on real changes and progress;
- locally adapted mechanisms for valuation of and payment for services, and financing of long-term collaborative watershed management processes;
- regional fora for exchanging experiences, identifying common interests and responsibilities and negotiating agreements, especially over transboundary watersheds.

International organizations such as FAO and its partners can effectively help promote actions directed at better management of water resources through normative and field programme activities at the national, regional and global levels. In this respect, it is important to underline that comprehensive policies and tools for sustainable natural resource management and for enhancing people’s well-being must build on an awareness of and respect for the cultural, technological and human resources of each area (UNESCO, 2005). With water issues now prominent around the world, it is time to promote and apply the interrelations between water resources management and the conservation and management of forest ecosystems. ♦



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Water, forests and the World Water Development Report

D.G. Donovan

Scope for further discussion of forestry in future editions of UN-Water's periodic report on the state of the world's freshwater resources.

The relationship between forests and water remains controversial, often surrounded by myths, misinterpretation and extrapolation from unsuitable examples. Farmers have complained of falling well-water levels as a result of afforestation projects intended to improve watershed conditions. Authorities have directed the removal of trees to conserve water. Logging and deforestation are widely blamed for flooding. The need for better understanding of the relationship of forests and water clearly remains a challenge.

The organizations in the UN system have taken on the task of systematically marshalling global water knowledge and expertise to prepare a periodic review and assessment of global freshwater conditions, called the World Water Development Report. The report is the flagship publication of UN-Water, the interagency mechanism established to promote coherence and coordination of all United Nations activities in the area of freshwater. Produced by UN-Water's World Water Assessment Programme (WWAP), the report pools expertise from 24 UN agencies working closely with governments, non-governmental organizations and civil society. The World Water Development Report is meant to provide an authoritative picture of the state of the world's freshwater resources and associated ecosystems, identifying key issues, monitoring progress and documenting lessons learned – information critical for better informed water-related policy and planning. The second edition, entitled *Water – a shared responsibility*, was released on 22 March 2006, World Water Day, at the fourth World Water Forum in Mexico City, Mexico.

Assessing freshwater worldwide

Organized in five sections, *Water – a shared responsibility* begins by highlighting the critical issues affecting water use and management today, most importantly the challenge of realizing good water governance through integrated water resources management and addressing the pressures of rapid urbanization and changing climatic conditions on water resources.

Next, an examination of supply-side issues draws the connection between the state of freshwater resources and the condition of associated ecosystems. It recognizes that maintaining

healthy ecosystems means not only preserving landscape diversity and habitats for other life forms, but also ensuring a regular supply of clean water for all living things.

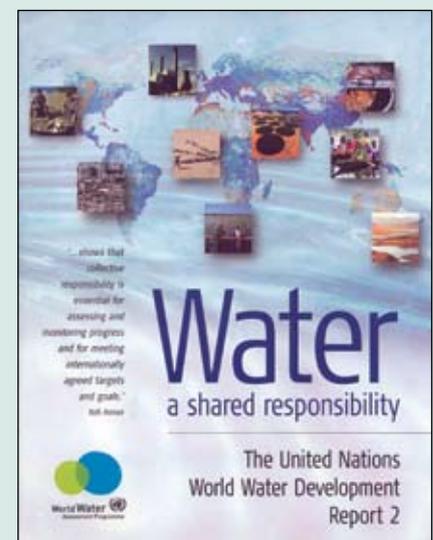
The third section voices the concerns of the main sectors accountable for water demand, namely health, agriculture, industry and energy, including issues of desalination and the harnessing of water's kinetic energy for electricity production.

Returning in the penultimate section to governance issues associated with changing environmental, political and economic conditions, the report focuses on water-related disaster risk management, sharing water resources and developing water-related knowledge and capacity as well as economic issues such as valuing and charging for water. Finally, examples from different countries and regions illustrate attempts to address specific water challenges, while the conclusions provide recommendations for the way forward.

The forestry angle

The World Water Development Report touches on the role of forests and forestry only briefly. It notes that poor forest management practices can lead to sedimentation. Given the challenge of providing adequate clean water supplies in the rapidly growing urban areas of many developing countries, the recognition that "a third of the world's largest 100 cities rely on forests ... for a substantial proportion of their drinking

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water” is significant. While the discussion on water in relation to food, agriculture and rural livelihoods focuses mainly on irrigated agriculture, it notes that crop production actually uses only a small fraction of land-destined precipitation as compared with non-domesticated vegetation, including forests and rangelands. The chapter on valuing water raises the question of payment for environmental services, such as catchment management.

Improving environmental governance is essential to more efficient, more equitable and more sustainable use of freshwater resources. Concluding remarks recognize that “healthy ecosystems are integral to the proper functioning of the hydrological cycle” and that environmental protection must therefore be at the heart of integrated water resources management. Better environmental management, however, requires a broad understanding of ecological systems and water-related eco-

logical processes, including those of forest ecosystems.

Policy-makers, planners and the public would surely benefit from a deeper discussion of the relationship of forests and water in future editions of the World Water Development Report. Beyond observing the harmful hydrological effects of poor forest management (e.g. sedimentation), it would be appropriate to note that properly managed forested watersheds can be a source of generous economic as well as environmental benefits, as is acknowledged by the developing field of “ecohydrology” – the cross-disciplinary study of the functional interrelations between hydrology and biota at the catchment scale. For example, the role of watershed forests and high mountain cloud forests in ensuring regular supplies of clean water and the role of mangroves and other littoral forests in protecting coastal populations against water-related disasters could be

further explored. Phytoremediation (removal of pollutants through uptake by plants) could be considered as an increasingly popular alternative to engineering solutions for industrial water pollution. The dependence of hydroelectric schemes, both large and small, on sound upland management could be examined. Consideration of good water governance could give more attention to problems of environmental management in transboundary catchments and the need for multidisciplinary training and research to support truly integrated water resources management. It is hoped that with the recent advancement of FAO to the leadership of UN Water, readers may look forward to greater recognition of the role and potential of forests and forestry in the next edition.

The second World Water Development Report is available at: www.unesco.org/water/wwap/wwdr/index.shtml



FAO FORESTRY

Future of forests in Asia and the Pacific

Unprecedented economic, social and environmental change in the Asia and the Pacific region is significantly altering the way its forests are regarded and used. Looking forward was the theme of a regional conference entitled “The Future of Forests in Asia and the Pacific: Outlook for 2020” held in Chiang Mai, Thailand from 16 to 18 October 2007. The conference attracted more than 250 participants from over 40 countries.

The conference was organized by the Asia-Pacific Forestry Commission (APFC) within the scope of the ongoing Asia-Pacific Forestry Sector Outlook Study (APFSOS II) – both as an opportunity for presentation of the study’s preliminary findings, and as a forum for gathering the views of diverse stakeholders on emerging changes and their implications for forests and forestry in the region. Participants, in addition to APFSOS national focal points, included foresters, students, educators, researchers, government officials, project managers and representatives from the private sector, non-governmental organizations (NGOs) and multilateral organizations. Special guests were five winners of an essay competition for young professionals who had eloquently provided their views on the future of forests in the region.

Conference participants analysed the major driving forces of change in the region, and how these forces are likely to shape the perception and use of forests in the coming years. Themes included macro-economic prospects, environmental change, institutional transition, urbanization, technological development and application, international trade, land-use trends, poverty alleviation and the growing importance of planted forests. Private-sector and civil-society perspectives were also presented.

In the keynote address, Jagmohan Maini, former coordinator of the United Nations Forum on Forests, spoke of the importance of far-reaching planning processes. Subsequent presentations took stock of the current status of the region’s forests and offered projections of many of the pressures expected to influence forests in the coming years. Many divergent views – pessimistic and optimistic in varying measure – led to vibrant discussions about the future of forests in the region and how best to address emerging challenges. A poster session with 55 entries highlighted prospects at the national level, providing participants an opportunity to engage in informal discussion on focused topics.

In general, the conference affirmed that the future of forests and forestry in the region will continue to be driven by an array of factors largely outside the forest sector. Expanding populations, a shift from subsistence to consumer economies, increasing wealth and economic activity and new markets will increase overall demand on forests, while growing environmental pressures will require that “new” forest values be captured for society in general. As the numbers and kinds of demands placed on forests increase, it is anticipated that so too will the numbers and kinds of stakeholders concerned with how forests are managed. This highlights the immense challenge of balancing competing demands.



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Corruption, while not unique to forestry, is likely to continue to hinder sustainable forest management efforts unless dramatic action is taken across all sectors to address the problem. The importance of flexible governance structures and active collaboration with other sectors and regions was a common message emerging from the conference.

More sophisticated thinking and new partnerships will be needed to address the challenges successfully. Viable solutions will entail nuanced, interdisciplinary and international thinking and cooperation. The conference was an important step in the direction of such needed exchange and collaboration.

The conference proceedings will be published in early 2008. The programme, presentations and papers are available at: www.fao.org/forestry/site/33592/en

Special Event on Forests and Energy

On 20 November 2007, at the biennial session of the Conference of FAO, Director-General Jacques Diouf convened a High-Level Special Event on Forests and Energy. Pedro Verona Rodrigues Pires, President of Cape Verde, delivered the keynote speech, and the session was chaired by the Minister for Forestry of the Congo and the Minister for Agriculture of Latvia.

Participation included 275 delegates from approximately 90 FAO member countries. Country statements recognized that bioenergy has become a global strategic issue which increasingly affects economic, social and environmental conditions and has potential to mitigate climate change. Wood is the most important biofuel and an economically and environmentally efficient substitute for fossil fuels. However, particularly in developing countries, a lack of information on wood used for fuel hampers countries’ decision-making on the sustainable use of this resource, and thus hinders an opportunity to mitigate climate change and strengthen countries’ energy mix. Furthermore, with growing population and increasing land allocation for energy production, trade-offs between forest, energy and agricultural use of land need to be carefully examined.



XIII World Forestry Congress, 2009: call for papers



From 18 to 25 October 2009, the international forestry community will meet in Buenos Aires, Argentina for the XIII World Forestry Congress – the most important forestry meeting worldwide. For one week, representatives of the public and private sectors, the scientific community, foresters, professionals and other interested parties will have an opportunity to analyse and discuss the gamut of forest-related issues.

Under the theme “Forests in development – a vital balance”, the congress will address sustainable forest management from a global and integrated perspective. It will cover seven thematic areas:

- Forests and biodiversity;
- Producing for development;
- Forests in the service of people;
- Caring for our forests;
- Forest sector: development opportunities;
- Organizing forest development;
- People and forest in harmony.

The complete thematic structure of the congress can be viewed on the congress’s Web site (www.wfc2009.org).

Voluntary presentations and poster sessions will be an important part of the congress. These must express new ideas and provide information on current investigations, field experiences, development projects, theoretical models or practical applications. The congress will seek to achieve a balanced representation of geographic regions and points of view.

All interested people are invited to submit papers before 30 June 2008. Papers must not exceed 4 500 words, tables included, and must include an abstract of not longer than 250 words. The author must identify the congress theme to which the paper corresponds, justifying this placement using three to five keywords.

All submissions will be peer reviewed and evaluated using the following criteria:

- **Relevance:** Is the topic relevant to the thematic sessions? Will it be interesting to a large number of participants?
- **Quality:** Is the argument coherent, well structured and comprehensible?

- **Originality:** Is the treatment of the subject innovative and original? Previously published papers are not eligible.

According to their ranking, papers will be published in full or in part on the congress’s Web site.

Some papers will be selected for presentation by their authors during the congress sessions, and some authors may be invited to prepare posters. For a paper to be considered for presentation, it must be of major interest to the congress deliberations and provide an exhaustive analysis of the topic addressed. It should apply to a significant number of countries or at least one ecoregion; be related to current and emerging issues; and address cross-sectoral and interdisciplinary linkages. Authors must accept that, without prior notification, their documents may be edited and translated into the official languages of the congress – Spanish, English and French.

All individuals who are planning to participate in the congress, including those invited to make presentations, are required to register and are responsible for payment of the registration fee and their own expenses.

Guidelines for submissions can be downloaded from the congress Web site (www.wfc2009.org). They can also be requested by mail or fax (see below) or by e-mail to: info@wfc2009.org

Authors are strongly encouraged to submit their contributions by uploading them on the congress Web site. Alternatively, papers, including abstracts, can be sent before 30 June 2008 to:

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00153 Rome, Italy
Tel: +39 06 5705-2198
Fax: +39 06 5705-5137
E-mail: WFC-XIII@fao.org

Individuals or groups wishing to receive future announcements by e-mail can subscribe at: www.wfc2009.org



Delegates expressed the following needs for coping with current and future challenges in this area:

- wood energy strategies based on sustainable forest management concepts;
- capacity building for integration of bioenergy strategies in national forest programmes and plans;
- attention to bioenergy as a cross-sectoral issue and its integration in forest, agricultural and other land-use policies;
- coordination of bioenergy strategies with poverty eradication and poverty reduction policies;
- enhanced capacities for the use of alternative renewable energy sources, including hydropower, solar energy and biogas;
- increased energy efficiency of wood combustion at household and industrial levels;
- better use of post-consumer wood;
- consideration of the value of wood for other end-uses before it is used for energy generation;
- effective dissemination of research and development findings, technologies and expertise for efficient and healthy energy use;
- avoidance of market distortions in the promotion of bioenergy;
- systems of continuous checks and balances for production of biofuels to avoid negative impacts on the environment and ensure the well-being of local communities;

- careful consideration of food security and negative effects on other sectors in the design and implementation of incentives for biofuel production.

Linking national forest programmes to poverty reduction strategies in Africa

Between November 2005 and July 2007, FAO conducted a study in ten countries in Africa (Kenya, Malawi, Namibia, Niger, Nigeria, Sudan, Tunisia, Uganda, United Republic of Tanzania, Zambia), in collaboration with the National Forest Programme Facility, to examine the linkages between national forest programmes and national strategies to reduce poverty. The study revealed that the two processes are not well connected for the most part, mainly because central authorities are often unaware of the many ways in which forests and trees outside forests help to reduce poverty and, by the same token, forestry officials are not generally engaged in national discussions on poverty. The study also found that weak forestry capacity in all countries is hindering efforts to strengthen collaboration within and outside the sector, including with central planning agencies and relevant line ministries.

In Nairobi, Kenya from 20 to 22 November 2007, a regional workshop was held to exchange ideas on how to increase the presence and influence of forestry in central decision-making

Comments requested on new FAO strategy for forestry

In March 2007, the Committee on Forestry (COFO) requested that a new FAO strategy for forestry be developed in consultation with FAO member countries and other partners. The consultative process has begun. In the first stage of the consultation, comments are requested on a discussion paper on elements of a possible strategy, posted online (see below). The paper presents the following potential strategic goals for forestry:

- Decision-making is informed, harmonized across sectors, and participatory.
- Benefits from trees, forests and forestry are increasing, equitably shared, and widely recognized and appreciated.
- Forest resources are increasing and ecosystem services are increasingly valued.

The paper also outlines potential elements of strategies for achieving the goals, including:

- strengthening country capacities to make good decisions about forests through participatory processes;
- strengthening information to support policy-making;
- improving forestry practices including through best practice guidelines developed using multistakeholder processes;
- promoting networks for sharing knowledge and implementing improved practices;
- working across sectors, helping countries mainstream forestry in national development processes;
- working in partnership with others in the public and private sectors to leverage resources and avoid duplication;
- improving vertical linkages, facilitating knowledge exchange between local, national, regional and global levels;
- improving advocacy to raise awareness and increase commitments to invest in better forestry;
- continuing to serve as a neutral forum for exchange of knowledge about forests and forestry.

Based on feedback received during the first part of 2008 – including discussions at the biennial sessions of the Regional Forestry Commissions – a draft strategy will be developed and circulated for comments during a second phase of the consultation in mid-2008. The goal is to propose a new strategy to COFO at its next meeting in March 2009.

Unasylva readers are invited to comment on the discussion paper. To review it and to send comments electronically, please visit: www.fao.org/forestry/strategy

Comments can also be sent by e-mail to: FO-Strategy@fao.org



processes. To this end, the ten countries that participated in the study explored practical ways to make national forest programmes an integral part of national development plans and poverty reduction strategies. The workshop, organized by FAO in partnership with the Kenya Forest Service and the National Forest Programme Facility, brought together more than 40 participants from government and international organizations, including ministries outside forestry – finance, planning and economic development, national statistics, environment, and agriculture, among others.

Following a rich exchange of views on how best to improve collaboration to reduce poverty – which validated the main findings and conclusions of the study – each country prepared a list of priorities for follow-up action and identified areas requiring support from the Facility and other international partners. As a positive sign of commitment to implement the suggestions contained in the country reports, participants from Kenya established a multidisciplinary task force during the workshop and scheduled a first meeting for the following week.

First Community Forestry Agreements signed in Cambodia

FAO projects over many years, funded by Belgium and New Zealand, have facilitated a major development in community forestry in Cambodia: the signing of the country's first ten Community Forestry Agreements. On 19 November 2007, a formal signing ceremony took place in Tbeng Lech Village, Siem Reap Province, between the Chief of the Forestry Administration of Siem Reap Cantonment and the chairs of ten Community Forestry Management Committees. Also present were the Secretary of State for the Ministry of Agriculture, Forestry and Fisheries, the Provincial Governor of Siem Reap and the Director General of the Forestry Administration.

In Cambodia, development of a legal framework for community forestry, clearly defining the rights, roles and responsibilities of the State and of communities, began in the early 1990s. As a result of these efforts, the Forest Law (2002) recognizes community forestry as one of the modalities for sustainable forest management in the country. Other elements of the framework include the Subdecree on Community Forestry Management (2003) and Guidelines for Community Forestry (2006).

Many donor-supported projects were simultaneously developing community forestry on the ground with interested communities. Throughout the country there are now more than 264 Community Forests at various stages of development, covering approximately 179 000 ha and involving more than 57 000 families who are beginning to realize direct benefits. Most of the communities have taken steps towards the formal recognition of their Community Forests and are working with the Forestry Administration and partners to complete the remaining steps required by the guidelines.

The FAO project "Community Forestry in Northwestern Cambodia", with 12 years of activity one of the longest-running community forestry projects in the country, has over the years supported the development of 37 Community Forests and six Community Protected Areas in Siem Reap Province. The Siem Reap Cantonment was the first to submit a list of potential Community Forests to the Ministry of Agriculture, Forestry and Fisheries, and the first to receive approval for these forests. The signing of the Community Forestry Agreements represents the final step in the formalization of these Community Forests, which can now begin to develop formal Community Forestry Management Plans.

The project will continue to provide support to help the other identified Community Forests reach the same stage.

FAO to develop report on the state of the world's forest genetic resources

At its eleventh session in June 2007, the FAO Commission on Genetic Resources for Food and Agriculture requested that FAO prepare a report on the State of the World's Forest Genetic Resources, for review at its twelfth session in 2009. The commission acknowledged the urgent need to conserve, manage and sustainably use forest genetic resources to support food security, poverty alleviation and environmental sustainability, and approved the inclusion of forest genetic resources in its Multi-Year Programme of Work.

Work on the report will be undertaken in close collaboration with international partners such as Bioversity International, and in synergy with ongoing regional and global programmes such as those carried out under the Convention on Biological Diversity. The report will focus on tree and shrub genetic resources of actual or potential value for human well-being, and will provide the basis for developing a framework for action to advance conservation and sustainable use at the national, regional, ecoregional and global levels.

The report will draw on data from the Global Forest Resources Assessment (FRA) 2005 and national and regional studies on forest genetic resources carried out with FAO support since the mid-1990s. However, with current knowledge most quantitative and qualitative variables commonly recorded in forest inventories cannot be used to determine status and trends at the level of tree species, provenances, populations and genes. It will thus be necessary to define variables for assessing biological diversity and to develop easily measurable genetic indicators for monitoring changes over time.



WORLD OF FORESTRY

Managing forests and water – workshop in China

The water budget of forest ecosystems depends heavily on climate, site and forest structure. Forest structure is strongly influenced by forest management measures such as tree species selection, stand structure and density management, and harvesting methods.

Although the water cycle in forest stands is well understood, the role of forests in sustainable management of water resources and flood mitigation is often debated, as is the development strategy of promoting afforestation.

To help ground the debate in reliable science, from 12 to 16 November 2007 the Chinese Academy of Forestry hosted the workshop “Water Management through Forest Management”, jointly organized with the Forest Ecosystems Research Center of Goettingen University, Germany under the International Union of Forest Research Organizations (IUFRO) Division 8.01.04 – Water supply and quality. Held in Beijing, China, it was attended by 77 participants from 11 countries.

The workshop explored relations of forest management to two important aspects of water supply: provision of high-quality water to humans and water supply to the forest itself. The balance between available water and the water demands of forests has been less researched but is of great importance as many countries step up forest planting for carbon fixation, energy and wood supply and environmental restoration.

Presentations were grouped in five sessions:

- Impact of forest management on water quality and quantity;
- Soil water and water use;
- Forest and water management under changing climate;
- Application of ecohydrological models – including their potential use in development of decision-support tools;
- Strategy and research for integrated forest and water management.

The rapidly changing climate and forestry development may put the water-related functions of forests at risk. Increased drought stress may weaken the stability of the forest itself. Although answers are still needed on how to integrate management of forests and water to solve the varied problems of different regions, this workshop identified gaps in knowledge to help shape future research in integrated forest-water management, and represents a positive step in overcoming the prevailing monosectoral approaches.

Ministers responsible for forests in Europe adopt resolutions on wood energy and water

The fifth session of the Ministerial Conference on the Protection of Forests in Europe (MCPFE), “Forests for Quality of Life”, concluded with a ministerial declaration and resolutions on promotion of wood as a source of renewable energy and forest’s role in water protection in the context of climate change.

The conference, held in Warsaw, Poland from 5 to 7 November 2007, was jointly organized by Poland and Norway and attended by delegations from over 40 European countries, including



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16 ministers responsible for forests and forestry. Discussions emphasized the role of forests in modern life in the face of challenges from socio-economic development, human pressure on natural resources and the consequences of climate change.

Lech Kaczyński, President of Poland, opened the conference, drawing attention to the need to reconcile economic development with protection of the natural environment.

The report *State of Europe’s Forests 2007*, jointly prepared by the MCPFE Liaison Unit Warsaw, FAO and the United Nations Economic Commission for Europe (UN-ECE), was presented at the conference. It indicates that both the area of forests in Europe and their productive potential are increasing. Over the past 15 years, the region has gained 13 million hectares of forest, an area the size of Greece. The quantity of wood resources is also steadily growing.

Forty MCPFE signatories adopted two resolutions for implementation at the national level. Warsaw Resolution 1, “Forests, wood and energy”, obliges States to increase the forest sector’s role in energy production and the use of forest biomass for renewable energy to reduce greenhouse gas emissions. Noting the increasing competition in demand for wood for energy and industry, it calls for enhanced partnership of public and private forest owners, wood industry and energy producers.

Warsaw Resolution 2, “Forests and water”, stresses the role of forests in protecting the quality and quantity of water, preventing floods, mitigating the effects of drought and counteracting soil erosion. Countries make a commitment to manage forests sustainably in relation to water; to coordinate policies on forests and water; to develop knowledge and strategies related to consequences of climate change on forest and water interactions; and to further the economic valuation of water-related forest services.

In the Warsaw Declaration, countries pledge to undertake further activities towards implementation of sustainable forest management as an indispensable element of sustainable development. The declaration recognizes the importance of forests in improving quality of life, and commits countries to enhance the contribution of forests and sustainable forest management in combating climate change, conserving biological diversity, providing renewable energy and



wood products, ensuring quality water supply and mitigating natural hazards and environmental degradation. Furthermore, it emphasizes collaboration of MCPFE with other regional processes, with synergies to facilitate a consistent Pan-European input to international initiatives.

In addition, delegates adopted ministerial statements on forest fires in South Europe and on a Pan-European Forest Week, to be held in October 2008, organized jointly by FAO, the United Nations Economic Commission for Europe (UNECE), the European Union and MCPFE.

The previous Ministerial Conferences were held in Strasbourg (1990), Helsinki (1993), Lisbon (1998) and Vienna (2003).

Forests in evidence at Bali climate change meetings

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), released in 2007, indicates that in the 1990s nearly one-fifth of greenhouse gas emissions resulted from land-use change, primarily deforestation. This awareness has raised the prominence of forest conservation and sustainable forest management in global climate change discussions, and in particular in recent negotiations under the United Nations Framework Convention on Climate Change (UNFCCC).

The United Nations Climate Change Conference, which included sessions of the Conference of the Parties (COP-13) to UNFCCC, its subsidiary bodies and the Meeting of the Parties to the Kyoto Protocol, was held in Bali, Indonesia from 3 to 14 December 2007. The combined meetings drew more than 10 000 participants. The role of forests was discussed intensively. COP-13 culminated in the adoption of the Bali Action Plan, which outlines actions to 2012 and beyond.

Forest-relevant decisions

The Bali Action Plan specifies an area for action related to forests: "Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries".

The COP also adopted a specific decision on reducing emissions from deforestation and degradation (REDD), which emphasized the urgency of taking further meaningful action to reduce emissions from deforestation and forest degradation in developing countries. Parties are encouraged to explore a range of actions to address the drivers of deforestation, including through demonstration activities. The UNFCCC Subsidiary Body for Scientific and Technical Advice (SBSTA) is requested to undertake a programme of work on methodological issues related to policy approaches and positive incentives.

Furthermore, the COP adopted a decision revising the limit for small-scale afforestation and reforestation project activities under the Clean Development Mechanism (CDM) – an effort to stimulate more small-scale projects of this type. The decision increases the upper limit of annual greenhouse gas removals eligible for emission reduction credits from 8 to 16 kilotonnes.

The conference approved an adaptation fund to improve the defences of poor and vulnerable countries against the effects of climate change. The fund is intended to finance adaptation projects such as improved water supplies for drought-prone areas and conservation and restoration of mangroves for coastal protection. The fund will be administered by the Global Environment Facility and overseen by representatives from both industrialized and non-industrialized countries. Funding will come from a 2 percent levy on revenues generated by the CDM and thus will not depend on aid budgets.

Forest Day

To draw attention to forest issues and inform the discussions related to forests under negotiation at COP 13, on 8 December 2007 the Center for International Forestry Research (CIFOR) organized a Forest Day which was co-hosted by the partners of the Collaborative Partnership on Forests (CPF). Four main sessions addressed methodological challenges in estimating forest carbon; market and governance; equity versus efficiency; and adaptation. In addition 25 side events focused on diverse climate-change related topics, including carbon emission abatement costs from reduced deforestation; the future of the land-use sector in carbon markets; funding for REDD; biofuels for climate change mitigation; and national experiences in baseline analysis of deforestation. Forest Day was attended by more than 800 people, including scientists, policy-makers and representatives of intergovernmental and non-governmental organizations.

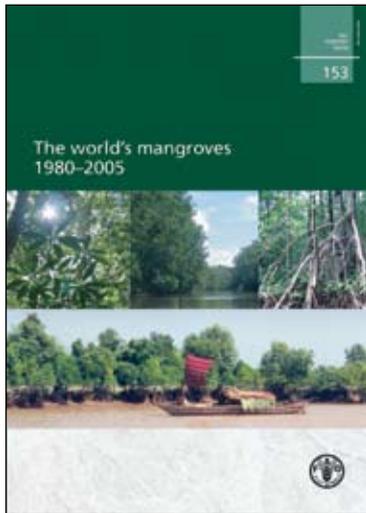
CPF presented key recommendations to the Executive Secretary of UNFCCC related to the role of forests in combating climate change, including the need for:

- addressing the drivers of deforestation, including those beyond the forest sector, for the success of mechanisms based on REDD;
- a combination of market and governance-based approaches;
- simple mechanisms with low transaction costs;
- clarified land rights and legal rights to carbon to ensure equity in the distribution of benefits from REDD;
- immediate adaptation focused on the most vulnerable, including forest-dependent people.

Initiatives launched in support of reducing emissions from deforestation and forest degradation

The World Bank launched the Forest Carbon Partnership Facility (FCPF), a ten-year initiative to establish a forest carbon market that economically favours forest conservation and benefits developing countries. Nine industrialized countries have pledged US\$155 million to start. Currently, developing countries cannot sell carbon credits from avoided deforestation or degradation; however, FCPF will support pilot efforts intended to help inform related decisions for the post-2012 climate change regime and for a potential carbon market mechanism.

Also at Bali, the Government of Norway announced that it is ready to provide funding of 3 billion kroner (about US\$570 million) per year over a five-year period to support REDD efforts.



Two new FAO books on mangroves: a global assessment...

The world's mangroves 1980-2005. 2007. FAO Forestry Paper 153. Rome, FAO. Mangroves are coastal forests found in sheltered estuaries and along river banks and lagoons in the tropics and subtropics. The term "mangrove" describes both the ecosystem and the plant families that have developed specialized adaptations to live in this tidal environment. Mangroves fulfil important socio-economic and environmental functions: providing wood and non-wood forest products, protecting shores against wind, waves and water currents; conserving biological diversity; protecting coral reefs, sea-grass beds and shipping lanes against siltation; and providing habitat, spawning grounds and nutrients for a variety of fish and shellfish, including many commercial species. High population pressure in coastal areas has, however, led to the conversion of many mangrove areas to other uses, including infrastructure, aquaculture, rice and salt production.

This publication, prepared as a thematic study within the framework of the Global Forest Resources Assessment 2005, provides comprehensive information on the current and past extent of mangroves in all 124 countries and territories in which they exist. It presents both regional and global overviews of mangrove vegetation, species composition and distribution, together with an indication of the main uses and threats in each region.

FAO prepared *The world's mangroves 1980-2005* in collaboration with mangrove specialists throughout the world. It builds on a 1980 assessment by FAO and the United Nations Environment Programme (UNEP), the FAO Global Forest Resources Assessment 2000 (FRA 2000) and 2005 (FRA 2005) and an extensive literature search. Some 2 900 national and subnational data sets on the extent of mangrove ecosystems were collected during the process.

The results indicate that global mangrove area is currently about 15.2 million hectares, with the largest areas found in Asia

and Africa, followed by North and Central America. An alarming 20 percent of mangrove area, or 3.6 million hectares, has been lost since 1980. More recently, the rate of net loss appears to have slowed down, reflecting an increased awareness of the value of mangrove ecosystems, but the annual rate of loss is still disturbingly high.

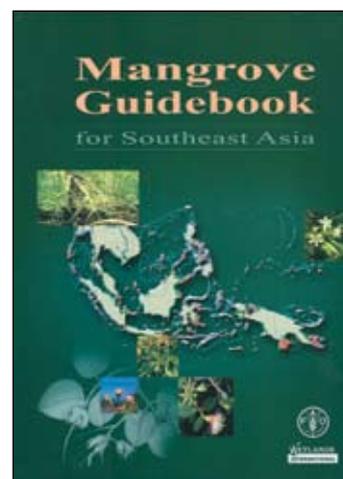
Removals of wood and non-wood forest products are rarely the main cause of mangrove loss. Human pressure on coastal ecosystems and the competition for land for other uses are the main causes of the decrease in area reported. The relatively large negative change rates that occurred in Asia, the Caribbean and Latin America during the 1980s, for example, were primarily due to large-scale conversion of mangrove areas to aquaculture and tourism infrastructure.

The information highlighted in the report, as well as the gaps in information revealed, will assist mangrove managers and policy- and decision-makers worldwide in ensuring the conservation, management and sustainable use of the world's remaining mangrove ecosystems.

...and a species guidebook for Southeast Asia

Mangrove guidebook for Southeast Asia. W. Giesen, S. Wulffraat, M. Zieren & L. Scholten. 2006. RAP Publication 2006/07. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific & Wetlands International. ISBN 974-7946-85-8.

Southeast Asia is endowed with the world's largest expanse of mangroves which are at the same time the world's most biologically diverse and varied in structure. In the past few decades, however, much of the mangrove area has been degraded and destroyed. Many mangrove conservation and rehabilitation programmes have been launched in recent years. In the course of such activities, programme staff have faced continual difficulties in identifying plant species growing in the field. This field guide to the mangroves and associated plant species of the subregion was developed to fill an important gap.





This extensive guidebook – almost 800 pages long – represents the first attempt to cover all mangrove plant species in Southeast Asia. In the first part, it introduces mangroves in general and Southeast Asia's mangroves in particular. The second part provides descriptions of 268 plant species divided in seven groups – ferns; grasses and grasslike plants; other ground-dwelling herbs; epiphytes; vines and climbers; palms, cycads and pandans; and trees and shrubs. Skillfully drawn black-and-white illustrations of the plants greatly enhance the usefulness of the book.

This book will help more people, especially students, learn about mangrove forests in Southeast Asia and will support further advancement of mangrove conservation and rehabilitation programmes. It is a useful tool for mangrove forest managers, foresters, coastal resource managers, scientists, educators, students and interested lay people, not only in Southeast Asian countries, but in all countries where mangroves grow.

Global assessment of bamboo resources

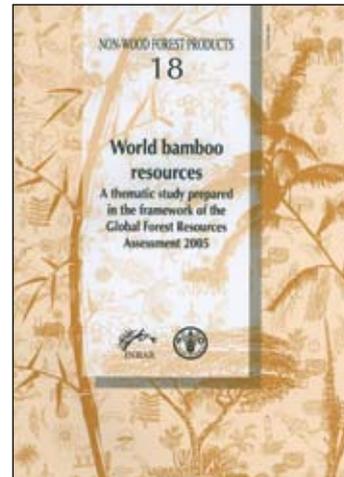
World bamboo resources. M. Lobovikov, S. Paudel, M. Piazza, H. Ren & J. Wu. 2007.

Non-Wood Forest Products No. 18. Rome, FAO. ISBN 978-92-5-105781-0.

Bamboo is a woody grass widely distributed in tropical, subtropical and mild temperate zones in all regions of the world. As a major non-wood forest product and wood substitute, it has always had an important economic and cultural role across Asia. Now the use of bamboo is growing rapidly in Latin America and Africa as well. In some countries, the processing of bamboo is shifting from low-end crafts and utensils to high-end, value-added commodities such as housing, pulp, paper, panels, boards, veneer, flooring, roofing, fabrics, oil, gas and charcoal (for fuel and as an excellent natural absorbent). The bamboo shoot is also a nutritious vegetable. Bamboo is an increasingly important economic asset in poverty eradication and economic and environmental development.

Bamboo is a forest plant but is also widespread outside forests, including on farmlands and riverbanks, along roads and in urban areas. Taxonomists still debate the total number of bamboo species and genera – an estimate is about 1 200 species in some 90 genera.

This study, prepared by FAO jointly with the International Network for Bamboo and Rattan (INBAR), was undertaken as one of seven thematic studies within the Global Forest Resources Assessment 2005 (FRA 2005) process and is a first attempt at systematic reporting of the best available information on bamboo resources and utilization at the global level. The study is the result of a three-year process of data collection and validation involving many partners from participating countries and international organizations, in line with the FRA 2005 philosophy of global partnership. Although data availability and quality are often weak, the main value of the study is that it established a systematic methodology and launched the most comprehensive assessment of global bamboo resources to date.



Sixteen countries in Asia reported a total of 24 million hectares of bamboo resources. Five African countries reported 2.8 million hectares. It is estimated that ten Latin American countries may have over 10 million hectares of bamboo resources, bringing the world total to some 37 million hectares or roughly 1 percent of the global forest area. However, the figures represent only rough estimates. They also include bamboo mixed with other species (in which bamboo is not necessarily predominant) and bamboo on non-forest land (including mixed with other trees or crops).

The publication also reports on species diversity, growing stock, biomass, removals, ownership and health status of the resource, and on bamboo products and trade.

It is hoped that the information and knowledge generated by this study will be useful to national policy processes, and that feedback from users will help improve future global resources assessments.

Tracing the causes of illegal logging

Illegal logging: law enforcement, livelihoods and the timber trade. L. Tacconi, ed.

2007. London, UK, Earthscan. ISBN 978-1-84407-348-1.

Illegal logging is widespread – accounting for more than 50 percent of all timber in some countries – and causes great damage. Once cut, illegal logs feed the great demand for exotic hardwoods in developed and developing countries. The result has been an enormous loss of both revenue and forest resources. Consequently the issue has risen to the top of the global forest policy agenda as one of the major threats to forests, and donors and national governments are starting to develop initiatives to combat illegal logging. Yet considering the magnitude of the problem, surprisingly little is known about the causes of illegal logging and its impacts on biodiversity, people's livelihoods and national economies.

Paradoxically, despite the negative impacts, illegal logging also benefits many stakeholders, including some marginalized



communities. How can illegal logging be tackled without causing poverty in local communities? This book, published with the Center for International Forestry Research (CIFOR), examines the key issues including legislation and law enforcement, supply and demand, governance and corruption, forest certification, poverty, local livelihoods, international trade and biodiversity impacts. It includes key case studies from forest-rich regions in the Americas, equatorial Africa and Asia.

Illegal logging can only be tackled by addressing the underlying economic, political and social causes. While there are clearly no easy answers, this book explores the many dimensions of the causes, impacts and implications of illegal logging for forests, people, livelihoods and forest policy. While much is still unknown about the subject, *Illegal logging* adds to the growing literature, highlighting the key issues that must be understood in order to develop policy that can make a difference.

Revisiting the state of the environment

GEO-4: Global environment outlook – environment for development. 2007. Nairobi, Kenya, United Nations Environment Programme (UNEP). ISBN 978-92-807-2836-1 (paperback), 978-92-807-2872-9 (hardback)

The 1987 report of the United Nations World Commission on Environment and Development report, *Our common future* (also known as the Brundtland Report), is widely credited for introducing sustainable development into the public consciousness. The fourth edition of *Global environment outlook (GEO-4)* takes stock of how far society has come in the 20 years since. The picture is grim, showing evidence of decline almost all across the board: more greenhouse gases, more widespread pollution, declining availability of freshwater, deforestation, degradation of farmland, depletion of natural resources, acidification of oceans.

Compiled and written by hundreds of researchers from a great variety of disciplines, *GEO-4* provides an overview of global social and economic trends and the state and trends of the global and regional environment over the past two decades, as well as the human dimensions of these changes. The publication reminds readers that issues of forestry, freshwater supplies, agriculture, biodiversity and desertification are connected to each other and to climate change. It also explores the links between social trends and environmental decline, examining how increasing population pressure and the increasing divergence between rich and poor influence the environment – resulting for example in more deforestation.

As defined in *Our common future*, “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. *GEO-4* finds, however, that current human society tends to focus on meeting the needs of the present, and in doing so is indeed compromising the ability of future generations to meet their own needs.

The nearly 600 page publication is divided in six sections. The first summarizes the evolution of issues since 1987. The second section describes the state and trends of the environment from 1987 to 2007, with separate chapters devoted to atmosphere, land, water and biodiversity. The state of forests is extensively explored in the chapter on land.

Section C presents the environmental status and trends from a regional perspective. Section D explores the human dimensions. One chapter probes areas of vulnerability and identifies opportunities for improving human well-being, while another examines environmental interlinkages and governance needs. The fifth section looks forward to 2015 and beyond; and the last summarizes options for action, categorizing possible solutions along a continuum from proven to emerging.

GEO-4 provides an outlook for the future and policy options to address present and emerging environmental issues. It will be of interest to policy-makers, professionals and academics in many sectors, as well as to the wider public.

