State of scientific knowledge on water and forest

by Thomas HOFER

The importance of the relationship between water and forests is increasingly recognised, not only in the scientific world but also in policy discussions. However education and capacity-building across disciplines is necessary in order to address this problem. The objective of this paper is to structure and synthesise a part of the existing knowledge about the interactions between water and forests.

Introduction

A substantive volume of scientific knowledge about the interactions between forests and water is available. Despite significant advances in the scientific understanding of forest and water interactions, the role of forests in relation to the sustainable management of water resources remains a contentious issue. Difficulties persist in transferring research findings to different scales, including national, regional or even watershed scales. There is a gap between research and policy, which persists partly because of the difficulties involved in formulating general principles about forest and water interactions, and partly because of a failure to communicate effectively the results of hydrological and forestry research to policy-makers. Further education and capacity-building across disciplines is necessary in order to address this problem. In addition, site-specific examinations regarding forest and water interactions are necessary for any concrete interventions.

The objective of this paper is to structure and synthesise the existing knowledge about the interactions between water and forests. Due to the broad spectrum of scientific research, this paper serves just as a brief overview of water and forest topic.

Picture1: A forested watershed in the Ecuadorian Andes. *Photo T. Hofer.*

Water and forest interactions

The relationship between water and forests depends on a number of factors:

– Climatic zones: for example, the relationship is different in a forest located in a temperate zone with humid conditions and abundant precipitation compared to a Mediterranean forest where semi-arid conditions prevail.

– Time of the year: in areas characterized by a monsoon climate, for example, more water can infiltrate into the soils at the beginning of the rainy season than towards the end when the soils are saturated and the ground water table is close to the surface.

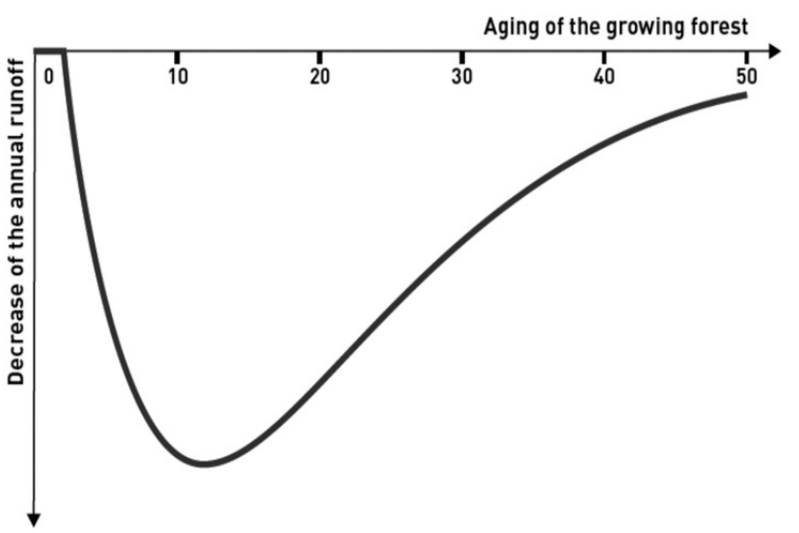
– Geological situation: in regions characterized by karstic phenomena, more rainwater disappears in the underground than in regions characterized by crystalline or metamorphic rocks.

– Tree species composition and structure: the relationship is different in a mono-culture forest plantation with even-aged stands and, possibly, barren ground surface in comparison to a forest stand which is characterised by a variety of tree species, a solid canopy, litter layer and trees of different age and height.

– Forest management practices: the interactions between forests and water are different in forests with extensive and low impact management than forest plantations with high impact harvesting and clear cutting.

Evidence has also shown that the water use of a forest plantation varies over the life cycle. The model developed by Kuczera (Figure 1) shows the relationship between the dynamics of the annual catchment water yield (vertical axis) and the ageing of the growing forest (horizontal axis). It reveals (within the Australian context) that in the initial phase of the growth of a new forest, the annual catchment water yield tends to decrease, reaching a maximum reduction at approximately 12 years, then tends to return to the original conditions prior to the planting (in this case, after approximately 50 years).

Figure 1: Kuczera model of water use over the plantation cycle. *(Kuczera 1987).*



Forests and water quantity

Forests influence the amount of water available and the timing of water delivery. Stream-flow regulation by forests is the result of processes in the forest canopy, on the surface and below the ground – a combination of interception, transpiration, evaporation, evapotranspiration and infiltration. In general, forests return less water to soils compared to grasslands or cultivated land because of their higher contribution to atmospheric moisture via evapotranspiration. Water infiltration and retention are facilitated in forest soils by dense, deep root systems and a thick, porous organic top layer. Surface runoff is, therefore, minimal in forests; and groundwater recharge efficient, resulting in more consistent stream flows over time compared to any other land cover. To support this regulating function of forests, forest managers should aim to main-

tain permanent groundcover, limit the compaction of soils, maintain a high amount of organic matter in the soil, and increase the "surface roughness" - that is, the unevenness of the soil surface, which helps increase water infiltration.

Forests and water quality

Forests make a great contribution in maintaining high water quality. Forests and trees stabilise soils, minimise soil erosion and reduce sedimentation in water bodies. A very important function of forests, particularly stands with a healthy litter layer and undergrowth, is the filtering of water pollutants from upstream activities. Riparian forests merit a particular mention in this regard. Healthy forests with their canopies, undergrowth, leaf litter and other forest debris reduce the impact of rain drops on bare soils and are, therefore, the most effective land cover for minimising water sediments. Because most forestry activities do not involve fertilisers or pesticides, forests are vital for the supply of safe drinking and irrigation water. Where forest extraction is carried out, sediment production (from roads, log landings, skid trails and soil compaction) and chemical pollution should be minimised by good forest practices.

Forests and disaster risk management

Forest soils act as sponges and retain water longer than soils under other land uses. Tree and forest removal therefore increases water discharge and the risk of flooding in rainy seasons, and the risk of drought in dry seasons. Reforestation and afforestation have the opposite effect on water quantity. However, the role of forests and trees in the moderation of floods and droughts is a question of scale: Forests and trees may reduce the peak and areal extent of flooding at the micro level, and for short-duration and low-impact rainfall events. The extent of large scale flooding in the lower parts of major river basins does not seem to be linked to the degree of forest cover and the management practices in the catchment

Picture 2:
Drinking water in a Nepali village which originates in a forested mountain watershed. *Photo T. Hofer.*

area. Accordingly, while afforestation and rehabilitation activities of forest land play an important role in the reduction of the flood risk at the local level, they should not be justified with expected reductions of flood risk in the lowland and delta areas of river basins. A similar differentiation has to be considered in the discussion about the role of trees and forests in slope stabilization: while forests can help stabilize slopes and protect them from shallow landslips, they cannot prevent large scale landslides and mass movements which are triggered by tectonic movements or extraordinary rainfall events.

Water and forests in semi-arid and arid areas

The interactions between forests and water require particular attention under semi-arid or arid conditions such as the Mediterranean region. There is no doubt that forests and trees consume water and, accordingly, reduce water availability for other uses. This water consumption obviously depends on the tree species considered. On the other hand, forests and trees prevent desertification and salinization, provide shade, improve water infiltration and protect against soil erosion and flash floods. Therefore, the trade-offs between water use by trees and forests and the environmental

Picture 3: Scattered trees and a dry river course in the High Atlas of Morocco. *Photo T. Hofer.*

services they provide requires careful consideration in land use planning and decision making. In particular, if the management goal is to increase water yield in a forest area through tree removal, the potential negative effects on water quality, landslip risk and biodiversity need to be taken into account.

Water, forests and climate change

Increasingly, the role of forests in climate change mitigation is recognised. In particular, forests have a great potential to reduce impacts of climate change on water resources. Accordingly, the water-related environmental benefits of trees / forests get more important. Intact forest ecosystems with their buffering functions (e.g. cooling effects, interception of precipitation and evapotranspiration, water storage and wind shield) can significantly contribute to the mitigation of and adaptation to extreme weather events and resulting catastrophes such as floods, droughts and temperature increase. For example, the shade of riparian forests can help reduce thermal stress to aquatic life as climate warming intensifies. However, forests themselves are vulnerable to climate change. Reduced and more erratic rainfall and runoff will influence the vitality, resilience and even survival of trees and forest ecosystems. Action needs to be taken to reduce the vulnerability of forests and enhance their resilience to climate change with the aim of ensuring the continued provision of vital ecosystem services, such as water, and protective functions ensured by forests.

Box 1: The importance of forests for water supply - some facts

– More than one in six people do not have access to safe drinking water.
– 80% of the global population lives in areas where water resources are insecure.
– By the year 2025, 1.8 billion people will be living in regions with absolute water scarcity.
– Forested watersheds supply 75% of the world's accessible fresh water.
– At least 1/3 of the world's biggest cities draw a significant portion of their drinking-water from forested area.

International attention and momentum regarding water and forests

The importance of the relationship between water and forests is increasingly recognised, not only in the scientific world but also in policy discussions (see Box 1). As part of the follow-up to the "Shiga Declaration on Forests and Water", developed in the context of the 3rd World Water Forum in 2002, and to the "Forest Europe Warsaw Resolution 2: Forests and Water" in 2007, a significant number of events on forests and water were organised from 2008 onwards by different institutions and with different entry points. By presenting experiences ranging from research to project implementation worldwide, these events provided new and up-to-date insight into the topic. Important recommendations for the way forward resulted from this process, including the need to translate scientific knowledge into tools that can be used by policy-makers and the need to share existing experiences related to joint forest and water management.

Having been involved in most of these events in one way or the other, the Food and Agriculture Organization of the United Nations (FAO) took the initiative of synthesising the main outcomes and recommendations from these meetings and this extended debate by developing a comprehensive plan to address future courses of action. As a

result, a publication entitled "Forests and Water: International Momentum and Action" was released on the occasion of the 1st International Day of Forests on 21 March 2013. This document includes a 20 point agenda on forests and water, structured into 7 clusters:

1. Process understanding and research.
2. Cooperation, policy and institutional development.
3. Economic incentives and mechanisms.
4. Climate change mitigation and adaptation.
5. International dimension.
6. Awareness rising, capacity development and communication.
7. Forests and water management.

The document can be downloaded from www.fao.org/docrep/017/i3129e/i3129e.pdf. Subsequently, an expert meeting in 2013 in Kunming, China was held with participation of key stakeholders from research institutes, the private sector, NGOs and international organizations and political processes. Kunming provided an opportunity to confirm the values of the agenda and to start the planning of concrete outputs, timelines and responsibilities for its implementation by drafting a Five-year Action Plan. FAO was invited to take the lead in facilitating and moderating the implementation of the Action Plan. The International Forests and Water Dialogue, which will be held on 8-9 September in the context of the XIV World Forestry Congress in Durban, South Africa, will be a milestone in this process and will see the official launch of the Five-year Forests and Water Action Plan (see Box 2).

Box 2: International Forests and Water Dialogue at the XIVth World Forestry Congress in Durban, 8-9 September

The International Forests and Water Dialogue will bring key stakeholders and implementation partners to the discussion table and will help to draw international attention to the significance and urgency of the Forests and Water Agenda. This two-day special event will see the finalization and launch of the Five-year Forests and Water Action Plan. Calling for action in the areas of science, policy, economics and practices for forests and water, the Plan was drafted over the last two years by an expert group and partner organizations from around the world.

Conclusions and recommendations

The numerous interactions and benefits between forest and water sectors highlight the need for strengthening existing and establishing new linkages between them, and fostering their collaboration. This cooperation is of particular importance as the forest and water sectors need to shape their responses to climate change, resulting in possible adjustments of relevant policies and legislations, institutional mechanisms, research reorientation and integrated management strategies and plans. Forests and water must be considered at the landscape level, taking into account ecological and hydrological aspects, as well as land use systems and social issues. Therefore, compensating forest owners for the water-oriented management of their forests can help preserve healthy forest ecosystems. For the promotion of the global Forests and Water Agenda, the following recommendations can be formulated:

– Improve knowledge, bridge science and policy.
– Share lessons learned.
– Harmonise interests, weigh trade-offs, balance solutions.
– Dialogue across administrative boundaries.
– Innovate institutional mechanisms.
– Value water-related environmental services.
– Develop planning, policy and legal instruments.

The Sustainable Development Goals, which are currently being negotiated by the General Assembly of the United Nations, provide a very appropriate framework for the implementation of the Forests and Water Agenda (see Box 3).

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Box 3: Reference to forests and water in the Sustainable Development Goals

– By 2020 protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
– By 2020 ensure conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands...

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Summary

State of scientific knowledge on water and forest

A substantive volume of scientific knowledge about the interactions between forests and water is available. The relationship between water and forests depends on a number of factors such as climatic zones, time of the year, geological situation, tree species composition, forest management, etc. Forests influence the amount of water available and the timing of water delivery. Forests make a great contribution in maintaining high water quality. Forests and trees can reduce the dimension of floods and droughts and the incidence of landslides. Forests have a great potential to reduce the impacts of climate change on water resources. In arid and semi-arid conditions, the trade-offs between the water consumption by forests and trees and the environmental services they provide require a careful consideration. The importance of the relationship between water and forests is increasingly recognised, not only in the scientific world but also in policy discussions. The International Forests and Water Dialogue, which will be held on 8-9 September in the context of the XIVth World Forestry Congress in Durban, will see the official launch of a global Five-year Forests and Water Action Plan.

Résumé

On dispose aujourd'hui de bonnes connaissances scientifiques sur les interactions entre la forêt et l'eau. Ces relations dépendent d'un grand nombre de facteurs, parmi lesquels la zonation climatique, l'époque de l'année, le contexte géologique, l'identité spécifique des arbres, la gestion forestière etc. Les forêts ont une influence sur les quantités d'eau disponibles dans l'écosystème et le calendrier des disponibilités. Leur contribution au maintien de la qualité de l'eau est considérable. Les forêts peuvent réduire l'importance des inondations et des périodes de sécheresse, ainsi que les risques de glissements de terrain. Elles ont enfin un fort potentiel de réduction de l'impact des dérèglements climatiques sur les ressources en eau. En milieu aride et semi-aride, les compromis entre consommation d'eau par les forêts et services environnementaux sont particulièrement importants à gérer. L'importance des relations entre l'eau et les forêts est de plus en plus reconnue, non seulement par la communauté scientifique mais aussi dans les discussions politiques. Le Dialogue International Forêt et Eau « *International Forests and Water Dialogue* », qui aura lieu les 8 et 9 septembre 2015 dans le cadre du XIXe Congrès forestier mondial, à Durban, sera l'occasion du lancement officiel d'un Plan quinquennal d'action global sur l'eau et la forêt (*Global Five-year Forests and Water Action Plan*).