International Water Resources Association
Water International, Volume 31, Number 4, Pg. 541-543, December 2006

Discussion Note

Comments by Nick A. Chappell on **"Forests and Floods: Moving to an Evidence-based Approach to Watershed and Integrated Flood Management" by Ian R. Calder and Bruce Aylward.** Published in Water International Volume 31, Number 1, March 2006: 87-99.

Introduction

Calder and Aylward contribute to the debate on the effects of forests and forestry on hydrology, and focus primarily on the presence or absence of evidence for impacts on floodwaters. While this scientific debate is not new, extending back for at least 150 years (Surell, 1841; Andréassian, 2004), the need for this debate followed by concerted action has never been more important. The last three decades have seen the greatest rate of forest loss within man's history, leaving tropical regions with only half of their former forest land. Within regions experiencing such extensive forest disturbance, there is the potential (at least on theoretical grounds) for water resources to be affected. Aspects of particular concern, if present, are changes to over-bank flows ('floods'), river low-flows and water quality – environmental phenomena most critical for human life and livelihoods.

Many questions regarding the hydrological functioning of forests versus other land-uses remain poorly researched, particularly in those tropical regions experiencing such large land-cover changes. A heightened level of scientific debate is needed to encourage essential research, but also to provide interim conclusions that can promote those management practices that have the best impact on people, economics and ecology within each tropical nation. Given the dearth of findings on the hydrological functioning of forests within tropical regions in particular, it is essential that hydrologists keep an open mind and avoid jumping to unfounded conclusions that they often accuse politicians and the wider public of doing. Within the *Water International* article and indeed elsewhere (e.g., Calder, 2005), the authors conclude that forests "have at best marginal benefit and at worst negative impacts" (p.87) and that forestation schemes (reforestation or afforestation) are a "wastage of development funds" (p.87). Given such a provocative statement, I would like to highlight some of the uncertainties in the scientific evidence supporting the conclusion that forests and forestry have on balance a negative impact on water resources, particularly flooding, within the wider environmental system of the tropics.

Long-term, Large-scale Evapotranspiration

Tropical water balance studies, almost exclusively utilising data from small catchments, show that forests generally return more water to the atmosphere by evapotranspiration than do most other land-covers (Bruijnzeel, 2004); perhaps with some notable exceptions such as irrigated agriculture (Schreider *et al*., 2002). The magnitude of the evapotranspiration differences are, however, incredibly variable and some would suggest (Hibbert, 1967; Andréassian, 2004), not very predictable even at small catchment scales. This is further complicated by the fact that none of these studies have been undertaken on basins underlain by deep rock aquifers (e.g., < 100 m depth), where the differential effect of trees over shallow rooted vegetation would be expected to be much less (Chappell and Bonell, 2005). Furthermore, studies reporting very elevated levels of evapotranspiration from certain plantation trees are invariably undertaken over the first few years of plantation establishment. There are very few studies that have monitored water use by mature plantations, perhaps 50 or 100 years in age, and some studies (e.g., Vertessy *et al*., 2003) show that evapotranspiration rates return to those of native forests over these longer timescales.

Uncertainties in water use increase substantially if we seek to quantify the effects of forest loss or its corollary, forestation, at the scale of the basins of the world's great tropical rivers, e.g., the Ganga in India or Zhu Jiang in Southern China. Certainly, at scales of greater than 100,000 km^2, the effect of local storm events on the annual river hydrograph would be damped by subsurface and channel routing over several days and weeks. Consequently, increases in the available riverflow resulting from extensive forest loss over the whole macro-basin are likely to raise all parts of the annual hydrograph, including the (flood) peaks. Our difficulty is that changes at this macro-scale due to a dynamic land-cover are likely to be masked by temporal variations in the climate. Thus, where studies fail to identify the effects of land-use change (e.g., the Hofer, 1998 study cited by Calder and Aylward), it does not mean that these changes have not had a 'significant' impact, only that our statistical modelling techniques may not be sophisticated enough the identify changes or discern the causal factors. This identifiably problem would relate equally to quantifying forest-cover impacts on low-flows, and requires further developments in time-series modelling to solve.

Land disturbance, channel sedimentation and sustainable management

Calder and Aylward highlight the potential negative impact of forestry roads on the stream peakflows seen within studies in the Pacific Northwest of the USA. They do fail, however, to note that even at the small basin scale of these studies there is debate about whether the impacts can be seen for larger storm events (Thomas and Megahan, 1998). Equally, there is no mention of the role of roads on peakflows within the agricultural landscapes that replace the forest lands (see e.g., Ziegler *et al*., 2004) or whether these effects are likely to persist as basin scale increases.

Extensive soil erosion and slope instability related to forest clearance or agricultural intensification, historically, has been successfully checked by extensive forestation across large areas of Honshu Island, Japan and the southern USA. Calder and Aylward belittle these achievements by only making cursory reference to this key environmental service of forests and forestry. While talking of "wastage of development funds" they state that these soil conservation benefits are "likely to be site, and possibly event, specific" (p.89). At any humid tropical locality, it is certainly well established that tropical agricultural practices involving regular tillage produce higher rates of erosion (Kimaro *et al*., 2005) than the natural forests that they replace. I agree with Calder and Aylward, that establishment of forest plantations within these agricultural or degraded areas will not automatically reduce erosion, as it will depend on the management practices adopted (see Evans and Turnbull, 2004). Sustainable Forest Management (SFM) practices are being developed to ameliorate the environmental impacts of plantations (e.g., Sankar *et al*., 2000) as well as those of natural forest harvesting within the tropics. Rather than dismiss the potential protective role of tropical plantations, hydrologists should be undertaking the necessary research that quantifies the impacts (negative or positive) of plantation establishment on hydrological services such as erosion control. We still lack the necessary hydrological case studies to underpin many practices involved in the sustainable management of tropical forests (Thang and Chappell, 2004). Critically, Calder and Aylward note the impact of this erosion on flooding via downstream sedimentation and consequent loss of channel capacity (p. 90). As large tropical rivers have relatively shallow and wide channels, small changes in channel capacity could easily increase the likelihood of over-bank flows and extensive flooding. This understudied topic needs considerably more research, as this effect of forest disturbance could potentially have a greater impact on over-bank flows than the change in evapotranspiration. At the small basin scale, un-surfaced roads are a key source of these river sediments (Chappell *et al*., 2004; Sidle *et al*., 2006). Again, more research is needed that can quantify the effect of roads on sediment delivery at the macro-scale and identify those agricultural or forestry practices associated with road construction and maintenance that have the least impact.

In conclusion, I feel that with the current state of knowledge of the hydrological functioning of primary and managed tropical forests, we cannot conclude that the overall hydrological impact of forests or forestry is definitely neutral or negative. Even where specific hydrological changes (e.g., peakflows) are examined, it can be seen that other indirect changes (e.g., erosion and subsequent downstream sedimentation) may have equally important impacts. This shows how individual forest or forestry impacts on the hydrological system must not be studied in isolation from the other interrelated impacts. We are in the position where we have lost half of our natural forest within the tropics, and where plantation development only covers a tiny fraction of this area. If a majority of hydrologists and NGOs continue to have only a negative attitude towards well-managed tropical forestry, rather than an awareness of the scientific complexities and uncertainties associated with forestry impacts and the need to study these, then we give licence for the last remnants of tropical natural forest (primary or managed) being converted to other land-uses. Within some regions it has been demonstrated that tropical forests can be managed in a certifiably sustainable manner (Thang and Chappell, 2004), but there a major gaps in the hydrological science, and forestry would greatly benefit from new, targeted research efforts by global community of hydrologists. I look forward to reading further stimulating discussions of new research findings by Ian Calder, Bruce Aylward and others on these forest-water interactions within the critical area of the tropics.

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