FUNCTIONAL VALUE OF BIODIVERSITY PROJECT

(A BNPP 'Forest and Biodiversity' Window Project)

Summary of findings

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Policy context and goal

Efforts to 'mainstream' biodiversity have been frustrated by lack of scientifically based, comprehensive assessments of the functional contribution of biodiversity conservation to rural livelihoods and economic development. While there are many such functional contributions, one of the most frequently discussed is the contribution of conservation to maintenance of key hydrological processes. Such processes include regulation of water flow (flood prevention, dry season flows) and maintenance of water quality. It is supposed – plausibly but without much evidence – that changes in upland land use practices could help poor hill-dwellers, conserve biodiversity, and provide 'bankable' benefits for downstream urban-dwellers. In particular, there is considerable policy interest in the argument that maintenance of biodiverse forests in upper watersheds can mitigate flooding in densely populated urban or agricultural lowlands. If so, large economic value attaches to maintenance of those upland forests. Policies that mobilize this value could simultaneously promote development and conservation.

Suppositions of this kind underlie many natural resources management policies and projects, and have real consequences for investments and for rural livelihoods. But an inadequate understanding of the hydrology-biodiversity-forest relationships could lead both to overlooked opportunities and to unrealistic expectations. ***The goal of the project was to better inform policy makers about the nature, magnitude, and geographic location of these hydrology-biodiversity-forest relationships.***

Scientific context

For decades (at least) the scientific view of deforestation and hydrology has diverged from the popular view. In particular, the popular view – and that of many policy-makers – is that forests constitute 'sponges', soaking up water in the wet season, slowly releasing during the dry season. This view is now discredited among scientists. In fact, research suggests that land management practices during and after forest clearing has a much larger influence on dry season flows than deforestation, *per se*. And it is now understood that reforestation will typically reduce rather than increase dry season flows.

There is less consensus about the role of deforestation and flooding, especially in larger river basins where floods cause severe economic damage and human suffering in dense lowland populations. The popular view firmly associates deforestation with large scale flooding. Scientific reasoning suggests that rainstorms large enough to drench the basin—causing a catastrophic flood -- would do so regardless of landcover. But empirical support for this argument is thin.

Indeed a recent literature review found no conclusive evidence, one way or the other, for the impact of land use change on water flows or sediment transport in watersheds greater in size than 100 km^2. The lack of evidence reflects, to large degree, the difficulty in finding natural experiments – comparable watersheds that differ only in land cover – as the scale of interest increases.

Project Methodology

For this reason, the project relied on a nested suite of hydrological simulation models. These models divide the watershed into grid cells. Soils, vegetation, and precipitation is specified for each grid cell, and the model computes soil moisture, water use by vegetation, and runoff for each grid cell. River flow is computed by accumulating runoff in a downstream direction along river networks derived from topographic data. The models are evaluated and calibrated by comparing observed and model-predicted river flows. A calibrated model can then be used to predict the effect on low flows, peak flows, and average flows of geographically specific scenarios of land cover change. Sensitivity analyses are used to assess the robustness of conclusions to uncertainty about parameters or data.

Because the project aimed at understanding forest-biodiversity-hydrology links in basins of widely varying scales, researchers employed a suite of models with different spatiotemporal resolution. These range from soil transport models operating at a spatial scale of meters and a temporal scale of seconds to a global-scale model (applied to the pan-tropical domain) operating at a spatial scale of about 50 km^2 and utilizing monthly data. Roughly similar with respect to the hydrological processes they consider, these models trade off detail against geographic scope. The project focused mostly on water quantity issues: total flows, peak flows, and low flows.

Principal Findings and their Policy Implications

The following does not attempt a comprehensive summary of the overall state of knowledge on forest-biodiversity-hydrology relationships – a task that will be addressed in policy briefs now in draft or under development. Rather it emphasizes the principal areas where the project was able to extend or enhance the current state of knowledge.

Simulation models can inform policy and project design regarding the impacts of land use management and biodiversity on hydrological functions

With relatively modest resources and limited new data, project researchers were able to -adapt existing hydrological software to calibrate and evaluate hydrological models of the Mae Chaem watershed in Thailand (a 4000 km^2 watershed). Taking advantage of pre-existing data resources, researchers calibrated and applied models for the Mekong and its tributaries; and for more than 100 large tropical watersheds, worldwide.

What makes this possible is:

- a growing portfolio of documented, 'off-the-shelf' hydrological models that use a simple gridded framework to keep track of precipitation, land cover, and water flows.

- increasing availability of spatial data on land cover, land use, biodiversity, hydrometeorology, and other biogeophysical data.

The accuracy of these models is however limited by the accuracy and scope of available data. Precipitation data are especially critical. Long time-series are important for modeling infrequent but severe flood and erosion events. Detail on the precise timing and location of rain is important for understanding flood frequency. Project researchers used innovative techniques – including the use of satellite data, and sensitivity testing to different spatiotemporal patterns of rainfall – to surmount data limitations. ***But one policy implication is that the unglamorous business of strengthening and maintaining meteorological and hydrological observation networks is of great importance for designing and implementing natural resource management policies.***

While hydrological models are not perfect, they do provide useful quantitative insight into the potential effect of land cover change on high, low, and average flows, and possibly on sedimentation and erosion. Projects that seek to invest millions or tens of millions of dollars in natural resources management, or policies that aim to influence land use management on a scale of hundreds of thousands of square kilometers, might justifiably invest tens or hundreds of thousands of dollars in hydrological or coupled hydrological-economic models in order to test assumptions and optimize project and policy design.

Deforestation increases total water yield at all scales

Trees pump water into the air. Project analyses underscore, and demonstrate across all watershed scales, this underappreciated relationship between forests (including those of biodiversity interest) and hydrological functions. ***Hence, while there are examples of forest conversion that result in diminished dry season flows, a general impact of forest conversion is to increase the availability of water for agricultural and other human uses. This potentially sets up a tradeoff between environmental and economic demands for water.***

How severe is this tradeoff, and what are the policy implications? In humid tropical areas, where rain forests predominate, the proportional increase in water yields from deforestation is low. Simulations show that even a catastrophic global loss of high biodiversity forest areas would benefit a relatively small number of people in water-scarce areas. In general, increased water use efficiency would be the most direct option for meeting the water needs of these areas. However, ***trade-offs between water use of forests and of agriculture are likely to be more acute in less-humid areas. Policy analysis here needs to confront the tradeoffs and avoid assuming, counterproductively, that reforestation or forest regeneration will improve water availability as well as enhancing biodiversity.***

Deforestation increases risk of moderate floods even in large basins

There is a large gap between the popular and scientific conceptions of forests and flooding. A popular view – echoed in policy actions and pronouncements – is of a relationship strong enough to justify maintenance of upland forests as a flood prevention mechanism in large watersheds. Scientists have been skeptical that any such ‘far-field’ relation exists in watersheds greater than a few tens or hundreds of square kilometers.

The FVB project supports an intermediate view. The project finds that extensive deforestation is associated with greater daily peak flows in basins on the scale of thousands of square kilometers, greater monthly peaks on the scale of tens of thousands to hundreds of thousands of square kilometers, and with greater annual flows in the largest basins. Taken together, the models suggest that basin-wide deforestation could increase seasonal peaks even in quite large basins. Loss of all forests in high-biodiversity tropical areas would increase annual water yield by more than 25% for floodplain areas inhabited by about 100 million people. The presumption is that the annual yield increases would be associated with significant peak season flow increases in these floodplains.

These results must be interpreted cautiously. They do not suggest that large scale deforestation would increase the incidence or severity of truly catastrophic floods such as might have occurred every hundred years prior to deforestation. The implication rather is that typical high season flows would increase and that moderate floods – say, the five to twenty year events – would become more severe. Nor do the results imply that forest protection is necessarily the most effective way to mitigate trends towards increasing population exposure to flood risk. Other interventions – especially maintenance of wetlands, avoidance of impermeable surfaces in urban and peri-urban areas, and a cautionary approach to floodplain development – deserve arguably greater attention. On the other hand, ***the results imply that maintenance of forest cover, for biodiversity reasons, in populated or agriculturally important watersheds could have important side-benefits in limiting the severity of large, but not catastrophic, floods. Note, though, that the effects of forest protection within a particular sub-basin are literally diluted as one goes further downstream into the parent basin.***

The project proposed and mapped some experimental indicators of 'high-leverage' locations – places where deforestation might be expected to have particularly large far-field effects.

"Local hazards" -- Biodiversity, hydrology, and poverty in small watersheds

Project-related research generally supported the proposition that the hydrological impacts of forest loss or conversion will be most keenly felt in smaller watersheds – on the order of hundreds of square kilometers. Here is where there is an elevated likelihood that a significant proportion of the watershed could experience rapid deforestation, and where impacts on water yield, flooding, landslides, and sedimentation are most rapidly felt downstream or downslope. ***Hence deforestation, and consequent biodiversity loss, are more likely to present local hazards – hazards to local populations – than far-field hazards. Even so, the combined population and area exposed to such local hazards could be large.*** This underlines the need for a comprehensive typology of landscapes that maps different sources and targets of risk.

The relevance of 'local hazards' to the hydrology-forest-vulnerability nexus depends empirically on where people, forests, and biodiversity overlap in small basins. A mapping exercise for Central America found that Guatemala a strong overlap of this kind. The most hydrologically sensitive watersheds occupy only one-sixth the country's area, but contain 42% of its montane forest and one third of its poor people. Honduras also was noteworthy for a poverty-forest-hydrology relationship, though not as concentrated as in Guatemala. In other countries examined the association was not as marked, based on currently available data.

Biodiversity protection as a side-benefit of watershed management, or vice-versa?

Project results suggest that ***biodiversity-motivated maintenance (or regeneration) of forest cover provide downstream hydrological side-benefits (with the qualification that forest cover reduces downstream water availability). These benefits attenuate in larger basins, or in relation to more distant downstream areas.***

On the other hand, biodiversity conservation is not necessarily the preferred choice where the goal is management of hydrological functions within a watershed. It is demonstrable that maintenance of riverine forests can have favorable impacts on both hydrological functions and on biodiversity. In general, however, project research showed that a different landscape arrangements can have similar hydrological behavior, but divergent implications for biodiversity and for livelihoods. The implication is that 'win-win' policies are not automatic, and may not even be available***. Hydrological management and biodiversity conservation are distinct goals that probably require distinct (though closely coordinated) policies.***

Project technical reports and databases are available at: http://www.asb.cgiar.org/BNPP/phase2.htm