Land cover change and catchment water yields: from local to regional scales

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Catchment water yields control the availability of the water resource and the levels of flood risk. With the demographic rise that is underway in the developing world, inter-dependencies between populations and flow variability become higher. A better management of watersheds, from local to regional levels, is therefore required.

The prerequisite for a sound catchment water management is a clear understanding of the drivers of flow variability, in relation to four main ranges of controlling factors, namely i/ the climate (rainfall-runoff relationship), ii/ water infrastructures (i.e. river flow regulated by hydropower dams), iii/ water withdrawals mainly for irrigation and iv/ land cover changes. The hydrological impacts of the first three categories of controlling factors are relatively easy to assess, as demonstrated by previous modeling efforts, noticeably in the Mekong Basin. In contrast, the way land-cover changes alter catchments' runoff responses is less obvious and still subject to controversy.

The most reliable facts, which seem to be widely and independently acknowledged, are that deforestation, via the reduction of evapotranspiration, increases annual basin water yield, while afforestation results, over the long term, in opposite trends. These relationships were established based on analyses of hundreds of paired catchments whose surface areas rarely exceed 2 km^2. The impact of land cover change on seasonal flows not only depends on evapotranspiration rates but also on soil properties such as permeability and water storage capacity, and rainfall intensities. For example, in very particular conditions, deforestation may reduce infiltration which, if not offset by a reduction in evapotranspiration, may result in reduced low flows during the dry season. For extreme flood events, the impact of reforestation may become imperceptible as over such short periods, evapotranspiration does not control the runoff response. These two examples indicate that, although deforestation and reforestation generally increases and decreases, respectively, low flows and flood peaks, the hydrological impacts of land cover changes do not follow a general rule as they depend on a complex convolution of climatic, edaphic and biological factors. However, a recent study undertaken in northern Laos in a 0.7 km^2 headwater catchment under shifting cultivation corroborates most of previous results observed in other parts of the world: the development of fallow vegetation reduces groundwater recharge, leading to a drop in annual stream flow due to a decrease in wet and dry season base-flow.

Studies on the hydrological impact of land cover change over large catchments (i.e. > 1000km^2) are extremely rare, in comparison with the abundance of small-scale studies. This is explained by several facts: over large areas, the heterogeneity of land covers combined with the spatial variability of climate compounds the attribution of observed hydrological changes; counteracting changes in vegetation covers may occur simultaneously and result in an apparent basin-wide stability of the runoff production. However, the sudden and irreversible bomb-induced deforestation that occurred over more than 50,000 km^2 in the lower Mekong Basin during the Vietnam War has been found to have significantly increased the runoff production. This unique example of flow change induced by broad-scale deforestation in Southeast Asia demonstrates that the causal link between flow and vegetation established in small catchments can still hold over an area 4 orders of magnitude larger.

The 5 key messages

- Deforestation and reforestation increase and decrease annual water yields, respectively.
- Seasonal flow response (base flow and floods) to land cover changes are less predictable and depend on climate, soil and biological conditions.
- Over large scales, the detection of hydrological change is difficult, due to the heterogeneity of land cover and of their change.
- Land-cover changes may have deeper hydrological impact than those expected from climate change, irrigation and hydropower development.
- The inclusion of land-cover changes in the Mekong hydrological models is urgently required as land-cover change is expected to continue at a high rate over the coming decades.