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Hydrological response to deforestation in a large tropical basin in Queensland, Australia

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Land use and land cover change (LUCC), particularly deforestation; have been shown to have influence on hydrology at small scales. Their effects at large scales are more difficult to discern due to spatial and temporal climatic variability, different patterns of land cover disturbance, vegetation regrowth and land management. We re-examined the hydrological response to partial deforestation in the Comet Basin, a large (16,000 km^2) sub-basin of the Fitzroy River in the dry tropics of Queensland, Australia. More than 45% of the basin's native vegetation (Acacia harpophylla and eucalypt woodlands) was rapidly cleared for cropping and cattle ranching in the mid-60s. A previous modelling study concluded that this clearing, and subsequent land use, may have resulted in a posterior 78% increase in annual streamflow.

Six approaches were explored to separate climate influences on streamflow from LUCC effects: (1) Time-series analysis of rainfall and streamflow; (2) a simple conceptual ecohydrological model based on the long-term coupled water and energy budget at the inter-annual scale; (3) a top-down modelling approach based on the Budyko framework; (4) signal analysis of daily streamflow descriptors based on the flow duration curve for periods before and after LUCC and ; (5) comparison of event runoff for the respective periods.

Time-series trend analysis showed that interannual changes in streamflow were mostly due to changes in rainfall. This was reinforced by the results obtained with the conceptual ecohydrological model. Nevertheless, the period 1967–1970, i.e. immediately after extensive clearance of native vegetation, showed an upward shift in streamflow reflecting a decrease in evapotranspiration associated with LUCC.

In order to apply the Budyko model, two periods with similar mean annual rainfall and rainfall frequency distribution were considered for calibration and prediction, 1919–1949 and 1980–2007 respectively. In contrast to results from small experimental catchments – which in many cases show an increase in streamflow proportional to the extent of deforestation – the present modelling results showed a non-statistically significant increment in mean annual runoff of only 0.5% for the period after LUCC. However, signal analysis of daily streamflow descriptors revealed a shift after LUCC, with an increased response of the basin to rainfall, enhanced high flows and decreased flows associated to delayed runoff pathways. In addition, event runoff response also increased for large rainfall events.

Based on signal analysis results, it is plausible that the long-term, progressive LUCC in this semi-arid landscape has changed the water balance and increase runoff response. However, at this scale the LUCC appear to have a smaller impact than would be expected on the basis of small-scale experimental catchment results.

Keywords: Deforestation, tropical hydrology, hydrological processes, hydrological models, streamflow, land use change