Cloud Forests:
Water, Livelihoods and Payments for Environmental Services
Costa Rica

Background. Land use change in upland catchments, including changes in tropical montane cloud forest, have direct impacts on nature and society. The Payments for Environmental Services (PSA, in Spanish) programme in Costa Rica recognises the opportunity of market mechanisms in linking environmental service provision with environmental sustainability and rural development. Payments are made for forest conservation, forest plantations and, more recently, for agro-forestry. Forest conservation has been the most popular option representing over 80% of contracts (in hectares) between 1997 and 2001.

The programme recognises four environmental services: biodiversity conservation, carbon sequestration, landscape beauty and watershed protection. Cloud forests provide the first three services and generates important benefits at local and global levels. Watershed protection services are less clear, especially those related to water quantity. Despite uncertainties, there are examples where downstream water users are compensating upstream farmers for (expected) improvements in water quality and quantity. It remains unclear who benefits from these arrangements and how sustainable they are in the long-run. These issues have been explored through hydrological and socio-economic studies. The results have implications for water supply, industry, agriculture, development and conservation projects at local and national levels, and provides lessons for similar mechanisms in other countries.

Water, cloud forests and pastures.

Horizontal precipitation. Conventional measurement of precipitation tends to underestimate the actual input of water in areas where horizontal precipitation (fog and wind-driven rain) are important, as is the case in the wet and windy mountains of Costa Rica.

- Depending on prevailing wind speeds, 10-90% of wind-affected rainfall is almost horizontal (between 500 and 10,000 mm per year).
- Capture rates of this near-horizontal precipitation are 25% for cloud forests and 15% for rough pastures. Depending on wind conditions, the remaining precipitation may fall elsewhere in the watershed, be transported to another watershed, or be evaporated into the atmosphere.
- Tree belts are effective in catching wind-driven rain. But, a common misconception is that all wind-driven rain is a net benefit to water resources. Wind-driven rain captured by tall trees or other obstacles, e.g. power pylons, result in less rain hitting the ground downwind. This capture of wind-driven rain may have a local benefit but this spatial distribution of deposition has no net water resource benefit at the catchment scale.

Average stormflows are doubled under pastures compared to forests at the sub-catchment scale (< 1km²). This is largely the result of soil compaction from cattle, which affects infiltration rates. The effect is seen throughout the flow spectrum although it is somewhat less for the most extreme flows. At the operational catchment scale (>100 km²) the effect mostly disappears because of re-infiltration of overland flow and high spatial variability in rainfall.

- Effects of cloud forest conversion to pasture on baseflows (dry season flows) are limited because the net loss of horizontal precipitation catch after clearing is roughly compensated by the smaller water use of pasture. At the local scale the effect may be an increase or a decrease in baseflows, depending on the balance between evaporation and horizontal precipitation as controlled by local topographic and climatic conditions.

Scenario analysis from conversion of cloud forests to pastures. Streamflow impacts related to horizontal precipitation depend on the location of the cloud forest, and the rate of capture of horizontal precipitation from pasture:

- Expected effects at the local level are nearly neutral for slopes of intermediate wind exposure measured at the catchment scale. They are the result of two processes: a reduction in the efficiency of horizontal precipitation capture to grassland, and a decrease in water use from pastures. At the measured catchment site, total conversion from (all types of) forests to pastures will result in an increase of 150 mm per year for the catchment. Conversion of only cloud forests to pasture, leaving everything else as a mosaic of forest/pasture, results in a very small increase of flows (40 mm per year). At the cloud forest sub-catchment scale, no significant effect on streamflow was obtained.
- Conversion of cloud forests on slopes with higher wind exposure and rainfall inputs will result in higher losses of net inputs and therefore in possibly reduced overall streamflow amounts.
- The modelled impacts on streamflows depend rather heavily on the assumed rates of capture of

horizontal precipitation. For example, applying a rate of 15% for pasture results in a minor increase in runoff after conversion of only 15mm. Applying a lower capture rate gives an increase in water flows after conversion.

- Dry season flows: Effects on dry season flows were not significant in any of the models applied at the operational catchment scale. However, their importance could be higher in areas with more humidity and more wind exposure.

Contribution of cloud forest at national level. The annual average contribution of fog to flows is locally up to 18 percent in streams draining exposed cloud forest but soon declines to 0 to 3 percent or less as one travels downstream through the lowlands. Nevertheless in some seasonally dry areas monthly contributions of fog (in the lowest rainfall month) both locally and to downstream lowlands can remain at 10% or greater for rivers passing through upper parts of the Atlantic lowlands and for the entirety of the long profiles of some Pacific rivers.

The people.

The main results from the socio-economic studies and local consultation process indicate:

- People living in upland areas believe forests (including cloud forests) increase and regulate water flows, and protect water quality. This popular belief does not necessarily coincide with hydrological evidence.
- People believe that their forests provide important environmental services, and they should be compensated for service provision. However there is limited participation from small and medium farmers in the PSA programme. Some of the reasons include:
  - Small and medium farmers are hesitant to enter contracts with the Government as they fear losing their land;
  - The understanding, adoption and support to the PSA programme from small and medium farmers is constrained by the limited presence of the PSA managers, and insufficient funds to cover demand.
  - Bureaucracy and programme qualification criteria generate high transaction costs. These costs are fixed, and fall harder on small farmers.
  - Disputed land ownership constrains participation.
  - Studies show that the payment levels do not significantly influence small and medium farmers to join the programme. This is partly due to opportunity costs of alternative land uses, including urbanisation.
- Scenario analysis indicates that the ability and willingness to enter the PES programme is higher for people with more than 10 hectares and land titles. It is more likely that these properties will already be conserving some forested land or will be able to leave land aside for non-productive uses.
- The economic value of additional flows of water from cloud forests at the catchment scale study site is relatively small due to the presence of a large inter-annual reservoir. The impact could be higher in areas where water is more scarce, and for hydroelectric projects with smaller storage facilities. Analysis of a daily reservoir model in another local catchment shows relatively small economic impacts on hydroelectricity production.
- Wastewater is considered the most important problem in the study area. No steps have been taken to address this issue. However, public (social and environmental) health is key to maintaining the area's image as an eco-tourism destination.
- The PSA programme does not directly benefit people without land.

Policy implications.

- Cloud forests cover 12% of Costa Rica and though they contribute relatively small additional flows their conservation protects important aquifer recharge areas. Attention should focus on protecting forests located on slopes with higher humidity and wind exposure.
- Wind-driven rain has important local benefits at the farm-level, but at catchment level these effects are almost neutral.
- It has not been demonstrated that cloud forests increase dry season flows.
- Most PSA payments for conservation are captured by large landowners. Reforestation or agro-forestry systems are an alternative for small landowners without forests. These activities can have direct impacts on income, biodiversity, and landscape beauty, and neutral (or even positive) effects on water quantity from cloud forests (this last does not apply to other types of forests).
- Participation from smallholders in the PSA programme is restricted by insufficient funds, disputed land titles, and red-tape. It is recommended to create a contingent fund targeting small and vulnerable farmers to ensure their participation.
- Complex and changing bureaucracy for accessing PSA weakens local capabilities, programme credibility, and willingness to cooperate with the Government. This can be improved through improvements in the PSA programme that support local presence and more dialogue with local communities.
- The community, private sector, municipality and the Government must work together to solve the wastewater problems around the Monteverde area.

Note: For more information contact Ina Porras (ina.porras@iied.org) or Sampurno Bruijnzeel (sampurno.bruijnzeel@geo.falw.vu.nl).

The results from the socio-economic studies are available at www.cluwrr.ncl.ac.uk.

Acknowledgement:
This is an output for a research project supported by the United Kingdom Department for International Development (DFID) for the benefit of Developing Countries. The views here are not necessarily those of DFID (R8174 and R7991).