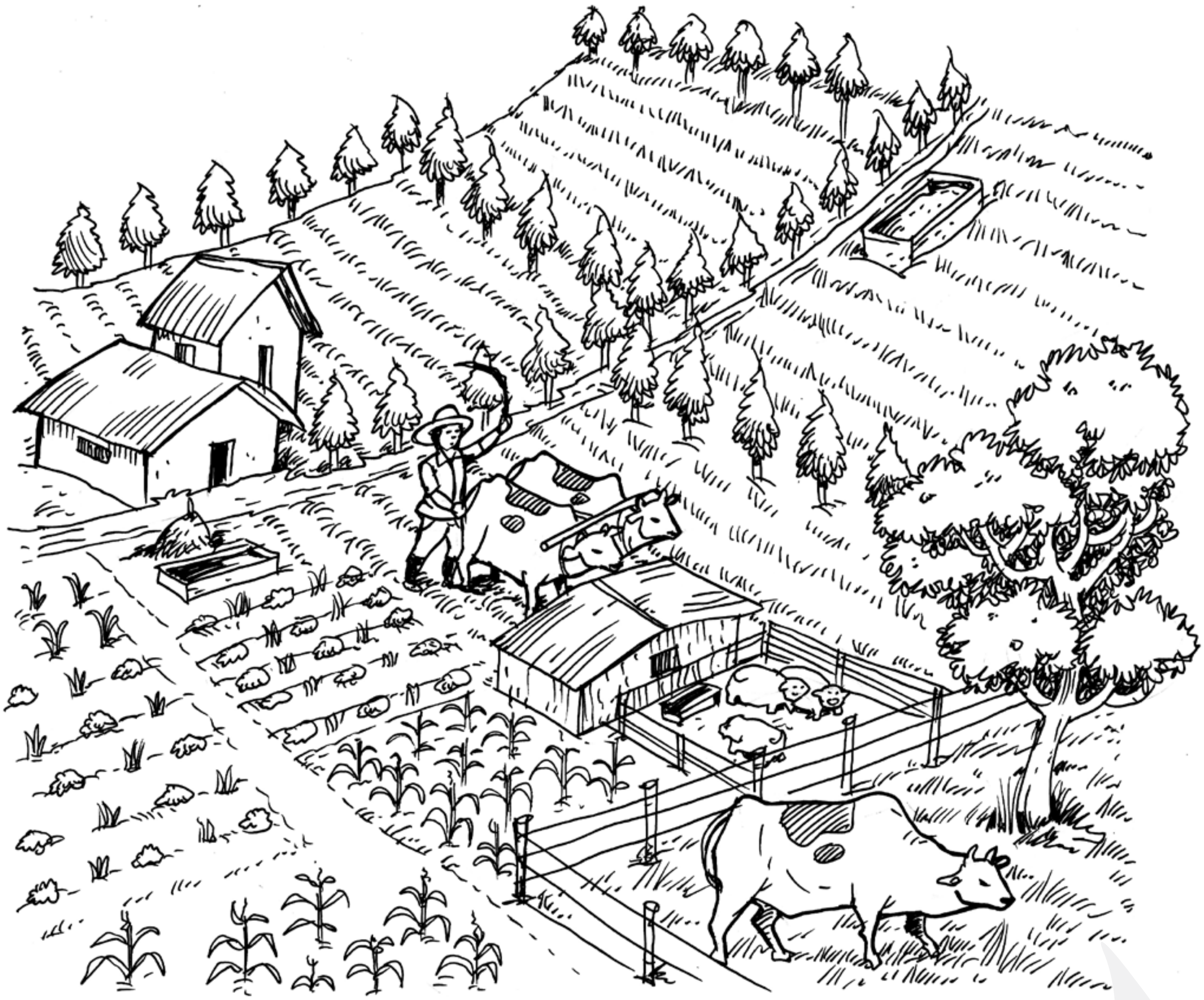
Simulation Modeling to Develop Pro-Poor PES Schemes



Payment for environmental services (PES) is a potential mechanism to contribute to rural sector development while at the same time preserving the environment. PES recognizes the economic value of environmental services and promotes the transfer of resources between the service providers and those who benefit from the service. Environmental service providers could be upland farmers adopting sustainable land-use and conservation measures and the recipients of the service are the people downstream who enjoy reliable water supply because of sustainable agriculture practices. In effect, PES uses environmental externalities as a driver to promote social investment and development in the upper watersheds. Meanwhile, PES has also evolved into PES-type schemes that not only offer direct payments but also comprise other kinds of incentives, like cheap loans.

Prioritizing the poor in the delivery of environmental services

Implementing PES in upper watersheds to conserve nature and at the same time increase the income of poor rural households has its difficulties. This is because areas with the highest potential to deliver environmental services are not necessarily where the poorest live. In the Andean watersheds, for example, many of the poor do not own lands and cannot, therefore partake in the incentives offered in PES as compensation for environmental services. Those with access to land may not be able to practice ecologically sound land-use as these patterns could mean a temporary decrease in net income. Understanding the potential of PES schemes to conserve environmental services and generate rural development requires an examination of many different scenarios. This is especially important when prioritizing the poorest whose options to participate in PES are limited. This task of generating and screening scenarios and options can be greatly facilitated by the use of computer-aided simulation models.

Approach for valuation of water-related environmental services

With ECOSAUT, assessment of the potential of PES is facilitated by creating scenarios to reduce negative environmental externalities and by analyzing the effect of each scenario on farm profitability and resource use. Some key questions to help form the scenarios are:

- **How would farm profitability and resource use be affected if regulations were imposed to reduce sedimentation to a given level?**
- **How would a shift to biofuels affect farm profitability and demand for farm labor?**
- **What land-use options would retain runoff at a certain maximum desired level without compromising farm profitability?**
- **What is the marginal effect of the proposed land use on sediment yields with respect to current land use?**

Assessment of the potentials of water-related environmental services to have positive impact on socio-economic conditions in the watersheds can be facilitated by the use of hydrologic and socio-economic models. An example of these simulation models is ECOSAUT. It provides an assessement of different land-use scenarios vis-á-vis hydrological services. It also gives a socio-economic and environmental assessment of the land-use scenarios or alternatives. ECOSAUT requires an understanding of computer-based linear programming and optimization models.

Simulation models help

- **prioritize sites by ability to deliver the greatest amount of environmental services.**
- **increase the efficiency of investments in watershed areas, through targeting investments in the watershed.**

The shaded portion in figure 1 represents the use of the two simulation models. SWAT and ECOSAUT. These are the outputs that serve as inputs to developing PES schemes. The social acceptability of the schemes among different stakeholders could be assessed through the use of "economic games" or contingent valuation methods, among other approaches.

SWAT is used first to define the hydrological response units (HRUs). These are areas within a watershed where the hydrological response to a given input would be similar. Among other

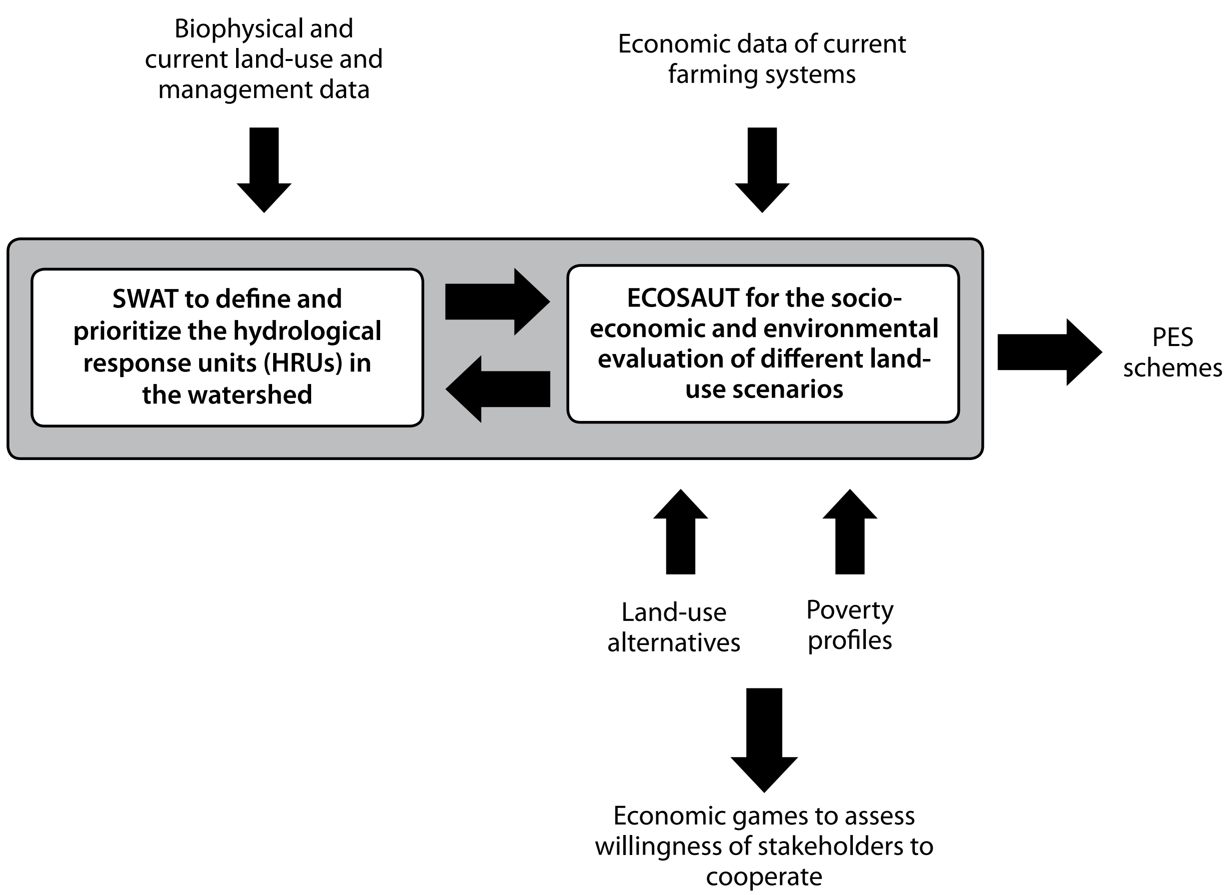


Figure 1. Developing PES schemes using simulation models SWAT and ECOSAUT

things, HRUs show the spatial heterogeneity of a watershed. In using SWAT, basic biophysical data are collected to quantify hydrological externalities in the study sites. The data are complemented by available primary data from digital elevation models, land-use maps, climatic stations and water flow gauges. Input data include topography, soil, land-use, weather, characteristics of main channels and groundwater aquifer, plant growth characteristics, land management (from tillage to harvesting) and water management (water use, water pollution discharges and location, characteristics and operation regime of ponds and reservoirs).

The second use of SWAT is in prioritizing those HRUs where water-related environmental services would have high impact. To determine these priority areas, SWAT has to be run with potential land-use/management scenarios and ECOSAUT. The ECOSAUT model integrates the valuation of the natural resources, economy and social impact with watershed management. The Consortium for the Sustainable Development of the Andean Ecoregion and its Latin American partners have developed ECOSAUT to analyze the economic, social and environmental trade-offs associated with alternative land uses. The model allows calculation of the socio-economic and the environmental costs and benefits associated with different land-uses based on perceptions of the highland farmers and the downstream communities. It estimates the quantity of an environmental service—e.g., water generation or carbon sequestration provided by a given land-use and the cost to farmers or landusers of supplying the environmental service.

Each HRU has unique soil and land-use properties. It is the level at which trade-offs between increases in hydrological services vis-á-vis different land-use scenarios are best studied.

Key findings

1. The HRUs with the highest potential to deliver environmental services are not necessarily occupied by the poorest people. Many of the poor people in the Andean watersheds do not own land. They cannot therefore capture any of the economic benefits derived from alternative land-use systems and from compensations for environmental services.

2. In Colombia, a set of minimum tillage and cover crop practices was found appropriate for improving an ecosystem service (i.e., sediment retention) with no opportunity cost. The practice positively impacts soil characteristics by improving stream flow regulation and reducing sediment production while increasing farmer income.

3. Simulation models in Colombia showed that increased accessibility to cheaper loans by small farmers could be effective in promoting conservation practices with proven positive impacts on reducing sediment yields and increasing carbon sequestration (Quintero 2009). However, this only reduced labor use implying reduced economic benefits to the landless.

4. SWAT simulations for the Altomayo watershed in Peru showed that changing the land-use in prioritized HRUs could potentially cut sedimentations by 18% while improving farmers' income. Related findings indicated that

    - Establishment of live barriers, forest plantations or shade-grown coffee may potentially reduce sedimentation by half.
    - Subsidized loans for shade-coffee adoption are better and cheaper than a permanent PES scheme.
    - Paying upstream farmers to abandon cropped areas in favor of forest re-growth is not feasible either economically or politically.

5. In the Jequetepeque River watershed of Peru, simulation results showed that reforestation, agroforestry systems and management practices in the agricultural systems to control erosion (contour strips) can reduce the production of sediments in the prioritized HRUs compared with the current land-use. Specially, reforestation and agroforestry systems can reduce the sediments by 41% and 54%, respectively.

6. For a proposed water reservoir project in the Ambato watershed in Ecuador, simulation models indicated that benefits to society would be 94% of the total benefits to be generated by the project (Estrada *et al.* 2009). The analysis showed that water consumers and society in general were the sectors that will capture more benefits and should therefore be involved in any scheme to recover investment cost and to compensate farmers upstream who may be affected by the reduction of stream flow. These results contradict the provincial government proposal to recover investment costs from the producers who were assumed to benefit most.

7. In some cases in the Fuquene watershed of Colombia, conservation tillage would increase net return implying a net economic benefit for the farmer. This means there are alternatives like conservation tillage in Fuquene with no opportunity costs. Payment or compensation for watershed services needs to be reconsidered here.

Lessons learned

- ◈ Understanding the spatial distribution and temporal hydrological behavior of the identified HRUs is essential to achieve high efficiency in the use of financial resources to compensate for environmental services.

- ◈ For the landless in the upper catchments, land-use changes promoted to provide environmental services will only generate benefits via a multiplier effect resulting from increases of labor use and income.

- Analysis of the effects of changing land-use should incorporate analysis of competitiveness because this may have more of an impact than changing the provision of an ecosystem service. This is especially important when the objective is to use PES as an entry point to ensure equitable sharing of benefits in a watershed.

- When modeling smaller watersheds, calibrating the model might not be straightforward. This is not because of the model itself, but because of watershed characteristics and the nature of streamflow and sediment measurements. Steep slopes and high intensity of peak rainfall events shorten the response time to 4 hours or less. In these situations, peak stream flows may not be reflected in the daily stream flow measurement generally measured every 24 hours.

Challenges for the Andes

There are two main challenges for the Andes where the CPWF Project was carried out. The first is to bring into practice the prioritization of HRUs by adopting appropriate land-use alternatives as evaluated through the simulation models. The second is to enhance the use of hydrological modeling by improving availability of input data related with climatic information, grasscover and soil characteristics.

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Centro Internacional de Agricultural Tropical
Consorcio para el Desarrollo Sostenible de la Ecoregion Andina (CONDESAN), Peru
Danish Institute for International Studies, Denmark
Entidad Prestadora de Servicios de Saneamiento, Peru
Farmer's Association of the Fuquene Watershed, Colombia
Fundacion para el Desarrollo Sostenible Territorial, Colombia
Programa de Manejo Integral de Cuencas, Bolivia
Proyecto Especial Alto Mayo (PEAM), Peru
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Universidad Javeriana, Colombia

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