



# **HERESY FROM THE HILLTOP:**

## **How useful is the watershed as an organizing principle for research and development?**

Ruben Dario Estrada and Josh Posner  
June 21, 1999

### **INTRODUCTION**

The goal of CONDESAN's (Consortium for the Sustainable Development of the Andean Ecoregion ) research and development program is to promote equitable, competitive, and sustainable development in the rural Andes. Due to the steep topography and erratic rainfall associated with these mountains, an obvious approach is to focus on watersheds as the unit of development. This strategy has several obvious advantages:

- Catchments permit estimating run-off and soil erosion on a landscape scale, two of the key criteria for measuring the sustainability of existing or new mountain production systems;
- Funds for natural resource management are very limited so prioritizing interventions and estimating their cost-benefit ratio within a watershed **should** be advantageous in attracting development funding;
- If downstream agriculture is profitable and threatened by upstream activities, than equitable tax systems **could** be designed to fund investments in upstream soil and water management activities; and,
- Small watersheds often approximate municipalities so can be congruent with local decision-making units.

However, using a watershed approach to design development plans, orient municipal investment, as well as attract national and international funding remains somewhat uncharted territory. Among other things, this approach requires: 1) collecting digitized and geo-referenced data, not simply district level maps and census numbers; 2) characterizing soils, slopes and vegetation on the entire landscape, not just the intensively farmed areas; and, 3) working with multiple levels of authority to set priorities, not just the farm family. As a result, research and development interventions at the watershed level require significantly more time, more data, more funds, and more actors.

However, the first limiting factor is neither data collection, nor community participation. The real challenge is how to use the data collected to evaluate current land use scenarios, to compare new scenarios, and most importantly develop evaluation criteria.

Since 1995, CONDESAN and its partners have been learning how to conduct watershed evaluations, in catchments of generally 5,000-25,000 ha, as a first step in designing research and development programs. To date, most of the work has been done in Colombia. The process that has been developed includes:

- **Estimating soil loss and water consumption under current land use patterns.** Initially this was done by creating a simple water budget (rainfall-evapotranspiration = run-off) and using programs like EPIC (Environmental Policy Integrated Climate) to estimate soil loss by vegetation type.

Currently, SWAT (Soil and Water Assessment Tool) is being used to estimate watershed stream flow, sedimentation, and the location of resource degradation “hot spots”. This later approach allows validating estimations against measured flow rates and turbidity readings--where they exist.

- **Constructing a farm model.** A farming systems survey is conducted with the goal of characterizing the farm assets (land, labor, capital) and the production systems (e.g. cropping calendar, tillage, fertilizer use, yields) of farms in different ecological zones of the watershed. A linear model is then built to estimate the impact of production changes on incomes;
- **Characterizing the externalities of upper catchment management on down stream users.** For irrigated agriculture, average and minimum stream flow rates are important, as well as sediment loads, when there is a dam. For engineering purposes, maximum stream flow rates are important and water quality is important for drinking water and many recreational uses. The key to capturing externalities however is not their importance, it is in showing the impact of change in management on the amount or quality of the resource.
- **Testing new scenarios.** Analysis based on changing vegetation cover (e.g. reforestation, improved pasture management, new crops) and agronomic practices (e.g. no-till, early planting, green manures, alley cropping) are then tested in the models to evaluate their impact on watershed stream flow, reduction of soil loss, and increasing farmer income. (Sustainability and Competitiveness Criteria)
- **Evaluating the impact of land use change on employment.** The new scenarios are compared to the current scenario for employment generation. (Equity Criteria).

Although only a few of the 8 test watersheds have been through the entire five-step process (see Table 1), we are able to draw some partial conclusions from this experience.

## RESULTS:

Standard farming systems surveys have proven adequate to get the base-line information necessary to accurately describe current production systems. When coupled with linear programming, estimates of the impact of production changes on incomes can be made. Typically small catchments of 5,000-25,000 hectares will include a change of 1500 to 2000 meters in elevation and can be usefully divided into 3 or 4 ecological zones.

Most farming practices in the higher rainfall (>3000 mm/yr) and lower elevation (2500-500 masl) watersheds in Colombia are fairly soil conserving. Measured losses associated with fallow and pasture systems are low (< 9t/ha/yr), with coffee somewhat higher (around 15 t/ha/yr), and highest under food crops like corn, plantain, and cassava (> 20t/ha/yr). However, these latter systems rarely represent more than 5% of the landscape. The higher rates of average soil loss reported (often as high as 50t/ha/yr) when stream flow and turbidity measurements are taken however, is most likely due to small landslides, erosion from road cuts and urban zones, and stream bank collapse.

The SWAT program allows subdividing the test watershed into as many as 10 sub-basins. If the data is available, this allows identifying which sub-basin is supplying the most water or sediment to the catchment outlet. Although this analysis was not particularly useful in two cases, in La Encanada it was estimated that 90% of the sediment load came from one of the six sub-basins.

Perhaps not surprising, most data isn't digitized or geo-referenced. What is unfortunate however, is that the data that is available for watershed evaluations is jealously guarded, usually expensive, and sold with severe limitations on the purchaser's ability to share the data with other users. This reality markedly increases the transaction costs of working with GIS tools and models.

In three Colombia watersheds, models were used to estimate the impact of improved vegetation management on stream flows. Increasing forest cover from 10% to 30% in the Guadalajara case, resulted in an estimated reduction of maximum daily flow by an impressive one-third, increased minimum daily flows by only 10% and had almost no effect on average flows.

In three cases, the analysis of externalities of current land use practices indicates that it is unlikely down stream users would pay for upstream soil and water conservation activities. For example, in Colombia it will take approximately 80 years at current sedimentation rates for hydroelectric production capacity to be affected at the La Miel dam. With stable coffee prices, as well as high interest rates, it would be a misuse of investor's funds (\$400/ha/yr) for the dam authorities to pay farmers to shift to pasture. In Peru, although the Gallito Ciego dam is rapidly filling with sediment, Pacific coast farmers are not likely to invest in upstream improvements. They are growing relatively low value rice and corn crops giving water a low shadow price during the dry season. And they know that the majority of the sediment (we estimate 70% of the accumulation over the past 10 years) comes during a catastrophic "el Nino year", not through annual

overland flow. In Carchi, Ecuador, farmers at the tail end of the El Garrapatal irrigation canal are sometimes up in arms because they don't get adequate irrigation water. Rainfall analysis, farmer surveys and CROPWAT suggest, for example that: 1) in 7 out of 10 years irrigation water is adequate to meet crop needs; 2) that at current irrigation efficiencies the first task is to improve on-farm water management; and 3) the major option to increase water availability would be through expensive civil engineering (a reservoir) and not alternative land use strategies. And perhaps most importantly, the irrigated farms are primarily planted to corn and beans (80%) where additional water has a relatively low value.

And finally, the research has suggested that "natural resource conserving" changes in current land use systems will have a negative effect on employment opportunities in the watershed, probably increasing rural poverty. In two cases in Colombia, it is estimated that the shift from coffee to pasture would reduce sedimentation rates by more than 50%, but also reduce employment by 20 to 30%. This would probably be a politically unacceptable solution to improving natural resource management.

## **DISCUSSION:**

These results throw into question the utility of working at the catchment level. While the jury is certainly still out, in these eight cases, moving the analysis beyond the farmstead level did not bring to light new approaches to development. What we have learned however is the following:

**Often, sedimentation problems cannot be addressed through incentives to farmers.** It appears that in some cases, much of the sediment load in the river is not due to agricultural activities. Rather, road cuts, urban areas, landslides, stream bank collapse and heavy rainfall years (el Nino) are the culprits. The public investments necessary to address these phenomenon require entirely different actors and sums of money than what would be necessary for the development of incentives to alter agricultural production practices.

**It is often hard to argue that national funds should pay for incentives to reforest tropical watersheds.** The models suggest that reforestation, in the humid Andes, can result in higher minimum stream flows, and lower maximum stream flows, but the differences will be modest. It appears unlikely that financial incentives to promote reforestation, based solely on improved soil and water management would be economically sound. To increase the potential profitability of reforestation, CONDESAN is investigating its use for sequestering CO<sub>2</sub>.

**Prioritizing watershed interventions may be of only academic interest.** While the analysis can indicate where the "hot spots" are, political reality places great pressure on upland authorities to disburse new development funds without regard to topography. For example the analysis showed that one area was an erosion "hot spot" in the La Encanada

watershed but the political decision was made to invest equally in all 23 “caserios” of the 12,000 ha watershed.

**Estimated externalities often indicate that improved natural resource management has little perceived economic value.** Generally speaking, farmers in the Andes rarely pay more than \$25-50/ha as annual dues for membership in an irrigation system and generally grow fairly low value crops. In many cases, these low rates are justified based on their low profit margins. Wealthy farmers get access to more water by buying more land or buying land with more water rights. Under these conditions, it is unlikely that people would agree to raise water taxes for use in upper watershed development.

**Some proposed watershed interventions will exacerbate rural poverty.** Shifting to lower intensity use of the land may reduce erosion losses but it will also result in loss of jobs. If this issue is not addressed, rural poverty would increase. CONDESAN is investigating the alternative approach of promoting land use intensification to reduce rural poverty and resource degradation with the help of terracing, higher value crops and irrigation.

**Resistance to sharing data remains an unfortunate reality in the Andes.** Data intensive models (quantity, need to be geo-referenced) can be very difficult to run without collaboration from state agencies. While not a complete surprise, this problem must be chipped away at, day by day, agency by agency through education and developing joint projects

## **CONCLUSIONS:**

Since the 1960's production agronomists and economists have gradually expanded their focus of inquiry from commodities to cropping systems, to whole farm analyses, and recently, some have ventured to the watershed level. Part of CONDESAN's portfolio of activities since 1995 has been an effort to see if this seemingly logical level of analysis for natural resource management and development was useful. It is surprising, but the initial evidence is beginning to suggest that while catchments and watersheds are all easily recognizable units, **they are not particularly obvious levels for designing research and development programs.**

On the other hand, we have been surprised at the level of interest at the local level as municipal authorities (Colombia) and Soil and Water Conservation programs (Peru) try to develop management plans. We are finding that this mixture of biophysical and economic modeling is responding to a need. At the local level, decision-makers are unable to estimate the physical impact of changes in land management on the environment, their economic effect nor their costs. They are attracted to this analytical approach even though they no longer expect any easy victories. Our intention is try to strengthen our efforts in this area over the next five years.

## **BIBLIOGRAPHY**

Arroyave, J.F., J.A. Tapasco, B. Rivera, F. Obando. 1998. Viabilidad del uso del modelo EPIC para estimar perdidas de suelo en zona de ladera. to appear in Suelos Tropicales, Colombia.

Chaparro, Oscar and R D. Estrada. 1998. Informe final de balance hidricos Acequia El Garrapatal. CONDESAN. 140 pp

Delgado, R. 1999. Estudio inicial de aporte de sedimentos del Rio Jequetepeque al Embalse Gallito Ciego. CONDESAN. 39 pp

Estrada, R.D. and F. Carabali. 1999. Estimacion de caudales, estres hidrico y produccion de sedimentos de la subcuenca del Rio Guadalajara, Valle Colombia. CONDESAN 33pp.

Instituto de Estudios Rurales. 1999. Revision de incentivos economics para proyectos de microcuencas-Anexo Hidrologico. Universidad Javeriana 33 pp.

Rios, G., G. Abad, R. Rivera and R.E. Estrada. 1998. Analisis de opciones de desarrollo en la ceunca alta del Rio Dona Juana-Victoria, Caldas, Colombia. IESA-AL-3. Agosto. 1998

Rivera B. and R.D. Estrada. 1998 Modelo para el empoderamiento de una comunidad local a partir del analisis de los terminos de intercambio entre criterios de politica. IESA-AL-3. Agosto, 1998

Rojas, H. G. Moreno, F. Carabali. 1998. Simulacion del la produccion del flujo de agua y produccion de sedimentos en la mircocurnc "La Encanada", Cajamarca, Peru. CONDESAN 40 pp.

**Table 1. Characteristics of catchments studied by CONDESAN and colleagues and analyzes conducted.**

WATERSHED	COUNTRY	RAINFALL (mm/yr)	SIZE (ha)	Elevation (masl)	Farm Survey Farm model	Est. Soil loss Water Use	Characterize Externalities	Ex-Ante Analysis	Impact on Employment
Rio Dona Juana	Colombia	3,900	4,050	1000	Yes	Yes	Drinking water	Yes	Yes
Rio San Antonio	Colombia	6,500	4,000	1100	Yes	Yes	Hydroelectric	Yes	Yes
Rio Lenguazaque	Colombia	820	16,500	3000	No	Yes	Drinking water	Yes	No
Rio Guadalajara	Colombia	1000-2000	12,500	2025	No	Yes	Drinking, Irrigation	Yes	No
Rio de Oro	Colombia	1790	7,600	1900	No	Yes	Drinking water	Yes	No
Irrigation Canal El Garrapatal	Ecuador	625	Irr.canal	2200	Yes	Yes	Irrigation	No	No
La Encanada	Peru	683	12,000	3500	Yes	Yes	No	No	No
Jequetepeque	Peru	200-900	350,000		No	Yes	Irrigation	No	No

**TABLE 2. Characterization of water flow and erosion losses with (SWAT)**

	RIO ORO		RIO LENGUAZAQUE		RIO GUADALAJARA		SAN ANTONIO	LA ENCANADA
	ACTUAL	PROPOSED	ACTUAL	PROPOSED	ACTUAL	PROPOSED	ACTUAL	ACTUAL
Weighted CN *	62.1	59.3	64.3	58.5	57	50	44.5	70
Q05 (l/sec)**	4000	NA	2150	NA	8400	5300	20,000	3,200
Q 95 (l/sec) ***	720	789	120	137	1,330	1473	5,000	50
Sediment (ton/ha)	57.5	31.6	No data	No data	52.1	18.1	51.2	8.5

\* Curve Number is based on the USDA SCS tables. The lower the curve number, less run-off and erosion takes place

\*\*A measure of high flow volumes. Only 5% of the time will flows be greater than these numbers

\*\*\*A measure of low flow volumes. 95% of the time the flow will be greater than this minimum.