The Watershed as an Organizing Principle for Research and Development: An Evaluation of Experience in the Andean Ecoregion

Authors: Dario Estrada, Ruben, and Posner, Joshua

Source: Mountain Research and Development, 21(2) : 123-127

Published By: International Mountain Society

URL: https://doi.org/10.1659/0276-4741(2001)021[0123:TWAAOP]2.0.CO;2

Mountain Research and Development Vol 21 No 2 May 2001: 123–127

The Watershed as an Organizing Principle for Research and Development:
An Evaluation of Experience in the Andean Ecoregion

Ruben Dario Estrada
Joshua Posner

Watersheds are an attractive unit for development in mountainous landscapes. However, watershed analysis usually requires significantly more time, data and funds, and must include more actors. Also, results may be disappointing. Many off-site effects are very difficult to modify without major changes in land use systems. Frequently, these land use changes (eg more pasture or reforestation) pit soil conservation against rural employment. In other cases, sediment may not be originating on-farm, but primarily in other parts of the landscape, implying civil engineering rather than on-farm solutions. On the other hand, we have found that good maps and valid models are of growing interest to municipal authorities as they consider alternative development plans.

Watersheds—a unit for development?

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. The watershed constitutes an obvious set of boundaries for this holistic vision of research and development. In mountainous landscapes wathersheds can vary a great deal (Figures 1 and 2). The watershed strategy has several obvious advantages:

- Catchments allow estimation of run-off and soil erosion on a landscape scale, two of the key criteria for measuring the sustainability of mountain production systems;
- If downstream agriculture is profitable and threatened by upstream activities, equitable tax systems **could** be designed to fund investments in upstream soil and water management activities;
- Funds for natural resource management are limited, so prioritizing interventions and estimating their cost-benefit ratio within a watershed **should** be advantageous in attracting development funding;

FIGURE 1 La Miel Watershed, Caldas, Colombia: humid Andes. (Photo by E. Mujica, CONDESAN)

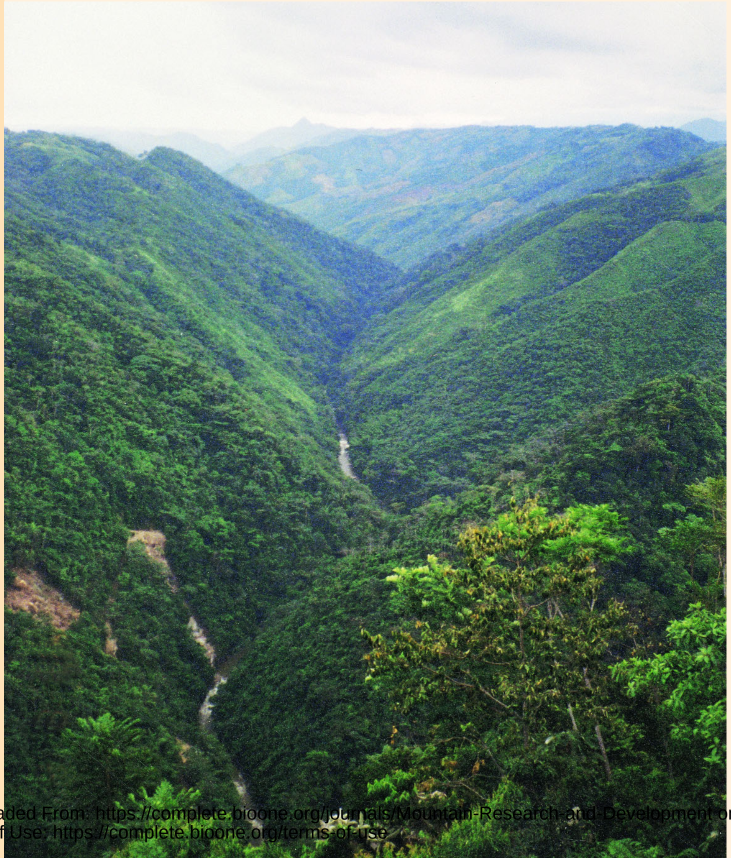

FIGURE 2 Cajamarca, Peru: semiarid Andes in the dry season. (Photo by J. Posner, CONDESAN)

TABLE 1 Catchment characteristics and analyses conducted by CONDESAN and its partners.

Watershed	Country	Rainfall (mm/year)	Size (ha)	Elevation (masl)	Farm survey, farm model	Estimated soil loss, water use	Characteristic externalities	Ex-ante analysis	Impact on employment
Rio Dona Juana	Colombia	3900	4050	1000	Yes	Yes	Drinking water supply	Yes	Yes
Rio San Antonio	Colombia	6500	4000	1100	Yes	Yes	Hydroelectric power production	Yes	Yes
Rio Lenguazaque[a]	Colombia	820	16,500	3000	No	Yes	Drinking water supply	Yes	No
Rio Guadalajara	Colombia	1000–2000	12,500	2025	No	Yes	Drinking water supply, irrigation	Yes	No
Rio de Oro[a]	Colombia	1790	7600	1900	No	Yes	Drinking water supply	Yes	No
El Garrapatal irrigation canal	Ecuador	625	Irrigation canal	2200	Yes	Yes	Irrigation	No	No
La Encanada	Peru	683	12,000	3500	Yes	Yes	None	No	No
Jequetepeque	Peru	200–900	350,000		No	Yes	Irrigation	No	No

[a]Watershed analysis conducted by the Universidad Javeriana.

- Small watersheds often approximate municipalities; hence they can be congruent with local decision-making units.

However, using a watershed approach to design development plans, orient municipal investment and 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;
3. Working with multiple levels of authority to set priorities, not just with individual farming families.

As a result, research and development interventions at the watershed level require significantly more time, data, funds and actors.

Making the concept of watershed analysis operational

Since 1995, CONDESAN and its partners have been learning how to conduct watershed evaluations, generally in catchments of 5000–25,000 ha. This work is at the interface of research and development since all the tools already exist. But to use them well, data must be collected by a multidisciplinary team and analyzed by the local actors. To date, most of the work has been done in Colombia. The process includes:

- **Estimating soil loss and stream flow under current land use patterns**. Using secondary and some primary data, information for watershed models is collected. We are currently using SWAT (Soil and Water Assessment Technique) to estimate stream flow, sedimentation, and the location of resource degradation "hot spots". This 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 (eg cropping calendar, tillage, fertilizer use, yields) of farms in different ecological zones of the watershed.
- **Characterizing the externalities of upper catchment management on downstream users**. In irrigated agriculture, for example, average and minimum stream flow rates and sediment loads are important. Maximum stream flow rates are important for flood management, and water quality is important for potable water or recreation. The key to capturing externalities (ie, downstreem costs that could be reduced if upstream activities were modified), however, is not the actual characteristics of the resource but demonstration

TABLE 2 Characterization of water flow and erosion losses using the Soil and Water Assessment Technique (SWAT)

	Rio de Oro		Rio Lenguazaque		Rio Guadalajara		San Antonio	La Encanada
	Actual	Proposed	Actual	Proposed	Actual	Proposed	Actual	Actual
Weighted CN[a]	62.1	59.3	64.3	58.5	57	50	44.5	70
Q 05 (L/sec)[b]	4000	NA	2150	NA	8400	5300	20,000	3200
Q 95 (L/sec)[c]	720	789	120	137	1330	1473	5000	50
Sediment (ton/ha)	57.5	31.6	No data	No data	52.1	18.1	51.2	8.5

[a]CN, curve number, based on the USDA SCS tables. The lower the curve number, the less run-off and erosion take place.
[b]A measure of high flow volumes. Flows will exceed this maximum only in 5% of all cases.
[c]A measure of low flow volumes. Flows will exceed this minimum in 95% of all cases.

of the impact of changes in land use management on the future amount or quality of the resource.

- **Testing new scenarios.** Analysis based on changing vegetation cover (eg reforestation, improved pasture management, new crops) and agronomic practices (eg no-till, early planting, green manures, alley cropping) is 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), some partial conclusions can be drawn from this experience.

Analytical results

Most farming practices in the higher rainfall (>3000 mm/yr) and lower elevation (2500-5000 m) watersheds in Colombia conserve soil fairly well. Measured losses associated with fallow and pasture systems are low (<9 t/ha/yr), somewhat higher with coffee (around 15 t/ha/yr), and the highest under food crops like corn, plantain, and cassava (>20 t/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 50 t/ha/yr) at the watershed level are most likely due to small landslides, erosion from road cuts and urban zones, and stream bank collapse—not just agriculture.

The SWAT program allows the test watershed to be subdivided into as many as 10 sub-basins. If the data are available, this makes it possible to identify 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 it is not surprising that most data are not digitized or geo-referenced. It is unfortunate, however, that the data available for watershed evaluations are 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. In the case of Guadalajara, increasing forest cover from 10% to 30% 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 (see Table 2).

In three cases, analysis of externalities of current land use practices indicates that it is unlikely downstream 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. In Peru, although the Gallito Ciego dam is rapidly filling with sediment, Pacific coast farmers are not likely to invest in upstream improvements. They know that the majority of the sediment (we estimate 70% of the accumulation over the past 10 years) comes during a catastrophic "El Niño year" (compare Figures 3 and 4), not through annual overland

FIGURE 3 Looking into the Asunción Watershed during the rainy season (Cajamarca, Peru). (Photo by E. Mujica, CONDESAN)

FIGURE 4 Landslides in the Asunción Watershed after the 1998/99 El Niño year (Cajamarca, Peru). (Photo by J. Posner, CONDESAN)

flow that might be managed by reforestation. 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) at current irrigation efficiencies, the first task is to improve on-farm water management; and 3) the major option for increasing water availability would be expensive civil engineering (a reservoir) and not upland conservation strategies. Perhaps most importantly, the irrigated farms are primarily planted with corn and beans (80%) where additional water has a relatively low value.

Finally, research suggests 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.

What general lessons have been learned?

These results have been very sobering and clearly indicated how complicated watershed reality actually is. While the jury is certainly still out, in these eight cases, moving the analysis beyond the classical "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 direct 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 Niño) are the culprits. The public investments necessary to address these phenomena 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 reforestation for sequestering CO_2.
- **Prioritizing watershed interventions may be of only academic interest.** While analysis can indicate where the "hot spots" are, political realities put great pressure on upland authorities to disburse conservation funds without regard to topography. For example, 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 per ha in annual dues for membership in an irrigation system, and generally grow crops of fairly low value. In many cases, these low rates are justified by 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 local producers would agree to pay higher water taxes for use in water conservation in the upper watershed.
- **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 will 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 improved irrigation techniques.
- **Resistance to sharing data remains an unfortunate reality in the Andes**. Data-intensive models (quantity, need for geo-referencing) can be very difficult to run without collaboration from state agencies. While not a complete surprise, this problem must be worked at, day by day, agency by agency, through education and by developing joint projects. Our vision is that in the future these agencies will not sell data but learn these analysis techniques and sell information.

Where do we go from here?

Since the 1960s production agronomists and economists have gradually expanded their focus of inquiry from commodities to cropping systems to whole farm analyses, and some have recently 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 very complicated levels for designing and prioritizing research and development programs.

On the other hand, we have been surprised by the general trends toward decentralization of political power and globalization in the marketplace, which has triggered increased local interest in natural resource use and management. We are finding that this mixture of GIS mapping and biophysical and economic modeling is responding to a need—for example, of municipal authorities in Colombia and soil and water conservation programs in Peru. Incorporating natural resource management information at the local level is helping to reinforce local planning exercises. Our intention is to try to strengthen our efforts in this area over the next five years.

This paper is a revised version of a paper in the "Papers from Centres" series published on the CGIAR Integrated Natural Resource Management web site. *Ed.*

AUTHORS

Ruben Dario Estrada and Joshua Posner
Consortium for the Sustainable Development of the Andean Ecoregion (CONDESAN), International Potato Center (CIP), PO Box 1558, Lima 12, Peru.
j.posner@cgiar.org

Ruben Dario Estrada is an agricultural economist with the Consortium based at the International Center of Tropical Agriculture (CIAT) in Cali, Colombia. r.estrada@cgiar.org

Joshua Posner is an agronomist and Coordinator of the Consortium for the Sustainable Development of the Andean Ecoregion (CONDESAN), Lima, Peru. j.posner@cgiar.org

FURTHER READING

Arroyave F, Tapasco J, Rivera B, Obando FH. 1999. Viabilidad del uso del modelo EPIC para estimar pérdidas de suelo en zonas de ladera. *Suelos Ecuatoriales* 29(1):71-75.

Instituto de Estudios Rurales. 1999. *Revisión de incentivos economicos para proyectos de microcuencas. Anexo Hidrológico*. Bogotá, Colombia: Universidad Javeriana.

Rios G, Abad G, Rivera R, Estrada RE. 1998. Analisis de opciones de desarrollo en la cuenca alta del Rio Dona Juana-Victoria, Caldas, Colombia. Trabajo presentado al Tercer Simposio Latinoamericano sobre Investigación y Extensión en Sistemas Agropecuarios (IESA-AL III) Lima (Perú).

Rivera B, Estrada RD. 1998. Modelo para el empoderamiento de una comunidad local a partir del análisis de los terminos de intercambio entre criterios de política. Trabajo presentado al Tercer Simposio Latinoamericano sobre Investigación y Extensión en Sistemas Agropecuarios (IESA-AL III) Lima (Perú).