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A Landscape that Unites: Community-led Management of Andean Watershed Resources[1]

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The hillsides agroecosystem of tropical America covers about 1 million square kilometers and sustains an estimated 10 million poor people in marginalized, rural communities. More than half of this area is undergoing rapid environmental degradation as a consequence of deforestation, overgrazing and destructive agricultural practices.

Environmental and economic problems these communities face often transcend the boundaries of individual farms and must be addressed through collective action across entire landscapes. Such action requires that rural communities be able to set clear objectives, quantify the various environmental, economic and social factors that enter into their decisions, and define with some accuracy the geographic area of interest. A usefully unit around which to organize these tasks is the Acommunity watershed'.

To encourage community-led management of multiple-use watershed resources, two parallel strategies, with examples, are presented. First, there are needs for increasing the accuracy and precision of data together with convenient decision support tools so that stakeholders can systematically analyze choices for resource-use. New methods and tools need to incorporate both strategic principles and local knowledge.

The second recommended line of research aims at developing replicable, multi-institutional alliances for establishing consortia with the analytical capacity to plan and support community watershed resource management. In cases of conflicting interests, a process of Adeal making@, in which costs of resource conservation are balanced by concrete incentives, can be catalyzed by a process of successive refinement of information and analysis.

The Challenge

The hillside agro-ecosystem of tropical America covers about 1 million square kilometers, is a major contributor to regional food security, and is the basis of livelihood for a large proportion of rural poor.

Principal countries (followed by percent area in steep-slope agriculture) include Bolivia and Colombia (40%), Ecuador (65%), Peru (50%), Venezuela and Costa Rica (70%), El Salvador, Guatemala (75%), Honduras and Nicaragua (80%). Tragically, an estimated half of the hillside agro-ecosystem resource base is degrading as a consequence of decisions that lead to deforestation, overgrazing and destructive agricultural practices. (UNEP, 1992).

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The hillside agro-ecosystem sustains an estimated 20 million people. Half of this total, or 10 million people, are classified as “poor”, living in marginalized, rural communities. Moreover, World Bank data show a significant portion indigent, i.e., without means to meet minimal nutritional needs; 23% of Colombian rural population is indigent; 46% in Peru and 57% in Guatemala (ECLAC, 1990). Female-headed households are a high proportion of the indigent rural population (ECLAC, 1993). Thus, in most countries with significant proportions of area in hillsides, the locus of poverty has yet to shift from rural to urban areas. Furthermore, World Bank figures for the 1990s indicate that rural impoverishment has recently increased in some of these areas.

In the more densely populated and drier areas, fallow periods have been shortened or replaced by organic or chemical fertilizers. When farmers cannot obtain or afford fertilizers, they work off farm, exacerbating the “feminization” of hillside farming in which the real farmers are women managing subsistence or semi-commercial small farms. Even in “well-watered” areas, erratic distribution of rainfall can lead to short but critical periods of drought stress. Pest, disease and weed control are major constraints in annual crops. Degraded fallows, largely synonymous with overgrazed pasture, occupy an estimated 40-60% of hillsides. Large farms maintain low stocking rates and sharecrop arable land. This reflects a strategy of investing in land to protect capital. Improved production is frequently not a primary nor even important objective of large landowners in the hillsides, who make up about 20% of farmers and own 80% of the land. Intensification of production on small farms is an important part of alleviating poverty that drives migrants to colonize, deforest and degrade increasingly fragile environments.

Environmental degradation of hillsides has serious implications not only for viability of agricultural production in the hillsides themselves, but also for “downstream” lowland agricultural and coastal ecosystems which can be affected by soil erosion and agrochemical contamination. Secondly the welfare of rural and urban population who draw water supplies from water courses originating in hillside watersheds is also intimately affected by contamination, soil erosion, sedimentation and major land slippage caused by misguided land use decisions

The third and potentially most irreversible damage due to poor planning and management decisions in hillside environments, and that with major social costs, is the loss of biodiversity due to disappearance of montane forest. This is estimated at between 15% of forest area in Bolivia to 55% in Guatemala. The rate of hillside deforestation is higher than in lowlands causing an estimated loss of 90% of montane forest by 1990. Montane forest has very high biodiversity, arguably higher than for lowland forest, especially with respect to herbs and shrubs found between 600-3000masl, which are considered important for conserving wild crop genetic resources in-situ.

The rapid rate of environmental degradation in hillsides is driven by a number of factors that include the unfavorable structure of incentives for hillside farmers to invest in sustainable management practices. These incentives are shaped by specific agro-ecological conditions, available technologies, prices of inputs and outputs, opportunities for off-farm employment and migration, as well as cultural and organizational norms of natural resource management. Income-generating activities that permit capital accumulation and agricultural intensification are key to changing rural stakeholders' environmentally destructive management decisions and practices.

In summary, links between agriculture, natural resource management and economic problems in lesser developed countries were addressed by a recent Consultative Group for International Agricultural Research (CGIAR) task force who concluded that there existed ΑΨan abysmal lack of data to validate Ψ conventional wisdom≅ (CGIAR, 1997). Clearly, progress toward the goal of more productive, sustainable and healthy hillside environments is being hindered by a lack of clear objectives, a failure to quantify variables and a lack of precision in defining physical areas of interest (Lal, 1994) all of which are indispensable for arriving at negotiated agreements for community action as well as reproducing results achieved. Information shortcomings can be largely attributed to a confusing range of temporal and spatial perspectives among stakeholders that so characterize many resource management problem

Framework for Research

One of the greatest challenges for CGIAR researchers, government and non-government organizations and resource-poor farmers is the need to adopt perspectives that transcend field or farm boundaries and accept solutions necessitating some form of collective action among landscape users.

Agroecoregional research requires that the traditional definition of research site and data collection be adjusted to include different spatial and temporal scales targeted by different stakeholders. This is essential for addressing issues through collective action. So far, with notable exceptions (Veldkamp and Fresco, 1996), "across-scale analysis" has resulted in little more than independent characterization of ever larger geographical areas in less and less detail; from plots through landscapes, as indicated in Figure 1.

As suggested in Figure 1, research needs to emphasize the *organizing principles and functional relationships that structure* multiple-scale systems. A key aspect of this strategy, based on hierarchical systems theory, is an increased emphasis on sample surveys and controlled prospective and retrospective studies vis-à-vis laboratory and field experimentation.

Outputs of this research are process-level analytical models that can define and categorize the biophysical and socioeconomic responses upon which agricultural systems depend; responses that may not manifest themselves in the space/time frame of typical crop/soil experimental studies. This information helps identify points of policy and management intervention, and, when combined with local knowledge, provides *ex-ante* analysis of trade-offs involved in choosing different interventions. In cases of conflicting interests, a process of Adeal making≅, in which costs of resource conservation are balanced by concrete incentives, can be catalyzed by a process of successive refinement of information and analysis.

Watersheds as an organizing unit of study

For the traditional CGIAR Center and national agricultural system researchers used to targeting problems, priority areas and beneficiary groups in terms of Asingle decision makers≅, the Acommunity watershed” offers a logical statistical population on which to begin addressing multiple stakeholder and common property resource issues.

Technical reasons for targeting community watersheds are well known. Overland and through-flow of water draining through catchments integrates and concentrates the effects of many crop and land management activities. Off-farm effects can be made explicit. Catchment boundaries are specifically definable and reproducible permitting application of systems analysis. Catchments are naturally organized into biophysical, and in some cases, socio-economic hierarchical systems.

Although watersheds are a useful unit for organizing research, this does not imply that the objective will always result in management plans that optimize water resources. Rather, the objective is to include analysis of water as well as soil and vegetation in the family of indicators which provide a "feedback mechanism" for stabilizing and sustaining hillside production systems (CGIAR, 1996).

The mandate of the CGIAR requires that research Centers like CIAT focus research towards international public goods and services in contrast to developing Asite specific” technologies appropriate for specific community watersheds. In keeping with this mandate, the remainder of this paper details two parallel research strategies. We begin with examples of procedures that are being established for database use in targeting problems, priority areas and beneficiary groups, and follow with protocols for catalyzing multi-institutional alliances capable of using information technology in planning and supporting community watershed resource management. We conclude with examples using simulation modeling as a tool for stimulating community discussions by characterizing responses to land management interventions.

Data Collection and Quality Control

As recommended by the CGIAR TAC (1997), ΑΨabysmal lack of dataΨ≅ requires major efforts in reviewing, editing, consolidating and relating/georeferencing biophysical and socio-economic data into user-friendly databases. These are prerequisites to analyses of relationships, for example, between poverty and environmental degradation. However, requesting proprietary data from national organizations requires extraordinary trust based on long working relationships. This is a comparative advantage of the CGIAR Centers like CIAT.

Data collection in tropical America is not as institutionalized to the degree it is in North America. Because of severe resource constraints, national agricultural and population censuses are not carried out regularly nor analyzed to the degree one might wish. Detailed climate and soils data are not usually available for more than the most intensively cultivated commercial areas and large scale (1:50,000) topographic maps, when digitized, need to be checked for common errors like rivers overlapping Αvalley≅ edges, contour lines at map edges not congruent, incorrect coding of contour elevations and inconsistent digitizing of river direction. Not as obvious, perhaps, as the aforementioned errors which are passed on to digital spatial coverages, is the issue of identification of original sources used in the creation of digital terrain models (DTMs). In the process of checking DTMs, we have found some models are dominated by the grid of digitized points generated from the original map. This effect can be seen as spikes in the histogram of almost any DTM fitted to digitized or scanned contour data. We have found that some DTMs were quite likely not constructed from the original sources and resolution they were supposed to have been.

Not withstanding potential problems, topographic data are being digitized and edited which allows development of DTMs and topological analysis. Fig 2(a and b) show a GIS analysis of a region of central Honduras for which Αcommunity-scale≅ watersheds of 3000 Β 15000 ha have been defined. Also shown, as point data, are communities. Since watershed landscapes are hierarchical, there is some latitude when apportioning communities and watersheds. This is an issue that is best resolved through need and Αlocal knowledge≅.

National censuses do exist and, continuing with Honduras as an example, in collaboration with INEC (Instituto Nacional de Estatistica y Censo) we have resurrected decade-old digital databases of past national population and agricultural censuses. For example, from household level 1974, 1988 and 1993 censuses, we have reconstructed digital databases allowing statistical characterization and aggregation at the village/*aldea* scale which is ten times more desegregated (about 3000 records versus 300 records) than heretofore available. Until now, population and agricultural census data for countries like Honduras were only available in hardcopy. However, with the availability of reasonably inexpensive hardware and software, and examples of the power of information and interactivity, meaning parameter ranges can routinely be defined, plotted, analyzed and interpreted, there is demonstrable enthusiasm for making digital databases available.

Enthusiasm, however, for new analytical software, like GIS applications, without training may lead to mishandling of data collection or derivation. Take the example of the large-scale map of watersheds in Fig 2. A rather startling revelation is that the areas of two typical watersheds, as determined by a routine analysis of the “flat” map representation, amounted to 11280 and 5130 hectares respectively (Fig 2a). The areas calculated from the three-dimensional representation of the DTM-GIS model are 13600 and 6115 hectares (Fig 2b), a difference of 20%!

It can be strongly argued that the most common and successful application for satellite remotely sensed imagery to date has been in mapping land cover and land use (LC/LU). This is particularly so for high spatial resolution products where the ground dimensions of a pixel are less than 100 m by 100 m. Many examples can be found in the literature where the reported levels of classification accuracy exceed 80%. It is noticeable, however, that the majority of the applications are based either in regions of large-scale forestry or in intensive agricultural systems of North America and Western Europe. Hillsides are a fundamentally different environment with physical characteristics that present a much greater challenge for deriving LC/LU maps. Current remote sensing research at CIAT using LANDSAT TM imagery of mountain hillside systems, characterized by small plots on steep slopes, has shown that thematic accuracy of LC/LU mapping as measured by per pixel parameter accuracy can be disappointing, giving an overall percentage agreement in the range of 35%. We have experimental evidence from a Colombian study site with an analytical technique that raises accuracy to acceptable limits using the error matrix itself to adjust or calibrate any bias in LC estimates. More importantly, as the landscape becomes more fragmented with more edge effects and mixed pixels, and as spatial patterns become more intricate, the technique itself becomes more appropriate and more defensible.

Other data collection activities include successive refinement of remote sensed imagery using SPOT panchromatic, RADARSAT and digital air orthophotographs. Work with digital orthophotographs has focused on deriving terrain slope estimates. Terrain slope is one of the most fundamental variables in agriculture as it affects such variables as cost of preparing seedbed, erosion, runoff, mechanization and access. Despite its importance, slope remains elusive as estimates change continuously depending upon the distance over which it is averaged, grid cell size and scale of the original elevation data (Berry, 1993). A study was carried out for an Andean watershed in southwest Colombia to compare accuracy that can be expected for slope and altitude values derived from low cost DTMs. Eight gridded DTMs were generated from digitized contour maps at a range of scales (1:10000, 1:25000, 1:100000 and 1:200000) and a range of contour intervals (25 m ,50 m and 100 m). A control DTM was produced from large-scale aerial photographs (1:28000) and field verified using 91 differentially measured GPS ground points. The control DTM showed a vertical RMSE well within USGS accuracy standards. In addition to cell size and slope relationships, cost of production of DTMs and accuracy of results were determined. Some of the conclusions reached were 1) substantial savings in time and expense in DTM production accrue from digitizing every *n-th* contour as long as the new interval is not more than 25 m wider than the original interval when modeling altitude and/or slope, 2) regarding slope determination, contour interval has more influence than map scale, 3) cartographic data sources at scales equal or greater than 1:100000 and with contour intervals equal or greater than 100 m do not provide sufficient detail to usefully represent slope in community watersheds in hillside agroecosystems.

Decision-support tools are often associated with mechanistic models or goal optimization models. However, many land use decision requirements may be satisfactorily and economically addressed through a strategy of successive refinement of data on demand. For example, first approximations of potential erosion risk and watercourse degradation were supplied to a local Colombian watershed consortium using a DTM and water routing analysis. For regions that are contentious and worth the added expense, overlaying land cover on the DTM is an option. Still further refinement is possible by incorporating soil profile characteristics at some additional cost of information. This interactive, heuristic and descriptive GIS analysis has more short-term operational value for stakeholders managing agricultural-dominated watersheds in the Andean hillsides than USLE-based models using parameters derived for temperate North America.

If a pathological situation is suspected for a given watershed, the next obvious task is diagnosis. Diagnosis might follow a sequence of inquiries such as, 1) assessing the extent, severity and rate of progress of soil and water degradation, 2) assessment of impact on agronomic productivity and health of water-related processes, and 3) evaluation of economic impact of the degradation.

We have explored a few diagnostic routines within a peri-urban watershed in southwest Colombia. Analogous to the first request of a medical doctor preparing for a diagnostic examination, we analyzed the “patient’s” history. Table 1 is an example of the history of land cover/land use (LC/LU) for our watershed recreated from air photo interpretation for three dates over fifty years. Important conclusions about the “aging” of the watershed followed from the analysis. First, on balance, proportions for major classes of LC/LU aggregated at the three dates, including severely degraded land, seem to have changed little over the past fifty years. Second, analysis of LC/LU of specific, georeferenced mapping units across the three dates proves individual fields have been rotated into and out of different LC/LU over time. The unmistakable conclusion is that there are important, scale-dependent dynamic temporal processes at work throughout the watershed that are not revealed from analysis of time-series snapshots of LC/LU classes aggregated at “large” spatial scales. This led us to the next diagnostic task, assessing the impact of field-scale LC/LU histories on agronomic productivity.

Traditionally, agronomic commodity-constraints research has focused on improving cropping productivity by, for example, measuring fertilization efficiency evaluated in terms of economic marginal rates of return for various fertilizer levels. This approach is an undeniably important element in predicting the acceptance and rejection of new technologies by individual decision-makers. However, an arguably more relevant task for assessing impact of soil degradation across a wide spectrum of land users within a watershed context is identification of land and crop management practices that put the soil resource at risk of exceeding a threshold of irreversible loss of soil productivity. For this study, 'irreversibility' was defined as a change of state of the soil which cannot readily be overcome by application of fertilizers, a normal human response to market forces responding to product shortages, and a definition consistent with evaluation frameworks found in the literature (Acton and Padbury,1994; Conway, 1988; FAO 1976 and 1993; Keulen et al 1986; Lal 1994; Riquier et al 1970;).

In many Andean hillside watersheds, like the Colombian watershed in which these studies were carried out, soil maps at scales of 1:50000 are generally available. At this scale, soil maps differentiate soils by association that generally means the mapping unit aggregates soils formed under conditions of similar climate, parent material, native vegetation and topographic sequence. For this study we used site elevation and topographic classes as proxies for localized weather to impose further stratification. A wide range of human induced land use pressures, either degrading or regenerative, are found within the watershed. Our task was to assess whether land use decisions had irreversibly changed, for better or worse, the productivity potential of defined mapping units. We selected a range of six land use types (LUT), from 50-year old secondary regrowth forest to a long-term cassava-fallow system traditionally associated with soils with greatly depleted fertility. Indicator crops of bean, cassava and maize were seeded for 6 crop cycles and non-limiting fertility, weed and pest management applied.

Figure 2 shows the directed graph of "path" coefficients (normalized partial regression coefficients) for variables analyzed for their effects on attainable maize yields. Limiting interpretation of the analysis to the sign and general magnitude of the coefficients, it can be seen land use type is "causing" significant variability in potential economic crop yield. Nevertheless, season-to-season variability, interpreted as predominantly 'climate' and represented by the variable '*semester*', is a more important source of variation in yield than LUT. Contrary to popular opinion, the data collected show the trend is for the more intensively cultivated LUTs to have higher attainable yields than the "non-cultivated" LUTs given non-limiting levels of fertility. Diagnostic soil chemical analysis for the two extreme LUTs mentioned above showed significantly lower exchangeable acidity and higher organic carbon in the long-term cassava-fallow system.

Evaluating economic impact from direct measurements of soil and water degradation at the watershed scale is a daunting task and one we have not yet undertaken. In practice, we propose following an analytical strategy of successive refinement of data collection based on value of information as it pertains to negotiating collective action among stakeholders. Following this pragmatic strategy, we recommend an initial screening of LUTs to assess the "financial fitness" of different cropping scenarios found in a specific watershed. For example, in the Colombian example, we asked the question, "how would financial sustainability of a specific, representative farm be affected by different scenarios for soil loss"? Table 2 shows the results of a simulation indicating there would be no significant loss of financial sustainability over a fifteen-year period even with assumed soil losses of up to 50 Mg ha-1 yr-1 (Hansen, 1996). The significance of this study is that it highlights potential conflicts that exist between private benefit and social benefit. From the individual's perspective, erosion control strategies may not be economically attractive while, from the perspective of social benefit, there are few alternatives to saving the public water system from degradation. With inferences drawn from this analysis, the population of farms in the watershed can be screened and "at risk" areas in the watershed targeted.

Finally, it is important to reiterate that CG Centers like CIAT receive virtually all their funding from humanitarian aid agencies that demand practical applications of results for improving the well-being of poor farmers. A contentious issue is the ill-defined cause-effect relationship between poverty and resource degradation. Addressing this objective and monitoring development project impact requires a multidisciplinary approach to identify who the poor(est) are, a description of their environmental conditions and relationships between the two. As a first step, it was necessary to develop a methodology for making regional poverty profiles based on local indicators of poverty or well-being. Using local indicators identified for different levels of well-being, a parametric model was constructed for the Río Cabuyal catchment (7000 ha and 1000 families) in the Colombian Andes mountains. This well-being index combines seven parameters including the extent to which family members are dependent on day labor as a source of income, land and cattle ownership, housing quality, crop diversity and level of resources. A comparison of the constructed index with rankings of families made by local informants shows the index corresponds significantly to the local concept of well-being; but none of the individual parameters in themselves sufficed to explain the variation in well-being found in the catchment. The procedure is currently being applied to a large statistical sample in Honduras after which analyses of relationships between poverty, resource environment and system scale will be addressed.

Multi-Institutional Alliances

Watershed management involves the integrated management of a multitude of resources such as crop land, pastures, forests and water to each of which a multitude of often conflicting interests relate. These interests arise from shareholders inside as well as outside the watershed. The identification and negotiation of these interests therefore is an important element in the design and development of appropriate technology and its adoption in the context of improved watershed management. Based on experiences with inter-institutional consortia and an experiment organizing local-level management of the Río Cabuyal watershed in Colombia, six functions have been identified as essential for local-level watershed management organizations. Of these, at least three appear to be specific to watershed management. Besides being important in themselves, these functions provide some principles for the process of organizing for local-level watershed management.

1. *Identifying stakeholders and ensuring their representation in management effort*

The first of these functions is to identify the distinct local-level interests or stakeholders that relate to the use and management of resources within the watershed and ensure their representation in management efforts.

Local-level organizations can be either community or interest group based. In cases where the individual resource manager's interests are determined by his or her geographical location, community-based organizations are likely to be representative. However, when other factors such as ethnicity or a resource manager's access to resources determine stakeholders' interests, chances of community-based organizations being representative are limited. Our analysis in Río Cabuyal confirms a caveat expressed elsewhere, that organizational participation in community-based organizations tends to be skewed towards resource-rich households (Bebbington, et al. 1994; Pretty and Chambers, 1993).

In watershed management, representation of diverse interests may be vital to institutional effectiveness, due to the interdependency that exists among different users: i.e. one group's use of a resource directly or indirectly affects other groups' possibilities for using the same or other resources within the watershed. This makes the participation of all interest groups or stakeholders, relevant to a given resource, important to planning and implementation. Thus a stakeholder-based rather than community-based organization is essential to effective watershed management.

2. Provide forums for analysis and negotiation of diverse interests

Once diverse stakeholders are identified and have representation, the second function which local-level watershed management organizations should perform is to provide a forum or "platform" (Roling, 1994), where these interests can be analyzed and negotiated. In the first place, this means specifying time and place for such negotiations as well as who should participate.

Because of conflicts of interests relating to watershed management are not easily overcome, such forums cannot assume that stakeholders share a common goal. For example, in the case of the Río Cabuyal watershed, a conflict arose over slash and burn agriculture. Stakeholder analysis showed that very concrete interests, led by the

poorest households who are either short of labor or renting land and feeling no incentives to engage in long-term land improvements, prefer burning as a method of cleaning fields despite their awareness of the risks.
During negotiations, participatory techniques are required to draw attention to conflicts and different interests. The principal role of the facilitator organization is that of the `devil's advocate' to stimulate such analyses. Examples of such techniques are described in (Guba and Lincoln, 1989). In most cases, the facilitation skills necessary to lead such negotiations do not exist locally, but will have to be provided from outside, at least in the early stages of organization, underlining the importance for local-level organizations for advice and skill formation with respect to the organizational process as such.

3. Define rules and norms for the use of resources within the watershed

An important function of forums for analysis and negotiation is the definition of norms and rules for use of specific resources within a watershed, as well as sanctions for non-compliance. This is the third function of local-level watershed management organization and is shared with other types of local-level resource management. Thus, Ostrom (1994) asserts that rules regulating resource use need to be carefully tailored to the local conditions by specifying time, place, technology and quantity of resource units, as well as rules specifying resource input obligations, to support management activities relating to common-pool resources. Ostrom argues that uniform rules established for an entire nation or region cannot take into account such specifics and are therefore bound to fail.

Experiences with creating buffer zones to protect water springs and watercourses in Río Cabuyal provide a case in point. For many years, the regional water authority attempted to mandate buffer zones in the watershed by applying national laws prescribing buffer zones of 50 meters around water springs and 20-30 meters along water courses. Their efforts met with little acceptance from the local population. As a result of the involvement of the new watershed “stakeholder” organization, adherence to the general “rules” was relaxed and negotiated on a case by case basis, often being determined by the existing boundary between natural vegetation and cultivated area. This has initiated the fencing of several thousand meters of buffer zones by the local population using community labor.

4. *Initiate a process of local-level resource monitoring research*

A fourth function that should be undertaken by local-level watershed management organizations is to initiate local research for monitoring purposes. The watershed consortium was successful in mobilizing local labor for reforestation and creation of protected areas, but did not set up procedures for monitoring results. Conflicts with slash and burn land management in the watershed illustrated the need for local problem diagnosis (“locals” interviewing “locals” about their reasons for burning) followed by local monitoring of compliance. Once the need for sanctions based on monitoring was recognized, the additional problem of where to locate enforcement in the organizational structure had to be resolved.

The Río Cabuyal experience shows that providing information about the “state of resources” is itself an important part of the negotiation of conflicting interests and the definition of compromises and rules for resource use. Local monitoring research has specific importance in watershed management because the interdependence between different resources within watersheds is usually poorly understood by local decision-makers. Efficacy of efforts to regulate use or to conserve resources in watersheds is often determined by that factor which is least understood rather than most thoroughly considered (D. Walker, personal communication). For example, in Río Cabuyal, local people believe that the upper watershed tributaries determine the water flow of Río Cabuyal while simple mapping shows that tributaries all the way down to the tail end of the watershed are as important as the upper ones. This information helps stakeholders to better target the creation of buffer zones referred to above.

5. Formulating and exerting demand for services from external institutions in support of local management efforts

The fifth function which CIAT research finds should be undertaken by local-level watershed management organizations is to articulate local demand for external organizations such as NGOs and government organizations providing services to local communities. As was the case in Río Cabuyal, local populations are often confronted with an array of organizations each having their own agenda, resulting in a supply-driven rather than demand-driven provision of services, be they technical, social or organizational.

One of the tasks of local-level watershed management organizations is to attempt to change this situation by formulating agendas, identifying problems and/or defining concrete proposals for action to which external organizations can respond. To be successful, this obviously requires willingness on the part of the external organizations to listen and respond to such demands as well as an institutional mechanism through which such demands can be communicated. The creation of a mechanism through which local organizations could 'pull in' services lacking in the upper-watershed communities was critical to the success of their motivational campaign to protect the upper-watershed water sources.

6. Negotiating internal versus external watershed interests

Without the process of organizing for local-level watershed management, attempts to accommodate external interests in watershed management are likely to fail.

The sixth fifth and final function to be carried out by local watershed management organizations is to negotiate internal versus external interests relating to the use of resources in the watershed. Interests in improving watershed management in Río Cabuyal originate as much from stakeholders outside the watershed (such as urban populations in need of drinking water or down river commercial, irrigated farms and industrial users) as from stakeholders within the watershed. Just as in the case of negotiating interests originating within the watershed, the likelihood of reaching a shared sense of a common goal is limited. Instead, based on a process of acknowledging the existence of legitimate but often conflicting interests within as well as outside the watershed, compromises will have to be made that provide incentives for watershed farmers to erode less or for urban and semi-urban populations to waste less water.

A strategic result of catalyzing local, multiple stakeholder consortia is to capture the creativity and extraordinary breath of proposals for improving family well-being and environmental health that flow from these groups. The following section briefly lists some of the activities developed and led by a unique community consortium in the Río Cabuyal watershed in the Andean hillsides of southwest Colombia.

Community-led management of Watershed Resources

The following are some activities initiated by a prototype community consortium in the Río Cabuyal watershed in the southwest Andean hillsides of southwest Colombia. In recognition of accomplishments, the consortium has received two prestigious awards including the 1997 national “Premio Nacional de Ecologia: Planeta Azul” (National Ecology Award: “Blue Planet”).

- Thus far 23 community projects for a value of $7.0 million pesos (about US$7000) have been approved, benefiting 230 families in the Cabuyal River catchment. Of the 23 projects, 65% have had an emphasis on production, 24% on conservation of natural resources, 7% on training and 4% on postharvest processing.

- An association of Cabuyal River micro-processing units was formed around the processing of dairy products. In three communities, organizations of some 25 people each have been formed around agricultural production projects, managing special Seed Capital Funds.

- Over a two-year period (1994-95), 30,000 lineal meters (equivalent to 100 ha) have been isolated and another 15,000 meters (55 ha) are in the process of being protected. Most of these protected zones (90%) have been in the upper reaches of the catchment while many of the 2800 farmers that have contributed labor have been from the middle and lower zones. This is an example of the degree of agreement and harmony of activities of general interest for the community. The communities' contribution in labor for this activity is equivalent to US$12,000.

- From 1994-96 a total of 172,220 trees were planted in 15 of the 22 villages in the Cabuyal River catchment, with the participation of 1050 farmers, school teachers and students. The farmers' participation and access to information and technologies have made it possible to increase the number of native trees. Of the trees planted, 60% have been fast-growing species as an energy source, an important need in the zone. The remainder was native species, bamboo, ornamentals and fruit trees.

- There has been a process of spontaneous adoption, i.e., with no direct intervention by extension agents, of live barriers. Barriers most acceptable to farmers are imperial grass (*Axonopus scoparius)* (91%), sugarcane (62%), citronella (48%), pineapple (30%), lemon grass (26%) and vetiver grass (14%). This selection of materials is related to their double purpose: not only do they retain soil nutrients, but they also serve as feed for animals, food or for making essential oils, and they do not compete with the main food crops.

- The community has contributed 750 days' labor towards activities restoring two lagoons used in the past for recreation. Activities included clearing aquatic weeds, planting ornamental trees and improving surrounding ground cover.

- Proposed curriculum in environmental education began a cultural process within the 32 elementary and secondary schools. This will gradually be extended to include community adult education.

- Establishment of rural agroindustries as an alternative for generating employment is high priority. Milk that was previously sold raw, with no value-added, is now processed into seven products including creamy white cheese, two types of farmers' white cheese, smooth cottage cheese, *kumiss*, provolone and yogurt

A Landscape that Unites

Throughout tropical American hillsides, the vast majority of watershed inhabitants scratch a living from small farms on infertile soils, often on steep slopes vulnerable to erosion. Shortages of just about everything - land, water, labor, inputs, cash, credit, schools, clinics, roads, transport and communications - frustrate their daily efforts to escape from poverty. In this difficult setting, what difference can local community consortia, like the one in the Río Cabuyal watershed make? One of the most significant contributions so far has been to give local people a tangible, physical view of the landscape that unites them. Taking up much of the floor space in the Consortium's small office is a cumbersome but colorful relief model of their watershed. Built in

Styrofoam and papier-mâché, using maps generated by geographic information systems (GIS), the model was taken to each of the watershed's villages in turn, where local people painted in the streams, roads, fields, houses, and other familiar features (Fig3a). A standard color coding was used to denote land use - brown for coffee, deep green for pasture, dark brown for areas cleared by burning, bright red for eroded land, and so on. The result is a powerful tool for stimulating group discussion and creating a sense of community (CIAT, 1996).

Add to the relief model, the power of strategic scientific knowledge and interactive decision-support systems (Fig3b), and the result can help stakeholders ranging from farmers to local government agencies or national policymakers assess more realistically the possible outcomes of different resource management choices. We close with an example of results of sophisticated simulation studies analyzing the financial sustainability for a fifteen-year period of an actual hillside farm from the Río Cabuyal watershed. The sustainability probability index of the base cropping system scenario was set at 0.64 and increases dramatically to 0.99 (scale 0 to 1.00) with the substitution of irrigated tomato for a rainfed crop (Hansen, 1996). An obvious question that arises from this analysis is, What would be the consequence if 200 farmers all demanded irrigation? A follow-up analysis of the tradeoffs of introducing irrigation in this particular watershed is that there is predictable risk of shortfalls of water needed for domestic purposes. Furthermore, the risks and sacrifices for stakeholders are not distributed equally across the watershed (Beinroth et al, 1997). As with the physical relief model, simulation models are another powerful tool for stimulating group discussion and creating a sense of community.

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Figures:

Fig 1. Schematic diagram illustrating a common physical and social organizational structure found throughout the hillside agroecosystem. Asymmetrical linkages act as control mechanisms affecting the introduction of change.

Fig 2. Directed graph of “path” coefficients (normalized partial regression coefficients) for variables analyzed for their effects on attainable maize yields.

Fig 3. Examples of how boundaries of community watersheds may be defined. Fig 2a illustrates first approximations of GIS-derived boundaries that rarely, if ever, correspond to political unit boundaries. Fig 2b illustrates a DTM for part of the area shown in Fig 2a, and notes the differing GIS-determinations of area (ha) for two typical watersheds.

Fig 4. Two examples of powerful tools for stimulating group discussions and creating a sense of community responsibility for management of watershed resources. Fig 3a shows a relief model of the watershed inspired by the local consortium and constricted with enormous community involvement. Fig 3b illustrates a complementary and more analytical approach using interactive GIS and simulation.