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Designing Policies to Reduce Rural Poverty and Environmental Degradation in a Hillside Zone of the Colombian Andes

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Summary. — A household survey in a hillside zone of the Colombian Andes was used to develop a typology of farm households based on their assets and productive activities. Household poverty was not found to be directly correlated with environmental degradation. Degradation seems to be a function of farmers' productive activities, depending on the type of assets that they own. Based on linear programming simulation, cost-efficient policy interventions were prioritized to account for both household poverty and the potential for environmental improvement.

Key words — Latin America, Colombia, hillsides, rural poverty, environmental degradation, natural resource conservation policy

1. INTRODUCTION

Poverty constitutes one of the leading problems facing Latin America (Grupo de Río, 2002). Yet despite copious investments, the evidence suggests not only that rural poverty has failed to diminish, but that in fact it has tended to grow in many countries (CEPAL, 2001). The high transactions costs faced by small farmers, due to problems of information, organization and exchange, are exogenous phenomena that act like structural barriers limiting their access to markets (Schejtman, 1998) and restricting small farmer competitiveness in a globalized economy. Weak institutional structures have also aggravated rural poverty by slowing resource transfers to the neediest and by stimulating a culture of dependency on state welfare programs (Haudry de Soucy, 1998).

At the same time, society has a growing interest in preserving natural resources and sustaining productive processes, especially those found in particularly fragile ecosystems, such as the Andean hillsides. Unfortunately, the intervention strategies meant to restore and improve natural resources have not achieved the desired impact (Winters, Espinosa, & Crissman, 1998).

Although poverty and environmental degradation have received ample study separately, their interactions have not been systematically analyzed. Consequently, policies have tended to create conflicting effects, to miss opportunities for synergy, to compete for implementation resources, and to send contradictory messages to rural people. Various case studies have shown that poverty can be both cause and effect of natural resource and environmental degradation (Biaggi, 1998; Larrea *et al.*, 1998; Miranda, Carvalho, & Dorado, 1998). The literature describes a vicious circle of poverty

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and environmental degradation from the two viewpoints, representing different processes with very different policy implications.

In the first case, producers are viewed as being pushed by population growth and poverty to exploit fragile, marginal soils, resulting in soil degradation while poverty deepens due to the low productive potential of the resource base (Reardon & Vosti, 1996). A vicious downward spiral ensues, where labor productivity and *per capita* food production erode to the point of subsistence, while population growth becomes unsustainable (Cleaver & Schreiber, 1994). This paradigm finds resource fragility and poverty to be the triggers of a vicious circle leading to exploitation of yet more fragile resources. Because the argument centers on the fragility of biophysical resources that in general cannot be modified (without migration to other areas), the poor are destined to increasing poverty and natural resource exhaustion.

A more optimistic point of view (Hazell, 2002) holds that the vicious circle can be broken when population pressure rises to the point that labor becomes less costly, generating a process of induced innovation whereby communities invest in agricultural intensification and improvement of natural resources. The efficiency of this process depends on the type of technological change induced, potentially boosting crop yields and farm resource productivity, including farm labor.

Although it acknowledges the fragility of some natural resources, Hazell's vision gives greater importance to human actions to transform the triggering conditions of the poverty–degradation circle. Rural household behavior—determined by the quantity and quality of assets at hand—shapes decisions about production, consumption and investment that affect links with the natural environment (Reardon & Vosti, 1996). Hence, poverty is not the direct cause of ecosystem destruction; rather it is a mechanism that transforms survival motives into human actions causing environmental degradation (Marambio, 1996).

Many factors conspire to discourage farmers from implementing sustainable practices. These factors include the high present value of consumption compared with the future, strong restrictions against rapid liquidation of resources, high initial investment costs for many projects, and a lack of opportunities to acquire relevant technology and information (Guevara & Muñoz, 1993).

Scherr (2000) contends that despite their limited resources, the rural poor possess an unusual ability to adapt to natural resource deterioration or to mitigate its effects. For example, indigenous peoples have developed methods for managing soil degradation, and some small farmers diversify productive activities to reduce degradation while maintaining incomes (Forsyth, Leach, & Scoones, 1998). This view of the poverty–environment relationship finds that poor farmers can achieve sustainable resource management, but they need improved skills, new technologies to boost the productivity of their resources, and participatory research in local communities for better policies and programs (Scherr, 2000).

Policy instruments (incentives, tariffs, trade barriers, and property rights) are receiving increased attention from researchers as efficient mechanisms for creating an environment for harmonious development of production systems (Merlo & Paveri, 1997). Despite evidence that asset levels influence the adoption of practices that degrade or conserve the environment, ignorance of the causal mechanisms between asset endowments and environmental degradation prevents policies designed to combat poverty or conserve natural resources from achieving the desired impact.

One new strategy for using incentive-based policy instruments is the identification and internalization of positive environmental externalities generated by rural systems for natural resource management. Such beneficial externalities as water availability and quality, carbon sequestration, biodiversity protection are captured by various societal groups, and hence are not correctly viewed by public investment projects (Estrada & Posner, 2001). Identification and proper valuation of these externalities would be the first step for society to allocate resources to start a virtuous circle that improves resource management generating better environmental and social impacts (Estrada & Posner, 2001). Implicit to this focus are both equity and efficiency criteria. Producers of a negative externality would pay a tax that ended the overproduction of the byproducts harmful to the environment. Moreover, revenues from taxes on negative externalities can be used to compensate the producers of positive externalities, alleviating the underproduction of positive externalities (Panayatou, 1996).

Due to the multiplicity of factors that affect the poverty–degradation nexus, Scherr (2000) argues that the results of any analysis are very specific, especially given the huge diversity of households and the production systems they manage. In order to improve resource allocation for societal benefit, the target areas for policy intervention should be identified and prioritized, including both the target population and the specific policy component. Unfortunately, methods for prioritizing viable and suitable policy interventions are hard to come by.

The objective of this research is to determine the relation between different types of poverty and environmental deterioration in an Andean hillside zone for the purpose of aiding political decision-making. More specifically, the research quantifies levels of household asset ownership, makes qualitative and quantitative measures of natural resource use and environmental degradation, creates a typology of household asset levels, correlates types of poverty with environmental impacts, quantifies the shadow price of productive resources, and identifies target niches for policy intervention that could jointly resolve problems of poverty and environmental degradation.

2. METHODOLOGY

This research is based on a survey conducted in the municipalities of Samaná and Pensilvania in eastern Caldas Department in Colombia. These municipalities typify the hillside environment of the Colombian Andes: steep slopes, heavy rainfall, fragile soils, biophysical constraints to farming activities, high levels of Unmet Basic Needs (NBI) among residents, and a quality of life index well below the departmental average (Fundación NATURA, 1994). Local agricultural systems and household incomes center on coffee mixed with subsistence crops (corn, beans, plantain and cassava), as well as sugarcane and pastured livestock, all in systems that receive minimal agrochemical inputs (Rivera & Estrada, 2002). Low coffee prices, scarce capital, and the challenging climatic and landscape conditions conspire to impede the development of alternative sustainable systems.

From an environmental standpoint, the zone has two special qualities: unusually rich biodiversity (Fundación NATURA, 1994) and exceptionally heavy rainfall, over 6,500 mm annually, that makes this a high-potential region for hydroelectric projects (Loaiza & Murcia, 1984). This great natural wealth is threatened however by land fragmentation and degradation that result from an advancing agricultural frontier (CORPOCALDAS, 2000).

(a) *Data collection*

A sample of 165 families (15% of the population) was selected in the watersheds of the San Antonio, Santa Marta, Moro, Tenerife and Manizalito rivers for interviews between May and November of 2000. The sample was stratified by watershed and altitude (high, medium and low zones), using cartographic information on altitude and property boundaries. Sampled farmers received a previously validated questionnaire covering household assets, agricultural management practices, and the status of natural resources. In addition, selected biophysical measurements were taken on each farm, including altitude, distance to the nearest paved road, distance from the road access point to the nearest market, and slope for each type of land use.

The data collected were used to calculate the following indicators of pressure on natural resources: firewood consumption (tons per household per year), wood gathered (cubic meters per household per year), deforestation (total hectares per farm), burned area (hectares per household per year), and hunting (kilograms of meat hunted per household per year). Soil loss (tons per hectare and tons per farm per year) was simulated for the different land covers using the EPIC (Environmental Policy Integrated Climate) simulation model, previously calibrated on runoff plots (Arroyave, Tapasco, Rivera, & Obando, 1999; Sarmiento, Tangarife, & Rivera, 2001). In addition, carbon sequestration potential of the forest cover was calculated using the net carbon growth rate estimated by Orrego and Del Valle (2001) for similar ecosystems. Hydrologic flow rates were not included in the analysis, as previous studies in the zone had already calculated the effect of this externality on the hydroelectric project (Rivera & Estrada, 2002).

The major variables used to measure wealth and income were farm area (hectares), resident labor availability (number of men in household aged 14–65 who work on the farm), labor sales (days per household per year), capital invested (value of land, infrastructure and livestock on the farm), and net income, expressed in monthly legal minimum wage equivalents (US$ 137 per month at the mean 2001 exchange rate of US$ 1.00 = COL$ 2,300).

(b) *Analytical methods*

The typology of households by asset level was developed using cluster analysis with principal components on the variables for household socioeconomic status and natural resource use. Descriptive statistics were developed for the household type developed from each cluster. The key socioeconomic variables—income, resident labor availability and capital invested in land, infrastructure and livestock—were standardized to z-values, where $z_i = (\mu - x_i)/\sigma$, and μ is the mean, x_i is the value of the variable in cluster i, and σ is the standard deviation, so that the variable is standardized with mean 0 and standard deviation 1. The sum of the standard values creates an artificial variable called "socioeconomic level."

A similar approach was used to create an artificial variable called "environmental pressure" standardizing and integrating the environmental variables: biodiversity loss (hunting and deforestation), farm soil loss, and carbon sequestration potential. The correlation between socioeconomic level and environmental pressure was analyzed by graphing both variables on a Cartesian plane.

A linear programming optimization model was built to simulate household behavior based on the interaction of the diverse factors that act as constraints (Estrada, Chaparro, & Rivera, 2001). The model's objective function was to maximize the farm's gross margin (gross income minus variable costs) by choosing productive activities that exist in the zone, subject to constraints on land, labor and capital resources, as well as a minimum area planted to subsistence crops.

The model simulated expected behavior for the year following the base year of the study. Additional cropped areas in the second year, obtained by cutting down forest, would add to household revenues. Consequently, the producer would not dedicate resources to conservation activities so long as the latter did not offer a gross margin greater than or equal to the potential added revenues that would be foregone. Likewise, households would be willing to produce an environmental service so long as its price were greater than the costs of production plus any net utility lost. The gross margin per unit of resource conserved corresponds to the shadow price of resource conservation.

In order to prioritize niches for policy intervention in the current systems, an index was developed (Seré & Estrada, 1996), based on household socioeconomic status and the potential for environmental improvement (measured by the shadow prices of resource conservation). The priority index was calculated by adding the artificial variable "socioeconomic level" of each cluster to the standardized value of each potential conservation variable (shadow prices of forest conservation, soil conservation, and carbon sequestration). Low values signified the highest priorities for intervention due to lowest socioeconomic status and lowest shadow price of the resource. The priority value of each cluster was transformed to a 0–1 scale where 1 represents top priority and 0 represents the bottom.

3. RESULTS

(a) *Typology of households by asset levels and farming activities*

Eight principal components explained 61% of the variability in the data. The first two components represent structural characteristics of the farm, including the variables total area, area in pasture, area in coffee, area in forest, and value of the livestock herd. The next three components represented the social part: labor availability, number of persons who live on the farm, educational level, and percentage of the farm in fallow. The final three components represent natural resource use, including quantity of wood harvested, area deforested, quantity of wood sold, and area burned. Table 1 presents the mean and range of the variables included in the principal components analysis.

Based on these components, nine household types were distinguished, differentiated by their socioeconomic characteristics, management practices, and pressure on natural resources with a coefficient of determination of 0.60 (Table 2):

(i) Small coffee growers. The largest group at 47% of households surveyed, these small-scale coffee growers average 3.6 ha, 55% of it in coffee. They farm at a mean altitude of 1,330 meters above sea level (m.a.s.l.), relatively near to roads (1.7 km). They rely on a relatively small and uneducated labor supply (270 man-days annually). They earn net household incomes equivalent to only 0.9 minimum wage equivalents. (Note: This household type includes a small subgroup, 3% of the sample,

Table 1. *Mean and range of relevant variables in the principal components analysis*

	Mean	Minimum	Maximum
Altitude (m.a.s.l.)	1,250	700	1,700
Resident labor available	1.46	0	3
Persons living on the farm	5	1	11
Days worked for pay off-farm	60	0	970
Farm area (ha)	10	0.5	100
Coffee area (ha)	3	0	18
Pasture area (ha)	3	0	80
Forested area (ha)	1.3	0	53
Net income (in monthly minimum wage equivalents = US$ 137 per month)	1.26	0	8
Value of livestock (COL$ 1,000's)[a]	963	0	13.143
Meat from hunting (kg/yr)	34	0	255
Firewood used (t/yr)	10	0	40
Deforested area (ha/farm)	1.56	0	30
Burned area (ha/yr)	0.22	0	3
Total soil loss (t/farm/yr)	31	12	175

[a] US$ 1.00 = COL$ 2,300.

Table 2. *Mean values of key assets and net income of the household types defined*

Household type	Percent of sample (%)	Area (ha)	Coffee area (ha)	Family labor[a]	Net income[b]
Small coffee farm	47	3.6	2.0	1.05	0.90
Medium-sized diversified farm	16	7.2	1.8	1.63	0.97
Day worker	11	3.8	2.0	2.35	1.13
Large coffee farm	10	12.0	8.0	1.73	3.22
Sugarcane farm	6	7.9	1.5	2.00	1.90
Frontier colonizers	5	31.0	3.6	1.43	1.38
Cattle ranchers on shares	3	26.0	0.5	1.25	1.20
Large cattle ranch	2	34.6	0.7	1.67	2.30

[a] Number of men in the family aged 14–65, who currently work on the farm.
[b] Expressed in monthly minimum wage units (unit = US$ 137).

of small-scale coffee farmers participating in a local program for conversion from coffee to blackberry production.)

(ii) Medium-sized diversified farmers. The mean land area of 7.2 ha on these farms is divided among pastures (55%), coffee (25%), and sugarcane (8%). The average farm is located 7.4 km by road from a market center and has 423 man-days available annually for farm labor. Net income is equivalent to one minimum wage.

(iii) Day workers. This group is made up of owners of small farms (3.8 ha), chiefly in coffee (2.0 ha). Unlike the small coffee farms, these households have large families (6.8 persons, on average) with high labor availability (612 man-days per year) of which 38% is sold for day work on other farms. The mean net income of 1.1 minimum wage equivalents comes chiefly from off-farm wages.

(iv) Large coffee growers. These farmers own farms averaging 12 ha that are chiefly planted to coffee (67%) and located at the optimal altitude for coffee (1,315 m.a.s.l.). Available family labor (450 man-days per year) is devoted to on-farm work, and these farms hire in the largest number of casual laborers among all the farm types (190 man-days per year). The investment in infrastructure and inputs for coffee is high, and these farms obtain the highest net income, at 3.2 minimum wage equivalents.

(v) Sugarcane growers. This group has medium-sized farms (7.9 ha mean) located in the lower reaches of the watersheds (1,000 m.a.s.l.);

they chiefly produce sugarcane for sugar-loaves (42% of land area) and manage pasture (28%), which they exploit by pasturing cattle on shares (i.e., cattle belonging to an absentee owner). They lack land in brush or forest. The sugarcane growers also have considerable labor available (520 man-days per year) and earn an average of 1.9 minimum wage equivalents.

(vi) Frontier colonizers. These producers own large farms (31 ha) that are largely devoted to forest and brush (72%). Located in the upper reaches of the watersheds (1,450 m.a.s.l.), they are remote from market centers and lack both roads and electricity. They are relatively short of labor (360 man-days annually), but sell labor to other farms (43% of available man-days). Educational levels are low, and their incomes average 1.4 times the minimum wage.

(vii) Cattle ranchers on shares. These owners of large farms (26 ha average) devote most of their land to pasture (89% of farm area) for cow–calf operations. They are located in the lower reaches of the watersheds (965 m.a.s.l.) far from both rural roads and paved highways. The area planted to subsistence crops is relatively large (1.0 ha), and the investment in livestock for home consumption is also high (COL$ 235,000). They invest little in owned cattle, as most of the animals belong to an absentee owner but are pastured by the rancher in exchange for a share of the offspring or sale income. Their mean available labor is 325 man-days annually, and their low net income equals 1.2 times the minimum wage.

(viii) Large livestock ranchers. This small group of farms (2% of total) own large areas of land (34.6 ha) devoted to ranching in warm altitudes that are marginal for coffee production (1,172 m.a.s.l.) and remote from population centers (13 km by road). Their typically large, well-educated families (7.3 persons) have available 430 man-days of labor annually, chiefly used on the farm. Livestock dominates these farms, which have a high proportion of land in pasture, significant income from hog production (COL$ 864,000 annually), investments in horses that exceed COL$ 2,000,000, and a high value of animals slaughtered for home consumption (COL$ 520,000). The net income of 2.3 minimum wage equivalents comes exclusively from livestock activities.

(b) *Environmental degradation by household type*

Based on seven key indicators (firewood use, wood gathered, deforestation, burned area, hunting, soil loss per farm, and soil loss rate per hectare), four household types were found to exert relatively low pressure on natural resources (Table 3): small coffee growers, medium-sized diversified farmers, day workers, and large coffee growers, who jointly represent 81% of the families surveyed. These farm types all rely upon coffee and have benefited from rural electrification by the Coffee Growers Federation, ergo the low use of firewood. Moreover, most of the firewood they do consume comes from coffee prunings rather than forest extraction. Soil erosion is the only environmental indicator that comes out relatively high, due to intensive cultivation practices.

The households generating the greatest relative pressure on natural resources were the large-scale ranchers and cattle ranchers on shares (Table 4). For both, livestock production was the principal activity, although they differed considerably in their capacity for investment and their family incomes. The ranching families extracted large quantities of

Table 3. *Environmental impact indicators (household means) among households exerting the least pressure on the natural resource base*

Environmental impact indicator	Small coffee farms	Day workers	Large coffee farms	Medium-sized diversified farms
Firewood used (t/yr)	7.1	8.8	8.6	9.4
Wood harvested (m^3/yr)	1.1	1.0	0.1	3.4
Deforestation (ha/farm)	0.6	0.3	1.0	3.1
Burned area (ha/yr)	0.0	0.1	0.0	0.3
Hunting (kg meat/yr)	7	80	17	12
Soil loss (t/farm/yr)	30	32	103	44
Soil loss rate (t/ha/yr)	11.4	8.6	8.7	4.6

Table 4. *Environmental impact indicators (household means) among households exerting the most pressure on the natural resource base*

Environmental impact indicator	Cattle ranchers on shares	Large livestock ranchers	Sugarcane farmers	Frontier colonizers
Firewood used (t/yr)	18.3	33.9	26.3	13.2
Wood harvested (m^3/yr)	4.2	4.8	1.9	1.9
Deforestation (ha/farm)	6.1	5.2	3.1	5.1
Burned area (ha/yr)	1.4	0.8	0.4	0.3
Hunting (kg meat/yr)	20	46	105	224
Soil loss (t/farm/yr)	143	91	44	43
Soil loss rate (t/ha/yr)	5.5	4.3	6.1	1.4

wood for the construction and maintenance of corrals and fences, they burned relatively large areas, and although erosion per hectare was moderate, their total soil loss was substantial due to the large areas farmed.

The sugarcane growers and frontier colonizers also generated relatively heavy pressure on the natural resource base. The sugarcane growers required large amounts of firewood to boil cane juice down to make sugarloaves. Lacking other energy sources, frontier colonizers gathered large amounts of firewood (13.2 t/yr), created major deforestation (5 ha/yr), and did the most hunting of any household type (224 kg/yr of meat).

(c) *Links between socioeconomic characteristics and environmental impact*

The graphical analysis based on artificial variables, illustrated in Figure 1, shows no linear relationship between socioeconomic status and pressure on natural resources. The coffee-farming households have the least impact on natural resources, independent of their asset level. The large-scale ranchers and sugarcane growers are relatively wealthy, but they also have a high impact on the natural resource base. The cattle ranchers on shares have relatively few assets, but they create the greatest environmental degradation.

(d) *Shadow prices of natural resource conservation*

The shadow price of resource conservation differs substantially across household types. The opportunity cost of maintaining production systems without felling more forest is highest among the small coffee growers, for whom not cutting a hectare of forest represents COL$ 1,000,000 in foregone revenues annually (Table 5). The lowest shadow prices of forest conservation are found among the large-scale ranchers and medium-sized diversified farms (COL$ 15,000 and COL$ 69,000, respectively). Among these households, forest conservation could be achieved at the lowest social cost. In the households of sugarcane growers and cattle ranchers on shares, the linear programming model simulated no deforestation, due to constraints on labor availability, meaning that

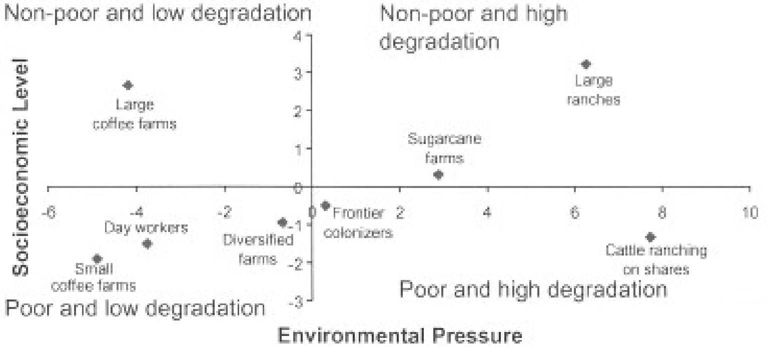

Figure 1. *Distribution of farms by socioeconomic level and environmental impact.*

Table 5. *Shadow price of natural resource conservation per resource unit by household type (in thousands of Colombian pesos[a] per year)*

Household type	Forest (COL$ 1,000/ha)	Erosion (COL$ 1,000 per ton)	Carbon sequestration (COL$ 1,000 per ton)
Small coffee farmers	975	85	150
Cattle ranchers on shares	0	9	18
Frontier colonizers	125	40	31
Medium-sized diversified	69	36	79
Day workers	600	50	77
Sugarcane growers	0	74	167
Large coffee growers	428	113	197
Large livestock ranchers	15	30	39

[a] US$ 1.00 = COL$ 2,300.

these producers raised no additional revenues by clearing land of forest. Consequently, these household types are not suited for policy interventions oriented toward reducing deforestation.

The cattle ranchers on shares and large livestock ranchers face the lowest shadow prices of soil conservation, at COL$ 9,000 and COL$ 30,000 per ton-year of sediment averted, respectively. Soil conservation policies can have the greatest impact at the lowest financial cost by intervening in these two household types. On the other hand, the highest economic costs of soil conservation are presented by the large and small coffee growers, where the cost would be COL$ 113,000 and COL$ 85,000 per ton-year of sediment averted, respectively (Table 5).

As for incentives to sequester carbon, the lowest shadow prices come from the cattle ranchers on shares, the frontier colonizers and the large ranchers (COL$ 18,000, COL$ 31,000, and COL$ 39,000 per ton-year of carbon, respectively, Table 5). Intervening with these groups would permit reducing CO_2 emissions at the lowest possible financial cost. By contrast, the highest opportunity costs for capturing carbon occur among the coffee growers (large and small) and the sugarcane growers (COL$ 197,000, COL$ 150,000 and COL$ 167,000, respectively).

(e) *Intervention niches for incentive policies*

Priority household types for policy interventions to reduce poverty and conserve natural resources depend on the resource that society wants to conserve. If the objective is to favor the poorest households while reducing forest loss, the priority household types for intervention should be medium-sized diversified farmers, day workers, and frontier colonizers (Table 6). For erosion reduction, the priority intervention niches would be the cattle ranchers on shares and the medium diversified farms. If the policy objective is to stimulate carbon sequestration, the priority groups would be the fron-

Table 6. *Policy intervention priority index for choosing household types to reduce poverty and natural resource degradation at the same time, by resource that society seeks to conserve*

Household type	Target natural resource[a]		
	Forest	Soil	CO_2
Small coffee farmers	0.55	0.50	0.69
Cattle ranchers on shares	0.00	1.00	1.00
Frontier colonizers	0.80	0.80	0.93
Medium-sized diversified	1.00	0.87	0.85
Day workers	0.84	0.64	0.86
Sugarcane growers	0.00	0.79	0.40
Large coffee growers	0.00	0.00	0.00
Large livestock ranchers	0.39	0.51	0.51

[a] 1 = highest priority, 0 = lowest priority.

tier colonizers and cattle ranchers on shares. The medium diversified and frontier farmers are high priority regardless of the resource that society wishes to conserve, whereas the large livestock ranches and large-scale coffee farms are relatively lower priority in all of the scenarios.

4. DISCUSSION

These results do not support the hypothesis of a linear relation between household socioeconomic level and natural resource degradation in the hillside zone of the Colombian Andes. Pressure on the natural resource base appears to be a function of household asset type, rather than the general wealth level. This finding is consistent with Scherr (2000), who found extreme heterogeneity in environmental management among the rural poor, including instances where the poor were highly efficient at natural resource conservation.

Specific agricultural production activities appear to determine the level of degradation. Indeed, coffee growers in general had a limited impact on natural resources, whereas livestock or sugarcane farmers had a substantial impact. This analysis conforms to that of Larrea *et al.* (1998), who found that natural resource management was a function of income-generating strategy or productive activity.

The choice of productive activity seems to be determined by the type and relative level of assets and income. Barrett, Mesfin, Clay, and Reardon (2001) documented how in some African communities, production decisions are conditioned by labor availability, educational level, special skills, risk attitude, and financial and human resources, assuming that a producer seeks an optimal equilibrium between expected income and exposure to perceived risk. Our findings for Andean hillside conditions indicate that when producers have ample investment capacity, they opt for large-scale livestock ranching. If, besides investment capacity, they also have available relatively abundant labor, then producers turn to large-scale coffee cultivation in order to utilize their labor more efficiently and obtain greater returns per day worked. When investment capacity is very low, farmers are obliged to develop small-scale coffee operations. Those small-scale coffee growers who also have ample labor available can increase their earnings by selling day labor. Although this research measured no risk attitude variable, price risk management and marketing skills may have something to do with the enterprise choices of the cattle ranchers on shares (with highest educational level of all household types), frontier colonizers and sugarcane growers, all of whom raise products (cattle, land and sugarloaves) that face uncertain market prices—unlike coffee, whose price is fixed by the producer marketing board.

The results show that the shadow prices of natural resources differ substantially across productive activities and the natural resources available to producers. The identification of household types for whom resource conservation would cause the least disruption of revenues, facilitates the design of cost-effective resource conservation policies. Such policies build on the assumption that households will only be willing to provide environmental services when the price paid exceeds the direct cost of production plus the opportunity cost of net income that is foregone.

If resource conservation policy is also to contribute to poverty alleviation, then the analysis must also identify the households most deserving public attention. These results indicate however, that the poorest households are not necessarily the ones where the shadow price of natural resource conservation is lowest. The priority index, by incorporating and standardizing household asset and natural resource management variables, helps to identify niches for targeting policy interventions to achieve the greatest potential impact on poverty reduction and natural resource conservation. Likewise, the creation of artificial variables made it possible to integrate socioeconomic characteristics and resource degradation by aggregating variables of different scales and units of measure, facilitating the analysis and interpretation of multiple decision criteria.

For the specific case of eastern Caldas department, sedimentation from soil erosion carries a high opportunity cost compared to other resources, due to the hydroelectric potential there. Given the economic impact of sediments on the useful life of the dam, policy should focus on the diversified producers and cattle ranchers on shares, who offer the greatest potential value for money, in terms of reducing soil erosion for public funds invested. One cost-effective approach to intervening among the diversified producers to reduce both soil erosion and deforestation would be improved maintenance and eventual expansion of the

Florencia Forest Bioreserve. The cost-effective approach to intervening among the cattle ranchers on shares would be to encourage efficient approaches to carbon sequestration.

Large-scale ranchers, sugarcane growers and large-scale coffee growers are not priority households for an incentives-based policy, due to their wealth and their relatively high shadow prices of resource conservation, making incentives costly to implement. In order to reduce environmental degradation by these farmer groups, society should design policy interventions other than economic incentives.

An important complement to the supply-side approach of employing the producer's calculated shadow price of conservation to measure *willingness to accept* payment for environmental services, is to estimate the demand for conservation in terms of society's *willingness to pay*. According to Panayatou (1996), markets are only capable of valuing, using efficiently, and conserving ecological functions and environmental services if these can be brought within a market framework that is capable of converting physical scarcity and physical interactions into economic scarcity and market interactions by means of prices. Rivera and Estrada (2002) found that the opportunity cost of sediments for the Miel I hydroelectric project, based on their effect on its useful lifetime, was US$ 2.56 per ton (equivalent to COL$ 5,880 per ton). This value is very low, compared to opportunity cost of soil conservation for these different household types (of which the lowest shadow price of sedimentation aversion was COL$ 9,000 among the cattle ranchers on shares). On the other hand, at the international rate of US$ 10 per ton (Centro de Investigaciones de la Universidad del Pacífico, 2000), carbon fixation could become attractive only for the cattle ranchers on shares, among whom the shadow price was US$ 7.20 per ton. No measures of the existence value of Andean forests have been found for comparison with household-type shadow prices of conservation.

The figures above indicate that environmental services that could be supplied by the hillside region of the Colombian Andes would cost producers more to provide than demand-side studies suggest society is willing to pay. Under current conditions, the market alone appears incapable of assigning values that reflect relative scarcity. As a result, strategies are needed to stimulate demand for environmental services and to regulate the market, determining an appropriate rate of natural resource use to narrow the discrepancy between supply and demand. Although such principles have been voiced for years, little experience has been garnered in field-level implementation and evaluation of technical assistance, cooperative actions, and the distribution of benefits resulting from natural resource management.

There exists a variety of mechanisms to internalize externalities so that someone who protects and improves the environment can be adequately compensated (Panayatou, 1996). But, assigning investment priorities in a setting of diverse actors, various interest groups, and scarce resources calls for more than the calculation of values. Natural resource management calls for decisions at the local level, and such decisions are based not only on incentives. They also depend upon public infrastructure and awareness, which in turn originate from institutional arrangements affected by policy design and implementation.

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