AGRICULTURAL ECONOMICS

Agricultural Economics 34 (2006) 141–153

Policies for sustainable development in the hillside areas of Honduras: a quantitative livelihoods approach

Hans G. P. Jansen[a,*], John Pender[b], Amy Damon[e], Willem Wielemaker[c], Rob Schipper[d]

[a] *International Food Policy Research Institute (IFPRI), Central America Office, San José, Costa Rica*
[b] *International Food Policy Research Institute (IFPRI), Washington, DC, USA*
[c] *Wageningen, The Netherlands*
[d] *Development Economics Group, Wageningen University, Wageningen, The Netherlands*
[e] *Department of Applied Economics, University of Minnesota*

Abstract

In this article, we use data for 376 households, 1,066 parcels, and 2,143 plots located in 95 villages in the hillside areas in Honduras to generate information needed by decision makers to assess the needs and opportunities for public investments, and design policies that stimulate natural resource conservation. We develop a quantitative livelihood approach, using factor and cluster analysis to group households based on the use of their main assets. This resulted in seven household categories that pursue similar livelihood strategies. We use a multinomial logit model to show that livelihood strategies are determined by comparative advantages as reflected by a combination of biophysical and socioeconomic variables. While 92% of the rural hillsides population in Honduras lives on US$1.00/capita/day or less, households that follow a livelihood strategy based on basic grain farming are the poorest because they often live in isolated areas with relatively poor agro-ecological and socioeconomic conditions. Opportunities for off-farm work tend to be limited in these areas and household strategies that combine on-farm work with off-farm work earn higher incomes. Per capita incomes can be increased by improving road infrastructure, widening access to land, policies that reduce household size and dependency ratios, and adoption of sustainable land management technologies that restore soil fertility. We used probit models to show that the latter can be promoted by agricultural extension programs and land redistribution. Investments in physical assets should be directed toward households that pursue livelihood strategies based on off-farm employment or coffee production, while agricultural training programs are best focused on livestock producers.

JEL classification: C23, O13, Q18

Keywords: Conservation measures; Hillsides; Honduras; Livelihood strategies; Logit; Probit; Rural poverty

1. Introduction

Honduras is one of the poorest countries in the Western Hemisphere. Even though recent decades have seen increasing rural-to-urban migration, poverty remains most severe and widespread in rural areas. The landscape of Honduras is dominated by hills and valleys. The most fertile agricultural land is generally found in the valleys. The hillside areas,[1] which account for 80% of the land area in Honduras, are generally considered to have lower agricultural potential. Land ownership patterns throughout Honduras have historically meant that large landowners own the majority of the most productive land in the valleys while smaller, poorer agricultural producers work on the hillside land.

About 60% of the total population of Honduras is considered rural, and 80% of rural people live in the hillside areas (PRONADERS, 2000). Past government policies have focused on the gradual replacement of the traditional economic import substitution model by a growth model based on trade and market liberalization. But macro-economic reform and structural adjustment strategies alone have proven insufficient to reduce poverty in the rural hillside areas, where 92% of the population lives on less than US$1.00/day.[2] Poverty alleviation requires the further development of these areas, with particular emphasis on the growth of the food and agriculture sector, given the

* Corresponding author. Tel.: +506 255 4011; fax: +506 222 6556.
E-mail address: h.jansen@cgiar.org (H. G. P. Jansen).

[1] "Hillsides" are defined as areas with slopes of more than 12% (PRONADERS, 2000). "Hillside areas" include not only hillsides but also include flat-floored valleys, 300– 900 meters in elevation, which are scattered throughout the interior hillsides.

[2] Based on own survey data.

importance of labor and land in the asset portfolios of rural dwellers.

Low land productivity and rural poverty are closely associated with insufficient protection of the natural resource base and resulting degradation of soil and water resources (Lee and Barrett, 2001; Vosti and Reardon, 1997). Soil erosion in the Honduran hillsides can reach 300 tons of soil loss per year (Thurow et al., 2002). Many hillside areas also have an important water storage function. Soils are a critical part of natural capital and play a vital role in providing farm income through agricultural production. Declines in agricultural productivity caused by soil erosion not only adversely impact farmers' incomes but also cause negative off-farm impacts such as silting of rivers, resulting in flooding, reduced water quality, and diminished reservoir capacity.

In Honduras, stagnation in the productivity of the basic grains sector[3] on which so many rural households depend (Jansen et al., 2002), disadoption of fertilizer bean in northern Honduras (Neill and Lee, 2001) and increasing demand, have resulted in an expansion of the agricultural frontier into primary forest areas and increasing pressure on the natural resource base in hillside areas. Migration out of these areas toward areas with higher potential or to other countries is a selective and costly process.

In Honduras, investments have generally been directed toward more favored areas and hillside areas have been left behind. Policy makers in Honduras lack reliable information needed to identify opportunities for public investments in hillside areas and to guide the design of promising policies that stimulate natural resource conservation. This article provides some of that basic knowledge. Using data from a detailed household survey, we identify and quantify livelihood strategies (LS) through clustering farm households on the basis of the use of their labor and land resources; isolate the main determinants of the household's LS choice; and analyze the main determinants of per capita income, including the role of LS and the household's asset portfolio. We also investigate the impact of LS and other factors on land management and soil conservation practices at the parcel level. Finally, we derive a number of policy implications.

2. The livelihood strategy concept

A livelihood strategy can be defined as a portfolio of activities and choices that people make to achieve their livelihood goals, including productive activities, investment strategies, reproductive choices, etc. (Adato and Meinzen-Dick, 2002; DFID, 1999; Ellis, 1998). These choices are reflected in the way that people use their assets and as such are an important part of household behavior, while determining well-being.

A number of previous studies have attempted to implement the sustainable livelihood strategy framework, either quantitatively or qualitatively. Pender et al. (2001) used data on primary and secondary occupation and land use changes over time to determine community development pathways. Common pathways were then grouped and used as units of analysis to explore conservation and cropping practices. Jansen et al. (2003, 2006) in a similar approach used qualitative information and expert knowledge to group rural communities in Honduras according to income-earning strategy. Birch-Thomsen et al. (2001) used indices to weigh the importance of different sources of household income. However, unless income composition is available over time, income shares from a particular year reflect a household's short-term coping mechanism rather than a long-term livelihood strategy. Lambin (2003) used clustering techniques to group farmers on the basis of their land use. Adato and Meinzen-Dick (2002) used qualitative methods in four case studies to assess the impact of agricultural technology and research on people's lives. Barrett et al. (2001) maintain that studies focused on livelihoods should use a diversity of indicators to assess sources of income and income-earning strategies, while arguing that assets, activities, or income all have limitations and therefore should be used in combination. Rakodi (1999) favors a conceptualization of household LS as managing portfolios of different types of assets for the identification of relevant policy recommendations.

In this article, we implement the LS concept through quantification of the household's asset portfolio and clustering households based on the use of their two primary assets, i.e., labor and land. Clustering a sample of households into a limited number of categories that pursue similar LS may be useful to policy makers by enabling them to better target households with certain common characteristics, in this way increasing the efficiency of public investment strategies and other policy measures. In addition, a clear delineation of the dominant LS would help in directing technology transfer programs toward their intended beneficiaries. The alternative to clustering is using continuous measures of asset types, but this does not allow an improvement in the effectiveness of policies through better targeting.

Given the key role of the household's asset portfolio in understanding its livelihood strategy, we based our clustering on the household's use of its main assets, i.e., labor and land. Once we obtained the household clusters (each of which represents a distinct livelihood strategy), we designated each of the clusters through a careful analysis of average time allocation, land use patterns, and income shares of households in each of these clusters.

3. Methods and data

We used factor and cluster analysis to group the individual household observations into distinct livelihood categories. We began by applying the principal factor (pf) method in STATA to analyze the correlation matrix of the following variables: (1) proportions of the time spent by its members on agricultural work on the own farm, off-farm agricultural work, and

[3] Throughout Central America, the term "basic grains" refers mainly to maize and beans but also includes sorghum and rice.

off-farm nonagricultural work; (2) proportions of total agricultural work spent on the following activities: basic grains, other annual crops, coffee, other permanent crops, livestock activities, and off-farm agricultural work; (3) proportions of the farm land used for basic grains, other annual crops, coffee, other permanent crops, pastures, and forest plus fallow. The rotated factor loadings from the factor analysis served as input into a cluster analysis consisting of agglomerative hierarchical clustering. This was followed by k-means cluster analysis to correct for possible misclassification of observations at the boundaries between clusters, using the number of clusters and the means of each factor in these clusters as starting centers for the k-means analysis (Hair et al., 1998). We used the ClustanGraphics software for both types of cluster analyses (Wishart, 1999).

Once the household sample is clustered into livelihood strategy groups, the household's livelihood choice can be explained based on a set of pre-determined asset-based variables that include natural, human and location capital. LS are an important part of a wider set of explanatory asset-based variables that determines household income and besides exogenous asset-based variables also includes physical capital, financial capital and social capital. Finally, resource conditions are linked to land management decisions which are influenced by the same set of variables as household income plus other variables that reflect field-specific characteristics. In this way a household's asset holdings has both a direct and indirect (via their impact on the livelihood strategy choice) influence on income and land management strategies.

Our research covers nine provinces (*departamentos*) and 19 counties (*municipio*s) selected purposively based on representation of agro-ecological conditions, dominant land use, population density, market access, and the degree of presence of projects and programs. In addition, the importance of a number of counties in the northeast of Honduras as recipient areas of migrants (extending the agricultural frontier) warranted their inclusion in the study. The remainder of the sampling process was done in a fully randomized manner. Five communities (*aldeas*) and two hamlets (*caseríos*) were selected in each county and community respectively, on the basis of data obtained from the latest population census (2000–2001). Finally, two farm households (*hogares*) were randomly selected in each hamlet on the basis of a farm inventory made in the field.

The household sample contains a total of 376 households, 1,066 parcels (defined as a contiguous piece of land based on tenure status), and 2,143 plots (sub-parcels defined on the basis of land use). Key socioeconomic elements of the household survey (carried out between November 2001 and May 2002) included household composition, education, asset ownership, sources of income, sales of crop and livestock products, participation in credit markets, membership of organizations, and participation in training and extension programs. Information collected at the parcel and plot levels included land tenure, cropping patterns, crop production, land management technologies including use of labor and other inputs, and conservation practices and investments.

In order to be able to analyze the adoption of soil conservation practices better, the survey collected detailed biophysical data for a (randomly drawn) sample of two plots on each farm. These included landscape attributes, plot size, soil type, erosion status, and presence of physical conservation structures. Soil samples were also taken and analyzed in a local soil laboratory and resulted in data regarding pH, nutrient content, organic matter content and texture. These data were mainly used for the calculation of soil moisture availability and soil fertility. Finally, the survey data were supplemented by adding secondary information regarding rainfall, population density, market access, and road density. Most of these data were obtained from CIAT (2001).

4. Results

4.1. Cluster analysis

The factor analysis on the household allocation of land and labor resources identified six main common factors. The subsequent hierarchical cluster analysis identified seven clear-cut and robust clusters. Of the total of 376 observations (households), k-means analysis regrouped 116.[4] Because the two smallest clusters consisted of only 12 and 8 households respectively, they were excluded from the econometric analysis.

Table 1 summarizes the means and standard errors for the variables that were used in the factor analysis. It also reports the results of the pairwise comparison for each variable between every combination of clusters. All variables used in the factor analysis show statistically significant differences between at least one pair of clusters and the results give us confidence in the stratification of our household sample into livelihood categories.

4.2. Description of livelihood strategies

We named LS based on a careful investigation of the utilization of land and labor resources in each cluster (Table 1) and corresponding levels and composition of income (Table 2), keeping in mind that income composition is an outcome rather than a determinant of a livelihood strategy. For example, households in cluster no. 3, on average, devote 72% of their land to the cultivation of basic grains which account for nearly 80% of their total income. Therefore, this cluster was denominated "basic grains farmers." A striking common characteristic of the all LS is the very high proportions of households that live in extreme poverty. In order to further help describe each livelihood strategy, Table 3 provides data asset ownership for each cluster.

The livelihood of households in cluster no. 1 is based on extensive livestock farming on relatively large farm holdings. Land use is characterized by a high share of pastures and a

[4] We also tried a straight cluster analysis without the preceding factor analysis, but such led to clusters that were both less clear and less stable.

Table 1
Final clusters and summary statistics[1] of factor analysis variables

Variable	Full sample		Cluster no. 1		Cluster no. 2		Cluster no. 3		Cluster no. 4		Cluster no. 5		Cluster no. 6		Cluster no. 7	
			Livestock producers		Coffee producers		Basic grains farmers		Basic grains farmers/ farm workers		Mixed basic grains/ livestock/ farm workers		Permanent crops producers		Annual crops/ intensive livestock producers	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Crop mix(share of area)																
Basic grains	0.420	0.029	0.132$^{(2,3,4)}$	0.021	0.343$^{(1,3,4,5)}$	0.043	0.720$^{(1,2,5,6,7)}$	0.061	0.751$^{(1,2,5,6,7)}$	0.059	0.230$^{(2,3,4)}$	0.026	0.238$^{(3,4)}$	0.056	0.178$^{(3,4)}$	0.024
Annual crops	0.021	0.013	0.009$^{(7)}$	0.005	0.000$^{(7)}$	0.000	0.000$^{(7)}$	0.000	0.004$^{(7)}$	0.003	0.006$^{(7)}$	0.003	0.003$^{(7)}$	0.003	0.590$^{(1,2,3,4,5,6)}$	0.048
Permanent crops	0.030	0.006	0.010$^{(6,7)}$	0.003	0.006$^{(6,7)}$	0.006	0.028$^{(6,7)}$	0.014	0.013$^{(6,7)}$	0.006	0.018$^{(6,7)}$	0.005	0.534$^{(1,2,3,4,5,7)}$	0.085	0.063$^{(1,2,3,4,5,6)}$	0.025
Coffee	0.050	0.009	0.024$^{(2)}$	0.012	0.410$^{(1,3,4,5,6,7)}$	0.035	0.005$^{(2)}$	0.004	0.020	0.007	0.025	0.011	0.001$^{(2)}$	0.001	0.000$^{(7)}$	0.000
Pasture	0.148	0.023	0.646$^{(2,3,4,5,6,7)}$	0.031	0.051$^{(1)}$	0.036	0.046$^{(1)}$	0.023	0.019$^{(1)}$	0.010	0.062$^{(1)}$	0.018	0.000$^{(1)}$	0.000	0.099$^{(1)}$	0.028
Fallow/forest	0.332	0.027	0.180$^{(5)}$	0.033	0.189$^{(5)}$	0.050	0.201$^{(5)}$	0.048	0.193$^{(5)}$	0.059	0.658$^{(1,2,3,4,6,7)}$	0.025	0.224$^{(5)}$	0.077	0.070$^{(5)}$	0.084
Family labor (activity time/ total family labor)																
On-farm work	0.360	0.015	0.471$^{(4,5,6)}$	0.037	0.338	0.060	0.432$^{(4)}$	0.040	0.255$^{(1,3,5)}$	0.037	0.343$^{(1,4)}$	0.019	0.247$^{(1)}$	0.030	0.317	0.027
Off-farm agricultural work	0.086	0.012	0.032$^{(4,5)}$	0.013	0.051$^{(4)}$	0.029	0.014$^{(4,5)}$	0.004	0.246$^{(1,2,3,5,6,7)}$	0.028	0.066$^{(1,3,4,6,7)}$	0.012	0.143$^{(4)}$	0.075	.009$^{(4)}$	0.009
Off-farm non-agricultural work	0.034	0.008	0.062$^{(6)}$	0.035	0.068	0.034	0.049	0.019	0.013$^{(6)}$	0.007	0.012$^{(6)}$	0.004	0.068$^{(1,4,5)}$	0.027	0.032	0.033
Agricultural labor (agricultural activity /total agricultural labor including hired labor)																
Basic grains	0.349	0.026	0.249$^{(3)}$	0.042	0.267$^{(3)}$	0.053	0.732$^{(1,2,4,5,6,7)}$	0.039	0.155$^{(3,5)}$	0.016	0.342$^{(3,4)}$	0.046	0.246$^{(3)}$	0.092	0.176$^{(3)}$	0.036
Annual crops	0.012	0.004	0.023$^{(7)}$	0.010	0.000$^{(7)}$	0.000	0.001$^{(7)}$	0.001	0.001$^{(7)}$	0.001	0.012$^{(7)}$	0.007	0.003$^{(7)}$	0.003	0.123$^{(1,2,3,4,5,6)}$	0.128
Coffee	0.046	0.010	0.029$^{(2)}$	0.013	0.376$^{(1,3,4,5,6,7)}$	0.087	0.000$^{(2)}$	0.000	0.006$^{(2)}$	0.004	0.032	0.008	0.005$^{(2)}$	0.005	0.000$^{(2)}$	0.000
Permanent crops	0.032	0.007	0.018$^{(6)}$	0.007	0.052$^{(6)}$	0.034	0.034$^{(6)}$	0.014	0.002$^{(6)}$	0.001	0.034$^{(6)}$	0.017	0.271$^{(1,2,3,4,5,7)}$	0.115	0.037$^{(6)}$	0.036
Livestock	0.208	0.028	0.544$^{(7)}$	0.055	0.035$^{(7)}$	0.018	0.127$^{(7)}$	0.040	0.047$^{(7)}$	0.019	0.199$^{(7)}$	0.042	0.039$^{(7)}$	0.029	0.614$^{(1,2,3,4,5,6)}$	0.173
Off-farm agricultural work	0.354	0.035	0.138$^{(4,5)}$	0.054	0.270$^{(4)}$	0.106	0.106$^{(4,5)}$	0.028	0.788$^{(1,2,3,5,6,7)}$	0.022	0.385$^{(1,3,4)}$	0.051	0.436$^{(4)}$	0.187	0.050$^{(4)}$	0.052

[1] Means and standard errors are adjusted for sampling weights.
$^{(x)}$ = statistically significant difference between cluster no. x and the column cluster at 5% level.

small share of basic grains. These households use most of their total family labor to work on their own farms. But even these households obtain about 30% of their total household income from working outside their own farm and highly value food security, evidenced by an average of 4 hectare devoted to basic grains production. These households have above-average education and are mostly located in lower altitude areas with relatively low population densities. Access to markets and public services is below average, but given the dominant focus on livestock keeping, this does not seem to negatively affect income. Even though average daily per capita income is only US$0.58, the *average* per capita income is somewhat misleading because the poverty rate in this livelihood group is lower than in all the other groups. Therefore, there are some households for which this appears to be a poverty-exit livelihood strategy.

Cluster no. 2 consists of coffee producers who on average devote 40% of their farm area and 34% of their family labor to coffee production. However, these farmers still rely on their own production of basic grains for their subsistence needs. Most coffee farms are relatively small and located at higher altitudes. Somewhat surprisingly, market access and education are below average for these households and they farm on relatively poorer soils. On average these coffee-producing households earned just over half the average per capita income of livestock households. However, the survey was taken during the period when coffee prices collapsed, so this may overstate chronic poverty among this group.

Cluster no. 3 represents subsistence farmers who devote most of their farmland and family labor to basic grains production that has low profitability. Land holdings are just over 2 hectare of land on average, which is slightly more than households in cluster no. 4, but they are the poorest group among all households, earning an average of just US$0.15 per person per day. They tend to be located at high elevations and on steep slopes, and have little in terms of other productive assets. These households work little outside their own farms and the probability of a female head is highest for this cluster.

Households in cluster no. 4 are similar to those in cluster no. 3 in that they devote most of their farm area to basic grains. These households have the smallest landholdings but by working 50% of their time off-farm they earn more than double the income of cluster no. 3 households. It seems that limited access to land "pushes" these households to be more entrepreneurial and seek out alternative employment opportunities, in or out of agriculture. On the other hand, differences between the cost of buying food and the price received by farmers for food crops sold may mean that this group may be worse off than cluster no. 3 in terms of food security.

The livelihood of households in cluster no. 5 is similar to households in cluster no. 4 but they have larger farms, hire more labor, and devote more time to livestock activities. Their average daily per capita income is between that of households in cluster no. 4 and cluster no. 3. Apparently by working on their own farm, these households have lower incomes than those seeking off-farm employment. On the other hand, these households may

Table 2
Mean household income and percentage composition, by livelihood strategy

	Total sample	Livelihood strategy name						
		Livestock producers	Coffee producers	Basic grains farmers	Basic grains farmers/ farm workers	Mixed basic grains/ livestock/ farm workers	Permanent crops producers	Annual crops/ intensive livestock producers
Variables								
Number of households	376	59	28	68	85	116	12	8
Total household income [a]	12,310	20,915	12,536	5,134	13,799	10,798	16,225	9,777
SE	*1,646*	*7,531*	*2,646*	*1,125*	*2,491*	*2,089*	*3,665*	*3,499*
Per capita income [b]	0.35	0.58	0.33	0.15	0.42	0.29	0.66	0.38
SE	*0.04*	*0.18*	*0.05*	*0.03*	*0.08*	*0.05*	*0.18*	*0.24*
Composition of household income								
Percentage income from basic grains	34.3	30.4	0.0	79.2	17.5	30.0	22.3	41.4
SE	*8.0*	*8.1*	*20.9*	*29.4*	*6.5*	*13.0*	*10.2*	*10.5*
Percentage income from annual cash crops[a]	1.3	5.3	0.0	0.0	0.0	1.2	0.0	0.3
SE	*0.8*	*4.4*	*0.0*	*0.0*	*0.0*	*0.8*	*0.0*	*0.1*
Percentage income from coffee	0.0	4.1	−22.9	0.0	0.6	1.1	0.0	0.0
SE	*4.2*	*2.8*	*51.6*	*0.0*	*0.4*	*1.5*	*0.0*	*0.0*
Percentage income from other permanent crops	6.9	2.4	4.0	24.4	0.5	4.5	5.2	1.1
SE	*4.3*	*1.7*	*3.6*	*21.0*	*0.4*	*3.9*	*2.7*	*1.5*
Percentage income from livestock	−3.5	31.0	83.2	−91.2	1.4	0.6	1.3	27.9
SE	*27.6*	*8.6*	*75.4*	*135.6*	*1.8*	*29.6*	*1.4*	*7.0*
Percentage income from off-farm agricultural work	38.9	13.6	16.7	9.4	76.1	55.5	38.7	4.3
SE	*8.9*	*5.5*	*9.0*	*7.1*	*7.3*	*25.8*	*17.3*	*4.8*
Percentage income from off-farm non-agricultural work	20.5	16.9	20.1	72.9	2.5	2.9	24.4	13.7
SE	*14.6*	*8.2*	*9.2*	*77.1*	*1.2*	*1.0*	*9.3*	*15.1*
Percentage income from transfers	34.7	6.6	1.1	103.3	14.0	33.5	19.7	13.0
SE	*19.1*	*5.5*	*10.8*	*107.8*	*1.8*	*12.7*	*13.8*	*1.6*
Percentage income from patio production	*−1.0*	1.3	−0.5	−4.1	0.5	−1.8	1.1	0.1
SE	*1.0*	*1.4*	*0.4*	*2.1*	*0.3*	*2.2*	*0.9*	*0.3*
Percentage net-rent income	−18.1	−8.8	0.0	−49.3	−7.0	−19.5	−0.3	−0.3
SE	*13.0*	*7.5*	*0.0*	*64.0*	*3.0*	*13.2*	*0.2*	*0.5*
Percentage of poor households [c]	92.6	77.1	99.1	97.3	94.4	95.8	95.2	86.2
SE	*2.4*	*10.8*	*1.0*	*2.8*	*4.0*	*1.5*	*4.7*	*14.4*
Percentage of extremely poor households [d]	92.3	75.5	99.1	97.3	91.8	88.4	74.5	77.0
SE	*2.4*	*10.9*	*0.0*	*0.0*	*4.6*	*1.4*	*17.3*	*14.6*

[a]In Lps per year.
[b]In US$ per day.
[c]Percentage of households with less than US$ 1.50/capita/day.
[d]Percentage of households with less than US$ 1.00/capita/day.

be less vulnerable to risks than those in cluster no. 4, because they have greater wealth and more diversified income sources.

Cluster no. 6 is a small group of permanent crop producers, who devote most of their land and time to intensive tree crop production (fruits, oil palm) or sugarcane. These households have the highest average incomes in the sample and smaller than average household sizes. They are located in favorable agro-ecological areas with high population densities, high rainfall, and good access to paved roads and public transportation, all of which are important for diversification into higher-value permanent crop production.

Finally, the few households in cluster no. 7 mostly are vegetable growers. These households work very little off-farm, probably because of the labor-intensive character of most vegetable crops. Despite being relatively far from a paved road in areas with relatively low population densities, these households are close to a nonpaved road. Their average daily income during the survey year (US$0.38 per capita) was only slightly above-average, possibly because of their dependence on middlemen for the marketing of their vegetables.

4.3. *Determinants of livelihood strategies*

Because LS choice is a polychotomous choice variable, we used a multinomial logit model (Greene, 1990) to explain the household's livelihood choice. We assumed that the latter is determined by fixed or slowly changing factors including the household's natural capital, locational capital and human capital. By excluding other types of household capital, we also minimize potential endogeneity problems. Natural capital included the amount of land owned (more land stimulates on-farm activities), share of total land holdings that has a title (importance

Table 3
Summary statistics regarding asset-related household characteristics, by livelihood strategy

Number of households	Livelihood strategy															
	Total sample		1		2		3		4		5		6		7	
	376		59		28		68		85		116		12		8	
	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
Natural capital																
Farm size[a]	14.3	*2.4*	45.6	*9.4*	5.0	*0.8*	3.4	*0.4*	2.7	*0.4*	15.3	*4.0*	3.4	*0.4*	6.3	*1.3*
Area of owned land[a]	7.7	*1.6*	22.7	*6.7*	3.2	*0.8*	1.2	*0.6*	0.55	*0.3*	9.3	*3.4*				
Percentage of land with formal title	29.4	*4.1*	36.9	*8.9*	56.7	*12.1*	18.5	*7.9*	14.8	*9.2*	34.6	*8.5*	58.4	*15.8*	6.7	*2.5*
Rainfall during primary season[b]	1,005	*17*	943	*37*	917	*41*	976	*41*	1,058	*45*	1,008	*25*	1,576	*74*	1,060	*53*
Altitude[c]	2,231	*127*	1,220	*198*	3,845	*169*	2,009	*265*	2,412	*232*	2,569	*240*	1,661	*182*	734	*111*
Rainfall deficit secondary season[d]	14	*3*	18	*7*	1	*1*	33	*11*	11	*4*	6	*2*	9	*4*	9	*10*
Soil fertility[e]	2,846	*67*	2,834	*159*	2,572	*171*	2,806	*166*	2,939	*94*	2,835	*140*	2,935	*183*	3,315	*263*
Physical capital																
Value of machinery, equipment, & transportation[f]	3,698	*631*	6,023	*1,113*	6,590	*3,612*	2,884	*947*	422	*159*	4,757	*1,527*	1,726	*930*	671	*144*
Value of livestock[f]	19,703	*5,077*	87,336	*23,146*	4,029	*848*	4,105	*1,148*	1,994	*660*	10,394	*3,097*	892	*371*	5,547	*1,076*
Human capital																
Household size	6.1	*0.2*	6.1	*0.5*	6.2	*0.6*	5.7	*0.4*	5.9	*0.4*	6.4	*0.3*	4.6	*0.5*	7.1	*0.9*
Dependency ratio[g]	0.9	*0.1*	0.6	*0.1*	0.7	*0.2*	1.1	*0.2*	1.2	*0.2*	0.9	*0.1*	0.9	*0.2*	0.5	*0.2*
Female headed HH dummy (%)[h]	9.4	*3.0*	14.8	*7.1*	1.4	*1.5*	17.7	*9.4*	12.9	*9.7*	2.2	*1.3*	0.0	*0.0*	3.2	*4.1*
Percentage of female adults in the HH[i]	49.7	1.3	44.7	*2.1*	51.4	*5.1*	50.4	*3.2*	46.2	*1.9*	52.4	*2.4*	60.7	*3.3*	56.3	*3.0*
Age of the household head	47.2	1.4	46.3	*2.4*	40.7	*3.4*	43.9	*3.6*	45.3	*3.5*	52.3	*2.5*	49.9	*6.7*	47.9	*1.5*
Median years of schooling[j]	2.8	0.2	3.4	*0.3*	1.9	*0.3*	2.9	*0.5*	2.3	*0.3*	3.0	*0.2*	2.5	*0.8*	2.5	*0.4*
Participation in programs/orgs (%)																
Conservation training[k]	17.7	*4.5*	7.4	*5.3*	29.2	*13.7*	1.8	*1.0*	16.1	*8.7*	32.5	*10.7*	23.5	*15.2*	0.0	*0.0*
Agricultural training[l]	7.6	*1.9*	5.8	*5.2*	5.5	*3.9*	4.1	*1.7*	4.5	*2.5*	10.5	*4.3*	38.7	*21.1*	12.8	*12.5*
Conservation extension[m]	7.3	*2.1*	7.0	*3.9*	1.0	*1.0*	12.5	*7.5*	5.2	*3.0*	7.2	*3.9*	18.2	*16.6*	0.0	*0.0*
Agricultural extension[n]	5.4	*1.6*	3.3	*3.0*	2.5	*2.5*	1.8	*1.2*	4.6	*2.7*	8.3	*4.0*	37.4	*21.2*	0.5	*0.6*
Participation in producer org[r]	7.2	*3.7*	7.9	*5,5*	14.2	*7.5*	0.3	*0.3*	1.3	*0.9*	14.4	*10.5*	0.6	*0.7*	0.0	*0.0*
Participation in rural bank/caja rur[r]	8.2	*1.9*	0.4	*0.4*	20.7	*13.1*	13.9	*5.6*	5.7	*3.1*	7.8	*2.9*	0.0	*0.0*	10.8	*12.0*
Participation in NGO program[r]	9.9	*2.9*	2.5	*1.8*	21.2	*13.6*	2.4	*1.4*	14.9	*8.2*	12.7	*6.4*	18.2	*16.6*	0.0	*0.0*
Location capital																
Population density[o]	104	*12*	51	*9*	81	*10*	132	*28*	125	*33*	99	*23*	263	*103*	52	*9*
Road density[p]	4.0	*0.3*	2.1	*0.3*	5.7	*0.4*	4.0	*0.4*	4.8	*0.6*	4.3	*0.5*	3.3	*0.2*	2.0	*0.2*
Market access[q]	73	*7*	99	*13*	85	*14*	60	*13*	62	*18*	74	*8*	88	*60*	24	*18*

[a] In manzanas (1 mz = 0.7 ha).
[b] In mm during the *primera* season (May–Sept); own calculations based on data from the nearest point in the atlas CD of CIAT (CIAT, 2001).
[c] Average altitude of sampled plots on each farm as measured by a GPS in feet above sea level.
[d] Average for sampled plots during the *postrera* season (October–January) in mm (see text footnote 5) .
[e] Approximated by potential maize yields (see text footnote 7).
[f] Value in Lps.
[g] Ratio defined as follows: (no. of HH members <12 and >70 years) / (no. of HH members between 12 years and 70 years).
[h] 1 = female head of household.
[i] Females > 12 years of age as a percentage of total household size.
[j] Median years of schooling of household members older than 7 years.
[k] Dummy variable (= 1 if HH has received conservation training, 0 if not).
[l] Dummy variable (= 1 if HH has received crop technology training, 0 if not).
[m] Dummy variable (= 1 if HH has received conservation extension visits, 0 if not).
[n] Dummy variable (= 1 if HH has received crop technology extension visits, 0 if not).
[o] No. of persons per km^2 in the community based on the 2001 population census (INE, 2002).
[p] Km of roads/km^2 in the community (data obtained from CIAT, 2001).
[q] Data obtained from CIAT. They reflect travel time from the center of the community to the nearest market outlet, using the most common form of transportation. Variable's values are based on geographical distance, road quality and slope. The higher the value of the variable, the worse is market access.
[r] Dummy variable (1 = HH participates, 0 otherwise).

of titled land as collateral and stimulates investments), rainfall during the main growing season (agricultural potential), rainfall deficit in the secondary growing season[5] (limits double cropping), altitude[6] (proxy for temperature), and soil fertility.[7] Location assets are represented by population density (influences both crop choice and production technologies, see Pender et al. (2001) and Jansen et al. (2003)), market access, and road density (both of which stimulate cash crop production and off-farm work). Human capital variables included household size and dependency ratio (both determine labor availability), gender and age of the household head (female-headed households have specific characteristics and face competing demand on the time of the household head), proportion of adults in the household that are female (influences the availability of nondomestic labor), and the median education of household members (important for off-farm employment opportunities).

The results of our multinomial logit model are presented in Table 4. The coefficients represent the effect of each explanatory variable on the ratio of the probability of the household selecting the particular livelihood strategy considered, relative to the probability of selecting the basic grains-only strategy. Note that there is little difference between the mean proportions of each cluster and the mean predicted probabilities of each cluster, indicating good fit of the model to the data.

The results show that basic grains-only farms are more likely to be in areas where secondary season rainfall deficits are greater, in areas of higher population density, among households that own less land, and if the household head is female, or younger. In general, subsistence basic grains production is the dominant livelihood strategy in more marginal and land-scarce areas, and among poorer households. Livestock production is more likely as the livelihood strategy in areas where the secondary season rainfall deficit is greater, among households with more land, lower dependency ratio, or a younger head. These findings are consistent with the theory of comparative advantage; i.e., crop production is less profitable relative to livestock production in areas of marginal rainfall, provided that households have access to enough land to support their livestock. The diversified basic grains/livestock/farm worker strategy is more common in areas with less rainfall deficit in the secondary season and among households who own more land, have a higher dependency ratio, are male headed but have more female adults, and where the head is older. This livelihood strategy appears to represent one destination in a household's life cycle; as households become more mature and acquire more land, female adults, and dependents, they seek and are able to diversify into off-farm activities as well as livestock. The opportunities for such diversification are greater in areas of higher agricultural potential because the main opportunities for off-farm employment are in agricultural activities on other farms. Few factors are statistically significant predictors of the probability of either the coffee production or basic grains/farm workers LS. Only road density has a weakly significant positive association with coffee production. This association could reflect reverse causality: construction of roads may be greater where coffee is produced because of construction of roads by the Honduran Coffee Institute (IHCAFE).

4.4. Determinants of household income

4.4.1. Model design

Annual per capita household income was hypothesized to depend on the household's livelihood strategy and asset portfolio. Compared to our earlier multinomial logit model, we expanded the set of asset-related explanatory variables in a number of ways. First, we included variables for physical capital (machinery, equipment and transportation assets; and livestock) and social capital (membership in various types of organizations and programs including training and extension programs, producer organizations, financial organizations and NGO projects). Second, we addressed the targeting issue, by analyzing how some of the program and policy-relevant variables interact with the livelihood strategy variables in generating income.

We ran two different model specifications, with and without interaction variables. The model specification without interaction variables indicates which of the policy variables are most significant and therefore require better understanding regarding which household types should be targeted when launching public investment programs that address these policy variables. The model with interaction variables contributes to our knowledge regarding which household types would benefit most from such public investment programs and thus helps public policy targeting.

We tested three different specifications of the income model without interaction variables including an ordinary least squares (OLS) model, a median regression (because of concerns about outliers) with bootstrapped standard errors, and an instrumental variables (IV) regression (because of potential endogeneity of some of the explanatory variables). Each of these specifications

[5] Besides rainfall, moisture availability in the soil is critical for crop growth and as such constitutes another indicator of the agricultural potential. Moisture availability is soil-specific and takes into account not only rainfall but also evapotranspiration, temperature, and soil characteristics. We used the data from our soil samples and operationalized moisture availability as crop water deficits for annual crops (for maize in the main and secondary growing seasons) and permanent crops (coffee). Water deficits were calculated on the basis of the data for monthly temperature, effective rainfall (taking runoff into account as determined mainly by slope, slope direction, contour curvature, profile curvature and position on slope), evapotranspiration, and soil characteristics including depth, texture, and organic matter content. All of these were measured in the field (Wielemaker, 2002). Only moisture availability for the second season was considered because the data indicated very few cases of main season water deficits. Moreover, moisture availability for coffee is highly correlated with moisture deficit for maize in the secondary growing season.

[6] Based on Pender et al. (2001) we *a priori* expect altitude to have positive influence on the probability of cluster no. 2 (coffee farmers).

[7] Soil fertility is yet another indicator of agricultural potential and was approximated by potential yields (nutrient-limited but not water-limited) which we calculated using the QUEFTS (QUantitative Evaluation of soil Fertility and response To Fertilizers) model. The latter uses nitrogen content, pH, and available potassium and phosphorous as its basic parameters (Janssen, 1990).

Table 4
Determinants of livelihood strategies (multinomial logit regression)

Explanatory variables[a]	Livestock producers (cluster 1)		Coffee producers (cluster 2)		Basic grains farmers/ farm workers (cluster 4)		Basic grains/livestock/ farm workers (cluster 5)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Natural capital								
Rainfall deficit secondary season	−0.00825	0.00681	−0.02432	0.01728	−0.01835***	0.00660	−0.02628***	0.00779
Soil fertility	0.00032	0.00046	−0.00012	0.00049	0.00062*	0.00034	0.00039	0.00043
Summer rainfall	0.00165	0.00148	−0.00475	0.00373	0.00091	0.00104	0.00147	0.00117
Altitude	−0.00095	0.00127	0.00214**	0.00091	−0.00067	0.00086	0.00059	0.00092
Owned land	0.20251***	0.05255	0.02757	0.11059	−0.52985*	0.27374	0.19469***	0.05277
Percentage of land w/title	−1.00209	1.15818	1.48094	1.04121	0.82708	1.19322	−0.74270	0.91573
Location capital								
Market access	0.13767*	0.07121	0.12030	0.07902	0.09003	0.05954	0.09858	0.06820
Road density	−0.08178	0.25495	0.85183**	0.33211	0.51997**	0.21144	0.31098	0.21955
Population density	−0.00805	0.00630	−0.02907***	0.00858	−0.00429	0.00414	−0.01523***	0.00503
Human capital								
Median schooling	0.07184	0.21005	−0.29940	0.18422	−0.17611	0.17871	0.23879	0.16939
HH size	0.10445	0.12784	0.01362	0.16298	−0.03015	0.10747	−0.00991	0.10817
Dependency ratio	−1.58529**	0.63010	−1.11618*	0.56986	−0.21426	0.46409	0.20291	0.41592
Female HH head	−0.39686	0.78423	−3.96464***	1.50166	−1.29206	0.85613	−3.71278***	0.92736
Percentage of female adults	1.57140	1.77866	1.05151	2.97171	−2.53423	1.81363	4.52182**	1.97987
Age of HH head	0.00332	0.02173	0.00336	0.02309	0.02956	0.01983	0.06815***	0.01724
Intercept	−3.45762	2.99668	−0.24639	2.98190	−3.05683	2.40960	−9.31718***	3.08394
Number of observations	59		28		85		116	
Proportion of observations	0.1791		0.0845		0.2142		0.3231	
Mean predicted probability of livelihood	0.1791		0.0845		0.2142		0.3231	

Notes: Basic grains farmers (n = 68) is the excluded category. Strategies 6 and 7 were not analyzed due to limited numbers of observations. Coefficients and standard errors adjusted for sampling weights and stratification, and are robust to heteroskedasticity.

[a]See Table 3 for definitions of explanatory variables.

*, **, *** mean statistically significant at 10%, 5%, and 1% level, respectively.

carries its own potential problems: the OLS model is likely to have some endogenous explanatory variables, the median regression model does not correct for sample weights, and the IV model may be influenced by weak instrumental variables.[8] First-stage regressions in the IV procedure confirmed the significance of the instruments for all endogenous explanatory variables. Hansen's J test of overidentifying restrictions was found not to be significant and therefore confirms the validity of our instrumental variables. On the other hand, the Hausman test indicates that the (more efficient) OLS model is preferred to the IV model and thus supports exogeneity of the potentially endogenous explanatory variables. Table 5 reports only the OLS version of the model with interaction variables.

4.4.2. Model results

The results in Table 5 confirm that households that follow a mixed basic grains/off-farm work livelihood strategy earn significantly higher incomes than do pure basic grains farmers. The results of the OLS model without interaction variables (not reported) suggest that livestock producers also have higher incomes. Even though the climate variables have insignificant association with income, they still may have indirect impacts, via their effect on LS. For example, lower moisture deficits significantly increase the probability of a household following a basic grains/off-farm work strategy (Table 4), which is associated with significantly higher income than pure basic

[8] In the IV regression, instrumental variables include predicted probabilities of LS (from regression in Table 4) and predicted probabilities of participation in programs and organizations from probit regressions including as explanatory variables participation in conservation training by the beginning of 2000, participation in agricultural or crop production training by 2000, existence of a producer or *campesino* organization in the community, existence of a rural bank or *caja rural* in the community, and existence of an NGO program in the community, and the explanatory variables in Table 4 reflecting agricultural potential, market access, population density, and human capital. The variables indicating participation in training by 2000 and existence of organizations in the community were also included separately as instrumental variables, in addition to being used to predict probabilities of participation. Full results are available from the authors upon request.

Table 5
Determinants of per capita income, including interaction terms (Lps/year)

Explanatory variable	OLS regression[a]	
	Coefficient	SE
Natural capital		
Altitude	−0.1393	0.1841
Summer rainfall (mm)	−0.4716	0.7180
Rainfall deficit in secondary season	2.2529	4.4758
Soil fertility	0.9510***	0.2790
Owned land	5.5853	13.5103
Percentage of land with title	−131.6669	437.3759
Physical capital		
Value of machinery/equipment (Lps)	0.0072	0.0243
Value of livestock (Lps)	−0.0007	0.0060
Human capital		
Median years of schooling	−25.6262	95.3169
Household size	−232.9582**	96.5350
Dependency ratio	−788.7933**	326.4692
Female HH head	−79.7882	633.1677
Percentage of female adults	−448.4123	1,230.0750
Age of HH head	−10.1592	12.2177
Migration index	1,285.3690	1,714.7940
Livelihood strategy (cf. basic grains)		
Livestock producer	1,186.5730	938.5464
Coffee producer	874.0251	658.4712
Basic grains/farm worker	733.7873**	361.5680
Basic grains/livestock/farm worker	654.8768*	383.3636
Participation in programs/organizations		
Conservation training	−445.1712	350.1854
Agricultural training	1,779.4080*	908.1467
Conservation extension	−333.2486	674.4493
Agricultural extension	−639.9922	614.9435
Producer/*campesino* organization	−779.4486	560.3380
Rural bank/*caja rural*	−46.6406	448.6455
NGO program	131.4425	423.0769
Location capital		
Market access	62.1511	39.8495
Road density	−58.2827	102.2556
Population density	5.5956***	1.9414
Interaction variables		
Livestock producer × Value of machinery/equipment	−0.0006	0.0481
Livestock producer × Agricultural training	10,446.7000***	1,687.8050
Coffee producer × Value of machinery/equipment	0.5920**	0.0273
Coffee producer × Agricultural training	−1,589.2100	1,211.7210
Basic grains/farm worker × Value of machinery/equipment	2.2236***	0.3394
Basic grains/farm worker × Agricultural training	−538.0840	2,821.6250
Basic grains/livestock/farm worker × Value of machinery/equipment	0.1094***	0.0352
Basic grains/livestock/farm worker × Agricultural training	−1,303.1760	1,108.0380
Intercept	567.6548	1,498.9580
Number of observations	342	
R^2	0.5339	

[a]Coefficients and standard errors adjusted for sampling weights and stratification, and are robust to heteroskedasticity.
*, **, *** mean statistically significant at 10%, 5% and 1% level, respectively.

grains farming. Soil fertility has a strong and significant direct positive effect on income, and again there is also an indirect effect through the LS, because better soils are associated with the basic grains/off-farm work livelihood strategy.

Greater land ownership alone does not guarantee higher income. Nevertheless, land ownership indirectly affects income through its effect on LS, though these effects are mixed. More land significantly increases the probability of a household following a livestock-based LS, which is associated with higher income levels in the OLS regression without interaction terms. However, greater land ownership is also associated with lower probability of the household following a basic grains/off-farm work strategy, which obtains higher income. No statistically significant direct or indirect effects of land titling on household income were found.

We find statistically insignificant direct associations of market access and road density with income but a positive effect of population density. However, there are also indirect effects. For example, road density has a positive indirect effect on income because it is significantly associated with higher probability of households pursuing the basic grains/farm worker strategy, the latter being associated with higher income. Higher population density also has an indirect effect but in the opposite direction.

Human capital has less effect on income than expected a priori, most likely because of the generally low levels of education in the hillside areas and relatively limited interhousehold variation. Of our human capital variables, the dependency ratio and household size have a negative direct effect on income per capita. Thus, having more dependents, and larger families in general, appears to reduce income per capita.

Ownership of machinery and equipment has a significant positive association with income in both OLS and IV regressions without interaction variables and suggests a high rate of return to investment in physical capital. The magnitude of the coefficient in the OLS model without interaction variables suggests that an additional Lempira (Lps.) invested in equipment contributes 0.071 Lps.[9] of additional annual income per capita, or about 0.42 Lempiras of total household income on average. Use of machinery and equipment increases the productivity of both labor and land, the former by speeding up agricultural operations and the latter through facilitating the adoption of improved production technologies. Furthermore, equipment for storing, processing, and transporting agricultural products facilitates the marketing of agricultural products and lowers transaction costs. Livestock ownership, on the other hand, does not have a statistically significant association with household income in none of our models, possibly due to high variance in estimated livestock incomes, which included negative values.

We found no statistical evidence of an impact of short-term agricultural extension or longer-term conservation-focused training on household income and also no robust statistical evidence that membership in NGO programs, producer organizations, or rural financial institutions have significant impacts

[9] During the survey period, 1 U.S. dollar averaged 16 Lempiras.

on income. However, we did find a large and statistically significant positive association of more general agricultural training with household income. In the model with interaction terms, households that have received agricultural training earn about 1,800 Lps/capita in extra income. It is hard to believe that agricultural training could have such a large effect on income, and this result may therefore be a statistical anomaly, resulting from outliers and errors in estimating income. We ran a median regression model (with interaction terms), which is more robust to such errors, and the results provide support for this explanation, given that the coefficient of agricultural training in this model was much smaller and statistically insignificant. However, we do not have full confidence in the median regression model either, because it is not able to account for the sampling probabilities of the households in the sample. Thus, there may be a positive impact of agricultural training on income, but we cannot be confident of this, and doubt that the impact is as large as the regression coefficient suggests. We find a very large and strongly significant positive association of training with incomes of livestock producers. Thus, if there are positive impacts of agricultural training programs, these positive impacts are greatest for livestock producers.

We find that the positive impact of machinery and equipment is mainly for households pursuing LS involving coffee production (where ownership of equipment such as a sprayer is likely to be quite important to the profitability of the enterprise) and for households pursuing off-farm employment. For the latter, farm equipment may yield high returns by enabling them to spare labor for more remunerative off-farm opportunities, as well as possibly contributing to agricultural employment opportunities off their own farm. Machinery and equipment appear to be much less remunerative for households pursuing basic grains or livestock production only.

4.5. Determinants of sustainable land management practices

Adoption of soil conservation measures in the hillside areas is generally low, and identifying the technical, institutional, environmental, and socioeconomic factors that condition farmers' adoption behavior is important for designing promising policies that could stimulate such practices and reduce resource degradation (Feder and Umali, 1993). We analyzed the adoption of three such measures—use of no burning, zero or minimum tillage, and incorporation of crop residues—and used probit models because dependent variables are of the dichotomous choice type (Maddala, 1992). Other practices were not sufficiently common to permit a reliable estimation of the parameters of the probit model. The regressions are estimated using parcel-level data, because this is the level at which data on these land management practices were collected. Compared to the income models, we expanded the set of explanatory variables by including parcel characteristics, land tenure, prior investments on the parcel, and prior land use.

Table 6 Shows our probit model results which indicate that agro-climatic factors influence a producer's decision to use conservation measures. Zero burning is more common at higher altitudes (where coffee is grown) and where main season rainfall is higher, perhaps the result of increased risk of run-off and higher intensity of cultivation in areas with better agro-climatic conditions. Zero/minimum tillage is less common where rainfall is higher because weeds are likely to be a greater problem. Incorporation of crop residues is higher where rainfall is more plenty but less on already fertile soils.

Not surprisingly, use of zero/minimum tillage is less likely among households who own more machinery and equipment, because some of their equipment is used for tillage. While human capital constraints are not binding for zero/minimum tillage adoption, no burning is more common among households for whom migration is important, perhaps because this practice can be labor saving (Deugd, 2000). Crop residue incorporation is less common in larger households and households with a higher dependency ratio. These results may reflect greater demand for such resources and greater poverty among larger households. The positive association of female household head with crop residue incorporation was unexpected; we are not sure why this was observed.

Opportunity costs of labor can significantly influence the adoption of sustainable land management practices (Neill and Lee, 2001). We find that households whose livelihood strategy is dominated by off-farm work and are located in areas with higher road densities and better market access are more likely, than basic grains farmers, to use no burning but less likely to use zero/minimum tillage, probably because of higher labor opportunity costs. Also, it appears that these practices are seen as alternatives to the usual tillage practice for basic grains production and most respondents did not report "zero tillage" or "no burning" on their perennial crops or other annual crops. The result that crop residue incorporation is more likely in areas with greater road density is contrary to our findings with regard to the impacts of road access on minimum/zero tillage, but may be caused by higher returns to labor invested in crop residue incorporation in such areas.

In agreement with Bonnard (1995), we found that lack of land titles is not a major constraint to the adoption of land management practices, but there are some differences in land management of leased or borrowed versus owned plots. For example, adoption of no burning is less likely on borrowed and leased plots, probably because this improves soil fertility in the longer term, but perhaps at the expense of short-term fertility due to the release of nutrients by burning.

All three practices are more common among farmers participating in agricultural extension, suggesting that more general agricultural extension programs are providing training on these practices, even if it was not mentioned by survey respondents as a specific emphasis of these programs. Zero/minimum tillage is more common among farmers who participated in conservation training programs but less common among households who participated in longer-term general agricultural training or are a member of a rural bank/*caja rural*. Financial institution membership also negatively influences incorporation of crop

Table 6
Determinants of land management practices (probit regressions)

Explanatory variable	No burning		Minimum/zero tillage		Incorporate crop residues	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Natural capital						
Altitude	0.00030***	0.00010	−0.00009	0.00008	0.00012	0.00012
Summer rainfall	0.00103***	0.00038	−0.00173***	0.00045	0.00115*	0.00061
Rainfall deficit in secondary season	0.00225	0.00292	−0.00364**	0.00184	−0.01211***	0.00462
Soil fertility	−0.00019	0.00014	0.00012	0.00013	−0.00055***	0.00019
Owned land	0.00251	0.00539	−0.00801	0.00566	−0.02065*	0.01055
Percentage of land with title	−0.14375	0.36723	0.39666	0.43907	−0.79819	0.58310
Physical capital						
Value of machinery and equipment	0.00000	0.00001	−0.00002**	0.00001	0.00000	0.00001
Value of livestock	−0.00001	0.00000	−0.00001	0.00000	−0.00001	0.00001
Human capital						
Median years of schooling	−0.08699*	0.04756	−0.00228	0.04719	0.03489	0.07323
Household size	−0.02897	0.03625	0.03212	0.03475	−0.14574***	0.05228
Dependency ratio	0.16564	0.15702	0.06804	0.15746	−0.51304**	0.24315
Female headed HH	0.13520	0.41749	−0.53418	0.38125	0.96794**	0.43695
Percentage of female adults	−0.14056	0.67252	−0.08206	0.67728	−0.88524	0.92686
Age of HH head	0.00872	0.00693	0.00382	0.00632	−0.00097	0.00886
Migration index	1.66290***	0.48703	0.45864	0.38737	0.73742	0.56510
Livelihood strategy (cf. basic grains farmers)						
Livestock producer	0.15738	0.38872	−0.15527	0.41943	−0.43337	0.49689
Coffee producer	−0.35487	0.38024	−0.73369	0.45014	−1.28124***	0.49666
Basic grains/farm worker	0.78447**	0.30482	−1.12176***	0.34645	−0.53155	0.38804
Basic grains/livestock/farm worker	0.50630*	0.29471	−0.62714*	0.36177	−0.31616	0.37204
Participation in programs and organizations						
Conservation training	0.24561	0.28844	0.91708***	0.25133	0.27376	0.34648
Agricultural training	0.47078	0.42046	−0.68528**	0.34801	−1.98802***	0.64474
Conservation extension	−0.33692	0.42501	−0.47262	0.31764	1.26840***	0.44800
Agricultural extension	0.86464**	0.38445	0.83674**	0.36259	2.19605***	0.43258
Producers/*campesino* organization	0.09204	0.37328	0.23775	0.35666	−1.59090**	0.63683
Rural bank/*caja rural*	0.31194	0.30474	−0.83068**	0.34971	−1.80687***	0.41727
NGO program	−0.16339	0.33625	0.30088	0.27397	1.50439***	0.48059
Location capital						
Market access	0.01110	0.02158	−0.04532**	0.02099	0.01773	0.02513
Road density	0.24360***	0.06445	−0.18260**	0.07627	0.36662***	0.08917
Population density	−0.00084	0.00077	−0.00107	0.00111	−0.00244*	0.00126
Parcel characteristics						
Area of parcel (mz.)	0.00803*	0.00458	0.01253	0.00921	0.02927***	0.00957
Travel time from parcel to residence (minutes)	0.00294*	0.00172	−0.00202	0.00235	−0.00525	0.00352
Travel time from parcel to road (minutes)	−0.00327	0.00481	−0.01164*	0.00700	0.00246	0.00512
Position on hill (cf., bottom)						
Top of hill	1.12731***	0.40867	−1.29756**	0.59294	0.19879	0.61334
Hillside	0.14117	0.23112	0.11731	0.23401	0.68288***	0.25952
Slope (cf., flat)						
Moderate slope	0.19763	0.25252	−0.11885	0.26331	−0.80551***	0.27468
Steep slope	−0.22478	0.31361	0.46503	0.32946	−1.33237***	0.41959
Land tenure (cf. usufruct ownership)						
Full title	−0.14709	0.27352	−0.16568	0.40627	0.17501	0.52359
Occupied communal land	0.10696	0.38146	0.28144	0.47464	−0.38417	0.52371
Borrowed plot	−1.06753***	0.27888	0.11227	0.27148	−0.29208	0.32117
Rented or sharecropped	−0.87832***	0.32504	−0.05103	0.31612	−0.20013	0.32900
Prior investments on parcel						
Stone wall	1.08242***	0.36211	0.24601	0.41272	1.22839***	0.42266
Live barrier or fence	0.66462**	0.29597	0.81895***	0.28247	−0.55983*	0.28509
Trees planted	−0.77211***	0.27057	0.83221**	0.32330	−0.39188	0.46935
Land use in 1999 (prop. of parcel area; cf. basic grains)						
Other annual crops	−3.32715***	1.05913	−1.61588**	0.76402	0.35532	0.61075
Coffee	−1.33549***	0.34968	−1.80552***	0.40774	−2.11164***	0.58072
Other perennial crops	0.15966	0.35542	−1.61227***	0.43222	−1.69658***	0.63848
Unimproved pasture	−0.58040*	0.32005	−1.82105***	0.48260	−0.64926	0.39474
Improved pasture	0.44644	0.51457	−1.78035***	0.60140	0.39004	0.58035
Fallow	−1.37974***	0.29793	−0.60730**	0.30670	−1.29574***	0.32590
Forest	−0.37226	0.49586	−1.48522***	0.52589	−0.89019**	0.43228
Intercept	−3.09006***	0.94312	2.57981***	0.83330	0.56157	1.28975
Number of observations	776		776		776	
Proportion of positive observations	0.3377		0.2321		0.1711	
Mean predicted probability of positive obs.	0.3424		0.2419		0.1641	
Hausman test of exogeneity of livelihood strategies and participation in programs/orgs (OLS vs. IV linear version of models)	$P = 0.9945$		$P = 1.0000$		NE	
Hansen's J test of overidentifying restrictions in IV linear model	$P = 0.7624$		$P = 0.8606$		$P = 0.6861$	

Notes: Coefficients and standard errors adjusted for sampling weights and stratification, and are robust to heteroskedasticity and nonindependence of observations from different parcels from the same household (clustering).

*, **, *** mean statistically significant at 10%, 5% and 1% level, respectively.

NE means the Hausman test could not be computed due to a negative value of the test statistic.

residues. Apparently training programs are promoting other technologies or practices to a greater extent. Given the earlier positive association of agricultural training with higher incomes of livestock producers, it may be that these programs are more oriented to technologies for livestock production than to crop technologies such as conservation tillage. Financial organizations often are associated with and promote rural nonfarm activities, which will tend to increase labor opportunity costs and thus may reduce households' interest in labor intensive farming practices. On the other hand, NGOs seem to promote the incorporation of crop residues.

No burning is more common on parcels that are on the top of a hill than at the bottom, (consistent with the earlier result that it is more common at higher altitude) while zero/minimum tillage and incorporation of crop residues are less common, probably because soils tend to be heavier and more difficult to till in valley bottoms. For similar reasons, incorporation of crop residues is less on steep and moderate than on flat slopes. Similar to the findings of Buckles et al. (1998) for cover crops, crop residues are more likely to be incorporated on larger plots (possibly because tillage using animal traction is easier on larger plots) but less likely where other land uses besides annual crops are important. This is not surprising, because tillage practices are used mainly for annual crops.

The slope of the hill seems to have little effect on a farmer's decision to use conservation measures, other than increasing the probability that stone walls will be used if a hill is moderately inclined and decreasing the probability that crop residues will be left on the parcel if the slope of the hill is either moderately or very inclined. The decreased probability of the use of crop residues is likely due to the labor and (possibly) equipment needed to plow under residues the practice of which may not be suitable for steep slopes.

Finally, no burning and incorporation of crop residues are more likely on plots where stone walls have been constructed. Use of no burning and zero/minimum tillage is more likely while incorporation of crop residues is less likely on plots having live barriers or fences. Use of zero/minimum tillage is more likely and no burning is less likely on plots where trees have been planted. The reasons for all of these associations are not fully clear, though some likely involve complementarity or substitutability between prior investments and current land management practices.

5. Conclusions and implications for policy

Households in the rural hillsides in Honduras hold widely differing asset endowments and follow different livelihood strategies, but the vast majority (>90%) are poor. Households that follow a livelihood strategy that is exclusively based on basic grain farming are the poorest because they often live in isolated areas with relatively poor agro-ecological and socioeconomic conditions. Opportunities for off-farm work tend to be limited in these areas but households who combine on-farm work with off-farm work are able to earn higher incomes.

Soil fertility has a strong direct positive impact on income while favorable agroclimatic conditions have an indirect positive income effect because they stimulate more remunerative livelihood strategies. Land ownership and tenure are not the key constraints limiting the potential for higher incomes, but the adoption of sustainable land-use practices is higher on owner-operated than leased plots and is stimulated by household participation in training programs and organizations. Agricultural training has a direct positive effect on income, particularly when directed toward livestock producers.

High dependency has a direct negative effect on income and a negative indirect effect through stimulating less remunerative livelihood strategies. Hillside households are not generally recipients of significant amounts of remittances and we find no significant impacts of migration on per capita household income. While population density has a direct positive impact on per capita income, road density and market access indirectly stimulate higher incomes by promoting livelihood strategies other than basic grains production.

The high reliance of rural hillside households on agricultural and related income means that any strategy targeted to these areas will have to build upon the economic base created by agriculture. Agriculture alone cannot solve the rural poverty problem, but those remaining in the sector need to be more efficient, productive, and competitive. Public investment programs should focus on broadening the physical asset base of poor households and extending the coverage of agricultural training. Extending households' physical asset bases (particularly machinery and equipment) will increase the returns to land and labor resources, and raise incomes. Such investments should have a primary focus on crop producers, but perhaps with a special focus on households that have relatively high opportunity cost of labor such as those pursuing off-farm employment or coffee production. Agricultural extension programs and conservation-oriented training programs can help improving income and maintaining soil fertility. With the virtual abolishment of government extension and increasing privatization, the farmer-to-farmer model of extension promoted by NGO-led programs becomes increasingly important for the economic and environmental sustainability of agricultural production.

Nonagricultural activities are relatively rare in rural Honduras because of the physical distances from urban centers and towns and the lack of good road infrastructure and transport services (Cuellar, 2003). Improving road infrastructure can stimulate livelihood strategies that emphasize off-farm work with higher returns than working on the own farm. High rates of fertility and dependency are important causes of poverty, and programs that succeed in lowering both household size and dependency ratios may also help in raising per capita incomes.

Improving access to land (not land titling *per se*) can have an indirect positive impact on income by enabling households to pursue more remunerative livelihood strategies such as livestock production. Land redistribution programs seeking to increase smallholders ownership of land may also be justified on the basis of sustainability considerations, because adoption of no burning is larger on owned land than on rental land.

Acknowledgments

The authors would like to thank Jordan Chamberlain from IFPRI and Sytze de Bruin from WUR for their help with the GIS work. We are grateful for the excellent collaboration with ESA Consultores during the field work and construction of the data base. We thank David Lee and the anonymous referees for their helpful comments. Any remaining errors are ours.

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