Land management decisions and agricultural productivity in the hillsides of Honduras

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Abstract

Increasing land degradation and concomitant low agricultural productivity are important determinants of rural poverty in the hillside areas of Honduras. Using data at the levels of the farm household, parcel and plot, we develop an econometric modeling framework to analyze land management decisions and their impact on crop productivity. Our econometric model allows for endogenous household decisions regarding livelihood strategy choice, use of labor and external inputs, and participation in organizations.

We found support for the inverse farm size-land productivity relationship which suggests that improved land access could increase total crop production. Land tenure has no impact on crop productivity, but adoption of soil conservation practices is higher on owner-operated than leased plots. Ownership of machinery and equipment and livestock ownership both positively influence crop productivity. Education positively affects perennial crop productivity. The gender of the household head has no significant effect on crop productivity, but does influence some land management and input use decisions. Even though household participation in training programs and organizations has only limited effects on crop productivity, agricultural extension plays a key role in promoting adoption of soil conservation practices. Location assets have limited impacts on crop productivity but do influence land management decisions. Road density and better market access have a positive effect on perennial crop productivity. Population density has limited direct impact on crop productivity, though it may have indirect effects by affecting farm size and livelihood strategies.

Key words: agricultural productivity, hillsides, Honduras, land management, soil conservation

1 Introduction

Rural poverty in Honduras is concentrated in the hillside areas. The latter are home to 50% and 80% of the total and rural population, respectively, and problems of low agricultural productivity and land degradation appear to be getting worse. Despite a few localized success stories (Deugd 2000; Cárcamo et al. 1994), adoption of conservation technologies is generally low, and identifying the factors that condition farmers' adoption behavior is important for designing promising policies that could stimulate such technologies. In this paper we develop an econometric modeling framework to assess land management decisions and their impact on crop productivity. Specifically, we analyze the adoption of the three most common soil conservation practices in the areas studied: zero burning, zero/minimum tillage, and incorporation of crop residues. Our econometric model allows for endogenous household decisions regarding livelihood strategy choice, use of labor and external inputs, and participation in organizations.

2 Methods and data

2.1 Empirical model

Making use of factor and cluster analysis techniques, we start by grouping our sample households into livelihood strategy categories, based on the household's time allocation on different types of productive activities, and the household's land use pattern (Jansen *et al.* 2005b). Livelihood strategies are then included with a set of asset-based variables to explain crop productivity and land management decisions. These asset-related variables include physical capital (machinery/equipment, livestock), financial capital (access to credit), natural capital (land, climate), human capital (characteristics of household and its members), location capital (population and road densities, market access) and social capital (participation in organizations and programs). Livelihood strategies and social capital are potentially endogenous variables influenced by natural, human and location capital. Resource conditions are linked to land management decisions which are influenced by the household's asset portfolio plus other variables that reflect field-specific characteristics. Finally, agricultural production is explained by the same set of variables as land management decisions, plus the use of labor and external inputs and land management decisions themselves. The use of labor and external inputs, in turn, is determined by a set of factors similar to that for land management decisions.

Based on the discussion above, our empirical model can be summarized as follows. The logarithm of the value of production per acre of crop type i (i indexes annuals or perennials) by household h on plot p in season t (y^i_{hpt}) is determined by labor inputs (L_{hpt}); land management practices (zero burning, minimum or zero tillage, incorporation of crop residues) (LM_{hpt}); use of external inputs (IN_{hpt}); "natural capital" of the plot (NC_{hpt}); the household's endowments of physical capital (PC_{ht}); the household's endowment of human capital (HC_{ht}); the livelihood strategy of the household (LS_{ht}); the household's social capital (P_{ht}); location capital (X_{vt}), the weather and other characteristics of the season in question (t), and random idiosyncratic factors (u_{yhpt}):

$$1)\ y^i_{hpt} = y^i(L_{hpt}, LM_{hpt}, IN_{hpt}, NC_{hpt}, PC_{ht}, HC_{ht}, LS_{ht}, P_{ht}, X_{vt}, t, u_{yhpt})$$

L_{hpt}, LM_{hpt} and IN_{hpt} are all choices in the current season, determined by NC_{hpt}; tenure status and accessibility of the plot (T_{hpt}); previous year's land use (LU_{hpt0}); PC_{ht}, HC_{ht}, LS_{ht}, P_{ht}, X_{vt}, and season specific and idiosyncratic factors:

$$2)\ L_{hpt} = L(NC_{hpt}, T_{hpt}, LU_{hpt0}, PC_{ht}, HC_{ht}, LS_{ht}, P_{ht}, X_{vt}, t, u_{lhpt})$$

$$3)\ IN_{hpt} = IN(NC_{hpt}, T_{hpt}, LU_{hpt0}, PC_{ht}, HC_{ht}, LS_{ht}, P_{ht}, X_{vt}, t, u_{ihpt})$$

$$4)\ LM_{hpt} = LM(NC_{hpt}, T_{hpt}, LU_{hpt0}, PC_{ht}, HC_{ht}, LS_{ht}, P_{ht}, X_{vt}, t, u_{lmhpt})$$

The reduced form version of equation 1) is obtained by substituting equations 2)-4) into equation 1):

$$5)\ y^{i}_{hpt} = y^{i}_{rf}(NC_{hpt}, T_{hpt}, PC_{ht}, HC_{ht}, LS_{ht}, P_{ht}, X_{vt}, t, u_{rfhpt})$$

LS_{ht} is determined by fixed or slowly changing factors including X_{vt}, T_{ht}, NC_{ht}, and HC_{ht}):

$$6)\ LS_{ht} = LS(NC_{hp}, T_{ht}, HC_{ht}, X_{vt}, u_{lsht})$$

Participation in programs and organizations is influenced by the same factors determining the household's livelihood strategy, plus past participation in training programs (P_{ht0}) and the presence of programs and organizations within the village (P_{vt}):

$$7)\ P_{ht} = P(NC_{hp}, T_{ht}, HC_{ht}, X_{vt}, P_{ht0}, P_{vt}, u_{pht})$$

We use single equation estimators appropriate to the nature of each dependent variable. L_{hpt} are measured as left-censored continuous variables (censored below at 0) since they include different types of labor (family labor, wage labor and piece rate labor); hence we use a tobit estimator to estimate equation 2). IN_{hpt}, LM_{hpt} and P_{ht} are dichotomous choice variables; we use probit models to estimate equations 3), 4) and 7). LS_{ht} is a polychotomous choice variable; we use a multinomial logit model to estimate equation 6). y_{hpt} is a continuous uncensored variable; thus ordinary least squares (OLS) regression is used for equations 1) and 5).

We tested for statistical endogeneity of L_{hpt}, IN_{hpt}, and LM_{hpt} in estimating equation 1) and endogeneity of LS_{ht} and P_{ht} in all equations using a Hausman (1978) test comparing these models to instrumental variables (IV) versions.[1] The results did not reject exogeneity (results reported below); thus we do not report the IV results since they are less efficient (coefficients were generally similar in the instrumental variables models, and the models passed tests of overidentification and relevance of the instrumental variables). In all models we tested for multicollinearity, and found it not to be a serious problem (all variance inflation factors less than 10, almost all less than 5). All parameters were corrected for sampling stratification and sample weights. Estimated standard errors are robust to hetereoskedasticity and clustering (non-independence) of observations from different plots for the same household.

2.2 Data

The data were collected during 2001-2002 in 9 provinces and 19 counties (Fig. 1) from 376 households, 1066 parcels (defined on the basis of land tenure type) and 2143 plots (defined on the basis of land use). Counties were selected purposively on the basis of agro-ecological conditions, dominant land use, population density, market access, and the presence of projects and programs. The remainder of the sampling process was fully randomized: 5 villages in each county, two hamlets in each village, and two farm households in each hamlet.

[1] In the IV regressions of equations 2) to 5), instrumental variables included predicted probabilities of livelihood strategies from the multinomial regression of equation 6) and predicted probabilities of participation in programs and organizations from probit regressions for equation 7). For testing purposes only, we assumed a linear probability version of equations 3) and 4), while we tested equation 2) using a truncated version of the model (dropping zero values) only for family labor, since there were few censored observations for family labor (only 35 out of 1635 observations). For equation 1) we assumed that LS_{ht} and P_{ht} are exogenous, since they were found to be exogenous in equations 2) – 5). The IV model of the unrestricted version equation 1) was (weakly) identified by the nonlinearity of L_{hpt}, IN_{hpt}, and LM_{hpt}. Additional identifying instrumental variables were based on theory (i.e., variables expected not to affect production directly controlling for use of labor, inputs and land management practices) and Wald tests (groups of candidate instrumental variables were tested for their significance in both OLS and IV versions of the model, and were excluded only if insignificant at 0.20 level in both models). Hansen's J tests and relevance tests (Davidson and Mackinnon, 2004) supported the relevance of the instrumental variables and validity of the excluded instruments. Detailed results of these tests are available in Jansen et al. (2005a).

We collected data at three levels (household, parcel, plot) and performed detailed biophysical measurements on a randomly drawn sample of two plots on each farm. Soil samples were also taken and their analysis allowed us to create soil fertility and water deficit variables as indicators of natural capital. Finally, we obtained secondary information regarding rainfall, population density and road density.

3 Results

We focus on the results regarding adoption of soil conservation practices and agricultural production. We begin with a brief discussion of the factor and cluster analyses results and a short description of the livelihood strategies.

3.1 Livelihood strategies

Our factor and cluster analyses resulted in the following categorization of households according to livelihood strategy:

1. Livestock producers (59 households)
2. Coffee producers (28 households)
3. Basic grains farmers (68 households)
4. Basic grains farmers/farm workers (85 households)
5. Mixed basic grains/livestock/farm workers (116 households)
6. Permanent crops producers (12 households)
7. Annual crops/intensive livestock producers (8 households)

Livelihood strategies in hillside areas are largely determined by comparative advantages (Jansen et al. 2005b) and were named based on a careful investigation of each cluster's aggregate asset portfolio and analysis of income levels and composition (data not reported).

Most livelihoods revolve around agricultural and small-livestock activities, with relatively few households engaging in higher-return activities such as production of vegetables or non-farm activities. Most off-farm work consists of agricultural wage labor and its importance is negatively correlated with farm size, which on average ranges from less than 3 manzanas (mz.) for cluster 4 to 46 mz for cluster 1.[2] The degree to which households depend on income from off-farm work varies greatly between livelihood strategies, varying from about 75% for strategy #4 to less than 10% for strategy #1. On average sample households are very poor, with per capita daily income ranging from US$ 0.15 for cluster 3 to US$ 0.66 for cluster 6. Ninety-two percent of all sample households live on less than US$ 1.00/capita/day. Clusters 6 and 7 are not part of the subsequent analysis due to limited numbers of observations.

3.2 Adoption of soil conservation practices

Adoption of soil conservation practices is generally low: zero burning, zero/minimum tillage and residue incorporation are adopted on respectively 34, 23 and 17% of parcels. Table 1 shows the results of estimating equation 4). The regressions are estimated using parcel level data, because this is the level at which data on conservation practices were collected. Subsequent regressions on external input use, labor use (not shown) and crop productivity were estimated at the plot level.

3.2.1 Zero burning

Zero burning is more common at higher elevation and where there is more rainfall in the primary rainy season (probably because of higher intensity of cultivation and increased risk of run-off in such areas); and in situations where labor opportunity costs are higher, like in areas with better road access and among households for whom migration or off-farm work is

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[2] One manzana equals 0.7 hectare.

important (e.g. livelihood strategies 4 and 5). Agricultural extension positively stimulates zero burning. Land tenure also influences use of zero burning, which is also more common on farmers' own usufruct land than on borrowed or leased in parcels, probably because of greater concern on the part of owners about the damage to investments and longer term soil fertility caused by burning. Consistent with this explanation, zero burning is more common on parcels where prior investments in stone walls or live fences or barriers exist.[3]

3.2.2 Zero/minimum tillage

Since rainfall stimulates weed growth, zero/minimum tillage is less common where there is higher summer rainfall. Zero/minimum tillage is less likely among households who own more machinery and equipment, since some of their equipment is used for tillage. Human capital constraints apparently are not binding for this type of technology which is, however, less common among households with higher opportunity costs of labor (livelihood strategies 4 and 5).

Farmers who participated in conservation training programs are, not surprisingly, more likely to use this practice, as are farmers who participated in general agricultural extension. On the other hand, households participating in longer term general agricultural training are less likely to use zero/minimum tillage. Apparently such training programs are promoting other technologies or practices to a greater extent. Households that are members of a rural bank are less likely than others to use zero/minimum tillage, possibly because such financial organizations often promote rural non-farm activities, which increase labor opportunity costs.

Use of zero/minimum tillage is less likely in areas further from an urban market and in areas of higher road density. These findings may seem contradictory but may reflect that access to an urban market has a greater effect on output and external input prices and

[3] However, zero burning is less common on parcels where trees have been planted. This may be because zero burning was seen by survey respondents as a specific practice that is associated with basic grains production, because burning is normally used to clear land for basic grains production. Thus, respondents may not have reported using "no burning" as a practice where other land uses such as perennial crops

availability than on labor opportunity costs, while road access within rural areas may have greater impact on local labor opportunity costs.

Soils tend to be heavier and more difficult to till in valley bottoms and on parcels where prior investments in live fences or barriers or tree planting have been made, making zero/minimum tillage more likely. Zero/minimum tillage is more common on parcels where basic grains are the dominant land use. As with zero burning, it appears that zero/minimum tillage is seen as a specific practice that is an alternative to the usual tillage practice for basic grains production, rather than simply the absence of tilling the land.

3.2.3 Incorporation of crop residues

Crop residue incorporation is less common in areas where the moisture deficit in the second season is higher (because of reduced fodder supplies), and less common where soils are more fertile (smaller beneficial effect). Crop residue incorporation is negatively associated with household size (possibly because larger households need more cooking fuel) and dependency ratio (because of tighter labor constraints and greater poverty and scarcity of fodder and fuel). The technology is not used for coffee production, and its negative association with agricultural training but positive association with agricultural extension is similar to our findings with regard to zero/minimum tillage. While NGOs appear to promote incorporation of crop residues, other producer and financial organizations focus more on other uses of household labor and resources. The negative association with population density likely reflects greater scarcity of fodder and fuel resources in more densely populated areas. Contrary to our findings for zero/minimum tillage, higher road density makes the technology more likely, possibly because it increases the returns to labor-intensive land management practices.

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were more important, even if they were not using burning. Consistent with this, we find that zero burning is more common where basic grains are a larger component of the prior land use, than for most other land uses.

Crop residues are more likely to be incorporated on larger plots, more common on hillsides than the bottom of a hill and more common on relatively flat slopes than on moderate or steep slopes, possibly because using animal traction is easier on larger plots. Crop residue incorporation is more likely where stone walls have been constructed on the parcel, perhaps because of the complementary nature of stone walls and crop residue incorporation, since both measures help to conserve soil and soil moisture. Since tillage practices are used mainly for annual crops, crop residue incorporation is less likely where other land uses besides annual crops are important.

3.3 Value of crop production

Table 2 shows the results of equations 1) and 5).

3.3.1 Annual crops

The main factors directly affecting production of annual crops are use of manure, external inputs, rainfall, and topography. Manure increases the predicted value of crop production by 58% (=1-exp(0.4546)). The impacts of external inputs ranges from +26% for herbicide use to +32% for fertilizer use. Family labor and hired wage labor also contribute significantly to annual crop productivity. Rainfall deficit, plot size and being on a hillside compared to the bottom of a hill all have a negative (-) effect, while better drainage on moderately sloped plots (compared to flat ones) positively affects productivity. The negative effect of plot size could be due to decreasing returns to scale in production at the plot level, differences in plot quality, or errors in measuring plot size.

Indirectly, many other factors may influence production by influencing use of external inputs and manure. The reduced form model tests which of these factors have significant impacts, whether directly or indirectly. They include rainfall deficit (-), dependency ratio (-), migration (+), livelihood strategies 2 and 4 (-, compared to strategy 3), plot size (-), hillside (-

), and moderate slope (+). These results suggest that there are costs of income diversification in terms of lost production of annual crops. While households pursuing more diversified livelihood strategies earn higher income per capita (Jansen et al., 2005a), diversification may involve a potential trade-off in terms of food security if high transaction costs in the infrastructure-deficit hillsides mean that farmers who are net buyers of food must pay substantially higher prices when they purchase it than the prices net sellers of food receive when they sell.

3.3.2 Perennial crops

The main factors with a direct positive effect on the production of perennial crops are use of zero burning, external inputs, hired wage labor, soil fertility, schooling, plot size, topography, market and road access, livestock ownership, participation in conservation training, and membership of a producers organization (Table 2). Zero burning and external inputs have large and significant positive effects on perennial crop productivity, increasing the predicted value of crop production between 138% (zero burning) and 321% (fertilizer). The reduced form confirms the (direct or indirect) positive influence of soil fertility, schooling, plot size and topography, as well as the negative impact of agricultural training and size of land ownership. The latter is consistent with a large body of literature showing an inverse relationship between farm size and agricultural productivity in developing countries (e.g., Lamb, 2003; Benjamin, 1995; Feder, 1985; Carter, 1984), and suggests that labor or management constraints limit productivity of larger land holders. The negative association of some types of agricultural training and extension programs with perennial crop productivity may also be due to management and other constraints, combined with the emphasis of these programs (i.e., these programs may be promoting other types of agricultural production). The finding of lower perennial crop productivity of coffee producers than those classified as basic grains producers is puzzling, but may reflect higher returns to production of other perennial crops such as fruits and pineapple during the survey year (when coffee prices were very low). Finally, these results suggest that investments in education and soil maintenance may contribute to higher income from perennial crops production.

4 Conclusions

Based on our analyses we draw the following conclusions:

1. The use of certain soil conservation practices can substantially increase crop productivity.
2. Agricultural extension plays a key role in the promotion of soil conservation practices.
3. Programs that improve access to land may be justified on both efficiency and sustainability grounds. The inverse farm size-land productivity relationship for perennial crops suggests that improved land access could increase total crop production by enabling more productive smallholders to expand their production. And adoption of certain soil conservation practices is larger on owned land than on rental land.
4. There is a need for soil conservation practices that can also be adopted by households that have higher opportunity cost of labor.
5. In areas with high transportation and marketing costs, diversification may have a cost in terms of decreased food security.

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Figure 1. Location of the 9 provinces and 19 counties

Table 1. Determinants of the use of soil conservation practices (Probit models)

	Zero burning		Minimum/Zero Tillage		Incorporate crop residues	
Explanatory variables	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Natural capital						
Altitude (average of sampled plots, ft)	0.00030***	0.00010	-0.00009	0.00008	0.00012	0.00012
Summer rainfall (May-Sept, mm)	0.00103***	0.00038	-0.00173***	0.00045	0.00115*	0.00061
Rainfall deficit in secondary season (avg. sampled plots during Oct-Dec, mm)	0.00225	0.00292	-0.00364**	0.00184	-0.01211***	0.00462
Soil fertility (approximated by potential maize yields, kg/ha)	-0.00019	0.00014	0.00012	0.00013	-0.00055***	0.00019
Owned land (mz)	0.00251	0.00539	-0.00801	0.00566	-0.02065*	0.01055
% of land with title	-0.14375	0.36723	0.39666	0.43907	-0.79819	0.58310
Physical capital						
Value of machinery and equipment (Lps)	0.00000	0.00001	-0.00002**	0.00001	0.00000	0.00001
Value of livestock (Lps)	-0.00001	0.00000	-0.00001	0.00000	-0.00001	0.00001
Human capital						
Median years of schooling members > 7 yrs	-0.08699*	0.04756	-0.00228	0.04719	0.03489	0.07323
Household size (# of members)	-0.02897	0.03625	0.03212	0.03475	-0.14574***	0.05228
Dependency ratio (# of HH members < 12 and > 70 yrs) / (# of HH members between 12 and 70 yrs)	0.16564	0.15702	0.06804	0.15746	-0.51304**	0.24315
Female headed HH (1=female head)	0.13520	0.41749	-0.53418	0.38125	0.96794**	0.43695
% of female adults (females > 12 yrs of age as a % of total household size)	-0.14056	0.67252	-0.08206	0.67728	-0.88524	0.92686
Age of HH head (yrs)	0.00872	0.00693	0.00382	0.00632	-0.00097	0.00886
Migration index (total # of months spent outside HH by members per year)	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 (dummies)						
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

Explanatory variables	Zero burning Coefficient	Zero burning Std. error	Minimum/Zero Tillage Coefficient	Minimum/Zero Tillage Std. error	Incorporate crop residues Coefficient	Incorporate crop residues Std. error
Producers organization	0.09204	0.37328	0.23775	0.35666	-1.59090**	0.63683
Rural bank	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 (ordinal index from CIAT)	0.01110	0.02158	-0.04532**	0.02099	0.01773	0.02513
Road density (km/km^2)	0.24360***	0.06445	-0.18260**	0.07627	0.36662***	0.08917
Population density (persons/km^2)	-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 (dummies)						
- 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 (proportion 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	

	Zero burning		Minimum/Zero Tillage		Incorporate crop residues	
Explanatory variables	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
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	

*, **, *** mean statistically significant at 10%, 5% and 1% level, respectively.
NE = Hausman test could not be computed due to a negative value of the test statistic.

Table 2. Determinants of value of crop output per *manzana*

	ANNUAL CROPS				PERENNIAL CROPS			
	OLS Structural Model		**OLS Reduced Form**		**OLS Structural Model**		**OLS Reduced Form**	
Explanatory variables[1]	*Coefficient*	*Std. error*	*Coefficient*	*Std. error*	*Coefficient*	*Std. error*	*Coefficient*	*Std. error*
Land management practices								
No burning	-0.06792	0.156465			0.86841***	0.24690		
Minimum/zero tillage	-0.05630	0.12789			0.12134	0.28455		
Incorporate crop residues	0.06894	0.16798			-0.55484	0.35857		
Mulch	-0.40335	0.30345			0.25666	0.39745		
Manure	0.45460*	0.23776			-1.50113	0.99156		
External inputs								
Fertilizer	0.28082**	0.11488			1.43689***	0.25978		
Herbicide	0.22801**	0.10973			0.94603**	0.46414		
Insecticide	0.24062**	0.11930			1.34909***	0.20998		
Other inputs	0.08759	0.11812			1.21779***	0.22873		
Labor inputs								
Family labor (days/mz)	0.00543 ***	0.00141			0.00234	0.00269		
Hired wage labor (days/mz)	0.01112 ***	0.00333			0.01459***	0.00338		
Hired piece labor (Lps/mz)	-0.00007	0.00026			-0.00001	0.00004		
Season (cf. 1st season 2000)								
- Primary season 2001	-0.09977	0.08580	-0.10057	0.08036				
- Secondary season 2000	0.12141	0.12654	-0.08473	0.11730				
Natural capital								
ln(altitude)	-0.02845	0.07864	0.02737	0.09545	-0.47894**	0.22357	0.24999	0.20885
ln(Summer rainfall)	-0.15494	0.21561	0.24348	0.25789	0.05464	0.68158	-1.42876*	0.74538
Rainfall deficit secondary season	-0.00626 ***	0.00214	-0.00611 ***	0.00228	-0.01762***	0.00493	-0.01157	0.00734
ln(soil fertility)	0.19937	0.19235	0.03371	0.20348	1.16059**	0.46990	2.19770***	0.81084
Owned land			-0.00347	0.00241	-0.02028***	0.00420	-0.01475***	0.00559
Share of land with title			0.37852	0.25223			0.74152	0.48960
Physical capital								
Value of machinery/equipment			0.00001	0.00000			0.00002*	0.00001
Value of livestock			0.00000	0.00000	0.00002***	0.00000	0.00000	0.00001
Human capital								
Median years of schooling			-0.03098	0.03143	0.16587***	0.05466	0.12020*	0.06993
Household size			0.02320	0.02419	-0.06774	0.04687	-0.01471	0.04671

	ANNUAL CROPS				PERENNIAL CROPS			
	OLS Structural Model		OLS Reduced Form		OLS Structural Model		OLS Reduced Form	
Dependency ratio			-0.20449**	0.10098	0.31707**	0.14920	-0.12972	0.20932
Female headed HH			0.00805	0.16145			-0.46433	0.61905
Share of female adults			0.07845	0.35903	-2.87884***	0.75356	-1.00297	1.28463
Age of HH head	-0.00061	0.00401	-0.00548	0.00389			-0.01028	0.01124
Migration index			0.37866*	0.19972			0.12845	0.35649
Livelihood strategy (cf. basic grains)								
- Livestock producer			-0.23380	0.23894	-1.11916***	0.38519	-0.22720	0.45501
- Coffee producer			-0.42670**	0.21057	-1.42228***	0.38045	-1.15578**	0.46416
- Basic grains/farm worker			-0.43157**	0.17994	-0.32967	0.32108	-0.12760	0.47147
- Basic grains/livestock/farm worker			0.04117	0.17657	-0.78561***	0.22983	0.01192	0.39051
Participation in programs/organizations								
Conservation training			0.17179	0.13273	0.67417**	0.33275	0.82336	0.53005
Agricultural training			0.06963	0.21795	-1.25931***	0.44257	-1.50618**	0.59899
Conservation extension			0.34996	0.24163	-1.42356***	0.31426	-1.49975***	0.39320
Agricultural extension			-0.04053	0.21263			0.36879	0.48500
Producers/*campesino* org.			0.27846	0.25003	1.13074**	0.44036	0.50634	0.48157
Rural bank/*caja rural*			-0.01289	0.18553			0.12837	0.53172
NGO program	-0.27237	0.25503	-0.17440	0.17057	0.77885**	0.34797	0.30771	0.51308
Location capital								
Market access			0.00499	0.00872	-0.03353*	0.01854	0.00074	0.02795
Road density			-0.01589	0.03974	0.16916**	0.06762	-0.00164	0.09408
Population density			-0.00023	0.00055			0.00466*	0.00270
Plot characteristics								
ln(plot area)	-0.17524**	0.08775	-0.31440***	0.07859	0.97522***	0.12199	1.19736***	0.18691
Travel time to residence (minutes)			-0.00036	0.00115	-0.00469	0.00297	0.00182	0.00323
Travel time to road (minutes)			0.00291	0.00438			0.00555	0.00648
Position on hill (cf. bottom)								
- Top	0.28868	0.22257	0.46062	0.29004	-1.41198***	0.34722	-0.38903	0.54143
- Hillside	-0.30291**	0.13837	-0.33862**	0.16445	0.43458	0.29154	0.14637	0.37014
Slope (cf. flat)								
- Moderate	0.40698***	0.15716	0.40648**	0.19344	-1.24307***	0.36389	-0.96998*	0.49065
- Steep	0.34977*	0.19735	0.31614	0.21165	-1.06756**	0.41541	-1.12428	0.72676
Land tenure (cf. usufruct ownership)								
- Full title			0.00273	0.26370			-0.27858	0.27774
- Occupied comunal land			-0.32453	0.34176			-0.11355	0.41377

	ANNUAL CROPS				PERENNIAL CROPS			
	OLS Structural Model		**OLS Reduced Form**		**OLS Structural Model**		**OLS Reduced Form**	
- Borrowed plot			0.07229	0.16237			-0.63886	1.56946
- Rented/sharecropped plot			0.07311	0.19977				
Prior investments on plot								
- Stone wall	-0.06216	0.23110	-0.12243	0.26490	0.64636	0.59362	0.08395	0.75437
- Live barrier or fence	0.18327	0.18752	0.07861	0.18174	0.17207	0.47399	0.46490	0.56137
- Trees planted	0.17513	0.16283	-0.16110	0.17488	0.56158**	0.22230	0.19811	0.34743
Intercept	6.56722***	2.21250	5.56534**	2.57767	3.33685	7.14800	-0.10824	8.15060
Number of observations	1164		1162		217		215	
R^2	0.2545		0.2528		0.8140		0.7166	
Wald test of excluded variables	P=0.3947				P=0.6815			
Hausman test of OLS vs. IV model			P=0.1370				P=0.9995	

[1] For units of measurement, see Table 1.
*, **, *** mean statistically significant at 10%, 5% and 1% level, respectively.