More Social Capital, Less Erosion:

Evidence from Peru=s Altiplano

by

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May, 2000

Selected paper for presentation at the annual meeting of the American Agricultural Economics Association, Tampa, FL, July 30-August 2, 2000.

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The author acknowledges financial support from Michigan State University and the International Potato Center (CIP) during a 1999 sabbatic leave in Peru. Special thanks are due to Roberto Quiroz for intellectual, financial and administrative support. For help in designing and implementing data collection and management, thanks are due to Jorge Reinoso, Roberto Valdivia, Sebastian Paredes, Silvia Agüero, Mariana Cruz, Yonny Barriga, Pedro Cabrera, José Rivera, and Andrés Valladolid. Thomas Bernet, Dominique Hervé, John Kerr, Tom Reardon and Tom Walker offered thoughtful comments following seminars at CIP and MSU.

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Abstract

The debate over sustainable intensification has hinged on private incentives to abate land degradation. Largely missing is the role of social capital in both creating incentives and removing barriers to soil conservation. Yet soil conservation embodies the externality problem that bedevils so many aspects of natural resource management. Action by one farmer to reduce water or wind erosion may benefit neighboring fields by slowing the rate of water or wind movement across those lands. Yet these benefits are not fully captured by the farmer making the conservation investment. However, when economic agents care for one another, these externalities can be internalized, reducing the individual's disincentive to perform a socially level of natural resource conservation. Likewise, community organizations may provide collective capital and labor to overcome adoption barriers faced by individuals.

The twin hypotheses that 1) farming practices influence soil erosion and 2) social capital influences the adoption of sustainable farming practices are tested with data from a 1999 survey of 197 farms in the Peruvian Altiplano around Lake Titicaca. The survey used cluster sampling of farms in villages to represent each of three arable agro-ecological zones in the Ilave-Huenque river basin. Relative asset levels were used to stratify resident households within villages. Personal interviews collected a wide range of data on farm household assets, management practices, and status of agricultural natural resources.

In the first stage of econometric analysis, the erosion causal model was tested using two dependent variables, the perceived changes over 20 years in soil depth and relative crop yield, respectively. Explanatory variables included physical factors (topography, agro-ecological zone, soil texture) as well as farming practices (orientation of tillage relative to slope, length of fallow period in crop rotation). Both the ordered probit soil depth change model and the tobit relative crop yield change model found longer fallows and vertical furrows to reduce soil erosion. These results were robust to Hausman tests of endogeneity.

In the second-stage analysis, two random effects generalized least squares regression models were run to identify determinants of these sustainable cropping practices from a range of candidate explanatory variables including price of potato (the dominant cash crop), physical factors, and farm assets (including land, equipment, buildings, labor force, human capital and social capital). Social capital variables included village land area managed in Aaynoca@ (a traditional collective crop rotation arrangement) and household members participating in community organizations. Results found crop price insignificant and most farm physical and financial assets to vary in effect between models. However, the social capital variables tended to be both significant and positive in favoring the adoption of both soil-conserving farming practices.

This evidence of local association links to sustainable natural resource management is encouraging for a setting where the track record of sustainable intensification via government or market channels is poor. The results merit verification research and examination of ways to strengthen promising local institutions.

Introduction

Steep slopes make mountain regions especially susceptible to soil erosion the world over. The mountainous regions of Latin America are no exception, and rising rural populations have created serious soil erosion problems in many parts of the region (García Barrios and García Barrios, 1990; Reinoso and Valdivia, 1994; Zimmerer, 1993).

The challenge of investing in soil conservation has been framed in the larger debate over sustainable intensification. Some authors argue that poor farmers have no choice but to put immediate food security ahead of long-term sustainability (Figueroa, 1998). Trapped in a downward spiral of declining productivity, a rescue from outside seems the only viable policy prescription. But as market solutions have displaced government-sponsored remedies to rural development problems, the ideas of Esther Boserup (1965) have gained notoriety. The Boserup school counters that rising land values (triggered by rising populations) motivate even poor farmers to invest in soil conservation (Boserup, 1965; Tiffen et al., 1994). From this perspective, declining productivity is endogenously self-correcting. Population growth may undermine agricultural productivity in the medium term, but in the long term productivity is a U-shaped function of population density (Templeton and Scherr, 1999). With growing demand for food, prices will rise, land values will follow, and conservation investments will occur (Tiffen et al., 1994). A middle ground between these schools contends that population growth can trigger unsustainable, immiserizing intensification based solely on increased labor input; by contrast, capital-led intensification tends to conserve soil and enhance fertility (Clay et al., 1998).

Rising population is axiomatic to the sustainable intensification arguments, notably in Africa (Boserup, 1965; Clay et al., 1998; Templeton and Scherr, 1999; Tiffen et al., 1994). But in recent years, rising population has been the exception, not the rule, in the central Andes of South America. Outmigration from the central Andes has been flowing toward the Pacific coast and the Amazon jungle for over two decades (Collins, 1988; Wiegers et al., 1999). At the state (or department) level in southern Peru, rural-urban migration has increased (Caballero, 1992). The migratory flows have been accelerated by rural terrorism in Peru during the 1980's and early 1990's and by the precipitous decline in government-financed agricultural research and outreach to peasant farmers during the same period throughout the central and southern Andean region.

Peasant agriculture in areas like the Andean Altiplano between Peru and Bolivia seems trapped at the bottom of the U-curve. Geographically remote from major markets and suffering a continual outmigration of the most productive aged residents, the region has defied generations of rural development projects. People publicly question how the region's agriculture could seem to be less productive today than under the Inca empire, five hundred years ago.

Absent the market opportunities created by growing populations and absent public investment in peasant agriculture and natural resource management, what hope is there to induce peasant farmers to abate soil erosion and related threats to natural resource sustainability in fragile mountain landscapes?

The debate over intensification has hinged on *private* incentives to abate land degradation. Largely missing from the debate is the role of social capital in both creating incentives and removing barriers to soil conservation. Economic definitions of social capital center on its ability to internalize economic externalities (Collier, 1998). However, the scale at which this occurs varies from one definition to another (Woolcock, 1998). At one extreme is a narrow focus on Putnam's local "networks of civic engagement" (Putnam et al., 1993, as cited in Grootaert, 1997). At the other extreme is the encompassing "social and political environment that enables norms to develop and shapes social structure" (Grootaert, 1997, p. 3). For our purposes, the essential characteristic is the shared notion that the relationships facilitated by social capital engender an increase in the economic efficiency at the community level.

The potential of social capital to internalize economic externalities is of particular interest in natural resource management. Agricultural natural resource management is notoriously prone to engender externalities in land (soil erosion), water (runoff and leaching) and air (spray drift, wind erosion) (Blaikie and Brookfield, 1987). Soil erosion by water or wind poses twin threats to productivity: the obvious internal threat is a reduction in the longterm productivity of the land, while the external threat occurs via the spread of eroded gullies to neighboring land, siltation of waterways, and air pollution by airborne soil. Likewise, some benefits of soil conservation are realized off the farm. Action by one farmer to reduce water or wind erosion may benefit neighboring fields by slowing the rate of water or wind movement across those lands. Although these benefits are not captured by the farmer investing in conservation, community organizations can internalize these externalities. Social capital in the form of shared norms and/or fellow feeling among community members has the potential to motivate individuals to act for the collective good. Where community organizations exist, social capital may further help individuals overcome resource barriers to conservation, by providing collective capital and labor.

The objective of this paper is to examine whether social capital holds promise for inducing sustainable land management under conditions where population growth is unlikely to trigger sustainable intensification. The paper first develops a conceptual behavioral model for natural resource management with externalities in order to characterize the effect of social capital on conservation investment. It proceeds with an empirical analysis of data from a 1999 cross-sectional farm survey in an erosion-prone river basin south of Lake Titicaca in Peru. The first stage analysis seeks to identify sustainable farming practices associated with reduced erosion. The second stage analysis then tests empirically whether social capital variables are important in determining the choice of sustainable farming practices.

Conceptual model

Consider an economic agent who cares about some other agent. A simple example would be an agent **i** whose utility function includes his own net income (π_i) plus a positively weighted multiple ($\delta \in (0,1]$) of the net income of another member (π_j) of his community. Members of the community engage in producing a farm product, $\mathbf{y(x,k,c_i,c_j)}$, whose production process can be characterized as a concave, increasing function separable in variable inputs **x**, capital inputs **k**, and conservation practices **c**. Conservation practices have the special attribute that conservation by agent **i,** $\mathbf{c_i}$, also enters the production function of agent **j**, and vice-versa. This might be the case where soil conservation in one farmer's field prevents gullying that would spread into the neighboring field, hastening soil and yield loss there. The optimization problem of agent **i** can be formulated as follows:

$$\max_{c_i} \ U_i(\pi_i, \pi_j) = \pi_i + \delta\pi_j \quad \textbf{(1)}$$
$$\textit{subject to}$$
$$\pi_i = py_i(x_i, k_i, c_i, c_j) - rc_i$$
$$\pi_j = py_j(x_j, k_j, c_j, c_i) - rc_j$$

First-order conditions for maximization of Equation (1) must satisfy

$$\frac{\partial y_i}{\partial c_i} + \delta\frac{\partial y_j}{\partial c_i} = \frac{r}{p} \quad \textbf{(2)}$$

Since the second term in Equation (2) is greater than zero by assumption, the optimal level of $\mathbf{c_i}$ must exceed the level that would satisfy the equation in the absence of the second term. Put intuitively, a farmer who cares about his neighbor and knows that his own conservation practices will benefit both himself and his neighbor will optimally choose to do at least as much conservation as he would if he ignored his neighbor.

Data and empirical methods

The key empirical question then becomes whether agents care about one another enough to engage in charitable conservation behavior. One way to test this hypothesis is to include empirical indicators of social capital as explanatory variables. A wide range of variables has been used in prior studies as indicators of social capital (Grootaert, 1997). In a village-level study such as this one, appropriate variables are measures of association membership and involvement, as well as the existence of institutions of collective action.

The null hypothesis that social capital variables have no effect on the choice of farming practice was tested with farm survey data from the Peruvian Altiplano (Ahigh plain@) around Lake Titicaca. The 1999 survey covered 265 farms in the Ilave-Huenque river basin in southern Puno department. The analysis presented here is based on data from the 197 farms located in the three agro-ecological zones where crop production was common. These zones ranged in altitude from 3,800 to 4,000 meters above sea level. Due to altitude and weather patterns, agriculture in the area is subject to risks of frost, drought, and floods. The Aymara-speaking inhabitants practice potato-based cropping systems that typically include quinoa and cereals (barley, oats and/or broad bean). Livestock, notably cattle, sheep and alpacas are key elements of local farming systems. Due to a history of hereditary field subdivisions (Caballero, 1992), farm fields are fragmented and small; farms average about one hectare of cropped area (Swinton et al., 1999). According to the 1992 census, district-level poverty in the study area ranged from 63 to 95 percent (INEI, 1994)

The survey used cluster sampling of farm households in 2-3 villages per zone to represent the three agro-ecological zone strata. Relative asset levels as subjectively assessed by village leaders were used to stratify resident households within villages as poor, average or less poor. Personal interview conducted in April-June, 1999 collected a wide range of data on farm household assets, management practices during the 1998-99 agricultural season, and the status of agricultural natural resources.

Following Putnam et al. (1993) and Grootaert (1997), the survey measured indicators of social capital at the local level of horizontal associations. Specifically, it measured a) the number of associations in which household members participated, b) whether or not the household head had held a position in local government during the past ten years, c) the village land area under the collectively planned but privately managed *aynoca* system, and d) the number of village families using communal grazing land. The first two measures are at the household level; the last two are at the village level.

The first stage of the econometric analysis aimed to test the hypothesis that certain farming practices reduce soil erosion. The erosion causal model was tested using two dependent variables. The first variable was the perceived change over 20 years in soil depth (measured as a Likert scale where 1=major increase in soil depth and 5=major decrease in soil depth). The second variable was the perceived relative crop yield decline in a typical recent year as compared to a typical year twenty years ago. This variable was only measured for the 89 percent of respondents who perceived a yield reduction over that period of time. Explanatory variables included physical factors (topography, agro-ecological zone, soil texture) as well as farming practices (orientation of tillage relative to slope, proportion of crop rotation time devoted to fallow).

The soil depth model was estimated as an ordered probit, while the relative yield regression was estimated as a tobit, both using Stata 6.0 (StataCorp, 1999). In order to correct for cluster effects, dummy variables were included for all villages and their contribution formally tested using Wald test. After identifying preferred models, key variables were instrumented and subjected to Hausman specification tests of endogeneity (Greene, 1993, p. 479). These were conducted by estimating predicted values for the key variable in question and then comparing the less efficient but unbiased model using predicted values of the key determinant variable with the more efficient but possibly biased model with the key variable itself.

The second stage analysis sought to identify the determinants of those erosion-reducing practices identified in the first stage regressions. Since the presence of other village-level variables made village dummies infeasible in these regressions, random effects generalized least squares (GLS) models were run (StataCorp, 1999). The degree of correlation between village clusters and individual households is captured by the correlation coefficient, rho, which is reported with the regression results. The explanatory variables in the choice of farming practice models included the price of potato (the dominant cash crop), physical factors, and farm assets (including land, equipment, buildings, labor force, human capital and social capital).

Results

1. Erosion determinants

Both the ordered probit model of change in perceived soil loss and the tobit model of relative decline in perceived crop yield generated highly significant regression results, based on chi-square statistics (Table 1). After controlling for other conditioning factors, the two practices that contribute significantly to reduced soil erosion are longer fallows and use of vertical furrows. Vertical furrows entered the soil loss ordered probit model as a quadratic term; both the linear and the quadratic variables had significant coefficient estimates indicating that vertical furrows reduce soil loss at a decreasing rate up to the point where 78% of fields had vertical furrows (Swinton and Quiroz, 2000).

With one exception, the Hausman tests failed to reject the null hypothesis that the original survey variables (proportion of rotation in fallow and proportion of fields with vertical furrows) were exogenous. The one exception was the case of vertical furrows in the perceived soil loss probit model (chi-square p-value = 0.018). For this case, the results from the perceived soil loss ordered probit with the instrumented vertical furrows variable are also presented in Table 1. Although coefficient magnitudes differ, the signs and significance levels of the coefficient estimates are identical to those in the original ordered probit.

It should be noted that the regression results are only partially consistent with prevailing scientific thinking about determinants of soil loss. That fallow can reduce soil loss fits with its effect of reducing soil disturbance. The beneficial effect of fallow is supported by prior research in the Altiplano (Bernet, 1995). But that vertical furrows reduce soil loss contradicts common wisdom about the effects of tillage orientation on the speed of runoff and associated erosion (Morgan, 1996). This result, which was statistically robust for the perceived soil loss model but not for perceived yield loss, merits further inquiry.

2. Social capital and the determinants of sustainable practices choices

Based on the first-round findings that fallow and vertical furrows were associated with reduced erosion, the second round analysis sought to identify the factors determining choice of these specific cropping practices. Both random effects GLS regressions were highly significant, as shown in Table 2. Neither model had a rho-value different from zero, suggesting no village cluster effect on variance.

The results were as notable for what they did not find as for what they did. Crop price proved insignificant, and most farm assets were consistent with expectations but not consistently significant across regressions. The fallow area model indicated that the fallow proportion of crop rotations is greater in certain agro-ecological zones, in villages with a prior natural resource development project and/or more land in *aynoca* management. Fallow is also more widespread on farms with well equipment, less off-farm income, more secondary school-educated adults, and more association memberships. The vertical furrows model indicated that the proportion of fields with vertical furrows is higher on farms where poverty (unmet basic needs) is less, home equipment (radios, looms, etc.) is less, association memberships are more common, and more fields are located at footslope.

The social capital coefficient estimates stand out. The number of household members participating in local associations was the sole significant variable common to both regressions. Like the highly significant *aynoca* land area coefficient in the fallow model, association memberships were positively associated with the adoption of both soil-conserving farming practices.

Hausman tests of endogeneity were again attempted on these social capital variables in order to verify the direction of causality (and rule out the possibility that, for example, households with more fallow therefore had more time to spend in associations). For village land area in *aynocas*, no suitable instrumental variables could be identified. In the instance of association memberships, instrumental variables were identified, but the Hausman test was insignificant.

Conclusions

In the case described here, social capital appears to contribute meaningfully to the use of cropping practices that conserve soil. These findings have two limitations. First, one of the “sustainable” farming practices (vertical furrows) is not normally associated with reduced soil erosion. Second, measurement is difficult – both for social capital and for soil erosion in a single-visit interview. With those caveats, the statistical results are encouraging.

That social capital at the village level may contribute to long term viability is especially encouraging in the specific context of the Altiplano. This is a setting where mountainous terrain limits potential agricultural productivity and access to markets. Compounding these natural limitations, public investment in agricultural research and outreach for mountain smallholders has been severely curtailed over the past 15 years. With government funds in short supply and markets too remote to induce endogenous intensification, alternatives to public programs and market solutions are needed.

The evidence presented here suggests that even where money is scarce, marginal gains to natural resource sustainability may be had from local efforts linked to participation in local, horizontal associations. The associations that mattered among these villages in the Peruvian Altiplano range from mothers’ clubs to irrigation committees. Of special interest is the traditional local institution of the *aynoca*. The *aynoca* is a land management system whereby designated land areas are to be planted to the same crop each year. *Aynoca* areas are composed of many individually owned fields, but the owners have a longstanding understanding that if they plant the agreed crop, then members will take turns watching over it to protect against marauding wildlife and thieves. *Aynocas* typically follow an established crop rotation. Since this includes one or more years in fallow, landholding in the *aynoca* tend to ensure that fallow remains part of the crop rotation. Indeed, some of the farmers interviewed blamed yield declines on the fact that they had withdrawn from an *aynoca* or the village had decided to eliminate the practice of *aynocas*.

The evidence here for natural resource benefits from local horizontal associations is not strong enough to compel policy prescriptions. But it is enough to call for more research to replicate these results. If local institutions can enforce norms that benefit the community, then strengthening (and perhaps extending) such institutions could constitute a low-cost means of contributing modestly to natural resource sustainability. Formal research is in its infancy on how the social capital embodied in local institutions can be strengthened. But the evolving body of knowledge suggests that opening opportunities for democratic participation encourages the establishment of new associations, and introducing linkages from the local to the regional scale allows local institutions to extend their reach (Bebbington, 1999; Evans, 1996; Fox, 1996; Ostrom et al., 1993).

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Table 1: Soil loss and 20-year yield loss regression results, cropped zones of Ilave-Huenque basin, Puno, Peru, 1999

Variable	Unit of measure	Soil loss (ordered probit) With original variables Coef.	z-stat.	Soil loss (ordered probit) With instrumented Vertical Furrows Coef.	z-stat.	Yield loss (tobit) Coef.	t-stat.
Zone: Suni A	Binary	1.784	4.67 ***	1.893	3.52 ***	-0.034	-0.68
Zone: Suni B	Binary	1.247	2.74 ***	1.809	2.64 ***	0.021	0.35
Fallow fields	Proportion of fields	-1.453	-1.90 *	-2.770	-2.34 **	-0.339	-3.23 ***
Small grains	Prop'n of planted area	-0.495	-0.96	-0.743	-0.96	0.076	1.07
Footslope	Proportion of fields	0.357	0.61	0.810	0.98	-0.370	-1.83 *
Sq. footslope	Proportion of fields					0.579	1.84 *
Slope	Proportion of fields	0.835	1.13	1.911	1.51	0.148	1.51
Sandy soil	Proportion of fields	-0.185	-0.51	0.477	0.89	0.117	2.34 **
Vertical furrows	Proportion of fields	-1.823	-2.15 **	-17.415	-2.80 ***	-0.059	-1.29
Sq. vertical furrows	Proportion of fields	1.170	1.82 *	14.173	3.22 ***		
Contour furrows	Proportion of fields	-0.546	-0.65	0.529	0.51	0.105	0.86
Fertilizer	Kg/ha	-0.002	-1.78 *	-0.002	-1.87 *	0.000	-0.23
Pesticides	Kg/ha	-0.030	-0.98	-0.041	-0.96	-0.009	-2.09 **
Sq. Pesticides	Kg/ha	0.001	1.33	0.001	1.10	0.000	1.97 *
Labor value	New soles	0.000	-0.62	0.000	-0.88	0.000	-2.34 **
Sq. labor value	New soles					0.000	1.95 *
Constant						0.464	7.58 ***
Regression diagnostics:							
	Observations (n)	173		124		172	
	Chi2	46.56		56.88		48.50	
	P-value	0.000		0.000		0.000	

Note: Asterisks denote coefficient significance at 0.10 (*), 0.05 (**), and 0.01 (***) levels.

Table 2: Determinants of cropping practices that reduce erosion: Random effects regression results, cropped zones of Ilave-Huenque basin, Puno, Peru, 1999.

Variable	Unit of measure	Fallow			Vertical Furrows		
		Coef.	z-stat.		Coef.	z-stat.	
Price of potato	Peru soles/kg #	-0.029	-0.29		-0.122	-0.51	
Unmet basic needs	Sum	0.027	1.42		-0.087	-1.91	*
Cropped area	hectares	0.012	0.89		0.016	0.49	
Pasture area	hectares	0.000	1.18		0.001	0.73	
Vehicles owned	Units	0.008	0.48		0.000	0.01	
Store/warehouse	Units	0.030	1.37		-0.027	-0.53	
Well equipment	Units	0.079	2.81	***	0.008	0.12	
Other ag. equipment	Units	0.001	0.09		-0.001	-0.04	
Home equipment	Units	0.007	1.04		-0.027	-1.65	*
Total SEVU's	Sheep value units	0.000	-0.42		0.000	0.49	
Family agric. labor available	Person-years	-0.015	-1.60		0.002	0.09	
Credit	Peru soles	0.000	-0.59		0.000	0.90	
Nonfarm income	Peru soles	.000007	-2.28	**	0.000	-1.31	
Distance to paved road	Minutes on foot	0.119	1.04		-0.097	-0.36	
Education of HH head	Years	-0.007	-0.83		0.004	0.22	
Adults with high school	Units	0.030	2.20	**	-0.032	-0.99	
Position of HH head	Binary	-0.004	-0.15		-0.053	-0.94	
Association memberships	Units	0.027	2.07	**	0.069	2.23	**
Aynoca area	hectares	0.001	2.65	***	0.001	0.80	
Families using communal pastures		-0.001	-1.18		-0.002	-1.12	
Suni A zone	Binary	0.188	3.85	***	0.055	0.48	
Suni B zone	Binary	0.364	5.42	***	-0.173	-1.10	
Footslope	Proportion of fields	-0.004	-0.06		0.265	1.79	*
Slope	Proportion of fields	-0.082	-1.13		0.028	0.16	
Sandy soil	Proportion of fields	0.025	0.63		0.061	0.67	
Fertilizer	Kg/ha	0.000	-0.97		0.000	-0.28	
Pesticides	Kg/ha	-0.001	-0.75		0.001	0.27	
Natural Resource project	Binary	0.161	2.34	**	0.161	0.99	
Constant		-0.227	-1.76		0.724	2.38	**
Regression diagnostics:							
	Nbr. of observations	178			179		
	Nbr. of groupings	8			8		
	Chi-square	314.1			57.7		
	P-value	0.000			0.001		
	rho	0.00			0.00		

Note: SEVU=sheep-equivalent value unit.

Note: Asterisks denote coefficient significance at 0.10 (*), 0.05 (**), and 0.01 (***) levels.

During 1998-99, the exchange rate of Peru’s nuevo sol was approximately US$1 = S/. 3.20.