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Determinants of farmers' indigenous soil and water conservation investments in semi-arid India

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Abstract

This paper investigates the determinants of farmers' indigenous soil and water conservation investments in the semi-arid tropics of India. A simple theoretical model is used to develop hypotheses about the determinants of investment under alternative factor market conditions, and these are tested using data on conservation investment from three villages. We find that conservation investment is significantly lower on leased land in two of the study villages and lower on plots that are subject to sales restrictions in one village, suggesting the potential for land market reforms to increase conservation investment. In one village, households with more adult males, more farm servants, and less land invest more in conservation, as predicted by the model of imperfect labor markets; and households with more debt and off-farm income invest more, consistent with the model of imperfect credit markets. Evidence that conservation investment is affected by factor market imperfections is weaker in the other villages, where investments are much larger, suggesting transaction costs as the source of the differences between villages. Other factors that have a significant effect on investment include the farmer's education and caste, characteristics of the plot (size, slope, irrigation status, and quality ranking) and the presence of existing land investments. The results suggest the importance of accounting for differences across communities and households in factor market and agroclimatic conditions in designing programs to promote investments in soil and water conservation.

Keywords: Soil and water conservation; Investment; Indigenous; India

1. Introduction

Soil erosion has received much attention in recent years, especially in developing countries. In India, large government programs have devoted substantial resources to promote soil conservation, but the results have been disappointing as adoption and maintenance of introduced conservation technologies has been limited (Kerr and Sanghi, 1992). Yet empirical evidence on the factors that determine farmers' investments in soil and water conservation (SWC) in India and other developing countries is still relatively limited.

Adoption of SWC practices may depend upon a wide variety of factors, many of which are specific to a particular village, household, or plot. Many of these,

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such as agroclimatic conditions and natural resource endowments, affect the costs, returns, and risks of SWC investments and practices. Labor, capital and land market distortions affect each farm household differently, depending on their endowments of these factors. As a result, different types of farmers may face different implicit costs and returns of investment. If we want to understand why some farmers invest and others do not, we need a clear understanding of the nature of factor markets. This is especially so in developing countries, where markets for factors often are poorly developed.

In this paper, we develop a model of farmers' investments in SWC and test it using data from three villages in India's semi-arid tropics. We focus on indigenous SWC practices, thus reflecting farmers' decisions unaffected by program incentives. We incorporate factor market imperfections explicitly into a theoretical model of the determinants of investment to show how they can cause the explicit costs and returns to conservation investments to vary among households. We build upon extensive empirical work already conducted on the nature of factor markets in the study villages to understand their implications for SWC investments. We find that differences in the nature of factor markets lead to substantial differences in the determinants of SWC investment across the three villages.

2. A theoretical model of conservation investments

In this section, we develop a simple investment model and derive the comparative statics of investment under four scenarios: (1) perfect credit and labor markets, (2) perfect credit but missing labor market, (3) perfect labor but missing credit market, and (4) no credit or labor markets. Imperfections in the land market are treated by considering land as either a perfectly tradable productive asset or as a non-tradable fixed asset.

These of course represent idealized cases, while the real world is more complex. Households may have access to a credit market, but credit may be rationed because of imperfect information (Stiglitz and Weiss, 1981) or enforcement considerations (Pender, 1996). Employment opportunities may also be constrained because of imperfect information and contract enforcement (Shapiro and Stiglitz, 1984). Land markets may exist but may be thin because of asymmetric information about land quality or credit constraints (Fafchamps and Pender, 1997). More generally, transactions costs may cause production factors to be 'non-tradable' for some range of implicit prices (de Janvry et al., 1991). However, the simple cases considered in this section can represent many such situations with only slight generalization.

Assume that a farmer lives for two periods. He is endowed with certain fixed assets (z), such as farming ability and the quality of the land he owns (if land is non-tradable). He also possesses three other types of assets, including savings (w_t), which earn a constant rate of return (r); the level of SWC investments the farmer has on his land (k_t), and other tradable productive assets (A_t), such as livestock (and land if land is tradable). Income in each period (y_t) is determined by the level of k_t, A_t, and z, and the amount of labor allocated to current production (h_t):

$$y_t = \pi_t(k_t, A_t, h_t, z), \qquad t = 1, 2$$

The production function π_t is assumed to be concave and all cross partial derivatives (π_{tkA}, π_{tkh}, π_{tkz}, π_{tAh}, π_{tAz}, π_{thz}) nonnegative.[2] The farmer has an endowment of labor time (L) that must be allocated between current production and SWC investment (I_t). The farmer may also hire or sell labor (l_t) at a constant wage rate (q) in the perfect labor markets case.

The farmer's objective is to maximize $u(c_1)+\beta u(c_2)$, where $u(\,)$ is a strictly concave function, and

$$c_1 = w_1 + \pi_1(k_1, A_1, L - I_1 + l_1, z) - ql_1 - A_2 - w_2$$
$$c_2 = (1 + r)w_2 + \pi_2(k_1 + I_1, A_2, L + l_2, z) - ql_2$$

The first order conditions for the perfect markets case are given by:

$$\frac{u(c_1)}{\beta u(c_2)} = \frac{\pi_{2k}}{\pi_{1h}} = \pi_{2A} = 1 + r$$
$$\pi_{1h} = \pi_{2h} = q$$

These are the standard results that the marginal rate of intertemporal substitution and the marginal returns to investment must equal $1+r$ if a perfect credit market

[2] We adopt the notation $\partial^2\pi_t/\partial k_t\partial A_t=\pi_{tkA}$, $\partial\pi_t/\partial k_t=\pi_{tk}$, etc.

Table 1
Comparative statics of conservation investment[a]

Effect of an increase in	Perfect factor markets	Missing labor market	Missing credit market	Missing credit and labor market
Labor endowment (L)	0	+	+ if $A(c_1)>A(c_2)$ 0 if $A(c_1)=A(c_2)$ − if $A(c_1)<A(c_2)$	+ if $A(c_1)\pi_{1h}\geq A(c_2)\pi_{2h}$ and $\pi_{2kh}/\pi_{1h}\geq\pi_{2Ah}$
Savings (w_1)	0	0	+	+
Initial level of conservation assets (k_1)	−	−	− if $A(c_1)\pi_{1k}\leq A(c_2)\pi_{2k}$ and $\pi_{2hA}=0$ and $\pi_{2kA}=0$	− if $A(c_1)\pi_{1k}\leq A(c_2)\pi_{2k}$ and $\pi_{2kA}=0$
Initial level of other productive assets (A_1)	0	− if $\pi_{1hA}>0$	+	?
Fixed assets (z)	+ if $\pi_{2kz}>0$, or $\pi_{2hz}>0$ and $\pi_{2kh}>0$, or $\pi_{2Az}>0$ and $\pi_{2kA}>0$ 0 if $\pi_{2kz}=\pi_{2Az}=\pi_{2hz}=0$	+ if $\pi_{2kz}/(1+r)$ $>\pi_{1hz}$ 0 if $\pi_{2kz}=\pi_{2Az}$ $=\pi_{1hz}=0$	?	?

[a]In the table, '+' means investment increases, '−' means decreases, '0' means no effect, and '?' means ambiguous effect. $A(c)$ is the coefficient of absolute risk aversion $(-u''(c)/u'(c))$. Subscripts of π_t indicate first and second order partial derivatives. For example, π_{1h} means $\partial\pi_1/\partial h_1$, and π_{2kz} means $\partial^2\pi_2/\partial k_2\partial z$. All of the conditions given in the table are sufficient, not necessary conditions.

exists, and the marginal return to labor must equal the wage rate if a perfect labor market exists. If the credit market is missing or credit is constrained, the final equation in the first set of equations no longer holds. If the labor market is missing or unused, the second set of equations no longer holds.

The comparative statics results for investment in the four scenarios are reported in Table 1.[3] In the perfect markets case, conservation investment is unaffected by the farmer's endowments of labor (L), savings (w_1), or other productive assets (A_1). Perfectly functioning labor and capital markets cause initial differences in these assets to be irrelevant for investment, since they do not affect the costs and benefits of investment. A higher initial level of conservation assets (k_1) reduces investment since the desired second period level of such capital is unaffected by the initial level. The effect of fixed assets (z) on investment depends upon whether they increase the marginal product of other inputs.

With a missing labor market but perfect credit market, the effects of initial savings and initial conservation assets are the same as the perfect markets case. Households with a larger labor endowment invest more in this case, because such households have a lower opportunity cost of labor in the first period. Households with a higher initial level of other productive assets will invest less in this case if those assets are complementary to labor in the first period, because this increases the opportunity cost of labor in the first period. A greater level of fixed assets will increase investment if the discounted effect of this on the marginal return to investment ($\pi_{2kz}/(1+r)$) is greater than the effect on the marginal return to labor in the first period (π_{1hz}). For example, if z is the slope of the land, an increase in z may be more complementary to conservation investment than to labor; thus, conservation investment would be greater on steeper land.

With a missing (or constrained) credit market but perfect labor market, greater initial savings or other productive assets cause greater investment, while the effect of the household's labor endowment depends on consumption smoothing motives, as reflected by the coefficient of absolute risk aversion ($A(c_t)=-u''(c_t)/u'(c_t)$). As in the perfect credit markets case, a higher initial level of conservation assets tends to reduce conservation investment, though this result also depends on $A(c_t)$, the marginal product of investment in each period, and the degree of complementarity of other assets with conservation assets. The effects of fixed assets on investment are ambiguous in this case. Note that the effects of credit constraints are not confined to cash investments, since we have not assumed that conservation investments are purchased with cash. Effectively, credit constraints affect investment by increasing the farmer's discount rate (Pender, 1996). Thus, it is not correct to argue, as is sometimes asserted, that credit market phenomena are irrelevant to conservation investments that involve only labor inputs.

If both credit and labor markets are missing, some of the results are similar to those in the preceding two cases. As in the no credit market case, a higher level of initial savings induces more investment, and the same conditions are sufficient to cause investment to fall with a greater initial stock of conservation assets. As in the no labor market case, a higher initial endowment of labor tends to increase investment, though this result is not certain. Sufficient conditions for this result are that the increase in labor has a greater effect on first period marginal utility than second period marginal utility and that labor is more complementary to conservation investments than other productive investments. The initial stocks of other productive assets and fixed assets have ambiguous effects in this case.

This simple model helps to explain why coefficients of similar variables may have different signs in different studies, depending on the nature of factor markets. It is thus very important to identify the market environment in which conservation decisions are made.

3. The study sample and study villages

The data for this study were collected in Kanzara and Shirapur, two villages in Maharashtra state, and Aurepalle in Andhra Pradesh. The sample included households that participated in the village level studies program of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) between 1975

[3]These comparative statics results are derived by Pender and Kerr (1996).

Table 2
Characteristics of the study villages

Characteristic	Aurepalle	Shirapur	Kanzara
Dominant soil type[a]	Red alfisols	Vertisols	Vertic inceptisols
Soil depth[b]			
<50 cm	47% of plots	16% of plots	75% of plots
>90 cm	0% of plots	63% of plots	0% of plots
Topography[b]			
<2% slope	53% of plots	66% of plots	92% of plots
>4% slope	5% of plots	7% of plots	0% of plots
Rainfall[a]	630 mm/yr, 31% coefficient of variation (c.v.)	630 mm/yr, 35% c.v.	890 mm/yr, 22% c.v.
Erosion[b]			
Severe gully/rill	16% of plots	29% of plots	3% of plots
Mild gully/rill	35% of plots	18% of plots	20% of plots
Conservation structures[c]	Small bunds	Large bunds terraces	Drainage
Irrigation[c]	22% of gross cropped area	20% of gross cropped area	17% of gross cropped area
Land market[a,d]	Secure tenure Some land sales restrictions	Secure tenure Active lease market	Secure tenure Active lease market
Labor market[a,d]	Active daily market Longer term contracts common	Active daily market Rural employment scheme	Active daily market Longer term contracts Seasonal migration
Credit market[a,d]	Active informal market Limited formal market	Very limited formal and informal market	Most developed formal market Very limited informal market

[a]Source: Walker and Ryan (1990).
[b]Source: Soil survey.
[c]Source: Household/plot survey.
[d]Source: Authors' observations, other studies.

and 1985. Walker and Ryan (1990) discuss the sampling methodology, provide detailed descriptions of these villages and synthesize numerous studies of their economies. Pender and Kerr (1996) provide a more detailed discussion of the conditions in the villages that may affect conservation investments.

A questionnaire was conducted in 1991/1992 to collect information about respondent households, their perceptions of erosion,[4] and initial stock of SWC investments. In addition, a professional soil surveyor collected information on the types and extent of erosion on a sample of plots in each of the villages. In 1994/1995, a follow-up questionnaire determined the extent of SWC investment on each respondent's plots during the three-year study period. There were 120 farmers and 280 plots total in the sample.

Agroclimatic and socioeconomic characteristics of the study villages are presented in Table 2. Agroclimatic conditions have important implications for erosion problems and measures to correct them. For example, Kanzara has mild slopes, but high rainfall and shallow soils bring the risk of erosion and accompanying yield loss. At the same time, the high moisture retention capacity of black soils makes them susceptible to waterlogging. As a result, Kanzara farmers' primary soil management problem is to dispose of excess water without losing soil to sheet erosion, rills or small gullies.[5] Kanzara farmers often line their fields with grass strips to help dispose of surface runoff without losing soil. They also place stone drains at the lowest corner of the field to facilitate safe runoff.

In Shirapur, most dryland plots are cultivated in the post-rainy season with receding moisture stored in the

[4]Kerr, J.M., Pender, J.L., 1997. Farmers' perceptions of soil erosion and its consequences in India's semi-arid tropics. EPTD, IFPRI, Washington, unpublished draft.

[5]Rills are small microchannels that form in the soil when runoff water concentrates in surface depressions. They gradually expand as the water washes away the soil. Gullies are large rills; the distinction between a rill and a gully is treated differently in different discussions. Our definition of gullies includes channels as small as one meter in diameter, since this is enough to significantly reduce cultivated area on many of the small plots in the survey.

deep, clay-laden black soils. The moisture-holding black soils enable farmers to plant at the end of the rainy season, when they know whether or not there is sufficient water in the soil to raise a crop (Walker and Ryan, 1990). One implication of this cropping strategy is that soils are bare during the rainy season, making them highly prone to erosion.

Shirapur's deep soils and sloped fields lead to relatively large investments in land leveling that demonstrate the inseparability of soil conservation and moisture conservation in the semi-arid tropics. Many plots in Shirapur have large earthen and stone bunds on the lower end, trapping soil that erodes from the upper side of the plot. This creates natural terracing that distributes soil moisture evenly. In some cases, farmers actively encourage soil movement within the plot, while in others they wait for it to move at its own pace. The soil is deep enough that its movement within the plot does not leave the upper end too shallow to be productive. Other soil physical properties of vertisols also favor this soil management system.

In Aurepalle's red soils, most irrigated fields are carefully terraced and bunded to facilitate water management for paddy cultivation. This contrasts with most dryland plots, which have small if any field bunds. Although about half of Aurepalle's plots have more than 2% slope, farmers rarely practice the system of encouraging soil movement within the field found in Shirapur. This is because on Aurepalle's shallower soils, soil movement within a plot reduces yields on the upper end. Also, unlike in black soils, the fine fertile silt in red soils tends to escape through stone barriers.

Soil characteristics that cause management problems to vary among the three villages also have important implications for the timing of SWC investments. In particular, black soils are relatively soft and easy to work with when they are dry, but sticky and difficult to manage when wet. Because of these characteristics, most investments in Shirapur and Kanzara take place in the dry season, when demand for labor is also lowest. Red soils, on the other hand, become extremely hard during the dry season; working with them to shape the land is only feasible during the rainy or post-rainy season, when crops are in the ground and labor is relatively scarce. This means that Aurepalle's red soil farmers cannot build earthen bunds during the dry season, except immediately after harvest. Details of the timing of investments are given by Pender and Kerr (1996).

All three villages are primarily oriented toward crop and livestock production, but there are some differences in their economies. Kanzara, with the most reliable climate, is the most strongly dependent on agriculture, while Aurepalle and Shirapur have more diverse economies. In Aurepalle, production of sheep and toddy (palm wine) are two very important non-crop activities, while in Shirapur there is more dependence on government employment schemes. Kanzara is the only village among the three with substantial seasonal labor migration by the landless and marginal farmers.

Land markets are fairly active in all the villages. Land sales are more common in Aurepalle and Kanzara than Shirapur, which has a very active lease market. Land sales are officially prohibited for about 15% of the land in Aurepalle, which was distributed under land reforms.[6] This restriction can reduce the incentive to invest, because investment costs are irreversible in the sense that they cannot be recouped by selling the land. It may also reduce farmers' access to credit because of the limited collateral value of this land.[6]

Lease markets in Shirapur tend to equalize the ratio of bullocks to land holdings (Jodha, 1981). Many landowners in Shirapur are poor farmers who do not own bullocks and thus cannot cultivate the land. This likely also limits these landowners' ability to invest in conservation structures. As a result of tenancy laws that confer increased rights to tenants as the duration of tenancy increases, almost all leases in the study villages are for less than two years (Jodha, 1981). This undermines the incentive for tenants to invest in long term conservation measures, since they cannot expect to recoup the returns. Discussion with villagers suggests that lease contracts never require conservation investment by the tenant.

There are active labor markets in the villages, including both daily laborers and long term regular farm servants (RFS), though RFS are uncommon in Shirapur. RFS contracts last for several months, and

[6] Pender, J.L., Kerr, J.M., 1997. The effects of non-transferable land rights: evidence from south India. IFPRI, Environment and Production Technology Division, unpublished working paper.

sometimes (mainly in Kanzara) specify particular types of work to be performed. While under contract, RFS are not permitted to join the daily labor market, implying that the opportunity cost of their time may fall below that of daily workers. As a result, households with RFS may have lower costs during the slack season of labor-intensive investments such as soil conservation. Many Shirapur households participate throughout the year in government employment programs. They have no tradition of seasonal labor migration. However, being situated just off a major highway, many households in Shirapur have members who work outside of the village, for example, as truck drivers. In Kanzara, government employment schemes exist but are less accessible. Many households in Kanzara have a tradition of seasonal migration to nearby areas where employment programs are active.

Formal credit sources are most important in Kanzara and least in Shirapur. Moneylenders are the most important source of credit in Aurepalle, and are virtually nonexistent in the other two villages. Studies have found evidence of credit constraints affecting poorer households in Aurepalle (Pender, 1996),[7,8] Shirapur, and Kanzara (Fafchamps and Pender, 1997). Credit from institutional lenders is available for land improvement investments related to irrigation, but not for soil conservation. Special credit arrangements tied to soil conservation improvement programs have tried to make credit available to farmers, but these efforts have had limited effectiveness because farmers rejected the specific conservation practices eligible for credit (Kerr and Sanghi, 1992).

4. Econometric analysis of conservation investment

We used Tobit regressions to analyze the determinants of conservation investment. The dependent variable is the total value of investment (including the value of labor time and cash expenses) on each plot between 1991 and 1994.

The explanatory variables included in the analysis are based upon the theory discussed above and the literature on conservation. The category of fixed assets (z) includes the agronomic characteristics of each plot, including the steepness of the plot (a dummy variable=1 if plot slope is more than 3%), the soil type (based on an indigenous classification documented by Dvorak (1988)), the plot size, the farmer's subjective ranking of the quality of each plot relative to his other plots (1 for highest quality), and the level of irrigation on the plot (the total area irrigated in the rainy and post-rainy seasons divided by the size of the plot). Household level variables that also loosely fit into the category of fixed assets include the caste and human capital endowment (measured by age and education of the household head), and off-farm income. We did not measure off-farm income directly, but instead measured the percentage of household income from farming.

The area of land farmed by the household may be a fixed asset (z) or an endogenous tradable productive asset (A), depending on how well the land market functions. We used the initial area of land owned in 1991 to avoid any endogeneity bias. The 1991 value of bullocks owned was also included as a tradable productive asset.

Dummy variables were used to represent the initial stock of four types of conservation assets (k_1): major conservation investments such as leveling and terracing; smaller bunds; uncompleted structures or structures in poor condition; and investments to control water runoff, such as grass strips and drains.

The household's labor endowment (L) was measured by the number of adult males and adult females in the household, and the number of RFS employed by the household in 1991.

We measured savings (w_1) as the sum of the value of gold, silver, cash savings, and financial savings owned by the household in 1991. We also included the household's debt in 1991 as a separate explanatory variable, since greater debt may indicate greater access to credit if credit is constrained.

Another factor potentially affecting SWC investment is the farmer's perception of erosion (Ervin and Ervin, 1982). We include dummy variables for whether or not the farmer perceived mild gully or rill

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[7]Chaudhuri, S., Paxson, C., 1994. Consumption smoothing and income seasonality in rural India. Department of Economics, Princeton University, unpublished paper.

[8]Morduch, J., 1990. Risk, production and savings: theory and evidence from Indian households. Department of Economics, Harvard University, unpublished paper.

erosion, severe gully erosion, or sheet erosion problems on the plot in 1991/1992.

We also included the tenure status of the plot. Since the tenure status of some plots changed during the period of observation, we use dummy variables to account for whether the plot was leased in the entire period, leased out the entire period, leased in for part of the period or leased out for part of the period. For Aurepalle, we also included a dummy variable for plots subject to sales restrictions.

The means and standard deviations of the variables used in the analysis are reported by Pender and Kerr (1996). The average size of investments and the likelihood of investment are largest in Shirapur, followed by Kanzara and then Aurepalle. Farmers use mostly their own labor inputs for conservation investments in Aurepalle, but purchase most of the inputs for such investments in Kanzara and Shirapur. This is not too surprising since conservation investments are much smaller in Aurepalle than in the other two villages. Among farmers that do invest, the average investment is worth over 3000 Rs in Shirapur, about 600 Rs in Kanzara and about 100 Rs in Aurepalle. These investments include mainly small bunds in Aurepalle; leveling, large bunds and stone drains in Shirapur; and bunds, drains and waterways in Kanzara.

Conservation structures were common in all villages in 1991. More than half of these were incomplete structures, either unfinished or in need of repair. Most plots in Aurepalle also had been leveled or had gully checks, and most in both Aurepalle and Kanzara had runoff control structures such as grass strips and stone drains.

Few farmers report severe gully erosion problems in Aurepalle and Kanzara, while Shirapur farmers report severe erosion on nearly 40% of the plots. Mild gully erosion is commonly reported in both Aurepalle and Shirapur, less so in Kanzara. The low incidence of gully erosion in Kanzara is probably due in part to the fact that land is relatively flat there, with none of the Kanzara plots having greater than 3 percent slope. Sheet erosion is most commonly reported in Aurepalle and Kanzara. Water stagnation is a problem only in Kanzara, and even there it affects very few plots.

Farmers have the most savings and bullocks and the least debt in Kanzara, and the fewest bullocks and most debt in Aurepalle. Kanzara's farmers tend to be younger, more educated, more specialized in agriculture, and to farm smaller areas than in the other two villages. More farmers are low caste in Aurepalle than in the other villages (over half of the farmers are low caste in the Aurepalle sample). In Shirapur, very few of the sample farmers are low caste and few households employ regular farm servants. Plots tend to be somewhat larger in Kanzara than in the other two villages. Irrigation is most prevalent in Aurepalle followed by Shirapur and Kanzara, though average irrigation intensity is not much different among the villages. Land leases are most common in Shirapur and least in Aurepalle.

5. Results and discussion

The regression results are reported in Table 3.[9] These results suggest that imperfections in land markets cause lower conservation investment on leased land in two of the study villages (Aurepalle and Shirapur). The magnitude of these effects is much larger in Shirapur than in Aurepalle because conservation investments tend to be much larger in Shirapur. The negative effect of land tenancy on investment is consistent with the short term nature of leases in these villages. It is also consistent with the findings of Clay et al. (1995) for Rwanda and studies of conservation investment in the United States (Featherstone and Goodwin, 1993; Norris and Batie, 1987).

In Aurepalle, the negative effect of sales restrictions is large relative to the average size of investment (roughly equal to the average investment when it occurs). This finding, together with the large effects of tenancy noted above, suggest that reforms of land tenure policies could have a substantial impact on soil and water conservation investment in two of the three study villages.

There is some evidence that credit market imperfections are affecting investment in each of the villages, though the evidence is not completely conclusive. In Aurepalle, households with more debt invest more (suggesting they may have more access to

[9]Coefficients are reported in Table 3 only for variables that are significant at the 10% level in at least one regression. Not reported are the intercept and the coefficients of age, value of bullocks, mild rill erosion, leased in part of the period, leased out entire period, soil types, and presence of small bunds. In Table 3, NE means the coefficient was not estimable.

Table 3
Tobit regressions of soil and water conservation investment (standard errors in parentheses)

Variable	Aurepalle	Kanzara	Shirapur
Savings (Rs)	−0.0030 (0.0023)	0.0475* (0.0282)	0.0138 (0.1395)
Debt (Rs)	0.00739*** (0.00127)	−0.0486 (0.0834)	0.1581 (0.1935)
Education (years)	35.5*** (10.2)	−60.3 (88.9)	767** (325)
% of income from farming	−2.44*** (0.85)	24.82 (20.22)	−57.4 (49.8)
Low caste	143*** (54.7)	−1378** (545)	9708** (4918)
Area farmed (acres)	−27.4*** (5.03)	−189.4*** (71.6)	209** (92.4)
Adult male labor days per month	3.87*** (1.02)	−3.79 (9.28)	−49.2 (38.2)
Adult female labor days per month	−3.40*** (1.28)	6.09 (7.04)	46.0 (34.5)
No. of regular farm servants	36.7* (21.8)	−61.5 (301.0)	−5035 (5173)
Severe erosion	462*** (91.7)	101 (550)	4902 (5920)
Sheet erosion	−214*** (66.6)	887 (451)	−3978 (6721)
Steep plot	−60.0 (44.7)	NE	3876** (1864)
Plot rank	39.8 (25.7)	−39 (258)	−1754* (926)
Plot size (acres)	48.0*** (11.9)	34.0 (66.4)	12.1 (173.0)
Share irrigated (rainy and post-rainy seasons)	151*** (40.5)	1442*** (531)	3148 (2359)
Leased in	−715 (674,540)	−2874 (11,300,000)	−8611*** (3324)
Leased out part of period	−303*** (76.7)	−70 (560)	−1341 (1999)
Subject to sales restrictions	−106** (44.2)	NE	NE
Runoff control structures	−134** (58.3)	565 (520)	3625** (1769)
Leveling, terraces, or large bunds	145*** (42.3)	−1416** (595)	−4678* (2768)
Incomplete structures	99.5* (53.9)	836 (558)	6672*** (2325)
No. of positive/total obs.	32/106	19/57	44/117

* means significant at 10% level, ** significant at 5% level, and *** means significant at 1% level.

credit and, hence, are less constrained), though the effect is small. Households with a lower share of income from agriculture (and by implication more off-farm income) invest more in Aurepalle, also consistent with the presence of financial constraints and with the findings of Clay et al. and Norris and Batie. The regression results for Aurepalle imply that a household earning all of its income from farming will invest about 100 Rs less in conservation than a comparable household that earns only half of its income from agriculture.

In Kanzara, households with more savings invest more, though the effect is also relatively small. In Shirapur, savings, debt, and off-farm income do not have a significant effect on investment, but larger farms invest more per plot. This could be because larger farms are less credit constrained, though other explanations are plausible. For example, there may be economies of scale associated with the relatively large conservation investments that farmers undertake in Shirapur.

The positive impact of education on conservation investment in Aurepalle and Shirapur also may be a reflection of more educated households being less financially constrained, though other explanations are also plausible (such as a more general relationship between education and land stewardship or innovation). These effects are relatively large, with an additional year of education associated with an additional 35 Rs of investment in Aurepalle (about one-third of average investment when it occurs) and an additional 770 Rs of investment in Shirapur (almost one-fourth of average investment when it occurs). A positive effect of education on conservation investment was also found by Ervin and Ervin (1982). If the positive effects of education found in two of our study villages are more broadly representative, education may have important spinoff benefits for soil and water conservation in India. This issue deserves further study.

Labor market imperfections are clearly evident in Aurepalle, with significantly more conservation investment occurring in households having more adult males, fewer adult females (an unexpected result), low caste households, and on smaller farms. All of these effects are large in magnitude relative to the average size of investment. In Shirapur, investment by low caste households is substantially greater than investment by other households. By contrast, low caste households invest substantially less in Kanzara. As in Aurepalle, larger farms invest less per plot in conservation than smaller farms in Kanzara (consistent with labor or management constraints), while larger farms invest more per plot in Shirapur, as mentioned above.

The conflicting effects of caste status on investment across villages is likely due to differences in the village economies, the occupations of low caste households, and the timing of investments. In Kanzara, low caste people invest less because they often migrate during the dry season, when most investments are made. In Shirapur, on the other hand, there is no tradition of migrating, and low caste people are discriminated against in the government employment scheme that operates in the village. As a result, they may invest more because the opportunity cost of their time is lower. Aurepalle has a much larger proportion of low caste people, many of whom are relatively well-off. About half of Aurepalle's households are low caste shepherds or toddy (palm wine) tappers. Both of these groups have become prosperous in recent years due to rising prices of meat and toddy, and both have invested in the purchase and improvement of agricultural land, due to the paucity of alternate investment opportunities. Moreover, the peak toddy tapping season is in the dry season, when soil conservation investment is lowest. Thus, low caste toddy tappers have more free time to invest in conservation investments at precisely the time when such investments are the most feasible.

The differential effects of farm size on conservation investment across the three villages may be due to competing effects of labor and capital constraints. In Aurepalle and Kanzara, credit markets are more developed than in Shirapur (informal market in the case of Aurepalle, formal market in the case of Kanzara) and investments are smaller in size, possibly causing the transactions cost of hiring labor to be prohibitive. In Shirapur, conservation investments are so large that the transactions cost of hiring workers is probably an inconsequential component of the total costs, while capital constraints may be a serious impediment. As a result, the dominant effect of larger farm size in Aurepalle and Kanzara may be to increase the opportunity cost of labor and thus, reduce investment per plot, while the dominant effect in Shirapur may be to relax the credit constraint (or allow realization of scale economies) and thus increase investment per plot.

The negative effect of female labor supply on investment in Aurepalle was not expected. One possible explanation for this result is that women participate in the hired labor market to a greater extent than men in Aurepalle, and their wages are less variable over the year than men's wages (Ryan and Ghodake, 1984). Households with more women may have less seasonal variation in their opportunity costs of labor, and their labor opportunity cost of investing in conservation structures may thus be higher. Further research is needed to test whether this or alternative hypotheses explain the observed relationship.

In general, the effects of factor market imperfections are most evident for conservation investments in Aurepalle and least in Shirapur, with Kanzara an intermediate case. A major reason why these markets appear to function best in Shirapur and worst in Aurepalle may be transactions costs. Conservation investments are smallest in Aurepalle and largest in Shirapur. To the extent that use of factor markets involves fixed transaction costs, these costs may have a much more inhibiting effect on small investments than on large ones. Thus, for many small investments, farmers' behavior may be as if these markets didn't exist.

If transactions costs are responsible for many of the differences in determinants of conservation investment among the study villages, there may be no 'market failure' as such that can be readily remedied by government or other intervention (ignoring the issue of externalities, which appear to be of limited importance in the study villages), unless such intervention can reduce these costs. General policy actions that promote the development of credit or labor markets may eventually reduce these costs through the force of competition in the longer term. Some targeted policies might address particular imbalances in the short run (e.g.., credit programs targeted to poorer households), though these risk contributing to inefficiencies and inequities if they are not effectively managed.

Soil conditions such as in Aurepalle further restrict policy options for encouraging investments. As discussed above, red soils are difficult to work with when dry, so conservation investments in such soils take place mainly during the rainy and post-rainy seasons, when soils are moist but labor's opportunity cost is high. Because many of these investments are small, the work is done by family laborers in their spare time. Daily labor contracts are normally for 6 to 8 h at a time, so hired labor is associated with indivisibilities that can significantly raise the cost of small jobs. Family laborers, on the other hand, can do the work gradually by devoting an hour or two at the end of each day. Not surprisingly, Aurepalle farmers in the survey indicated almost uniformly that they prefer to undertake conservation investments gradually, over several weeks or months, rather than all at once.

Our results show that other things besides market imperfections are also important determinants of conservation investment. Many of the factors that affect conservation investment in the study villages are related to subjective profitability or risk (e.g., perception of erosion, slope, soil type, plot rank, irrigation, plot size, initial presence of conservation structures). Plots with greater perceived erosion receive more conservation investment in Aurepalle, probably because expected returns to such investment are higher. Steeper plots receive more investment in Shirapur, where steeper plots are more common and the relatively deep soil makes terracing feasible. Higher quality plots (as measured by a lower plot rank) receive more investment in Shirapur (significant at 10% level), probably because of higher expected returns. Irrigated plots receive more investment in all the villages for the same reason (although the result for Shirapur was not statistically significant). Larger plots receive more investment in Aurepalle, probably also due to greater returns. Plots where runoff control structures were in place in 1991 received more subsequent investment in Shirapur but less in Aurepalle, perhaps because of different relationships of complementarity or substitutability between the prior and subsequent investments.[10] The initial presence of terraces or large bunds was associated with greater subsequent investment in Aurepalle but less in Kanzara and Shirapur. This is likely because the subsequent investments were mainly small complementary investments in bunds and runoff control in Aurepalle, whereas similar types of large investments were being made in Kanzara and Shirapur. Finally, the initial presence of incomplete structures was associated with greater subsequent investment in all villages (though not statistically significant in Kanzara), probably because the rate of return to investment is higher where part of the investment costs had already been paid.

Some of the explanatory variables that were expected to affect conservation investment did not have statistically significant effects. This may be because the effects of these variables are truly inconsequential; however, it could also be due to a relatively small sample size (especially in the case of Kanzara) or multicollinearity, resulting in low statistical power. Using the test proposed by Belsley et al. (1980), multicollinearity was found to be a problem mainly for the Kanzara regression, significantly affecting the ability to disentangle the effects of savings, age, education, share of income from farming, caste, farm size, labor supply variables, bullock ownership, erosion, soil type, and prior conservation investments. Thus, we do not have a high degree of confidence in accepting the null hypothesis for many of the insignificant coefficients in the Kanzara regression. In the other two regressions, most variables were slightly affected by multicollinearity, particularly those used to test for the implications of factor market imperfections.[11]

Other potential problems with the regression results include possible non-independence of the error terms for multiple observations within households, and heteroscedasticity. We tested for non-independence by estimating random effects probit models, and found that the within household correlation of the error term was small (0.15) and statistically insignificant.[12] We also tested for heteroscedasticity by assuming the error variance was a linear function of plot size. The regression results indicate the presence of hetero-

[10] Since the types of conservation investments differ across the villages, the relationships of complementarity or substitutability among different investments likely also differ, and lead to different predictions as emphasized in Table 1. This underscores the complexity and location specific nature of the determinants of conservation investments.

[11] More detailed discussion of the results of the tests for multicollinearity and other concerns are reported by Pender and Kerr (1996). The discussion here is limited by space considerations.

[12] We were unable to obtain estimates using a Tobit model with random effects in LIMDEP.

scedasticity in Aurepalle and Shirapur. The qualitative results in the corrected regressions are very similar, but have lower statistical significance. In the case of Aurepalle, almost all of the significant coefficients remain significant, while all of the coefficients in the Shirapur regression are insignificant (at the 5% level) after accounting for heteroscedasticity. This reduces our confidence in the findings for Shirapur.

6. Conclusions

If policy makers, non-governmental organizations or external donors seek to promote conservation investments, it is useful for them to keep in mind several key issues.

- Local agroclimatic and soil conditions vary greatly by location and have a strong impact on the kinds of erosion problems that arise, the types of investments that farmers use to control them, and the time of year during which investments are made.
- Factor market conditions also vary by location and can affect the private profitability of different types of investments. Conservation investments would be promoted by reforming land tenure laws to encourage long term leasing and eliminating land sales restrictions. Improving credit markets could help promote conservation in some cases. On the other hand, existing labor market distortions may actually encourage conservation investments by some farmers (e.g., discrimination against low caste workers) by reducing the opportunity cost of their labor. This is not to argue in favor of such distortions; rather, it argues for accounting for them in considering program interventions.
- Irrigation is an important complement to soil conservation, so irrigated plots may need less external stimulus than dryland plots to encourage conservation investments. Development and adaptation of conservation measures profitable in rainfed areas is an urgent need.
- Since agroclimatic and factor market conditions vary by location, efforts to promote soil conservation must be designed according to local conditions. There is no 'one-size-fits-all' solution to soil erosion problems. Standardized project designs that work in one location are likely to encounter unexpected constraints elsewhere. This is true both within and across villages.

As mentioned above, public sector projects have not succeeded in promoting widespread adoption of soil and water conservation practices in India. Traditionally, these projects have pursued a uniform approach covering a single state or even many states. Given the findings of this paper about the location-specificity of the determinants of investment, the difficulties that these programs have faced is not surprising.

By contrast, several non-government organizations (NGOs) have focused on participatory project planning and implementation approaches in which farmers and project officials work together to design soil conservation efforts. These programs are able to address location-specific opportunities and constraints associated with specific agroclimatic and socioeconomic conditions. Such projects have yielded many reported cases of sustained efforts to conserve soil (Hinchcliffe et al., 1995), but so far they cover only a small area. In the last few years, government projects have been redesigned to follow the example of the successful NGO programs. While this is a positive development, changes in the guidelines are translating into change on the ground only gradually.[13]

Even among the projects that are considered success stories in promoting soil conservation investments, farmers have invested with the assistance of substantial subsidies that cannot be extended to all dryland farmers in the Indian semi-arid tropics. Clearly, research is needed to develop more cost-effective soil and water conservation practices that can be widely adopted without subsidies. Conservation investments are more likely to be made (other things equal) if they are less costly to farmers, both in terms of monetary costs as well as labor and animal power requirements. This is true regardless of the nature of factor markets; however, if credit or labor constraints are binding or land markets are poorly functioning, such costs may prohibit even highly profitable investments from occurring.

[13] This is being clearly revealed in a review of watershed management projects in India currently being conducted by IFPRI and the Indian National Center for Agricultural Economics and Policy.

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