Watershed Management and Farmer Conservation Investments in the Semi-Arid Tropics of India: Analysis of Determinants of Resource Use Decisions and Land Productivity Benefits

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Introduction

As in many developing regions, soil erosion and land degradation are major concerns for agricultural development in India. This is especially the case in the arid and semi-arid areas where water scarcity, frequent droughts, soil degradation and other biotic and abiotic constraints lower agricultural productivity and the resilience of the system. An estimated 18% of the cultivable area is categorized as degraded and a major portion (about 40%) of it is in the arid and semi-arid tropics (SAT) (Reddy 2003). The rainfed regions account for two-thirds of the cultivable land and house a large share of the poor, food-insecure and vulnerable population of the country. Moreover, as growth of productivity in the more favored Green Revolution areas is showing signs of slowing down or stagnation (Pingali and Rosegrant 2001), further growth in agricultural production and food security is likely to depend on improving it in the semi-arid rainfed areas. There is also some evidence indicating that marginal returns to investments would be substantially higher in these regions when compared to the irrigated regions, where the potential for productivity growth has been exploited through Green Revolution technologies (Fan and Hazell 2000). In recognition of the social, economic and environmental benefits, India has one of the largest micro-watershed development programs in the world. Over $500 million is being spent annually through various projects supported by the government, NGOs and bilateral funds (Farrington et al. 1999). The watershed development program was further strengthened in the 1990s by introducing new guidelines, additional funds and the creation of new institutional structures to make it more participatory and sustainable. Despite the progress in terms of coverage and effectiveness, the program has been rather slow given the magnitude of the problem; only about 10% of the land requiring treatment has been covered to date (Rao 2000).

Being a catchment-based technology covering large areas, micro-watershed development requires active community participation for its implementation and sustenance. The government heavily subsidizes the watershed development work in India. This approach may have its own problems in terms of budgetary implications and creating long-term incentives for farmers and communities to maintain the investments after the interventions cease. However, given the breadth of the area that needs to be covered, it is important to examine the incentive systems that encourage small farmers to undertake their own investments in land and water management. It is also important to examine the complementarity between public and private investments in land and water management. Incentives for private investments in soil and water conservation (SWC) are often low due to the long impact lags, and the impact itself is seldom impressive or dramatic (Kerr 2002; Reddy et al. 2001). What are the economic benefits small farmers derive from their own SWC investments and from public investments in watershed management? What is the relationship between these public and private efforts on farmers' fields? How do livelihood strategies, markets, policies and local institutional structures influence investments in private resource conservation in the process of community watershed management? Despite its policy relevance, empirical research on the underlying (socioeconomic and biophysical) factors that influence farmer resource management, incentives and the factors that contribute to differential impacts of watershed development programs is rather limited.

This paper attempts to examine the economic incentives to small farmers to undertake private SWC investments in the context of watershed development and the determinants of land productivity benefits. Some of the important issues in this regard include: a) on-site land productivity gains from private conservation activities and community watershed development, and b) factors influencing farmers' decisions, productivity benefits and the level of SWC investments either independently or as complementary activities to community-based public watershed development programs. These investments could be in the form of adoption of SWC measures, technologies, and productivity-enhancing inputs. These relationships are analyzed and tracked using plot-level data collected over two seasons by ICRISAT from 120 smallholder farmers in six villages in the Indian SAT. The paper first reviews conceptual issues and the role of markets and institutions in determining farmer investment strategies. Building on these important concepts, it develops a theoretical framework for the empirical model, followed by a discussion of the results and findings and their policy implications.

Market imperfections and farmer investment choices

Benefits from investments in SWC can be viewed from two angles, private and social. Private benefits include on-site productivity and sustainability gains, while social benefits also account for the effect of positive and negative externalities. SWC measures attract private investments, provided the expected net private benefits from such investments are positive. In the absence of positive net private benefits, there is no incentive or rationale for private entrepreneurs to invest in SWC though there could be substantial social benefits. In a risky environment, these expected benefits could also be in terms of mitigating risks and increasing the stability of incomes. In situations where resource investments provide low net private benefits but high net social benefits, markets could fail to provide incentives to private resource users. This may lead to private under-investment and socially excessive resource degradation. This may occur due to low on-site benefits, high costs of exclusion and high external benefits. If the social gains are high, public investment becomes necessary to protect the social interests. This seems to be the rationale for widespread public investment in watershed management (including SWC investments on private lands) in India. Similarly, market imperfections result in sub-optimal land use and investment patterns (Shiferaw and Holden 1998, 2000).

In the context of smallholder agriculture in developing countries, the functioning of markets, especially factor markets, plays an important role in influencing a household’s resource conservation decision (Pender and Kerr 1998; Holden et al. 2001). Depending on the prevailing market conditions in the local economy, different factors of production may have differential impacts on a household’s resource conservation decision. For example, household labor endowments and savings will have a positive impact on production and conservation investments when labor and credit markets are missing or imperfect (Pender and Kerr 1998). Similarly, diversification into nonstaple commodities depends on the functioning of food markets. When such markets are fairly competitive, farmers will be able to switch to other profitable options relatively easily. Returns to labor and capital investment on farm and off farm will in turn influence the incentives for improving land and water productivity.

Individual decisions on investments in SWC are often determined by site-specific biophysical conditions in a given policy environment. Micro-level biophysical heterogeneity, the household’s perceived benefits of conservation and the expected losses due to degradation influence these decisions. It was observed that in a given policy context, farmers’ perceived erosion damage provides conservation incentives on shallower soils while soil mining may be economically rational on deep soils (Walker 1982). This may partly be due to differences in the crops grown on different soils and their market prices. Similarly, higher commodity prices may encourage conservation practices on steep slopes but discourage them on shallower slopes with better soils (Pagiola 1996).

In the presence of credit market imperfections and insecure property rights that may lead to divergence between private and social rates of time preference, the inter-temporal flow of net benefit from SWC is also important for investment decisions. Often, short-run benefits from soil conservation are negligible and hence work as a disincentive for private investments for poor, credit-constrained farmers. In the context of negative short-run benefits, Shiferaw and Holden (2000) found that incentive policies like fertilizer subsidies linked to conservation were ineffective unless the social rate of discount is less than 10%. On the other hand, when the short-run benefits are zero, a mix of cross-compliance policies was found promising for stimulation of private SWC investments. This shows how poor rural land users may heavily discount long-term conservation benefits in order to meet short-term subsistence needs like food security. Therefore, when trade-offs between conservation and productivity benefits prevail, credit-constrained farm households are unlikely to change their land use practices without appropriate economic incentives (Barbier 1990).

Interestingly, policies that focus on short-term productivity gains may also encourage soil degradation rather than conservation. These include fertilizer and irrigation subsidies that may discourage soil conservation and encourage depletion of groundwater. When economic benefits are low, farmers either fail to adopt the recommended practices or abandon them once the subsidized projects are phased out (Lutz et al. 1994; Reddy et al. 2001). Lutz et al. (1994) observed that subsidies fail to be economically efficient and effective unless there are positive off-site benefits or substantial market distortions in prices that discourage private investments. On the other hand, access to irrigation when tied to conservation could stimulate considerable investment in conservation even in the absence of subsidies. Water harvesting attracts significant private investments, as the benefit flows are quick, significant and more certain. Moreover, water is also a risk-reducing and productivity-enhancing resource. Higher expected short-term gains and risk-reduction benefits address the key bottlenecks to private investment in SWC (Baidu-Forson 1999; Shiferaw and Holden 1998). This has important implications for policy. When expected private benefits are high, public subsidies may not be required to stimulate private investments, and public programs should help enhance the return to private investments and address the problem of social organization and externalities.

Another important influence of the structure of local markets is the role of assets and liquidity (savings) on the incentives to invest in conservation practices. When credit and labor markets are missing or imperfect, households endowed with more working members and higher savings (liquidity), *ceteris paribus*, will be able to make higher investments. This result has also been articulated as one of the important factors for the highly debated interaction between poverty and the environment. It indicates how in the absence of supportive policies and pervasive credit and labor market imperfections, poor rural households could be caught in a poverty-degradation nexus (Shiferaw and Holden 1998; Scherr 2000; Pender et al. 2002).

Theoretical framework

Based on this conceptual review, a theoretical model was developed to test the hypotheses and set the stage for the empirical analysis. The context of farm household decision-making under imperfect markets was used, whereby production and investment decisions are affected by household and farm characteristics. When credit, labor, land and other factor markets are imperfect, production and investment decisions will not be separable from consumption and labor demand decisions of the farm household (Singh et al. 1986; Sadoulet and de Janvry 1995). When labor and land markets are imperfect or missing, the household’s decision price for allocation of these factors will be endogenous, ie, the village prices (if observed) will differ from the subjective shadow prices. In this case, the nonseparability of production and investment decisions from consumption choices will imply that the endowment of labor, land, water for irrigation and other fixed farm and household characteristics will determine the level of production and sustainability-enhancing investments. The empirical model can be used to test these hypotheses.

Suppose that crop production is determined by:

$$q = q(A, I, S; L, X) \tag{1}$$

where q is total output, A is the area of the farm, I is the level of investment in soil and water conservation, S is the inherent quality of the soil, L is the level of labor input and X is the level of other productive inputs (seeds, fertilizer, pesticides, etc). If the land area is fixed (no land market), while other markets function well, the returns to land and family labor in farm production will be given as:

$$p = pq(\overline{A}, I, S; L, X) - wl - eX \tag{2}$$

where À is the returns to land, p is the net price of output q, w is the village price of hired labor (l), and e is a vector of prices of other purchased inputs X =(x_1, x_2… x_n). In this case, a missing market for land does not create inefficiency because the marginal returns to land will not be a function of any endogenous prices. Labor and other purchased inputs will be allocated according to the standard profit maximizing conditions; ie, $p\partial q/\partial L = w$ and $p\partial q/\partial x_i = e_i$. In this case, production decisions will not be affected by household characteristics and consumption choices (consumption decisions will however depend on the level of farm income). As Holden et al. (2001) demonstrate, no distortions should occur in resource allocation and farm profits will be a function of the fixed asset land, its characteristics and the exogenous input and output prices:

$$p = p\left(p, w, e_i, \overline{A}, I, S\right) \tag{3}$$

Now suppose that in addition to land, the labor market is missing or imperfect. Let us assume that the farm household maximizes utility subject to income, labor supply and land constraint:

$$Max\ u = u(c_q, c_m, c_l, h) \tag{4}$$

subject to

$$\sum_{ze(q,m)} p_z c_z = \sum_j A_j p_j q(I_j, S_j; L_j, X_j) - \sum_j \sum_i A_j e_i x_{ij} \tag{5}$$

$$\sum_j A_j L_j + c_l = \overline{L} \tag{6}$$

$$\sum_j A_j = \overline{A} \tag{7}$$

where C_q is consumption of own crop produce, C_m is purchased consumer goods, C_l is leisure time, $q(.)$ is the yield function for the production of crop j, and h represents fixed household characteristics. A_j and L_j are land area and labor used in the production of j. Equations (6) and (7) define the labor and land constraints in farm production. The Lagrangian from (4) to (7) could be given as:

$$\begin{aligned} Max\ u = u(c_q, c_m, c_l, h) + l\left(\sum_j A_j p_j q(I_j, S_j; L_j, X_j) - \sum_j \sum_i A_j e_i x_{ij} - \sum_{ze(q,m)} p_z c_z\right) \\ + m\left(\overline{L} - \sum_j A_j L_j - c_l\right) + q\left(\overline{A} - \sum_j A_j\right) \end{aligned} \tag{8}$$

The following first order conditions (FOCs) could be derived from (8)[1]:

C: $u_c = l p_c^*$ where [$p_c^* = \overline{p}_c$ for $c_z = \{c_q, c_m\}$ and $p_c^* = m/l$ for $c_z = \{c_l\}$] (9)

A: $\left(p_j q - \sum_i e_i x_{ij}\right) - (m/l) L_j = q/l$ (10)

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[1] We use the notation q_F = ¶q(.)/¶F for the partial derivatives of input factors $Fe(A,L,X)$.

L: $\left(p_j q_L\right) = (m/l) = p_l^* = w$ (11)

X: $\left(p_j q_x\right) = e_i$ (12)

Adding the FOCs for l, m, and q, the system (9) to (12) could be solved to provide the utility maximizing allocation of land, labor and other inputs in production and the demand system $c^* = c\left(p^*, w^*, y^*, h\right)$, where $y^* = \sum p_z c_z$ is the full income of the household. Equation (9) specifies the utility maximizing condition that marginal utilities per unit price of the commodity (U_c/P_c) equal the marginal utility of income (l). The endogenous price of family labor (p_l^*) is given by the value m/l. Equation (10) (J = 1, 2,... n) establishes that land will be allocated until the returns to land are equated across crops. The optimal use of land requires that the returns to land (net of all labor and other variable costs) will be equal to the perceived scarcity value of land (q/l). It also shows how market imperfections affect productivity of land. Since the market for land and labor is assumed to be missing or highly imperfect, the return to land is a function of the endogenous shadow value of labor (m/l). This indicates that productivity of land, in addition to crop type and fixed biophysical farm characteristics, will be influenced by household attributes that determine the shadow value of family labor resources.

If the land constraint is binding, the shadow value of land (q/l) will be positive. Whereas if land is abundant and a land market is absent, the shadow value of land will be zero and some of the land will be underutilized. This indicates the importance of farm size, labor, traction and credit in the efficient use of the fixed land resource when a land market is missing. Similarly, if the labor constraint is non-binding, the shadow price of labor (m/l) will be zero and some of the family labor will be underemployed on-farm.

As equation (11) indicates, family labor will be allocated until its marginal returns equal its shadow value. This implies that the marginal value product of labor may differ across households depending on the subjective wage for family labor. This will in turn determine the opportunity cost of leisure; the higher the shadow wage, the lower the demand for leisure time and conversely. The allocation of other tradable input factors is not influenced by labor market imperfections. Equation (12) shows that the standard conditions (marginal value product of the input equals its unit price) for input use hold in the use of these factors of production. When there are credit market imperfections and the credit constraint is binding, the decision price of credit-constrained inputs may differ from their market price. In this case, asset endowments and liquidity will be important in determining production and investment decisions (Sadoulet and de Janvry 1995).

These results indicate that if factor markets function well, land productivity and input demands for production on plot k will be a function of the crop grown, farm fixed characteristics and input and output prices, such that:

$$p_k = p\left(c_j, p_j, w_h, e_i, I_k, S_k\right) \quad (13.1)$$

$$F_k = f\left(c_j, p_j, w_h, e_i, I_k, S_k\right) \text{ for } Fe(A, L, X) \quad (13.2)$$

If the market for land, labor, bullocks, credit, water for irrigation and other input factors is missing, the level of use of such inputs cannot exceed household endowments of such resources. If the product market is missing, the consumption of the product or use of the input factor cannot exceed what is produced or owned. When markets are missing or imperfect, production and investment choices will be a function of endogenous shadow prices of the output and/or input factors. In this situation, crop productivity, input demand and conservation investments will be a function of the endogenous prices (p^* and e^*), exogenous prices $\left(\overline{p}, \overline{e}\right)$ and household (h) and farm fixed characteristics (I and S).

However, the endogenous prices are determined by the exogenous prices and fixed factors such that land productivity and input demands on plot k will be:

$$p_k = p\ \left(c_j, \overline{p}_j, \overline{e}_i, I_k, S_k, h\right) \tag{14.1}$$

$$F_k = f\left(c_j, \overline{p}_j, \overline{e}_i, I_k, S_k, h\right) \text{ for } Fe(A, L, X) \tag{14.2}$$

However, in a crosssection of households in a given location, the exogenous prices will not be expected to vary significantly across households ie, all households face the same prices. Hence, under market imperfections for some factors, land productivity and input demands at the plot level will be determined by other non-price exogenous factors:

$$p_k = p\ \left(c_j, I_k, S_k, h\right) \tag{15.1}$$

$$F_k = F\left(c_j, I_k, S_k, h\right) \text{ for } Fe(A, L, X) \tag{15.2}$$

In the next section, farm investments are endogenized and the empirical model and methods used in estimating crop productivity and input demand equations (15.1 and 15.2), along with private investments in land and water management based on plot level input-output data are developed.

Data and socioeconomic conditions

The study is based on household and plot-level data collected by ICRISAT during the year 2002 covering six villages in Ranga Reddy district of Andhra Pradesh, India. In one of the villages (Kothapally), a participatory community watershed management program was initiated in collaboration with the Drought Prone Area Programme (DPAP) of the Government of India during the year 1999. Along with ICRISAT, a consortium of NGOs and national research institutes is testing and developing technological, policy and institutional options for integrated watershed management in the village. A package of integrated genetic and natural resource management practices is being evaluated on farmers' fields (including IPM and new varieties) through participatory approaches (Wani et al. 2002). Before the commencement of a detailed socioeconomic survey, a census of all households within the watershed and five adjoining villages lying outside the catchment area was carried out. Analysis of this data provided useful information about the general profile of the rural economy and institutions, which formed the basis for random selection of 60 households from each group (within and outside the catchment) for a detailed survey. The purpose of this study is not to evaluate the on-going project, but to understand the effect of the structure of markets and assess the emerging pattern of economic incentives for farmer investments in natural resource management within and outside the project area. An interesting research question is how local institutional structures (mainly market imperfections) and public investments in watershed management (observed in the project village) influence private incentives for improved land and water management and how this pattern differs across villages.

Along with other standard socioeconomic data, detailed plot- and crop-wise input and output data were collected just after harvest from the operational holdings of all the sample households for the 2001 production year. The associated biophysical data on major plots was collected using locally accepted soil classification systems. Trained enumerators lived in the villages during the course of the survey. Some important features of the sample villages are presented in Appendix 1. Due to their geographical proximity, the sample villages are considered to be generally similar in biophysical conditions, including rainfall. Access to markets may differ slightly as some may be closer to the main road leading to the nearest town (Shankarpally). The major difference is in terms of access to new production and resource management technology. Households within the catchment benefit from new varieties and land and water management options, which are being evaluated in close participation with the community. Households outside the project area do not have such access yet. As is typical for many rural villages in India, the social structure is characterized by a multi-caste and heterogeneous social system. Crop production is the main livelihood activity followed by off farm income and livestock. Landlessness is not a major problem in these villages because of a recent land reform. In terms of percentage of area under irrigation and general development, Kothapally seems to be slightly ahead of some of the villages. Nearly 20% of the area which was under irrigation before the advent of the project in 1998, increased to about 35% in 2002. Whereas the watershed interventions have increased the recharging of groundwater, there is evidence indicating that farmers in Kothapally are increasingly shifting towards paddy and other irrigated crops (eg, vegetables), a practice which could not be sustained in water-scarce dryland areas. This is an important policy failure that poses a threat to the viability of the watershed development program. Proper policy and institutional instruments that enhance collective community effort in the utilization and management of groundwater are needed.

However, cultivation and SWC practices are followed across the villages although the watershed program is active in only one of the villages. Farmers are familiar with indigenous SWC practices though water conservation methods like check dams are not well known. The majority of the households use farmyard manure (FYM), fertilizers and pesticides. Fertilizer use intensity ranges between 125 and 250 kg/ha, though the average use is 125 kg/ha. It has been observed that input use and yield rates have increased over the last two decades. However, farmers indicate that the incidence of soil degradation has also increased over the period. On the other hand, shortage of water for irrigation is increasingly being felt while the drinking water situation has improved in all the villages. In most of the villages, the major cropping period is during the main rainy (*kharif*) season, but some crops (eg, chickpea, paddy, flowers and some vegetables) are also grown during the postrainy (*rabi*) season. Crop production is highly diversified and farmers practice intercropping (eg, sorghum-pigeonpea and maize-pigeonpea). With increasing access to markets and irrigation, the cropping pattern is gradually shifting in favor of commercial crops like cotton, vegetables and flowers. However, paddy is the highly remunerative low-risk crop most preferred by small farmers in irrigated conditions.

Black fertile soils (vertisols) dominate in all the sample villages. The watershed management activities in Kothapally have increased the availability of groundwater (Wani et al. 2002). In the other villages, groundwater resources are under severe stress due to frequent droughts. Most of the wells, including borewells, have dried up. In the event of drought, migration and nonfarm employment become the main livelihood activities for many of the households.

Empirical methods

Investigating farmer incentives to invest in land and water management technologies requires analysis of net returns from such investments across plots and crop types. As was given in equation (1), land productivity will depend on a host of exogenous (predetermined) and endogenous variables. The latter group includes all variable inputs used on a plot. The choice of crops and the level of use of different inputs in a given plot is an endogenous decision by the household, which will be determined based on exogenous variables like access to markets and credit, soil types and household assets. This means that estimating land productivity using these endogenous variables would cause a simultaneity bias. Hence, the standard assumption of the independence of the regressors from the disturbance term will not hold. The simultaneity problem makes the ordinary least squares (OLS) estimates biased and inconsistent. A better approach is to use simultaneous equation methods, which would provide consistent and asymptotically efficient estimates. The two-stage least squares (2SLS) and three-stage least squares (3SLS) are commonly used in such situations. However, 3SLS is likely to be more efficient than 2SLS since a system of simultaneous equations is estimated accounting for cross-equation error correlations and endogeneity of independent variables (Green 1997). The empirical method to estimate a system of six structural equations based on 3SLS is developed below. Using the expanded structural forms of (15.1) and (15.2), we could define:

$$p_k = p\left(c_j, L_k, X_{fk}, X_{bk}, I_k, S_k, z^q, h^q, R_1\right) \tag{16.1}$$

$$L_k = L\left(c_j, K, S_k, z^q, h^q, R_2\right) \tag{16.2}$$

$$X_{fk} = X_f\left(c_j, K, S_k, z^q, h^q, R_3\right) \tag{16.3}$$

$$X_{bk} = X_b\left(c_j, K, S_k, z^q, h^q, R_4\right) \tag{16.4}$$

$$I_k = I\left(K, S_k, U_k, V_k, z^q, h^q, R_5\right) \tag{16.5}$$

$$V_k = V\left(I_k, S_k, z^q, h^q, R_6\right) \tag{16.6}$$

where the system of equations, respectively, represents: net returns to owned land and family labor; expenditure on labor (hired and family); expenditure on fertilizer, seeds and pesticides; expenditure on other capital inputs (bullocks, tractors, etc); cumulative investments in SWC practices; and market value of the land as perceived by the owner. All the variables were computed in terms of values per hectare. The structural equation system was estimated using 3SLS in the SAS package. The productivity of land is modeled as a function of crop grown (c_j), labor use (L_k), variable inputs (X_{fk}), capital inputs (X_{bk}), SWC investments (I_k), soil and plot characteristics (S_k), household assets and farm characteristics (z^q), household characteristics and social capital (h^q) and other exogenous variables (R). Among the other variables, the level of use of inputs depends on the amount of credit received (K) during the year. Investments in SWC practices may also require access to credit. However, there is no institutional credit for such investments. Nevertheless, the effect of cumulative credit obtained during the last three years was tested. Further, SWC investments depend on land quality characteristics (S_k), farm characteristics (z^q), exogenous public investments (U_k), and the market value of the land as perceived by the owner (V_k). The latter depends on the level of private and public SWC investments on the plot as well as land quality and farm characteristics. The exogenous variables in the set (R_1 to R_6) capture a set of specific pre-determined variables with a special influence on a given equation. Some of these exogenous variables may however also affect other equations in the system. For example, cropping season and cropping system (sole or intercropping) are important variables that affect input use as well as the productivity of land. The explanatory variables included in the analyses were selected based on the theoretical framework developed earlier. A summary of the important variables used in the econometric model is given in Table 1.

In addition, two probit equations were estimated to examine the determinants of cropping and SWC investment decisions on a given plot. The probit equation for the cropping choice was used to identify the determinants for leaving some land fallow during the year. Similarly, there were no SWC investments on several cultivated plots and the probit model was used to identify factors that influence farmer investment decisions on a given plot. In order to correct for the censoring of the dependent variable and the selection bias, the Inverse Mills Ratio (IMR) from the investment choice model was included in the SWC investment equation of the simultaneous system.

Table 1. Descriptive statistics for important variables used in the analysis.

Description of variables	Mean	Std deviation	Min	Max
Household assets (Rs 1000/ha)				
Total asset value	57.34	43.42	8.67	304.43
Tractor assets (tractors, threshers, sprayers)	0.60	3.02	0.00	23.67
Bullock assets (bullock carts and implements)	0.88	1.53	0.00	13.17
Motor assets (electric and diesel motors)	3.33	14.64	0.00	148.26
Other assets	52.53	36.18	6.92	160.52
Livestock wealth	6.91	9.44	0.00	69.19
Total nonfarm income	13.93	17.07	0.00	86.73
Bullocks owned by the household (in numbers)	0.90	1.03	0.00	4.00
Household characteristics				
Male workforce in numbers per hectare (household)	1.56	1.76	0.00	12.36
Female workforce in numbers per hectare (household)	1.59	1.74	0.04	9.88
Male workforce in numbers (household)	1.94	1.30	0.00	6.25
Female workforce in numbers (household)	1.69	0.88	0.25	4.50
Number of consumer units in the household (standardized)	4.81	2.21	1.21	14.34
Age of the head of the households (in years)	44.73	11.17	25.00	76.00
Sex of the head of the household (1 = Male, 2 = Female)	1.05	0.21	1.00	2.00
Education of the head of the household (in years)	2.92	4.30	0.00	18.00
Education of the household (for all members) in years	22.55	21.12	0.00	156.00
Family size (in number of members)	5.90	2.68	2.00	18.00
Plot and farm characteristics				
Farm size in hectares (owned area)	2.22	2.46	0.10	16.19
Total operated area irrigated (ha)	0.65	0.83	0.00	2.83
Plot size (ha)	0.48	0.33	0.04	2.02
Value of the plot (Rs 1000/ha)	139.68	58.91	49.42	345.95
Area irrigated of plot (ha)	0.11	0.21	0.00	1.21
Irrigable area of plot (ha)	0.11	0.21	0.00	1.21
Land tenure (dummy; 1 = owned)	0.98	0.14	0.00	1.00
Irrigation plot (dummy)	0.29	0.45	0.00	1.00
Plot located within the watershed	0.49	0.50	0.00	1.00
Soil dummy (local soil classification); 1 = *regadi*; 0 = Others	0.72	0.45	0.0	1.00
Soil depth (d) on the plot in ordinal categories; 1 = shallow ($d<0.5$ m); 2 = medium ($0.5<d \leq 1$ m); 3 = deep ($1<d \leq 1.5$ m); 4 = very deep ($d>1.5$ m)	1.98	0.81	1.00	4.00
Fertility of soil (ordinal variable) on the plot; 0 = very poor to 3 = very good	1.94	0.62	1.00	3.00
Risk of soil erosion (ordinal variable) on the plot; 0 = no risk to 3 = high risk	0.92	0.87	0.00	3.00
Distance from the nearest market (km)	11.03	3.90	5.00	16.00
Distance of the plot from home (km)	1.02	0.70	0.10	3.00
Distance of the plot from check dam (km)	5.34	4.62	0.00	10.00

Continued

Table 1. *Continued.*

Description of variables	Mean	Std deviation	Min	Max
Distance of the plot from well (km)	0.91	0.93	0.00	10.00
Reported production stress on plot (1 = yes)	0.15	0.35	0.00	1.00
Plot-level input use (Rs 1000/ha)				
Expenditure on labor (male and female)	3.42	3.60	0.13	33.61
Expenditure on fertilizer, FYM, seed and pesticides	3.54	3.69	0.03	27.83
Expenditure on variable capital inputs (bullocks, tractors, etc)	1.24	1.27	0.00	12.36
Male labor used (days/ha)	38.20	45.22	0	395.00
Female labor used (days/ha)	87.77	111.38	1.08	1457.00
Access to credit (Rs 1000/ha)				
Credit for 2 years	5.34	11.38	0.00	88.96
Credit for 1 year	0.93	8.69	0.00	88.96
Plot-level returns (Rs 1000/ha)				
Production value of the crop (grain and by-product)	13.58	14.67	0.00	112.02
Net returns to owned land and family labor when Rs 1.5/hr is charged for water for irrigation	7.43	11.15	–19.12	95.53
Plot-level SWC investments (Rs 1000/ha)				
Private investments	0.65	1.61	0.00	20.11
Public investment	0.70	1.55	0.00	11.86
Crop patterns and crop choice				
Cropping system: 1 = Sole cropping; 0 = intercropping	0.64	0.48	0.00	1.00
Crop variety: 1 = Improved, 0 = Local	0.64	0.48	0.00	1.00
Vegetable crop (dummy)	0.17	0.37	0.00	1.00
Cotton crop (dummy)	0.06	0.24	0.00	1.00
Dryland cereal crop (dummy)	0.18	0.38	0.00	1.00
Legume crop (dummy)	0.28	0.45	0.00	1.00
Paddy and sugarcane (dummy)	0.06	0.23	0.00	1.00
Maize and wheat (dummy)	0.11	0.31	0.00	1.00
Oil seeds and spices (dummy)	0.07	0.26	0.00	1.00
Fallow land (dummy)	0.10	0.31	0.00	1.00
Previous legume crop (dummy)	0.32	0.47	0.00	1.00
Season dummy: 1 = *kharif*, 0 = *rabi*	0.84	0.37	0.00	1.00
Social capital indicators				
Years of participation	1.39	1.76	0.00	5.00
Member of local association	0.09	0.29	0.00	1.00
Backward Caste	0.53	0.50	0.00	1.00
Scheduled Caste	0.17	0.38	0.00	1.00
Minorities (Muslims)	0.08	0.27	0.00	1.00

Results and discussion

The cropping decision

The cropping decision determines the farmer's choice on whether to crop or to leave the plot idle during a given production period[2]. Land fallowing is a traditional system used to restore and maintain soil fertility. However, the decision to leave land idle may also be influenced by many other factors. In the vertisol areas, difficult working conditions compel fallowing during the rainy season. In an inter-temporal perspective, land taken out of production is proportional to the level of rainfall (Reddy 1991). Low rainfall years result in extensive fallowing of lands. In a crosssectional context analyzed here, land may be left idle because of constraints related to labor, water for irrigation, credit, migration, or due to its low productivity. Results of the probit model are presented in Table 2.

Table 2. Probit model estimates for farmers' cropping decisions.

Variables	Estimated Coefficient	Asymptotic Standard Error	T-Ratio
Male workforce	0.138	0.896	0.153
Female workforce	0.717	1.095	0.654
Square of male workforce	–0.001	0.335	–0.402
Square of female workforce	–0.262	0.382	–0.687
Off-farm per capita income	–0.034	0.066	–0.518
Off-farm per capita income squared	0.000	0.002	0.204
Total SWC investments Rs 1000/acre	–0.119	0.341	–0.350
Total SWC investments Rs 1000/acre squared	–0.043	0.082	–0.524
Cumulative credit last 3 years per acre	0.023	0.027	0.854
Cumulative credit last 3 years per acre squared	0.000	0.000	–0.470
Previous crop (dummy; legumes)	1.602	0.482	3.323***
Farm size per capita	0.395	0.250	1.576
Number of bullocks owned	0.160	0.136	1.183
Value of tractor assets per acre	0.182	0.161	1.129
Soil type (dummy; vertisols)	0.609	0.278	2.189**
Irrigation (dummy)	8.611	23.567	0.365
Years in fallow (last 20 years)	–1.148	0.161	–7.116***
Soil fertility ranking (ordinal ascending levels)	0.417	0.239	1.7461*
Distance of the plot from home (km)	–0.335	0.160	–2.090**
Age of the household head	–0.010	0.010	–0.963
Years of education of the household head	–0.048	0.035	–1.396
Backward Caste	0.094	0.480	0.195
Scheduled Caste	0.378	0.601	0.629
Minorities	–0.265	0.560	–0.473
Constant term	0.309	1.035	0.299
Log of likelihood function	–185.09		
Percentage of right predictions	95		
Sample size	Dep. variable at one = 511, at zero = 57		

Note: *, ** and *** indicate levels of significance at less than 10%, 5% and 1% respectively.

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[2] In a strict sense, the cropping decision is determined during each cropping season. Availability of water for irrigation is a major determinant of whether a given plot will be cropped in the postrainy season (*rabi*). In some high rainfall areas, heavy soils are typically fallowed during the rains (*kharif*) and cultivated only in the postrainy season. The analysis of the cropping decision here is based on plots fallowed during the entire year.

Several variables were included in the model, including access to irrigation, soil types and their fertility, history of cropping and fallowing, ownership of bullocks and tractors, male and female workforce, distance from home, access to credit, off farm income and household education. The results indicate that the most important determinants of the cropping decisions were related to soil type, soil fertility, previous crop, history of fallowing and distance from home. Consistent with the traditional system of crop rotation, farmers are less likely to fallow plots where legumes were grown the previous year. In order to exploit the improved soil conditions from symbiotic nitrogen fixation, these plots will have a high probability of being cropped. Often farmers sow nitrogen-fixing legumes before sowing high input extractive crops like cotton and chillies. However, farmers are very likely to keep idle those plots which have not been cultivated for a long time. Based on analysis of comparative advantages of different plots for alternative crops and livestock production enterprises, farmers allocate some plots for grazing. Such plots that may have low fertility and which have not been cultivated for some time are most likely to remain fallow. Fertile plots and those characterized with better soils (vertisols) have a high probability of being cropped at least for one season in a given year. After controlling for many variables, it seems that plots more distant from the homestead are likely to remain idle. This could be due to supervision problems and high transaction cost. The cropping decision did not differ across the social groups in the community. Interestingly, these results show that none of the household characteristics (eg, family labor, skills, etc.) had any significant effect on the cropping decision. This indicates better functioning of labor markets in the area.

The soil and water conservation decision

The data shows that farmers have made some soil and water conservation investments on 48% of the plots (n = 568 plots). The incentive to undertake such investments is likely to be influenced by the biophysical conditions of the plot and the structure of markets, which jointly determine the economic returns from such investments. We included several variables in the probit regression model, including plot characteristics, household assets, access to credit, household characteristics and social capital. The results are presented in Table 3. The most important determinants of farmer investment decisions are related to soil quality variables, access to credit, labor force, scarcity of land, off farm income, distance from home, caste background and social capital. Soil quality variables seem to have a positive impact on conservation investment decisions, indicating that farmers are more interested in maintaining current fertility levels rather than in rehabilitating degraded plots. However, the likelihood of investing in soils perceived to have low risk of degradation (like the vertisols) is low. Availability of credit and tractor assets per acre is also associated with positive investment decisions. Households with a higher male workforce are more likely to invest in SWC. This indicates that male workers are better able to make field level assessments, select required conservation methods and initiate the process of SWC. The increase in female workforce however seems to reduce the probability of undertaking such investments. The squared values of these two variables turned out to be significant, indicating a non-linear relationship. Jointly, these results indicate some kind of imperfect labor market for resource conservation investments. This activity seems to be more dependent on family labor than on the cropping decision. In addition, with an increase in farm size, the incentive to invest in SWC in a given plot seems to decline. Controlling for quality of land, scarcity of land as reflected in low land-to-person ratios encourages the conservation decision. A less intuitive result is the effect of distance from home; the probability of farmer conservation investments seems to increase with distance from home. A similar result is found for the level of conservation investments. However, nearby plots may still receive more fertility-enhancing investments like farmyard manure

Table 3. Probit model estimates for farmers' SWC investment decisions.

Variables	Estimated Coefficient	Asymptotic Standard Error	T-Ratio
Male workforce	0.138	0.896	0.153
Public SWC investments Rs1000/acre	0.070	0.069	1.016
Years in fallow (last 20 years)	–0.071	0.071	–0.997
Ordered fertility of the soil	0.177	0.115	1.539
Soil type (dummy; vertisols)	–0.653	0.176	–3.703***
Plot size (acre)	–0.057	0.065	–0.878
Irrigable area of the plot (acre)	–0.169	0.148	–1.147
Soil depth (Ordinal variable)	0.188	0.102	1.850*
Land tenure (1= Owned)	0.386	0.222	1.744*
Plot located in the watershed (dummy; 1 = yes)	0.267	0.159	1.680*
Credit used during 2002	0.012	0.006	2.043**
Male workforce	0.476	0.198	2.403**
Female workforce	–0.562	0.361	–1.557
Square of male workforce	–0.096	0.035	–2.756***
Square of female workforce	0.205	0.083	2.464**
Farm size per capita (acre)	–0.045	0.013	–3.573***
Tractor assets per acre	0.071	0.042	1.688*
Bullock assets per acre	–0.094	0.120	–0.781
Distance of the plot from home (km)	0.206	0.074	2.777***
Distance of the plot from well (km)	–0.007	0.071	–0.986
Social capital (membership to various local associations and networks)	0.597	0.244	2.448**
Age of the household head	0.003	0.007	0.389
Years of education of household head	0.036	0.019	1.853*
Off-farm income (Rs 1000/year)	–0.008	0.003	–2.413**
Households belonging to Backward Castes	–1.665	0.284	–5.857***
Households belonging to Scheduled Castes	–1.361	0.332	–4.094***
Households belonging to Minorities	–1.683	0.362	–4.656***
Constant term	0.292	0.628	0.465
Log of likelihood function	–393.28		
Percentage of right predictions	71		
Sample size	Dep. variable at one = 273, at zero = 295		

Note: *, ** and *** indicate levels of significance at less than 10%, 5% and 1% respectively.

and fertilizers. Another interesting finding is the effect of off-farm income on conservation decisions. Although the effect of nonfarm orientation on resource-improving investments is indeterminate on theoretical grounds, there is empirical evidence of a degree of substitution in the allocation of labor on and off-farm labor (agricultural wages and nonagricultural employment). As off-farm income becomes an important means of livelihood, the incentive to invest in sustainability seems to decline significantly. This is consistent with findings in other countries (eg, Shiferaw and Holden 1998, in Ethiopia). This indicates that as household dependence on agriculture decreases, policies should explore options on how to improve/maintain land productivity.

Land productivity effects

It was hypothesized that the economic productivity of land (returns to family labor and land per ha) would be influenced by soil quality, the type of crop grown and its genotype, crop rotations, cropping season, access to irrigation, intensity of input use, access to credit and off farm orientation of the household. In order to explore any differential impacts of the watershed project, a dummy variable for the plots located in the watershed village was included. Table 4 presents the results estimated using 3SLS and OLS. Partly due to pest and drought stress (on 14% of plots) limiting crop yields, the net returns were negative on 13% of the plots. Therefore, a semi-log formulation was used where the dependent variable is linear while all the continuous variables (adjusted per ha) are in logarithmic forms. This reduces specification errors, especially multicollinearity problems arising from the use of

Table 4. Determinants of land productivity (net returns to family labor and land) in cropping.

Variables	3SLS			OLS	
(Dep. variable: Net returns) (Rs 1000/ha)	Parameter estimate	Elasticity at means[a]	P-Value	Parameter estimate	P-Value
Intercept	12.24		0.007	10.21	0.013
Ln (expenditure on labor per ha)	5.17	0.70	0.004	0.44	0.571
Ln (expenditure on fertilizer, seeds and pesticide per ha)	–6.88	–0.94	<.0001	0.95	0.105
Ln (other capital expenditure per ha)	1.87	0.25	0.004	0.20	0.381
Ln (private SWC investment per ha)	–0.15	–0.02	0.116	–0.02	0.748
Ln (off farm income per ha)	–0.16	–0.02	0.011	–0.08	0.125
Ln (cumulative 2 yrs credit per ha)	–0.11	–0.01	0.058	–0.11	0.054
Soil type (dummy; 1 = vertisols)	0.45	0.06	0.733	0.19	0.869
Soil depth	2.02	0.54	0.003	1.90	0.003
Soil fertility level	–1.28	–0.33	0.122	–0.69	0.359
Season (1 = *kharif*)	1.74	0.23	0.204	2.82	0.024
Land tenure (1 = owned)	–3.21	–0.43	0.318	–2.85	0.333
Crop variety (1 = improved)	3.27	0.44	0.002	2.46	0.013
Incidence of stress (1 = Yes)	–8.95	–1.20	<.0001	–8.60	<.0001
Vegetable (dummy)	–7.35	–0.99	0.001	–9.88	<.0001
Cotton (dummy)	–3.14	–0.42	0.292	–9.32	0.0002
Dryland cereal (dummy)	–17.21	–2.32	<.0001	–12.25	<.0001
Pulse (dummy)	–9.91	–1.33	<.0001	–9.63	<.0001
Maize and wheat (dummy)	–12.17	–1.64	<.0001	–11.41	<.0001
Oils and spices (dummy)	–11.34	–1.53	<.0001	–10.36	<.0001
Paddy and sugarcane (dummy)	–14.75	–1.98	<.0001	–13.24	<.0001
Previous legume crop (dummy)	1.01	0.14	0.290	0.83	0.374
Log (farm size ha – plot size ha)	–0.03	–0.004	0.829	0.15	0.254
Irrigation (dummy)	7.13	0.96	<.0001	5.81	<.0001
Watershed (dummy)	1.72	0.23	0.154	0.98	0.361
Ln (Years of education of household head)	–0.001	0.000	0.988	–0.004	0.933
Model fitness		System Weighted R^2 = 0.83 Degrees of freedom = 2909		Adj. R^2 = 0.34, F = 11.60 Degrees of freedom = 508	

[a] Elasticities at the means for the logarithmic variables are computed as $\hat{b}_i / \bar{Y}$, where $\hat{b}_i$ is the estimated parameter, and $\bar{Y}$ is the mean of the dependent variable.

non-linear polynomial forms for some of the endogenous input factors. The system weighted R^2 of 0.83 – this approximate indicator for the fit of the joint model estimated by stacking all the models together and performing a single regression indicates a good fit. The explanatory power of the OLS model was not high (adjusted $R^2 = 0.32$), but the model was highly significant.

As anticipated, the 3SLS results show that returns to land and family labor are determined by a number of factors including intensity of input use, crop type and its genotype, access to irrigation and quality of soil. The signs for the estimated 3SLS and OLS parameters are similar for many of the variables. None of the inputs except fertilizer use had significant effect on net returns in the OLS estimates. The 2SLS results (not shown) are very consistent with the 3SLS results. As expected, the m-statistic of Hausman's specification test (Hausman 1978; Hausman and Taylor 1982) confirmed that 3SLS estimates are more preferred than OLS estimates ($P<0.001$). Therefore, while the OLS estimates are presented for interested readers, the 3SLS results are mainly used in the discussions.

Net returns were positively associated with the use of labor and capital inputs. For example, a 10% increase in expenditure on labor use and capital inputs would increase returns by about 7% and 2.5%, respectively. Controlling for land quality and type of crops grown, the expenditure on fertilizer and pesticides was however negatively related to net returns per ha. This is a counter-intuitive result. However, this may be because farmers are diversifying into new high-value crops (eg, flowers and oilseeds) where expenditure on fertilizer and pesticides is much lower than for other dryland crops (eg, cotton and vegetables). This was confirmed from the associated composite demand function (fertilizer, pesticides and seeds) jointly estimated with net returns and other endogenous variables which showed that the expenditure on these inputs was 202% higher for cotton and 67% higher for vegetables than for growing flowers and oilseeds. There is also a possibility that smallholder farmers may be using fertilizer and pesticides for reducing yield risk than for increasing profitability. A negative association was also found between off farm income (earnings from agricultural wages and off farm sources) and net returns to cropping. Increase in average off-farm income per capita or per ha of cultivated land is associated with lower labor input per ha, fertilizer use, and investment in SWC, which in turn resulted in lower economic productivity of land. Viewed in relation to conservation investment decisions, this interesting relationship requires policy interventions to limit undesirable tradeoffs on land productivity and sustainability as households diversify their incomes into non-agricultural activities.

Among the soil quality indicators (soil type, fertility and depth), soil depth was the most important. It was measured as an ordinal variable (1 = shallow to 4 = very deep). A 10% increase in the mean soil depth will increase the economic productivity of land by 5%. Farmer investments in SWC, other than irrigation investments, seem to reduce short-term returns from crop production. Farmers seem to have realized the long-term sustainability benefits in terms of reducing the risk of soil degradation even at the cost of reduced returns to cropping in the short-term. When it comes to productivity-enhancing and risk-reducing investments like irrigation, the situation is quite different. Controlling for soil quality, input use, seasonality and crop type, the returns to cropping are much higher (Rs 7130/ha) on irrigated plots than on non-irrigated plots. A 10% increase in irrigated area will increase net returns by about the same proportion, indicating strong economic incentives to farmers to invest in water harvesting and supplementary irrigation. Coupled with the risk-reducing benefits of smallscale irrigation investments, the high economic returns explain why farmers are willing to spend significant resources in exploring groundwater and replacing open wells with more efficient tube wells. In the plot-level analysis across all crops and controlling for irrigation and other variables in the model, the effect of the watershed project was not significant. The effect of integrated watershed management was however significant in a separate regression analysis (not shown) where only cereals and pulses – crops promoted in the watershed village through dissemination of high-yielding varieties of sorghum, chickpea and pigeonpea – were included.

The results also show that adoption of improved varieties increases returns significantly. On an average, returns per ha were Rs 3270 higher on plots with improved varieties. The returns to cropping however decline substantially when stress related to drought, pest and disease reduces crop yields. A 10% increase in the area affected by the incidence of pests, diseases and other stresses will reduce net returns by about 12%, indicating the extent of losses incurred in the event of such risk. Seven crop dummies were introduced to control for the differential effects of crop choice. As hypothesized, crop choice also influences returns to family land and labor in cropping. Compared to the reference group of flowers, the net returns were significantly lower for all crops except cotton. The OLS results even indicate a lower net return for cotton relative to the high-value crops (flowers). The low returns to some of the dryland crops like sorghum and pulses (chickpea and pigeonpea) are also due to policy distortions (public distribution and pricing policies in India) that lower the relative prices of these commodities compared to other competing crops like rice and wheat (Gulati and Kelley 1999). Under the existing structure of incentives, farmers are likely to move away from these water-saving crops to other water-intensive commodities like paddy, cotton, vegetables and flowers.

Input use and market imperfections

The demand for inputs was estimated as a function of plot and farm attributes, the crop type, access to credit, off-farm orientation, and household assets and characteristics. Household characteristics were included to test whether imperfections in rural input markets are causing nonseparability between production and consumption decisions. The 3SLS results for the plot-wise expenditure on labor and other inputs estimated jointly in the system are presented in Table 5. The most important determinants of input use (mainly labor, fertilizer and pesticides) are the type of crop grown, the type of cropping (whether intercropped or not), access to irrigation and distance from home. Input use is higher on irrigated plots and in the case of sole crops. There is a higher demand for labor (73%), fertilizer-seed-pesticides (88%) and other capital inputs (85%) on irrigated plots. The level of use of these inputs is also significantly higher on non-intercropped plots, indicating that intercropping cereals with legumes may compensate for the demand for some of these inputs. The intensity of input use is also higher on cotton and vegetables where fertilizer (202%) and pesticide use is (67%) higher compared to flowers. Compared to these reference crops, the intensity of labor use is 43% and 26% lower for pulses and oilseeds and spices, respectively. The level of use of many of the inputs declines as plot distance from home increases, and as household income from off-farm sources rises. If household income from agricultural wages and other off-farm sources were invested on-farm, the demand for labor and other productivity-enhancing inputs would have increased. This does not seem to have happened and there is an indication of decreasing intensification as the income from non-agricultural sources increases.

As anticipated, the labor demand is also higher on vertisol soils and on crops grown during the main cropping (*kharif*) season. Household liquidity and credit received per unit of land were not very important determinants of input use. This may perhaps indicate that households are diverting input loans to other purposes (including consumption and migration). However, there is evidence of labor market imperfections, especially for female labor. The household's labor demand for crop production on a given plot is positively correlated with the endowment of female family labor. This indicates that agricultural labor demand cannot be determined independently of family female labor endowments. Due to cultural and related factors, the average wage rate for female labor is about half that of male

Table 5. Determinants of input expenditures in crop production (3SLS estimates).

	Ln (expenditure on labor)		Ln (expenditure on fertilizer, seeds and pesticides)		Ln (other capital expenditure)	
Variable Names	Parameter estimate	Elasticity at means[a]	Parameter estimate	Elasticity at means	Parameter estimate	Elasticity at means
Intercept	–0.32		–1.66		–1.39	
Ln (Cum. credit per ha)	0.004	0.004	0.00	0.00	0.03	0.03
Ln (Male workforce per ha)	–0.01	–0.01				
Ln (Female workforce per ha)	0.15***	0.15				
Vegetable dummy	0.18	19.65	0.53***	67.89	–0.11	–16.31
Cotton dummy	0.18	19.08	1.13***	202.66	0.39	31.37
Dryland cereal dummy	0.09	9.39	–0.10	–11.04	1.09***	169.64
Pulse dummy	–0.56***	–42.72	–0.21	–19.90	–0.19	–24.28
Maize dummy	–0.06	–6.00	0.13	11.49	0.15	5.92
Oils and spices dummy	–0.29**	–25.28	–0.21	–20.18	0.18	7.56
Paddy and sugarcane dummy	0.15	15.69	0.01	–0.72	0.09	–2.27
Season (*kharif* = 1)	0.13	13.49	0.07	6.63	0.07	3.29
Cropping system (sole cropping = 1)	0.87***	138.85	1.03***	177.45	1.19***	216.90
Crop variety (improved = 1)	0.04	3.82	0.05	4.60		
Soil type (vertisols =1)	0.16**	17.35	0.06	5.89	–0.26	–24.75
Soil fertility level	–0.02	–2.27	–0.06	–5.57	0.09	8.55
Ln (Total area irrigated in ha)					–0.02	–0.02
Ln (Tractor assets per ha)	–0.01	–0.004	–0.002	–0.002	–0.02	–0.02
Ln (Bullock assets per ha)	0.01	0.01	–0.01	–0.01	–0.01	–0.01
Ln (Motor assets per ha)	–0.002	–0.002	–0.02***	–0.01	0.01	0.01
Ln (Other assets per ha)	0.03	0.03	0.21***	0.21	0.09	0.09
Ln (Livestock value per ha)					0.0001	0.0001
Ln (Farm size per ha)			–0.05	–0.05		
Land tenure (dummy)			–0.14	–15.47	–0.57	–52.50
Irrigation (dummy)	0.55***	73.15	0.64***	88.59	0.65***	85.73
Watershed (dummy)	–0.24***	–21.68	–0.10	–8.57	0.13	11.24
Ln (Distance from home, km)	–0.07**	–0.07	–0.08*	–0.08	0.04	0.04
Ln (Age of the household head)	0.09	0.09	0.13	0.13	0.15	0.15
Ln (Education of household head)	–0.001	–0.001	0.005	0.005	0.03***	0.03
Ln (Nonfarm income per ha)	–0.01***	–0.01	–0.01***	–0.01	–0.01	–0.01

Note: *, ** and *** indicate levels of significance at less than 10%, 5% and 1% level respectively.

[a] Elasticities for the logarithmic variables are simply the coefficients themselves. For the dummy variables, the elasticities are computed as $e_i = 100[e^{(\hat{b}_i - 0.5\, var\, \hat{b}_i)} - 1]$. The interpretation of these elasticity values is the relative change (percentage change) in the dependent variable per unit change in the independent variable (Garderen and Shah 2002).

All the dependent variables are in Rs 1000/ha.

labor. On an average, female labor accounts for about 70% of the 120 working days per ha of labor required for crop production. With a high degree of feminization of agriculture, certain cultural and structural rigidities that limit the mobility of female labor and sustain inequitable wages will have an impact on crop production and the welfare of women.

Level of farmer investments in SWC

Private investment in SWC includes investments that households make in various conservation activities like contour bunding, gully plugging, tree planting, leveling, drainage, etc, and the associated periodic expenditures for maintaining these structures. Earlier, the factors that determine the decision to invest in land and water management were explored. Now, the determinants of the *level* of farmers' SWC investments once the decision to invest has been taken, are dealt with. A number of variables related to land quality, other plot characteristics, household assets, public SWC investments, social capital, family labor endowments and other household characteristics were included. In order to correct for the selection bias in relation to the censored dependent variable, Heckman's two-stage estimator (Heckman 1979) was used and the Inverse Mills Ratio (IMR) derived from the probit model of investment decisions was included. As shown in equation (16), along with other land quality variables, the level of SWC investments was hypothesized to affect returns to cropping. Land values, anticipated to depend on land quality and such investments, were not however expected to have a direct effect on net returns. Because of the simultaneity, the level of conservation investments was jointly determined with land values. The results are presented in Table 6.

Table 6. Factors that determine the level of soil and water conservation investments by smallholder farmers.

Variables:	3SLS			OLS	
LN (Private SWC investments, Rs 1000/ha)	Parameter estimate	Elasticity[a]	P-Value	Parameter estimate	P-Value
Intercept	–13.51		<.0001	–2.08	0.230
Ln (Inverse Mills Ratio)	3.57	3.57	<.0001	3.64	<.0001
Ln (Land value per ha)	3.33	3.33	<.0001	1.00	<.0001
Ln (Public SWC investments Rs 1000/ha)	–0.04	–0.04	0.007	–0.02	0.101
Ln (Credit last 3 years per ha)	0.00	0.00	0.998	0.01	0.531
Ln (Male workforce per ha)	0.001	0.001	0.967	–0.002	0.994
Ln (Female workforce per ha)	0.31	0.31	0.032	0.31	0.033
Erosion risk	–0.11	–11.32	0.249	–0.21	0.029
Soil type (dummy; 1 = vertisols)	–1.44	–76.88	<.0001	–0.70	0.0005
Social capital	1.27	244.18	<.0001	1.36	<.0001
Ln (Livestock value per ha)	0.03	0.03	0.030	0.02	0.188
Ln (Tractor assets per ha)	0.02	0.02	0.153	0.018	0.141
Ln (Bullock assets per ha)	0.04	0.04	0.075	0.039	0.077
Ln (Distance from home in km)	0.58	0.58	<.0001	0.23	0.029
Ln (Distance from check dam in km)	0.01	0.01	0.887	0.02	0.689
Ln (Age of the household head)	–0.02	–0.02	0.951	–0.15	0.655
Ln (Years of education for household head)	0.004	0.004	0.703	0.01	0.203
Ln (Total nonfarm income per ha)	–0.02	–0.02	0.076	–0.02	0.070
Ln (Plot size per ha)	–0.61	–0.61	<.0001	–0.35	0.010
Ln (Farm size ha – plot size ha)	0.04	0.04	0.120	0.04	0.137
Watershed (dummy)	0.95	151.13	<.0001	0.95	<.0001
Irrigation (dummy)	–1.26	–72.39	<.0001	–0.25	0.224
Backward Caste	–1.57	–79.78	<.0001	–1.40	<.0001
Scheduled Caste	–1.44	–77.45	<.0001	–1.27	0.0002
Minorities	–0.96	–64.22	0.010	–0.89	0.019

[a] Elasticities computed as in Table 5.

The results indicate that land quality is an important determinant of the level of conservation investments. Controlling for soil type, land values (in turn closely correlated with soil depth and fertility levels) are positively associated with farmer conservation investments. Like the conservation decision itself, the level of protective SWC investment is higher on high-valued plots. This is contrary to the perception that farmers invest on degraded soils to restore soil fertility. Instead, farmers seem to invest more on high-valued plots where the perceived risk of soil degradation is high. The level of investment is lower on vertisols perhaps because the risk of soil erosion is relatively lower. We find that public conservation investments are not necessarily complementary to private investments. This is mainly because the watershed programs supported through public funds target low-value degraded lands (often under the ownership of poor farmers) while farmers' own investments are mainly aimed at mitigating degradation on erodible but relatively fertile soils. The focus of public support for conservation of degraded private and communal lands is consistent with the structure of the underlying economic incentives to farmers, ie, low expected benefits from the restoration of degraded soils. If complementarity is sought between the private and public efforts, other approaches and policies that link the two initiatives are needed. While the decision to invest in conservation is positively associated with family male workforce, the level of investment attained is determined by female labor endowments. This interesting relationship emerges perhaps because female labor is dominant for farm activities including work in SWC practices, and its availability would release male labor for other income-generating activities.

Income from off-farm sources is negatively correlated with private conservation investments, an effect that translates to the extent of lower net returns to cropping, indicating an important trade-off between land productivity and off-farm diversification. Education is often the key resource that increases the relative returns to labor and increases the propensity to migrate to cities or enter into skill-intensive sectors. Livestock wealth and tractor assets seem to have a positive effect on the level of conservation. Controlling for other factors, the level of investments is lower on larger plots. The effect of farm size is not significant (but this was important in the decision problem analyzed above). Social capital expressed in terms of membership to formal and informal networks in the village is positively correlated with private investments. Perhaps due to the enhanced awareness and sensitization, farmers in the watershed seem to invest more than those outside the catchment. Conservation efforts are lower on irrigated plots mainly because irrigation-related investments for proper water management on such plots lower the risk of soil erosion. After accounting for many relevant variables, it was found that households belonging to certain underprivileged castes invest relatively less than those belonging to the 'forward' castes. These groups, with limited resources and lower ability to pay for conservation, need to be targeted through public watershed projects. Finally, the IMR was positively correlated with the level of investments indicating that farmers are more likely to invest on plots where the likelihood of undertaking such investments is higher.

Land values and conservation investments

The results above show that farmers' soil and water conservation investments are higher on high-value plots. An important question is whether such investments increase the value of land in the villages. Do public and private soil and water conservation efforts contribute to improving the value of land in local land markets? In order to test this simultaneity effect, along with private and public conservation investments, variables like land quality indicators, plot characteristics, village dummies and household education were included. The results (Table 7) indicate that land values are mainly determined by land quality, including soil depth and level of soil fertility. Compared to the reference

Table 7. Determinants of perceived market value of land.

Variables: Ln (Land values, Rs 1000/ha)	3SLS Parameter estimate	3SLS Elasticity at means[a]	3SLS P-Value	OLS Parameter estimate	OLS P-Value
Intercept	4.10		<.0001	4.01	<.0001
Ln (Private SWC investments Rs1000/ha)	0.004	0.004	0.107	-0.003	0.137
Ln (Public SWC investments Rs1000/ha)	0.003	0.003	0.168	0.01	0.074
Soil type (dummy; 1 = vertisols)	0.37	43.98	<.0001	0.39	<.0001
Soil type (dummy; 1 = *baraka*)	0.22	24.47	0.001	0.27	0.0001
Soil depth	0.05	5.57	0.009	0.06	0.004
Soil fertility level	0.18	17.75	<.0001	0.17	<.0001
Erosion risk	0.00	-0.01	0.994	0.004	0.799
Ln (Plot size in ha)	0.09	0.09	<.0001	0.08	0.0003
Watershed (dummy)	0.004	0.36	0.911	0.01	0.768
Irrigation (dummy)	0.37	45.11	<.0001	0.37	<.0001
Ln (Distance from home in km)	-0.12	-0.12	<.0001	-0.10	<.0001
Ln (Distance from check dam in km)	0.006	0.006	0.456	0.01	0.354
Ln (Distance from well in km)	-0.002	-0.002	0.208	-0.004	0.052
Ln (Years of education of household head)	0.003	0.003	0.079	0.004	0.009

[a] Elasticities computed as in Table 5.

group, soils locally known as *regadi* (vertisols) and *baraka* have higher values. At the means, a 10% increase in soil depth and soil fertility will increase land values by about 5% and 18%. Controlling for land quality and other characteristics, larger plots fetch higher per unit prices perhaps because of the working convenience and economies of scale in cultivating larger parcels. Interestingly, neither the perceived risk of soil degradation nor the private and public investments had a significant influence on land values. This indicates that land prices in the village do not properly reflect farmer and public conservation investments. Land values are mainly determined by land quality characteristics associated with higher economic returns in the short-run. Investments in sustaining productivity or mitigating the risk of degradation are not reflected in higher land values. This imperfection in local land markets and the lack of tradability of conservation investments are likely to discourage conservation efforts by small farmers.

Nevertheless, it was found that irrigation investments boost the value of land. The village market prices for irrigated plots are about 45% higher than for non-irrigated plots. This is consistent with the earlier finding that land productivity is significantly higher on irrigated plots. In the watershed villages, it was expected that plots close to water-recharging facilities (check dams) and those benefiting from such community investments would have higher values. However, after controlling for land quality and irrigation investments, neither the distance from home, the check dam nor the well had any independent significant effect on land values. The value of land did not vary significantly across the villages. Education has had a positive impact on land values, indicating that better educated household heads attach higher value to land. This may be because of better access to information or the households' higher perceived returns to investments on land.

Conclusions

Land degradation and water scarcity are major constraints to improving the productivity of agriculture in the arid and semi-arid tropics. Poverty alleviation and security of rural livelihoods in these fragile regions are therefore closely linked with the ability to relax these development constraints. In an effort to transform agriculture in these less-favored environments, research and development (R&D) agencies have been developing options to address these constraints. India is one of the countries in South Asia which is implementing an extensive watershed development program through integration of genetic and natural resource management options. Given the magnitude and spread of the problem, public-funded programs alone will not succeed unless complemented with private conservation and resource-improving investments. Experience has shown that the active participation of resource users through cost-sharing and other arrangements is critical for the success of public-funded watershed management programs. It has also been frequently observed that farmers often abandon structures established through public funding once the external support is phased out. The sustainability of watershed programs continues to be questioned because of these concerns. What are the conditions that motivate smallholder farmers to invest in SWC activities and in their maintenance? Do watershed programs create sufficient economic incentives to encourage private investments? Despite the significance of the problem, not much research has gone into understanding the underlying factors influencing private investments in land and water management. Based on analysis of primary plot, household and village-level data collected in selected villages where technological interventions for watershed management are being evaluated in close partnership with farmers and local communities, this study attempted to answer these questions and shed light on farmer incentives and productivity benefits from improved land and water management.

The analyses indicate that soil quality, labor, capital, improved seeds and irrigation investments are the most important factors that determine land productivity. Private SWC investments seem to be important for providing long-term rather than short-term benefits to smallholder farmers. Investment benefits are especially higher in small-scale irrigation when high-valued crops like flowers, vegetables and other cash crops are grown and when improved varieties of other dryland crops are adopted. This shows the benefits of diversification into new crops that would increase the economic incentives for more sustainable intensification of agriculture in the dryland tropics. Farmers seem to be using more than optimal levels of fertilizer and pesticides as a means of reducing the risk of crop failures. The high intensity of fertilizer and pesticide use on some crops like cotton and vegetables, relative to other high-value crops, is lowering the economic returns from intensification. There is a need to rationalize the level of use of these inputs. The watershed program seems to have differential effects on land productivity by raising the net returns from growing dryland crops (cereals and pulses). Nevertheless, the plot-level productivity effect of the watershed project was not significant in a pooled analysis across all crops and villages. However, both per capita and household incomes from aggregate crop production were significantly higher in the watershed villages, indicating the strong joint and cumulative effect of the program.

Some degree of substitution between agricultural incomes and earnings from off-farm sources was also found. The level of fertilizer use, labor use, and conservation investments per unit of land declines as the level of off-farm income per unit of land cultivated increases. Hence, land productivity (net returns per unit of land) is lower for households that earn a significant portion of their income from off-farm sources. This shows that diversification into nonfarm livelihood strategies is being attained at the expense of lower land productivity. Possibly, households which specialize in off-farm activities are those with less productive land. Such reverse causality was not explored because off-farm income is not endogenous in the estimated model. However, the study controlled for land quality effects. Future research needs to explore this possibility. However, regardless of the causality effects, the negative correlation between land productivity and off-farm orientation requires proper policies to reduce unwanted tradeoffs and stimulate desirable win-win outcomes. Moreover, the findings show that public and private investments in land and water management are not necessarily complementary. This requires further research with additional case studies. While small farmers invest in better quality soils where they perceive a risk of degradation, public-funded watershed programs generally aim at restoring soil fertility or preventing further degradation of eroded lands. There are indications that imperfections in labor markets particularly for female labor are influencing production and resource conservation investments. Hence, households with more female workers have higher land productivity and invest more in land and water management. Farmer and public investments are not necessarily reflected in the market value of land, an effect that could further discourage sustainability-enhancing investments. However, the watershed programs may increase land values by raising the demand from rich farmers and asset speculators. Further studies covering wider agroclimatic and socioeconomic regions in the dryland areas are needed to test these results and to draw broader lessons and conclusions.

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Appendix 1

Important socioeconomic features of the sample villages (2001)[a]

Features	Kothapally	Husainpura	Masaniguda	Oorella	Yankepally	Yarveguda
No. of households	308	40	160	460	175	206
Land resources						
Common property resources (acres)	8	10	8	3	10	0
Permanent fallow (ha)	10.53	22.28	1018.58	263.25	89.10	25.11
Cultivated land (ha)	465.75	142.97	810.00	799.88	377.87	144.59
Area irrigated (%)	34.8[b]	9.90	10.00	14.10	10.70	4.20
Dry land (%)	65.20	90.10	90.00	54.90	89.30	95.80
Degraded previously cultivated land (ha)	8.10	4.05	12.15	0.00	4.05	4.05
Other land (ha)	14.58	2.03	24.30	18.23	12.15	4.86
Total area (ha)	502.20	175.37	1868.27	1082.57	487.22	178.61
Degraded cultivated area (%)	1.74	2.83	1.50	0.00	1.07	2.80
Water harvesting						
No. of check dams	10	0	0	0	0	1
No. of open wells	64	13	80	150	50	5
No. of tube wells	34	3	14	9	27	18
No. of community wells	13	1	2	2	11	10
Social infrastructure						
No. of private schools	1	1	0	0	0	0
No. of government schools	1	0	1	1	1	1
Highest school standard	9	5	7	10	6	7
Children sent to school (%)	74.7	75.0	75.0	82.6	80.0	72.8
Number of clinics	1	0	0	0	0	0
Number of telephones	18	1	11	11	7	9
Households having electricity (%)	100.0	100.0	100.0	100.0	91.4	87.4
Quality of roads	V. good	Bad	V. good	Good	Good	Good
Asset ownership and poverty						
Landless households (%)	3.2	0.0	1.9	0.7	2.9	2.4
Food secure households (%)	100.0	100.0	100.0	100.0	100.0	96.1
Poor (as per local norms) (%)	1.6	12.5	12.5	2.6	1.7	2.4
No. of seasonal migrants (%)	4.9	0.0	9.4	43.5	5.7	4.9
No. of permanent migrants (%)	1.6	15.0	31.3	0.9	2.3	2.9
Soil and water conservation						
Trees planted in 2001	5000	100	200	185	800	500
Households planting trees (%)	51.9	37.5	25.0	15.4	45.7	15.5
Households investing in SWC (%)	7.1	25.0	18.8	10.9	11.4	4.9
Households using FYM (%)	60.0	100.0	93.8	34.8	80.0	87.4
Households using mineral fertilizers (%)	100.0	100.0	93.8	93.5	100.0	97.1
Amount of fertilizer used (kg/ha)	123.45	123.45	123.45	123.45	123.45	246.90
Households using pesticides (%)	90.0	100.0	93.8	70.0	90.0	82.5
Livestock (average ownership)						
Cattle	1.0	0.8	0.4	0.4	1.1	0.6
Buffaloes	0.7	0.1	0.9	0.0	1.4	0.6
Sheep	0.9	0.0	0.0	0.9	0.0	1.2
Goats	0.7	0.8	1.3	0.2	0.9	1.5

[a] Data collected through focus group discussions during the village-level surveys. Open and tube wells include those that may have dried up.

[b] Prior to the watershed interventions, about 20% of the estimated area was under irrigation.