Collective Action for Integrated Community Watershed Management in Semi-Arid India: Analysis of Multiple Livelihood Impacts and the Drivers of Change

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1. Introduction

Integrated watershed management (IWM) is being promoted as a suitable strategy for improving productivity and sustainable intensification of agriculture in rainfed drought-prone regions. 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 program was strengthened since the mid 1990s through new initiatives and creation of new institutional structures that aimed to increase community participation, sustainability and program impacts. The strategy emphasizes the need to go beyond conservation technologies to include multiple crop-livestock interventions that support and diversify livelihood opportunities for the poor and create synergies between targeted technologies, policies and institutions to improve productivity, resource use sustainability and market access (Reddy, 2000; Kerr, 2001).

The level of spatial and temporal coordination required for efficient resource use and the implications for collective action and property rights differ by the type of resource and the institutions required for efficient management (Knox and Meinzen-Dick, 1999). Investment in watershed management, unlike adoption of high yielding varieties, however is not scale neutral and requires more secure property rights along with spatial coordination and cooperation among affected users.[1] Despite increasing recognition of the vital roles that farmer organizations and collective action can play in improving management of common resources (Runge, 1986; Jodha, 1986; Ostrom, 1990; White and Runge, 1995; Agrawal, 2001) and reducing rural poverty, much less is known about the multiple impacts of community-based IWM interventions and the institutional and policy options that condition such impacts.

[1] Collective action (CA) is broadly defined as action taken by a group (either directly or on its behalf through an organization) in pursuit of members' perceived shared interests (Marshall 1998). Collective action occurs when individuals voluntarily cooperate as a group to coordinate their behavior to solve shared problems.

Based on a case study and econometric analysis of panel data from semi-arid villages in Andhra Pradesh, this study examines whether and how collective action has contributed towards improvement of livelihoods and resource conditions. It provides insights on how community institutions and water availability for supplemental irrigation coupled with better access to markets and agricultural technologies contributed to improvement of incomes, commercialisation of dryland agriculture and reduced vulnerability to drought for the rural poor.

2. Collective action in watershed management

A watershed is a spatially defined unit that includes diverse natural resources that are unevenly distributed within a given geographical area. The actual size of the watershed that is suitable for technical interventions depends on topographic and agro-climatic conditions. This implies that effectiveness of watershed interventions will depend on the ability to treat the entire hydrological landscape, not just a portion of it. This creates interdependence between resources as well as resource users over time and space, requiring mechanisms for internalizing externalities and coordination of resource use and management patterns.

On the other hand, investments in several natural resource management technologies required for watershed management do not payback in a short period of time. Some benefits of IWM are non-tangible public goods, and hence not fully captured by individual resource users. Another important factor is the role of clearly defined and secure property rights that combine the elements of excludability, duration, robustness and assurance (Place *et al*., 1994). The distribution of IWM costs and benefits is determined by the stock of resource use rights and entitlements and the ability to exclude others. Excludability depends on biophysical conditions, rights of access, and the prevailing legal and institutional frameworks. In the absence of collective action, groundwater and other open access resources in watersheds are often overexploited.

Moreover, watersheds are typically inhabited by diverse social groups with differing entitlements and right use rights. Coupled with fragmented land ownership and settlement patterns, unequal rights of access, control and use of resources induce conflicts among diverging interest groups. This requires mechanisms for improving thrust and user cooperation. There is however a classic mismatch between a watershed (hydrological unit) and village/community (social unit). Rivers and natural boundaries often delineate villages whereas they lie at the interior of watersheds (Swallow *et al*., 2002). This can be offset by working within larger hydrological units that embed multiple micro-watersheds that overlap with communities or villages. The biophysical and social complexities and the need to harmonize the two for effective IWM require innovative policy options and institutional arrangements that stimulate both private and collective efforts.

3. Data and methods

Collective action in watershed management has the potential to provide multiple economic and environmental benefits to rural communities. Such CA allows smallholder farmers to jointly invest in management practices that provide collective benefits to all members. The functions of the group can also extend to include collective marketing activities, which increase the economies of scale and enhance the bargaining power of small farmers. While watershed management contributes to productivity growth and sustainability, increased market access allows diversification into high-value crops, and creates the economic incentives for intensification. However, evaluating the multi-faceted impacts of NRM interventions is complicated by problems of measurement, valuation and attribution. More rigorous approaches and methods for evaluating such impacts are just beginning to emerge (Shiferaw *et al*., 2005). This study uses qualitative approaches along with quantitative analysis of panel data from a case study of Adarsha watershed in semi-arid India, to investigate multiple benefits associated with IWM interventions.

Adarsha watershed located in Ranga Reddy district of Andhra Pradesh covers about 465 ha and is inhabited by about 350 households. The interventions were implemented through a multi-institutional consortium and the local community. The integrated agricultural and watershed management intervention started in 1999 and the site was selected for its vulnerability to drought, land degradation, water scarcity and incidence of poverty. Community surveys and census of households within the watershed and five adjoining villages outside the project area provided background information for the sample surveys. Repeated household surveys generated data for 2001 and 2002 to understand impact pathways and assess the effect of the integrated agricultural and resource management interventions.

Five adjoining villages that did not benefit from the project were included in the panel survey to address attribution problems. These 'without project' villages are similar to the 'with project' village, in both agro-climatic and socio-economic conditions, allowing us to separate the likely impact of the interventions after controlling for village-level and other fixed effects. The year 2002 recorded the lowest rainfall since 1998, while the 2001 rainfall was about 20% higher and better distributed (Figure 1). This provided a good opportunity to test the effectiveness of IWM under drought conditions.

Data was analyzed using two stage least squares (2SLS) procedures to test the effect of the IWM project on: (a) resilience of livelihoods and drought mitigation, (b) variability of crop income and contributions to household income, (c) changes in overall household income, and (d) changes in commercialization of production. The 2SLS was used to control for the effect of endogenous variable bias in the regressions. The procedure uses selected instrumental and exogenous variables for predicting the value of endogenous variables used in the second stage regressions (Greene, 1997). The analytical framework for the study is given as:

$$Y = \alpha + \beta X + \delta Z + \varepsilon_1 \qquad (1)$$

where Y is a vector of dependent variables measuring performance; X is a vector of exogenous variables affecting Y and uncorrelated to the error term ε; and Z is a set of endogenous variables (correlated to ε). Given that Z is endogenous, the OLS estimates of (1) will not be consistent. In order to control for this endogeneity effect, the 2SLS procedure for (1) uses the predicted values of Z estimated from the following instrumental variables procedure:

$$Z = a + gX + hR + \varepsilon_2 \qquad (2)$$

where X is a vector of exogenous variables affecting both Z and Y; and R is a set of instrumental variables affecting Z but not Y. We use selected village and household characteristics as instruments as they may influence farm household input use decisions (but not actual productivity directly) when rural markets are imperfect (de Janvry *et al*., 1991). Environmental impacts were assessed through empirical measurements under comparable set ups with and without the interventions. Changes in groundwater levels were monitored using geo-referenced open wells.

4. Benefits of collective action

The discussion highlights the multiple impacts in relation to environmental, drought mitigation, economic and commercialization benefits associated with collective action in community-based watershed management.

4.1 Environmental benefits

The environmental benefits were not valued but measured using selected biophysical indicators such as changes in runoff, soil loss, groundwater levels and ground cover that were monitored over time. The soil and water management measures implemented in the watershed included field bunding, gully plugging and check dams built at certain intervals along the main watercourse that passes through the village. The evidence collected for five years (2000-2004) shows a significant reduction in runoff and soil loss from the treated segment of the watershed compared to the untreated portion (Table 1). The runoff has declined by about 20 to 60%, the highest reduction coming from years with high rainfall. Soil erosion levels also declined significantly (up to 60%) and systematically under land treated with conservation.

Changes in groundwater levels were monitored using 62 geo-referenced open wells located along the main watercourse in the watershed at differing distances from check dams constructed for recharging groundwater. The results show a significant improvement in the yields of most wells, particularly those located near check dams (Figure 1). The land cover and vegetation density was studied using satellite images shows an increase in vegetation cover from 129 ha in 1996 to over 200 ha in 2000.

4.2 Drought mitigation benefits

The basic goal of watershed management in drought-prone rainfed systems is to improve livelihood security by mitigating the negative effects of climatic variability while protecting or enhancing the flow of essential ecosystem services. Increased availability of water has enabled expansion of small-scale irrigation using improved varieties, high value crops and cropping systems, promoted through the project. The mean income for the two groups of households from alternative sources (crops, livestock and off-farm) in 2001 and 2002 is given in Table 2.

Crop and household incomes are generally higher in 2001 than the drought year 2002. In 2001, crop incomes constituted about 36% and 44% of household income in the project and non-project villages, respectively. In 2002, crop income for the non-project village declined by 80% while the relative decline was smaller in the project village. The drastic decline in the contribution of crops to household income in the non-project villages was compensated by increased migration and off-farm employment; the share of off-farm income jumped from about 50% in 2001 to almost 75% in 2002. This shows how IWM has contributed to stability of agriculture in the project village despite the serious drought in 2002. This was confirmed from econometric analysis of panel data (not shown due to space limitations). After controlling for drought, the average share of crop income in the project village was 32% higher (P<0.06), showing how effectively such interventions could contribute to mitigating adverse effects and stabilizing household incomes.

4.3 Economic benefits

Crop and household incomes were computed as returns to family labor and land (2001 constant prices), i.e., net of all variable costs other than owned land and family labor. Did IWM make a significant contribution to crop and total household income? Table 2 seems to support a positive contribution of IWM. The 2SLS was used to isolate the effect of other correlated influences and estimate the relative effect of IWM and drought on crop and total household income.

In addition to variables that control for drought and IWM interventions, a number of variables were included in the income models. These included endogenous variables like irrigated and rainfed crop area and average costs of variable inputs used in production, and exogenous variables like sex, family education, family male and female labor, value of livestock and other physical assets. For total income we also included other exogenous variables like distance to markets and household caste background. The results for crop income show a significant effect of drought, watershed interventions, irrigated and rainfed cultivated area, family male workforce, and the value of fungible family assets (Table 3). Other factors kept constant, drought reduces average crop incomes by about Rs 9000. Controlling for drought and other factors, average income from crops is about Rs 3260 higher in the project village than non-project villages. This confirms that average crop income is higher within the project village even during drought years.

The important determinants for total household income were incidence of drought, watershed investments, irrigated cropland, family education, female workforce, and fungible household assets (Table 4). *Ceteris paribus,* drought reduces average household incomes by about Rs 12,000. This is higher than the estimated loss of crop income as it includes loss of livestock and village employment in the event of drought. However, IWM could significantly raise household incomes even in the event of drought; average household incomes in the project village are about Rs 13,000 higher than the non-project villages.

4.4 Agricultural commercialization

Another important social benefit of IWM is related to its contribution for transforming and re-orienting traditional agriculture towards commercial farming. Integrated interventions that combine improved soil, water and pest management with high-yielding cultivars and livestock management options were designed to address limiting constraints in semi-arid systems. Improved water availability helps to boost productivity as well as mitigate the risk of drought-induced crop-livestock losses. This structural and technological change makes it possible for hitherto subsistence farmers to generate marketable surpluses. Coupled with reduced production and market risk, increase in productivity opens new opportunities for farmers to participate in markets. This creates the basic production conditions for commercialization of some products although high idiosyncratic risk and market imperfections may continue to push farmers towards self-sufficiency in some staples.

In order to test this effect, an econometric model was used to identify the factors that determine the value of aggregate marketed surplus of crops. The 2SLS results after controlling for the sample selection problem using Heckman's two-step procedure are presented in Table 5. The results show that incidence of drought, watershed interventions, investment in variable inputs, owned irrigable and rainfed cropland, family education, family male workforce, and livestock had a significant effect. After controlling for the effect of drought, aggregate marketed surplus is about Rs 4760 higher in the watershed village (P<0.09). Investment in yield increasing inputs like seeds and fertilizer also significantly contributed to generating additional surplus.

5. Summary and conclusion

Drought-prone areas in the semi-arid tropics suffer from high levels of poverty associated with low and erratic rainfall and high levels of agro-ecosystem degradation. Landscape-based IWM interventions and improved access to markets and agricultural innovations are useful strategies for reducing poverty, improving livelihood resilience and sustainability in these less-favored areas. India has adopted micro-watershed development as a strategy for poverty reduction and sustainable rural development in dryland areas. This approach cannot however succeed without local participation and coordination of resource use decisions by several actors and communities. Experience has shown that when property rights are clearly defined and beneficiaries respect norms, drought-prone areas can benefit from increased availability of drinking and irrigation water, improved fodder availability, reduced soil erosion, and enhanced sustainability associated with community watershed management (Farrington *et al*., 1999; Kerr, 2001; Joshi *et al*., 2004). Such collective investments also enhance the profitability of other divisible inputs like fertilizer and improved seeds, and encourage adoption of productivity-enhancing innovations.

The results from our case study support these findings. The case study demonstrates that landscape-based agricultural and resource management interventions can significantly improve the level and stability of crop and household incomes. Higher crop income shares and higher crop and household incomes (even after controlling for drought) were achieved in the project village. This shows the vital contribution of IWM interventions in mitigating the effects of drought-induced shocks on livelihoods. We also found higher marketed surplus and market participation in the project village, indicating positive effects towards commercialization of production.

The experience of Adarsha watershed provides useful insights on the drivers of higher impact and effective collective action. Government support for establishing key local institutions and the focus on tested interventions was a critical first step in laying the foundation for collective action. The basic incentive problem for farmer participation in community programs was addressed through on-farm income-generating interventions. This was enhanced through linked non-farm opportunities for landless and marginal farmers. Low-cost water recharging and harvesting structures built across the watershed improved the equity impacts of the project. However, there are several cases of failure of collective action in watershed management in India and large scale studies are needed to understand the facilitating and enabling conditions for emergence and sustainability of effective community action.

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Table 1. The effect integrated watershed management (IWM) interventions on runoff and soil erosion from Adarsha watershed.

Year	Rainfall (mm)	Runoff (mm)		Soil loss (t/ha)	
		Untreated	Treated	Untreated	Treated
2000	1161	118	65	4.17	1.46
2001	612	31	22	1.48	0.51
2002	464	13	Nil	0.18	Nil
2003	689	76	44	3.20	1.10
2004	667	126	39	3.53	0.53

Table 2: The effect of IWM interventions on alternative sources of household income (Rs 1000).

Year	Villages group	Statistics	Crop income	Livestock income	Off-farm income	Household Income
2001	Non-Project	Mean	12.7	1.9	14.3	28.9
	(N=60)	Std. dev	23.3	3.8	12.6	26.3
		%	**44.0**	**6.6**	**49.5**	**100.0**
	Project	Mean	15.4	4.4	22.7	42.5
	(N=60)	Std. dev	16.4	6.4	45.0	51.3
		%	**36.2**	**10.4**	**53.4**	**100.0**
2002	Non-Project	Mean	2.5	2.7	15.0	20.2
	(N=60)	Std. dev	13.4	4.7	30.0	36.9
		%	**12.2**	**13.3**	**74.5**	**100.0**
	Project	Mean	10.1	4.0	13.4	27.6
	(N=60)	Std. dev	19.4	6.7	17.8	31.3
		%	**36.7**	**14.6**	**48.7**	**100.0**

Table 3: The effect of IWM on crop income

Variables: dependent is crop income (Rs 1000)	Estimated coefficient	P-Value	Elasticity at means
Drought year (2002)	-9.030	0.000	-0.444
Watershed village	3.257	0.048	0.160
Male household heads	1.206	0.743	0.110
Variable costs in crop production (Rs 1000/ha)	-0.278	0.715	-0.112
Rainfed area cropped (ha)	7.725	0.000	1.016
Irrigated area cropped (ha)	15.795	0.000	0.635
Cumulative level of household education (yrs)	0.063	0.406	0.136
Family male workforce	-2.977	0.004	-0.540
Family female workforce	-0.345	0.762	-0.056
Livestock wealth (Rs 1000)	-0.094	0.419	-0.079
Value of other assets (Rs 1000)	-0.031	0.033	-0.275
Constant	4.560	0.203	0.448

N= 240; Durbin-Watson = 1.9999; Von Neumann Ratio = 2.0082; Rho = -0.00489

R-Square between observed and predicted = 0.6217; Adj. R-Square = 0.5944

Standard errors not shown.

Table 4: The effect of IWM on household income

Variables: dependent is household income (Rs 1000)	Estimated coefficient	P-Value	Elasticity at means
Male household head	6.167	0.336	0.192
Drought year (2002)	-11.904	0.000	-0.200
Watershed village	13.029	0.006	0.219
Backward cast	-4.520	0.283	-0.082
Scheduled cast	-4.203	0.413	-0.035
Rainfed area cropped (ha)	-1.307	0.661	-0.059
Irrigated area cropped (ha)	11.047	0.012	0.152
Distance to nearest market (km)	-0.637	0.290	-0.235
Cumulative level of household education (yrs)	0.916	0.000	0.676
Family male workforce	-3.006	0.133	-0.186
Family female workforce	4.082	0.069	0.227
Livestock wealth (Rs 1000)	-0.019	0.930	-0.005
Tractor assets (Rs 1000)	-0.241	0.136	-0.018
Other physical farm assets (Rs 1000)	-0.283	0.358	-0.046
Other household assets	0.143	0.000	0.390
Constant (Rs 1000)	0.355	0.969	0.012
N= 240; Durbin-Watson = 2.0788; Von Neumann Ratio = 2.0875; Rho = -0.04322			
R-Square between observed and predicted = 0.6482; Adj. R-Square = 0.6246			

Standard errors not shown.

Table 5: The effect of IWM on the total value of marketed surplus of crops

Variables: dependent is value of marketed surplus (Rs 1000)	Estimated coefficient	P-Value	Elasticity at means
Drought year (2002)	-7.747	0.001	-0.237
Watershed village	4.761	0.090	0.146
Variable costs in crop production (Rs 1000/ha)	1.978	0.021	0.496
Owned irrigable land (ha)	10.768	0.000	0.248
Owned rainfed land	5.558	0.000	0.562
Distance to nearest market (km)	-0.167	0.650	-0.113
Cumulative level of household education (yrs)	0.355	0.000	0.479
Family male workforce	-3.063	0.008	-0.346
Family female workforce	-1.955	0.125	-0.198
Livestock wealth (Rs 1000)	0.235	0.041	0.123
Value of motorized assets (Rs 1000)	-0.029	0.763	-0.009
Value of other assets (Rs 1000)	0.008	0.612	0.039
Inverse Mills Ratio	3.170	0.123	0.000
Constant	-3.047	0.455	-0.187

Durbin Watson = 2.1545; Von Neumann Ratio = 2.1636; Rho = -0.07916

Standard errors not shown.

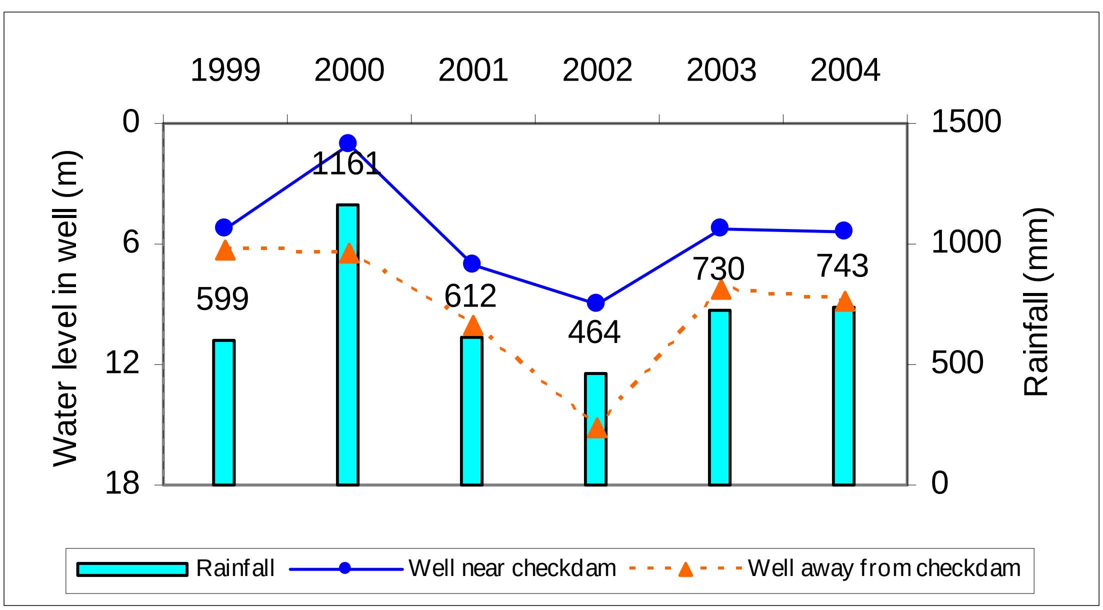

Figure 1. The effect of watershed management investments on groundwater levels.