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5 authors, including:

Ramarao Ca
Central Research Institute for Dryland Agriculture, India

Kalakada Kareemulla
National Academy of Agricultural Research Management

Bandi Venkateswarlu
Vasant Rao Naik Maratwada Krishi Vidya Peeth , Parbhani , India

Shalander Kumar
International Crops Research Institute for Semi Arid Tropics

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Estimation of Economic Returns to Soil and Water Conservation Research – An *ex ante* Analysis[§]

C.A. Rama Rao*, K. Kareemulla, K. Nagasree, B. Venkateswarlu and Shalander Kumar
Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad – 500 059, Andhra Pradesh

Abstract

The economic returns to investment made in soil and water conservation research have been analyzed. Technologies such as conservation furrow, residue incorporation have been found to be economically viable under farmers' conditions. The study has covered four locations, viz. Agra and Varanasi in Uttar Pradesh, Kota in Rajasthan and Jabalpur in Madhya Pradesh. The economic surplus analysis has revealed that when adopted on a large scale, soil and water conservation technologies generate significant economic surplus as reflected in high NPV and BC ratio. The share of producer surplus has been found to be higher in the total economic surplus generated from technology adoption. Thus, investments in generation and transfer of soil and water conservation technologies have been found be justified in terms of economic benefits. However, various constraints that hamper adoption of these technologies are to be addressed so that the potential benefits could be realized by both farmer and consumer.

Introduction

About 82 million hectares out of 142 million hectare of net cultivated area in the country is rainfed. The rainfed area contributes about 40 per cent to the total food production in the country. It is estimated that 91per cent of coarse cereals, 91 per cent of pulses, 80 per cent of oilseeds and 65 per cent of cotton are produced in rainfed area of the country (CRIDA, 1997). The average productivity of dryland crops is about 0.8 t/ha. The All India Coordinated Research Project for Dryland Agriculture (AICRPDA) has shown that the productivity can be doubled by following appropriate technologies. However, the realization of this potential still remains elusive due to lack of adoption of new technologies. While there are a number of reasons for non-adoption of recommended technologies, the most important one is the risk involved in rainfed agriculture, which is a gamble with monsoon.

Since water is the major limiting factor in rainfed agriculture, management of rainwater has received much attention of researchers As a result of research carried out in the past, strategies have been developed for better management of rainwater through *in-situ* moisture conservation, water harvesting and recycling and groundwater recharge. Early research efforts through AICRP for dryland agriculture network during 1970s and 1980s helped identify potential production through a combination of simple agronomic techniques to enhance *in-situ* water conservation, improved varieties of crops, soil fertility management to overcome nutritional constraints and weed control to avoid non-productive use of stored soil moisture and nutrients. It was clearly recognized that to bring about stability and improvement in rainfed agriculture it is essential to adopt conservation and production technologies in an integrated manner.

Most of the studies (e.g. Evenson and Jha, 1973; Evenson, 1989; Arndt *et al.*, 1997) on returns to investment in agricultural research have focused on

* Author for correspondence, E-mail: carrao@crida.ernet.in; chitiprolu@yahoo.com

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improved crop varieties. In spite of its significant share in the agricultural research resources, soil and water conservation have attracted little attention in this regard (Joshi and Bantilan, 1998).

Keeping this in view, the economic returns from investment have been assessed in a project, funded under National Agricultural Technology Project (NATP), which was concerned with refinement and transfer of soil and water conservation technologies. This project, ‘Evaluation and Improvement of Indigenous Methods of Moisture Conservation and Runoff Management (for details, see http:// www.crida.ernet.in/NATP%20 Projects/ index.html) aimed at identifying and effecting improvements in *in-situ* moisture conservation and runoff management practices. The project was carried out in various dryland research centres in the country. The details of target crops, target area and technological interventions have been given in Appendix I.

Study Area and Methodology

To assess farm level impact of the technology, primary farm data were collected from the farmers in the selected villages in the districts of Agra and Varanasi (Uttar Pradesh), Jabalpur (Madhya Pradesh) and Kota (Rajasthan) where the project was carried out. The data were obtained for farms where the particular technology was adopted and for farms where technology was not adopted. Data on inputs and outputs and technology adoption were obtained from twenty farmers from each location for the crop year 2002-03 using pre-tested interview schedules. Using this data, the impact of technology on costs and returns was examined.

To assess the wider-scale impact on an *ex ante* basis, the economic surplus model, as applicable to a closed economy with little spill-over effects on international trade, was applied (Alston *et al*., 1995, Mills, 1998). The model assumes that supply function experiences a parallel shift in response to the technology-induced changes. The formulae used for estimating changes in producer surplus and consumer surplus due to the technology adoption-induced supply shifts are given below:

$$\Delta \text{ Economic surplus} = \Delta \text{ Producer surplus} + \Delta \text{ Consumer surplus}$$

$$\Delta \text{ Producer surplus} = (K_t - Z_t)\, P_0\, Q_0\, (1+0.5\, Z_t\, \eta)$$

$$\Delta \text{ Consumer surplus} = P_0\, Q_0\, Z_t\, (1+0.5\, Z_t\, \eta)$$

where,

K_t = Net change in cost of production × Adoption rate × Depreciation of the technology × Probability of success,

Z_t = $K_t\, \varepsilon / (\varepsilon + \eta)$,

P_0 = Price of the commodity in the base period,

Q_0 = Production of the commodity in the base period,

K_t = Shift in the supply curve,

ε = Elasticity of supply, and

η = Elasticity of demand.

The returns were estimated for a period of 15 years starting from the start of the project. The cost and return flows were then discounted to compute net present value (NPV), benefit cost ratio (BCR) and internal rate of return (IRR). The yield gains and the changes in cost of production were computed from the data collected from the farmers The production and farm harvest prices of the crops concerned in the target regions for the triennium ending 2000-01 were used as base values on which the economic surplus was computed. The values of other variables used in the computation of economic surplus are given in Appendix II.

Results and Discussion

The changes in costs, yield and returns associated with the technology adoption vis-à-vis is farmers’ practice were described for each location.

Agra

The normal monsoon starts between the last week of June and first week of July and ends by middle of September with an average annual rainfall of 735 mm. Normal rainfalls during the months of June, July, August and September are 62 mm, 98 mm, 262 mm and 113 mm, respectively. The target crop was mustard and technology assessed was ‘growing green gram + diking for residue incorporation’. It required additional input of human and bullock labour. Adoption of technology influenced the yield and profitability of the crop significantly (Table 1). Adoption of this technology increased the cost of cultivation by Rs 950/ha and yield by about 45 per cent and net returns by 126 per cent.

Table 1. Impact of conservation furrow on yield and profitability in mustard, Agra: 2002-03

Particulars	With technology	Without technology	Difference*
Cost of cultivation (Rs/ha)	15201	14251	950 (6.67%)
Yield (kg/ha)	1680	1161	519 (44.67%)
Net returns(Rs/ha)	15049	6657	8391 (126.00%)
Cost of production (Rs/kg)	9.04	12.26	-3.22 (-26.26)

Note: *Significant at 10 per cent level; Figures within the parentheses indicate per cent change.

As a result, the cost of production of mustard fell from nearly Rs 12/kg to Rs 9/kg. Thus at the farm level, adoption of technology was observed to be highly remunerative.

The project incurred a total expenditure of Rs 2.26 million during the three years of its implementation. Using the economic surplus model, it was estimated that these technologies would generate a total economic surplus of Rs 77.8 million of which Rs 51.8 million was producer surplus and the remaining Rs 25.9 million was consumer surplus (Table 5). The net present value (NPV) of the project was estimated to be Rs 76 million after accounting for the project cost with an internal rat of return (IRR) of 185 per cent (Table 6). This shows that the investment in the project has been highly remunerative. Even if the yield gain with the technology were halved, the investments in these conservation technologies would have been still proved remunerative. Under this scenario, the NPV would fall to Rs 33 million and IRR to 124 per cent.

Kota

The selected area is situated in the south-eastern Rajasthan and lies between 23°56′ – 25° north latitude and 75°37′-76°38′ east longitudes. The average annual rainfall is 741.9 mm and is received in 38 rainy days. The average monthly rainfall is maximum in the month of July (264.0 mm), followed by August (244.35 mm) and September (98.2 mm). About 91 per cent of the annual rainfall in the district is received during the monsoon season (June to September). The target crop was chickpea and technology assessed was ‘use of mould board plough in conjunction with opening of conservation furrows’. The technology required additional input of human and bullock labour. The additional cost involved and yield obtained have been given in the Table 2. It was observed that the adoption of technology influenced the yield and profitability of the crop significantly. Adoption of technology with an additional expenditure of Rs 1196/ha, increased the yield by 29 per cent and net returns by 41 per cent. As a result, the cost of production of chickpea came down from nearly Rs 6.80 kg/ha to Rs 6.11 kg/ha. Thus at the farm level, adoption of this technology was observed to be highly remunerative.

A total expenditure of Rs 2.26 millions was incurred on the project during three years of its implementation. Assuming an adoption ceiling of eight per cent and an adoption rate of two per cent per year, the producer surplus generated as a result of adoption of this technology was estimated to be about Rs 42.4 million (Table 5). After considering the project cost, the NPV of the project was estimated to be Rs 58 million with an IRR of 153 per cent (Table 6). This shows that the investment in the project has been highly remunerative. The sensitivity analysis with half of the observed yield gains found the technology to be economically viable with an NPV of Rs 21 million and IRR of 93 per cent.

Varanasi

The target area received about 1043 mm of rainfall, which is less than the mean annual potential evapotranspiration (1527 mm) by 18.9 per cent. The region represents sub-humid (dry) moderate seasonal water surplus mega thermal, a summer concentric C- type with aridity index 48.81, humidity index 20.56 and moisture index 28.24. For impact assessment, the target crop selected was chickpea. The technology assessed was ‘adoption of conservation tillage’. It required additional input of human and bullock labour. The additional cost involved and yield obtained have been given in the Table 3. It was observed that the adoption of technology influenced the yield and profitability of the crop significantly. With an additional expenditure of Rs 2046/ha, the level of yield could be increased by 38.63 per cent and net returns by 37.01 per cent as a result of technology adoption. Thus at the farm level, the adoption of conservation tillage has been observed to be remunerative.

Table 2 . Impact of conservation furrow on yield and profitability in chickpea, Kota: 2002-03

Particulars	With technology	Without technology	Difference*
Cost of cultivation (Rs/ha)	8652	7456	1196 (16.04%)
Yield (kg/ha)	1415	1095	319 (29.13%)
Net returns (Rs/ha)	11157	7884	3273 (41.51%)
Cost of production (Rs/kg)	6.11	6.80	-0.69 (10.14%)

Note: *Significant at 10 per cent level; Figures within the parentheses indicate per cent change.

Table 3. Impact of conservation tillage on yield and profitability in chickpea, Varanasi: 2002-03

Particulars	With technology	Without technology	Difference*
Cost of cultivation (Rs/ha)	6406	4360	2045 (46.91%)
Yield (kg/ha)	1758	1268	490 (38.63%)
Net returns (Rs/ha)	30523	22277	8245 (37.01%)
Cost of production (Rs/kg)	3.64	3.43	-0.21 (6.12%)

Note: *Significant at 10 per cent level; Figures within the parentheses indicate per cent change.

Using the economic surplus model, the technology adoption was estimated to generate a producer surplus of Rs 48.8 million and a consumer surplus of Rs 19.5 million (Table 5). The project incurred a total expenditure of Rs 1.8 million during over a period of three years The NPV of the project was estimated to be Rs 66 million with an IRR of 153 per cent (Table 6). This shows that the investment in the project has been highly remunerative.

Jabalpur

The target area of Jabalpur lies between 22°49′, N to 24°8′ N latitude and from 78°21′E to 80° 58′ E longitude. The climate of area is hot sub-humid characterized by hot summers and mild winters, the annual rainfall is 1260 mm, covering about 80 per cent of the mean annual potential evapotranspiration (1300-1500 mm), the target crop was lentil and technology assessed was 'broadcast sowing with furrowing across the slope and key-line sowing with furrowing'. The additional investment was required in the form of human and bullock labour. The additional cost involved and yield obtained have been given in Table 4. It reveals that the adoption of technology influenced the yield and profitability of the crop significantly. With an additional expenditure of Rs 187.97/ha the yield was increased by 41 per cent and net returns by 78 per cent. As a result, the cost of production of lentil fell down from 7.26 kg/ha to Rs 5.25 kg/ha. Thus at the farm level, adoption of 'line sowing with furrowing' was observed to be highly remunerative.

Using the values of different parameters given in Appendix II, producer and consumer surplus were estimated. The producer surplus was estimated to be Rs 53.8 million and consumer surplus of Rs 21.5 million. The project incurred a total expenditure of Rs 22.56 lakh during three-year period. The NPV of the project was estimated to be Rs 73 million with an IRR of 106 per cent. This shows that the investment in the project has been highly remunerative. The NPV and IRR were found to be Rs 31 million and 103 per cent, even if the yield gain was reduced by half in the economic surplus model.

In all the cases, besides the yield gains and reduction in cost of production included in the economic analysis, improvement in soil moisture and nutritional status were observed, which could not be quantified. These technologies also reduced leaching of chemicals to the water streams and thereby prevented water pollution. If these environmental benefits could be measured and included in the analysis, the returns to adoption of such technologies would be still higher.

Further, interaction with farmers and scientists revealed that in spite of yield and economic advantages of these technologies, the adoption levels were less than expected because of such reasons as lack of awareness, inadequate soil moisture to make

Table 4. Impact of conservation furrow on the yield and profitability in lentil, Jabalpur: 2002-03

Particulars	With technology	Without technology	Difference*
Cost of cultivation (Rs/ha)	9336	9148	187 (2.05%)
Yield (kg/ha)	1777	1259	518 (41.20%)
Net returns (Rs/ha)	17332	9738	7594 (77.98%)
Cost of production (Rs/kg)	5.25	7.26	-2.01(27.76%)

Note: *Significant at 10 per cent level; Figures within the parentheses indicate per cent change.

Table 5. Estimated total economic surplus generated by adoption of conservation technologies

(in million Rs)

Location	Producer surplus	Consumer surplus	Total economic surplus
Agra	51.8	21.9	73.7
Kota	42.4	17.0	59.4
Varanasi	48.8	19.5	68.3
Jabalpur	53.8	21.5	75.3

Table 6. Estimated returns from investments in soil and water conservation technologies using economic surplus method

Location	With yield gain observed in the project efforts			With half of the yield gain observed		
	NPV (Rs million)	BC ratio	IRR (%)	NPV (Rs million)	BC ratio	IRR (%)
Agra	76	53	185	33	24	124
Kota	58	40	153	21	15	93
Varanasi	66	46	153	22	16	88
Jabalpur	73	34	106	31	15	103

conservation efforts, rainfall sensitivity of the yield effects of conservation technologies and lack of access to draught power.

Summary and Conclusions

The analysis of farm level effect of adoption of conservation technologies at Agra, Kota, Varanasi and Jabalpur has revealed that the conservation technologies give higher yields and returns compared to the farmers' practice justifying the investments in these technologies. The *ex-ante* analysis in an economic surplus framework, assuming an adoption ceiling of eight per cent of target area, has shown that these technologies if adopted on a larger scale would generate sufficiently high economic surplus to justify the investments in research and extension. A large proportion of generated economic surplus has been found to be going to the producers compared to the consumers, indicating a significant welfare gain to the producers. The gain in consumer surplus has also been significant at about 30-33 per cent of the total economic surplus generated. It is to be noted that the costs of research done earlier to this was not included in the analysis and so were the benefits arising out of such other efforts. Constraints such as lack of awareness, lack of complete information on the yield effects on different rainfall situations and inadequate access to draught power are to be addressed if these conservation technologies are to be adopted on a wider scale.

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Appendix I

Key interventions at various locations

Centre	Target crop	Target area	Key interventions
CSWCRTI (RS), Agra	Mustard	Agra	Residue incorporation
CSWCRTI(RS), Kota	Chickpea	Kota	Improved tillage
			Conservation furrow
BHU, Varanasi	Chickpea	Varanasi	Conservation tillage
			Criss-cross sowing
JNKVV, Jabalpur	Lentil	Jabalpur	Modification of haveli field bandhi
			Key line sowing

The project was also implemented at three other centers, viz. CRIDA, Hyderabad; UAS (B), Bijapur; and MPKV, Solapur. The findings at these locations were reported in Rama Rao *et al.* (2005)

Appendix II

Values of key variables in the economic surplus model

Variable	Agra	Kota	Varanasi	Jabalpur
Probability of success	0.5	0.5	0.5	0.5
Target area	Agra district, UP	Kota district, Rajasthan	Varanasi district, UP	Jabalpur district, MP
Adoption rate (%)	2	2	2	2
Adoption ceiling (%)	8	8	10	8
Elasticity of supply	0.2	0.2	0.2	0.2
Elasticity of demand	0.5	0.5	0.5	0.5
Base year production (t)	18900	24600	16460	18900
Base year price (Rs/t)	12000	12000	12000	10000
Research (project) cost (Rs million)	2.26	2.26	1.8	2.26
Discounting rate (%)	8	8	8	8