Zero tillage for weed control in India: the contribution to poverty alleviation

ACIAR Project CS1/1996/013

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Centre for International Economics

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Foreword

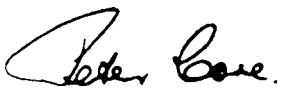
Alleviation of poverty is a foundation dimension of Australia's overseas aid program, of which the Australian Centre for International Agricultural Research (ACIAR) is a part. In general, the public-good nature of much agricultural research means that its primary impact on poverty alleviation comes through its wider effects on the agricultural sector. This is because, in most developing countries, growth in the agricultural sector is crucial for the overall economic development that provides opportunities for the poor to increase their incomes.

However, in choosing collaborative research projects to fund, ACIAR places significant weight on whether the research outcomes are likely to benefit the poor. During the past few years, measurement of the poverty-alleviation impact of ACIAR projects has been a focus of several studies published in the Impact Assessment Series. In particular, these studies have focused on how poverty is influenced by agricultural research and development, and what might be needed to quantitatively measure this impact. It has been found that this is a data-intensive exercise that requires detailed knowledge of the activities of the poor that is usually available only from expensive surveys.

The study included in this report took the opportunity of an existing survey in India to try to measure poverty-reduction impacts of research. This survey has been undertaken for some time for an area where a previous impact study had been undertaken for an ACIAR project that developed weed-management strategies for zero-tillage farming systems.

The study provides a detailed illustration of how surveys of rural households can be adapted to provide effective measures of poverty impacts. Unfortunately, when the survey results were analysed in detail it was found that the area of India included in the study did not have many people who, using World Bank criteria, were regarded as living in poverty. This meant that although the study provides good information about the income-group impact of the research outcomes, which have been extensively adopted, it does not show that the very poor have benefited directly. The report concludes that the poor in India will still have benefited from the impacts of the research, but that this will be through the significant effect the outcomes have had on productivity improvements and the flow-ons from this.

The study is an important addition to guide those who want to quantify poverty effects of agricultural research, and highlights the significant complexities in these studies.



Peter Core
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Summary

- The ACIAR-funded project CS1/1996/013, 'Herbicide-resistant weeds of wheat in India and Australia: integrated management', was designed to find a long-term method to control *Phalaris minor*, a problem weed in the rice–wheat cropping system of north-western India. By 1993 the weed had developed resistance to isoproturon, a herbicide which had delivered effective weed control for 15 years.
- In an impact analysis of the project, Vincent and Quirke (2002) identified eight components of benefit. Their analysis calculated the gains attributable to ACIAR to be $238 million in net present value terms over the next 30 years.
- Following the Vincent and Quirke study, the Centre for International Economics (CIE) and ACIAR commissioned Haryana Agricultural University to conduct an income and expenditure survey on 100 farms in the project target group. This report applies a number of techniques to the resulting survey data to assess the benefits identified by Vincent and Quirke as well as the overall impact of the project on incomes and poverty.
- Using the survey data, we calculate the direct farm benefits from using zero-tillage technology, finding a 'zero-tillage premium' of 175 rupees (Rs) per acre. That is, where zero tillage is implemented, farmers received, on average, Rs175 more per acre under zero tillage than otherwise. Average per capita incomes increased by around 0.5% as a result of the project. There was, however, no impact on absolute or relative poverty levels given the relative wealth of the regions and the relatively small impact on overall per-person incomes.
- The increase in wheat production may lower overall wheat prices. This may have second-round impacts on poverty levels, with urban and rural poor benefiting from lower prices. It was not possible, however, to quantify this benefit using the survey data that formed the basis of this report.
- This highlights a key issue with undertaking poverty analysis. On average, the Haryana region is one of India's richest and, within the state, the farmers surveyed are towards the top end of the state's income bracket. Thus, while a number of farmers have benefited from the project, the project has not made an impact on measurable poverty levels. That being said, improving agricultural productivity is the first step in achieving sustained growth and poverty reduction.

1 Background

Between 1997 and 2000, ACIAR part-funded a project examining ways of controlling the weed *Phalaris minor* in the Indian wheat belt. An economic impact evaluation of this research was undertaken in 2002 (Vincent and Quirke 2002).

In 2002, ACIAR started considering ways of incorporating poverty impact analysis into its impact reviews. Pearce (2002) set out some broad principles for thinking through and analysing the impact of research on poverty. Since then, two reviews (Warner and Bauer 2002; Bauer et al. 2003) have specifically considered the poverty impacts of ACIAR-funded projects.

The methods used for this poverty analysis have varied. This report is a contribution to understanding the poverty impacts of ACIAR projects by adopting a slightly different analytical technique to those used in the past. In particular, this report uses a detailed farmer survey as a core source of empirical information against which to examine the poverty impacts of the project.

Income and expenditure surveys, particularly in rural areas characterised by non-market exchanges and subsistence consumption, are expensive and expertise-intensive activities. In order to minimise the costs of ACIAR's initial foray into such analysis, the survey presented in this report builds on existing surveys already taking place in a relevant region of India. The approach taken has proved to have both costs and benefits.

While the approach has tended to minimise costs, the subsequent quality of the data is, at best, mixed.

The most significant problem is that the measure of benefits emerging from the analysis presented here is not the same as those that emerged from the previous impact analysis.

2 Poverty and agricultural productivity

India accounts for about 20% of the world's population and 40% of the world's poor. Poverty, measured in terms of income deprivation, is a major problem in India, with around 260 million people currently living below the government's official poverty line. With over half of the population living in rural areas, improving agricultural productivity and rural incomes could have a significant impact on Indian poverty levels.

Poverty and agriculture: strong linkages

It is widely agreed that improving agricultural productivity is the first step in achieving sustained growth and poverty reduction.

There are many ways that agricultural research can affect poverty. The most obvious is through the direct effect of the research on the farming household or enterprise income. The research may lower costs or improve productivity and so directly increase income. The research could also lead to lower food prices and so to an increase in real purchasing power of consumers, whether or not their income is based on farm products.

Generally, we would expect the research to affect both factor (input) markets and product markets, although the factor market effects may be indirect. The changes in the factor and product markets will tend to change the prices of factors and products, and this will change income sources and expenditure patterns of households, which will, in turn, feed back to the factor and product markets.

For the farming household, the research may directly change costs and so increase income from particular sources. This will change the household's production decisions and may lead them to demand more or fewer factors of production. This will have an effect on factor markets that will feed through to other households that are not necessarily directly affected by the research.

The farming households' production decisions will also influence product markets. They may increase output, which will lead to a decline in prices via interactions in product markets. This will, in turn, change the spending and income patterns of other households, leading to further effects in factor and product markets.

The key point is that the poverty effects of the agricultural research will come through both the income and expenditure sides of the household budget.

Poverty in India

With India accounting for 40% of the worlds poor and with an economy geared to agriculture, agricultural reform projects, such as the ACIAR-funded zero-tillage research, have a real potential to make significant gains in reducing poverty.

The Indian Government uses a calories-based food-energy method to derive poverty lines for rural and urban dwellers in each state. Poverty lines correspond to total household per capita expenditure sufficient to provide, in addition to basic non-food items, a daily

intake of 2,400 calories per person in rural areas and 2,100 calories in urban areas. These poverty lines differ between states (see Table 1).

Haryana and Punjab, the two states benefiting most from the ACIAR project, have among the highest rural poverty lines of Indian states.

Previous research

The extent and causes of India's poverty have been extensively studied—by Indian Government officials, by academics inside and outside India, and by international development organisations such as the World Bank. These studies have drawn on the long time-series of household expenditure surveys conducted by the Indian Government since the 1960s to closely monitor poverty. Household expenditure is compared with the poverty lines and the percentage of people whose expenditures fall above or below the line measured. There is now a very large published literature on the subject (see, in particular, World Bank (1997, 2000)).

Table 1. Indian state-specific poverty lines in 1999–2000 (rupees per capita per month)

State	Rural	Urban
Andhra Pradesh	262.94	457.40
Assam	365.43	343.99
Bihar	333.07	379.78
Gujarat	318.94	474.41
Haryana	362.81	420.20
Himachal Pradesh	367.45	420.20
Karnataka	309.59	511.44
Kerala	374.79	477.06
Madhya Pradesh	311.34	481.65
Maharashtra	318.63	539.71
Orissa	323.92	473.12
Punjab	362.68	388.15
Rajasthan	344.03	465.92
Tamil Nadu	307.64	475.60
Uttar Pradesh	336.88	416.29
West Bengal	350.17	409.22
Delhi	362.68	505.45
All India	327.56	454.11

Source: Planning Commission 2002, p. 166.

Although there is a good deal of controversy in the literature around some of the technical measurement concepts and the results that are emerging, a number of strong propositions can be advanced as follows.

- Economic growth is the key to poverty reduction. India's economic reforms of the early 1990s have significantly raised its per-capita income growth and the rate of progress in reducing the proportion of the population in poverty.
- How economic growth affects poverty depends on how the additional income generated by growth is distributed within a country.
- Poverty is higher in rural than urban areas. In rural areas, higher agricultural productivity is crucial for pro-poor economic growth. The rural poor are heavily concentrated in those states with low agricultural productivity. The trend rates of growth of simple indicators of farm productivity improvement, such as changes in agricultural output per hectare, are significant in explaining cross-state differences in the rate of rural poverty reduction.
- Agricultural productivity by itself is, nevertheless, not enough to reduce rural poverty. It must be accompanied by overall economic growth to provide an opportunity for those displaced from agriculture through productivity growth to be absorbed productively in other sectors of the economy.
- Investment in agriculture has raised average living standards in rural India without accentuating inequalities. In particular, the green revolution technology, which was initially thought to favour the larger landowners, has generally proven to be scale neutral in terms of income distribution. This observation has important implications for the present study. Zero tillage is being described by many as a second green revolution.

Current poverty levels in India

While India is making steady progress in reducing the extent of poverty (between 1991 and 2000, the number of people living in poverty fell from 300 million to 260 million, a decline of over 10%), within both rural and urban areas, there is still widespread poverty, with over a quarter of the population still living below the national poverty line (see Table 2).

However, the benefits of growth and development have not been felt equally across the country. As expected, some states have managed to reduce the poverty rate to less than 5%, while in others almost half of the population lives below the poverty line (see Table 3).

With such widespread poverty levels, both within states in terms of urban and rural communities, and across states, there is significant potential for development activities such as the ACIAR activity to make a significant impact to the welfare of India.

It is important to note that the two states most affected by the project, Haryana and Punjab, have some of the lowest poverty rates in the country.

Table 2. Progress in reducing poverty in India (percentage of population below the poverty line)

Year	All India (%)	Rural (%)	Urban (%)
1973	54.9	56.4	49.0
1978	51.3	53.1	45.2
1983	44.5	45.7	40.8
1988	38.9	39.1	38.2
1994	36.0	37.3	32.4
1999	26.1	27.1	23.6

Source: Central Statistical Organisation 2002, p. 160.

Table 3. Persons below the poverty line, by state, 1999–2000

State	Rural		Urban		Combined	
	Millions	%	Millions	%	Millions	%
Andhra Pradesh	5.81	11.1	6.09	26.6	11.90	15.8
Arunachal Pradesh	0.38	40.0	0.02	7.5	0.40	33.5
Assam	9.22	40.0	0.24	7.5	9.45	36.1
Bihar	37.65	44.3	4.91	32.9	42.56	42.6
Goa	0.011	1.4	0.06	7.5	0.07	4.4
Gujarat	3.98	13.2	2.89	15.6	6.79	14.1
Haryana	1.19	8.3	0.54	10.0	1.73	8.7
Himachal Pradesh	0.48	7.9	0.03	4.6	0.51	7.6
Jammu & Kashmir	0.30	4.0	0.05	2.0	0.35	3.5
Karnataka	5.99	17.4	4.45	25.3	10.44	20.0
Kerala	2.10	9.4	2.01	20.3	4.10	12.7
Madhya Pradesh	21.73	37.1	8.12	38.4	29.85	37.4
Maharashtra	12.51	23.7	10.28	26.8	22.79	25.0
Manipur	0.65	40.0	0.07	7.5	0.72	28.5
Meghalaya	0.79	40.0	0.03	7.5	0.82	33.8
Mizoram	0.14	40.0	0.05	7.5	0.19	19.5
Nagaland	0.52	40.0	0.03	7.5	0.55	32.7
Orissa	14.37	48.0	2.54	42.8	16.10	47.2
Punjab	1.02	6.4	0.43	5.8	1.45	6.2
Rajasthan	5.50	13.7	2.68	19.9	8.18	15.3
Sikkim	0.20	40.0	0.004	7.5	0.21	36.6
Tamil Nadu	8.05	20.6	4.99	22.1	13.05	21.1
Tripura	1.25	40.0	0.05	7.5	1.30	34.4
Uttar Pradesh	41.20	31.2	11.79	30.9	52.99	31.2
West Bengal	18.01	31.9	3.34	14.9	21.35	27.0
A & N Island	0.058	20.6	0.02	22.1	0.08	21.0
Chandigarth	0.006	5.8	0.05	5.8	0.05	5.8
Dadra & Nagar Haveli	0.030	17.6	0.003	13.5	0.03	17.1
Daman & Diu	0.001	1.4	0.005	7.5	0.06	4.4
Delhi	0.007	0.4	1.14	9.4	1.15	8.2
Lakshadweep	0.003	9.4	0.008	20.3	0.01	15.6
Pondicherry	0.064	20.6	0.18	22.1	0.24	21.7
All India	**193.24**	**27.1**	**67.01**	**23.6**	**260.25**	**26.1**

Source: Central Statistical Organisation 2002, p. 161.

3 The methodology for this report

Information on the impact of the project on incomes and income distributions pre- and post-project is essential when undertaking a poverty analysis. For such a study, there are various techniques that can be used. For this analysis, we decided to take advantage of the fact that a research group at Haryana Agricultural University was doing a regular survey of farmers in the region. The key component of our methodology was to append income and expenditure questions to the survey already being undertaken.

Haryana Agricultural University survey group

Professor Malik's group at the Haryana Agricultural University conducts an annual survey of farmers in the Haryana region. The survey is conducted in May of each year, after farmers have finished the rice harvest. The survey is funded by the National Agricultural Technical Project through World Bank support.

Professor Malik's group uses a stratified sample of 100 farmers who they have now surveyed for a number of years. Stratification is according to farm size. These farmers are drawn from 10 districts within the state. It takes time to win the trust of farmers to ensure participation in a survey and Professor Malik's group has achieved this. The survey is undertaken via personal interview, and each survey interviewer covers about five interviews per day. The 100 surveyed farms cover a farming population of 546, with 342 adults and 204 children.

Although it does not record incomes directly, the questionnaire used in this survey contains a large number of relevant socioeconomic questions to record information about individual farmers and their families. These questions include caste, education, material possessions, land holding, farm implements, crops grown, attitude to zero-till, costs of growing wheat and rice and yields, participation of children in farm labour etc.

At the request of CIE and ACIAR, the survey was extended to include a number of direct questions about farm family income. These questions were asked in the survey round of early 2004. In all, 11 categories of questions relating to income were asked in addition to the standard questions asked by Professor Malik's group.

Boxes 1 and 2 detail the specific additional questions on income and expenditure asked as part of the poverty survey. Of the 1,005 variables within Professor Malik's survey data, 211 relate to the additional income and expenditure questions asked on behalf of ACIAR.

The additional income and expenditure questions were worded in such a way so as to ensure that incomes were being correctly measured. This is because many farmers take a loan from a middleman (at generally high interest rates) to fund their crop, with the crop being offered as collateral to the middleman. Farmers are reluctant to disclose how much interest they are paying. There is also considerable borrowing from banks to fund large expenditures such as tractors. Education of children is also a major expenditure item. A number of farmers prefer to invest in their children's education rather than in further farm development.

When these questions are combined with existing questions in the survey, the result is a very detailed picture of the socioeconomic status of farmers directly affected by the introduction of zero tillage.

Box 1. Additional survey questions relating to household income

A.1 Sources of income

What are your main income sources (rupees per year)?

- Own farm activities; Casual labour; Long-term agricultural employment; Salaried employment; and Other business

A.2.1 Income from farm activities

Please indicate total income earned from your own farm activities (broken up into advances, loans, sales by quantity and sales by value)

- Wheat; Barseem; Sugarcane; Rice; Basmati rice; Cotton; Jowar; and Other

A.2.2 Expenses related to farm income

Please indicate expenses incurred in generating the income indicated in A.2.1 above (broken up by quantity and value)

- Seed; Fertiliser; Herbicide/weedicide; Other materials; Hired labour; Land rent; and Loan repayments

A.3 Casual labour

Please indicate any casual labour earnings from any family member (by average hours per week and average wage per hour)

- Household head; Member 2; Member 3; Member 4; and Member 5

A.4 Long-term agricultural employment

Please indicate any earnings from long-term agricultural employment by any family member (by average hours per week and average wage per hour)

- Household head; Member 2; Member 3; Member 4; and Member 5

A.5 Salaried employment

Please indicate any earnings from salaried employment by any family member (by activity, average hours per week and average wage per hour)

- Household head; Member 2; Member 3; Member 4; and Member 5

A.6 Other business

Please indicate earnings from other business activities (by activity, average hours per week and average wage per hour)

- Household head; Member 2; Member 3; Member 4; and Member 5

Box 2. Additional survey questions relating to household expenditure

B.1.1 Food purchases—outside expenditure

Please indicate typical monthly quantities and expenditure on each item purchased outside the household (by quantity and value)

- Rice, Wheat, Maize, Barley, Other cereals, Pulses, Gram, Gur, Sugar, Milk or products, Edible oils, Eggs, Tea/coffee, Salt/spices, Vegetables, Fruit, Cigarettes, Alcohol, Meals purchased outside home, and Other

B.1.2 Consumption of food produced at home or received in kind

Please indicate the amount consumed of products produced at home (per month) or the amounts received in kind for each of the following items (by quantity and value)

- Rice, Wheat, Maize, Barley, Other cereals, Pulses, Gram, Gur, Sugar, Milk or products, Edible oils, Eggs, Tea/coffee, Salt/spices, Vegetables, Fruit, Cigarettes, Alcohol, Meals purchased outside home, and Other

B.2.1 Regular food expenditure items

Please indicate the amount spent on the following items in the past 30 days (by value)

- Wood, Cowdung cakes, Kerosene oil, Coal & charcoal, Cylinder gas, Electricity, Matches & candles, Toiletries, Newspapers & books & entertainment, Transport, Wages paid to servants, Dry cleaning and washing, Household cleaning articles, and Other

B.2.3 Less frequent items

Please indicate the amount spent on the following items in the past 12 months (by value)

- Clothing or men, Clothing for women, Clothing for children, Footwear, Medical expenses, Toys & sports goods etc., Religious expenses, Education, Social expenses, Taxes and charges, and Other

4 Exploring the dataset

Using the Haryana survey data, it is possible to calculate the post-project income distribution and poverty levels at the time of the survey.

Data issues

As the survey is an ex-post evaluation, the income and poverty levels identified in the survey data are the *post-project* levels. However, before analysing the data, it is necessary to undertake data cleaning, one of the less glamorous but very important tasks in data analysis. From the data, the per-acre net farm income for each household was calculated. Figure 1 sets out the frequency of the average per-acre net farm income for the 100 farms surveyed.

Clearly, there are a number of data points that are extreme outliers. Specifically, there are three data points that exceed the mean by two standard deviations. Additionally, two data points recorded negative net monthly per-acre incomes, one by as much as Rs455,614 per acre. That is, the farm *loses* roughly $14,000 per acre per year! Given the large upper values and implausible negative ones, it was decided that the three upper values and two negative values be removed from the analysis. This is not an instance of data variability being punished. Rather, data that exceed an acceptable limit have been removed so that the results are not unduly influenced by a minor number of outliers.

Reassuringly, the remaining 95 farms have per-acre net farm incomes within a reasonable range around broader Indian average per-acre net farm incomes (ICPD 1999). Figure 2 sets out the revised distribution of per-acre net farm incomes.

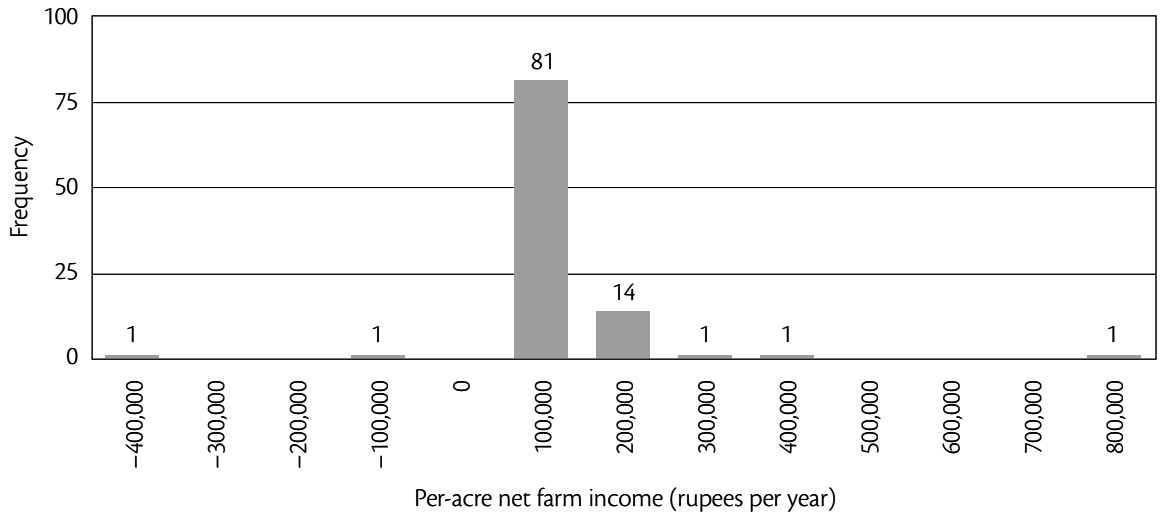

Figure 1. Raw distribution of per-acre net farm incomes. Data source: Malik (2005)

The cleansed data cover a farming population of 518, comprising 324 adults and 194 children.

Of the 95 farms within the acceptable range, the income and expenditure data have varying degrees of responses:

- 30 variables (14%) have 90 or more responses
- 8 variables (4%) have between 75 and 90 responses
- 11 variables (5%) have between 50 and 75 responses
- 162 variables (77%) have fewer than 50 responses.

Income distribution and poverty levels

Using the cleansed data, the current distribution of net per-person income can be calculated for the 518 individuals (see Figure 3).

In the dataset, the average per-person net income is determined as Rs4,798 per month (in 2003 rupees), while the minimum is Rs600 per month. This minimum exceeds the official poverty line for rural Haryana (see Table 3). Thus, the poverty head-count ratio is 0%. This is

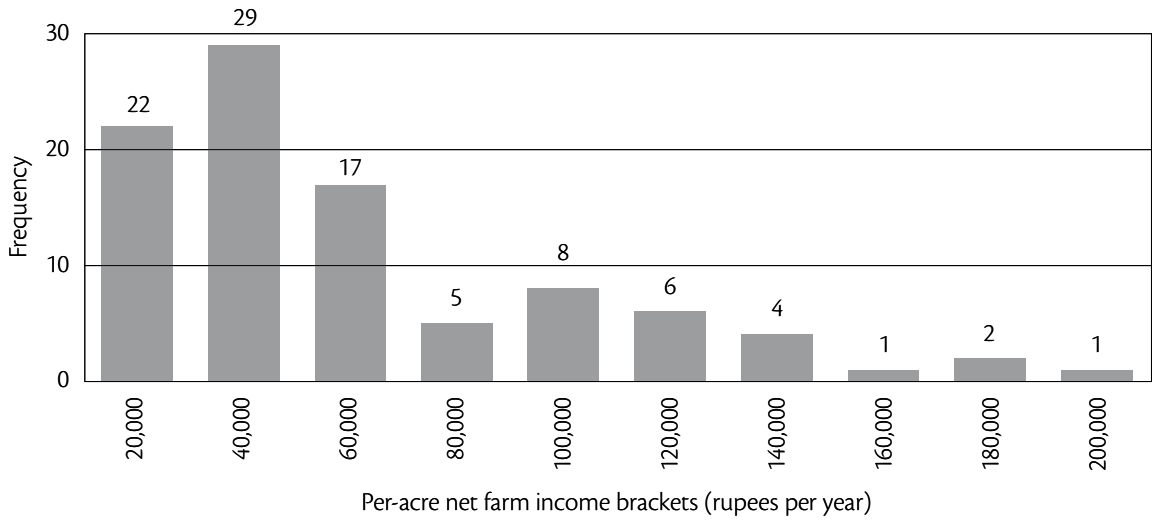

Figure 2. Cleansed distribution of per-acre net farm incomes. Data source: Malik (2005) and CIE

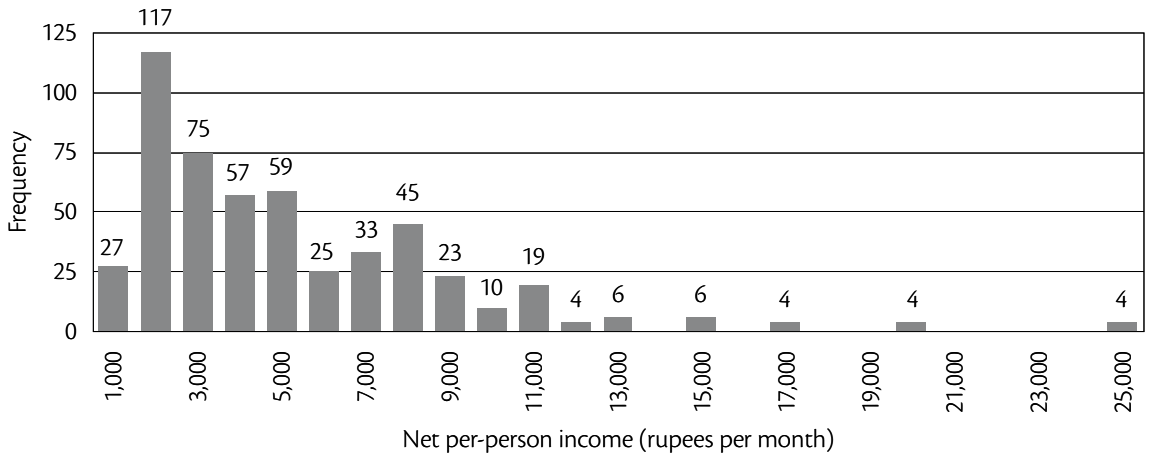

Figure 3. Current (post-project) income distribution. Data source: Malik (2005) and CIE

significantly below the official head-count ratio of 8.3% in 1999–00 for the state and 26.1% for the country as a whole (Planning Commission 2002). Clearly, this group is wealthier than the region and the country at large. As the dataset covers landowners and land managers, there is a degree of sampling bias in the dataset. That is, the rural landless and poor are not surveyed.

This approach to measuring poverty requires use of an absolute poverty line. These measures, however, fail to take into consideration the distribution of income within the community. For example, if everyone's income in an economy increases, but the income distribution stays the same, the absolute poverty line will indicate that there has been an overall improvement. This, however, masks the reality that the poor are still just as poor as before, *relative* to the rich.

Given the surveyed farmers relative wealth as compared to the state, and to the country more broadly, the state-specific measure of poverty may be misleading, particularly when examining the impact of the project on overall poverty levels. An alternative, relative poverty line that is applicable to this group of farmers is to set it at half the median of the per-person net monthly income, which in this case is Rs1,870 per person per month (or 3.8 times higher than the official Planning Commission poverty line). Using this approach, 138 people are below the relative poverty line in the Haryana survey sample group. This equates to 26.6% of the population living below the relative poverty line.

An alternative approach to measuring poverty is to examine income distributions. The most common tool for measuring the inequality of income distributions is known as the Lorenz curve. The curve plots the cumulative fraction of the population (starting from the poorest) against the cumulative fraction of income. Measuring the area between the actual income distribution curve and the line of perfect equality determines the Gini coefficient. A Gini coefficient of zero indicates perfect income equality, while a coefficient of 100 indicates perfect income inequality. Pearce (2002) discusses in detail how these measures are calculated. In this case, the Gini coefficient is calculated as 40.8 (see Figure 4).

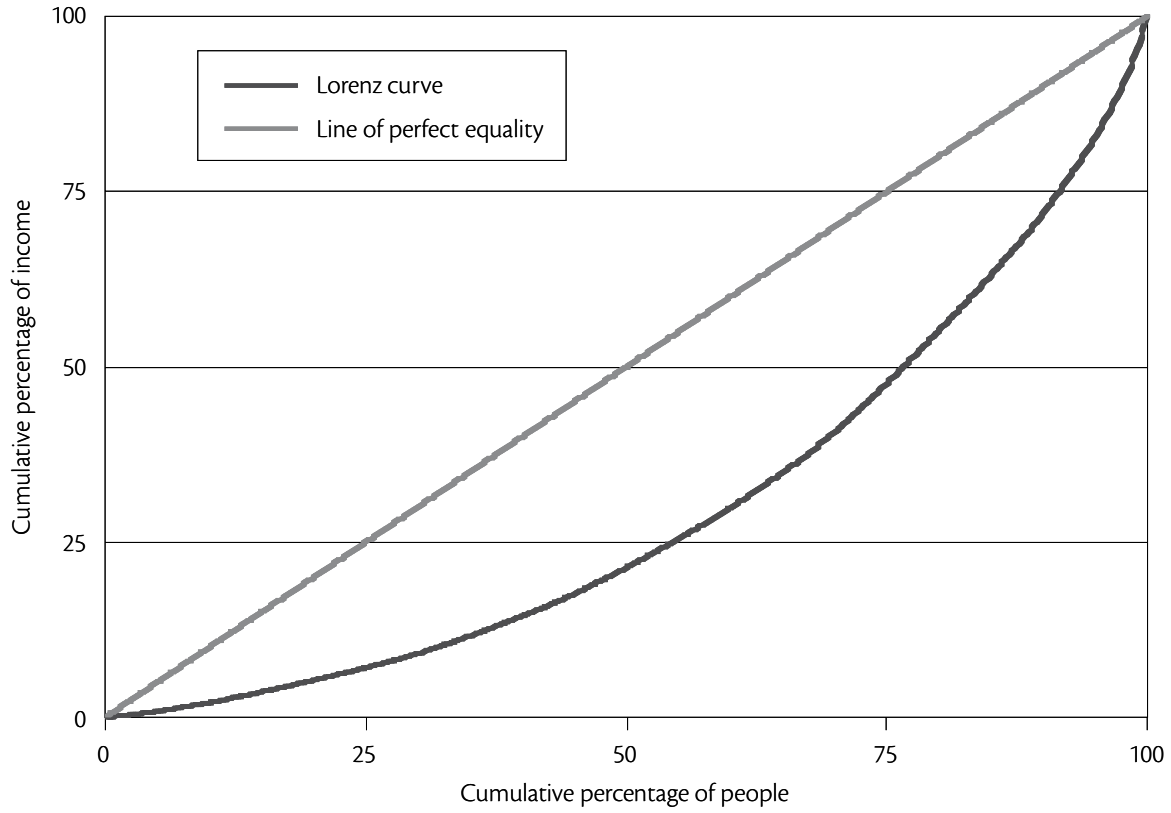

Figure 4. Income distribution. Data source: CIE 2006

5 The impact of the project on poverty

The project to control herbicide-resistant weeds has the potential to alleviate poverty through a number of pathways. First, there is the direct impact of the weed-control package on the income and expenditure profiles of farm families in the north-west rice–wheat cropping system. Second, there is the prospect of more dispersed economy-wide effects.

The first impact-assessment analysis of the ACIAR-funded project 'Controlling *Phalaris minor* in the Indian rice–wheat belt' (Vincent and Quirke 2002) concluded that the activity was likely to have significant poverty alleviation and wealth creation benefits in eight components:

- prevention of future decline in yield through re-emergence of herbicide resistance
- reduction in herbicide outlays
- reduction in tillage costs
- avoidance of long-term yield decline through adverse effects of conventional tillage
- yield premium through early sowing and closer spacing
- capacity building and training
- improved environmental outcomes
- prospects for more weed-competitive varieties in the long term.

Once appropriately valued, these eight components can be used to analyse the gap between the with and without project outcomes and so can identify the overall economic gain from the project. The Haryana survey goes some way to answering these questions—the available data provide us with a good picture of the household incomes and spending patterns. However, as can often be the case with data, there are also parts of the picture that cannot be revealed.

Beyond the aforementioned eight components, there are potentially additional benefits from the flow-on of increased productivity on broader income levels. That is, even if the direct impacts are on relatively well-off farmers, the flow-on effects on the local–regional and national economy could mean that the demand for labour and supply of food will change and this could have trickle-down effects on the poor.

Testing the dataset: revisiting the propositions from the first impact study

Using appropriate data at the farm level, it should be possible to identify and quantify the benefits to farmers from using zero tillage across the following areas:

- reduced herbicide outlays
- reduced tillage costs
- yield premium due to early sowing and closer spacing.

The remaining five components identified by Vincent and Quirke (2002) cannot be quantified using the data available from the survey.

Differences in herbicide outlays

Vincent and Quirke (2002) note that the use of zero tillage would reduce the size of *Phalaris minor* seed banks. Thus, the quantity of herbicides required to control the disease would be reduced over time. They estimated that cost savings could be around Rs600 and Rs700 per acre per year, potentially rising to above Rs1,000 per acre per year.

The Haryana survey dataset contains information on annual expenditure (in rupees) on herbicide, farm sizes and the amount of land under zero tillage. Farm sizes can be calculated from the sum of the amount of farmed land with and without irrigation, while the amount of land under zero tillage is also detailed. All farms had some area under zero tillage. Combining the above, the amount of land *not* under zero tillage can be calculated.

Importantly, while only 17 of the 93 responses indicated ownership of a zero-tillage drill, all farms indicated that they had at least some land under zero tillage. While a farmer may not own the equipment, farmers may have access to it; for example, by hiring the equipment from a neighbour. However, it is not possible to determine whether or not these farms had access to and used zero-tillage equipment before the project given the data's post-project perspective.

Table 4. Herbicide expenditure coefficient estimates

Variable	Expenditure on herbicides per acre under various land management systems (rupees per acre)
Land under zero tillage	65.5 (7.62)
Land not under zero tillage	60.1 (12.6)
Observations	95
F-statistic	93.1
R^2	0.667
Adjusted R^2	0.660

Standard errors in brackets. All results are significant at the 99% level. Source: CIE

Using econometric techniques to test the relationship between expenditure on herbicides and the area of land under or not under zero tillage, the data indicated that herbicide expenditure was higher for land under zero tillage. In fact, the data indicate that herbicide expenditure is Rp5.4 per acre more for land under zero tillage than otherwise. Table 4 gives the regression results. All results were calculated using the statistical package Stata 8.0.

The increase in herbicide costs may be explained by the short time between zero-tillage technology being adopted and the survey being collated. That is, farmers may not have had sufficient time to see the full effects of zero tillage, particularly in relation to the long-term trends in *Phalaris minor* seed banks. Thus, the appropriate adjustments to herbicide usage may not have been made. The dataset does not provide a breakdown on the exact herbicides used.

Differences in tillage costs

Vincent and Quirke (2002) note that the use of zero tillage would also reduce the costs of seed planting. Requiring less time, less machinery and implements, and thus diesel usage, it is estimated that cost savings of up to Rs800 per acre per year could be achieved under zero tillage.

Using expenditure data contained in the Haryana survey, farm-wide tillage costs can be derived from the expenditure on seed, fertiliser, hired labour during tillage and expenditure on other materials. These data are then combined with the farm size and land under zero tillage data used above.

Using econometric techniques, the data indicated that tillage expenditure is higher for land under zero tillage than otherwise by around Rs23 per acre. Table 5 presents the regression results. It should be noted that this finding is contrary to the findings of Vincent and Quirke.

With only 17 farms owning zero-tillage equipment, the remaining 76 farms are required to hire the equipment from these (and other) farms. Thus, while 17 farms would experience an increase in farm income due to the rental returns on the zero-tillage machinery, the remaining farms would be forced to incur higher expenditure. This additional cost for the majority may, to an extent, offset the savings from using the equipment in the first place.

Yield premium through early sowing and closer spacing

Under zero tillage, the time taken between rice harvest and wheat sowing is considerably shortened. Detailed in Vincent and Quirke (2002), when wheat is planted late in the season, yields fall by 12 kg per acre per day that sowing is delayed. Conversely, early sowing (up to 10 days earlier than normal) can increase yields by up to 1% per day. In their paper, Vincent and Quirke assume a yield increase of 61 kg per acre. The calculated gain from earlier sowing and closer spacing was determined to be Rs291 per acre per year.

Table 5. Tillage cost coefficient estimates

Variable	Tillage costs per acre under various land-management systems (rupees per acre)
Land under zero tillage	1,279 (185)
Land not under zero tillage	1,256 (306)
Observations	95
F-statistic	63.2
R^2	0.576
Adjusted R^2	0.567

Standard errors in brackets. All results are significant at the 99% level. Source: CIE

Table 6. Yield premium coefficient estimates

Variable	Wheat output per acre under various land-management systems (rupees per acre)
Land under zero tillage	11,217 (1 969)
Land not under zero tillage	11,012 (3 268)
Observations	95
F-statistic	42.7
R^2	0.479
Adjusted R^2	0.468

Standard errors in brackets. All results are significant at the 99% level. Source: CIE

Comparing the value of wheat output against land under the two land-tenure types, the results indicate that farmers receive Rs205 per acre more for land under zero tillage than they do for land under conventional tillage (see Table 6). This estimated output premium is 70% of the value predicted by Vincent and Quirke (2002).

Unquantifiable benefits

The Haryana survey data are unable to elucidate many of the eight components of gain identified in the previous economic analysis of the project.

Being a single year 'snapshot' of 100 surveyed farms, the data do not reveal the project's impact on the time-series benefits identified by Vincent and Quirke. As such, the following long-run benefits cannot be analysed:

- prevention of future decline in yield through the re-emergence of herbicide resistance
- avoidance of long-term yield decline through adverse effects of conventional tillage
- the prospect of more weed-competitive varieties in the long term.

Furthermore, Vincent and Quirke identify that farms using zero tillage are likely to use less diesel per hectare, leading to reduced carbon dioxide emissions. However, with less than 20% of the financial variables containing 90 or more responses, the gaps within the data also restrict the level of analysis. As such, it is not possible to assess the project's environmental impacts. It is also not possible to assess the change in on-farm water usage as a result of using zero tillage.

Vincent and Quirke also identify the likely benefits associated with the specific training in weed management provided to eight Indian weed scientists at the University of Adelaide. These scientists, through their collaboration with Australian and other experts, are now better equipped to put together holistic solutions to future weed-management problems, helping to avoid future sustained losses from weed infestation. Unfortunately, from the data available, it is not possible to quantify the benefits from the skill development and collaboration associated with the project.

What the data imply: the impact at the household level

As seen above, the Haryana survey data provide limited insights into the benefits from using zero tillage at the highly specific level of the Vincent and Quirke study. Zero tillage had no identifiable impact in reducing herbicide outlays or reducing costs associated with tillage. There is, however, an identifiable positive output response from improvement in wheat yields. Thus, the premium from using zero tillage is Rs175.5 per acre per year (see Table 7).

Applying these benefits to poverty analysis

Using this zero-tillage premium, it is possible to estimate the ex-ante farm profits by calculating the premium on all land under zero tillage and then subtracting that from the ex-post farm incomes, and thus establish a base-case scenario from which the farm level poverty impacts of the project can be established. It should be noted that this process is an estimate only, as it is difficult to exactly determine the baseline without pre-project survey data. For example, negative farm and household incomes may be calculated by subtracting the average zero-tillage premium from a particularly inefficient post-zero-tillage property. In this context, negative incomes are not evidence of poverty, but rather a function of poor data.

Pre zero-tillage incomes and poverty measures

Undertaking the calculations, the average per-person net income before the project being implemented is determined as Rs4 774 per month (in 2003 rupees) (Figure 5). Using the official poverty line, there are no individuals below the official poverty line for rural Haryana. That is, the poverty head-count ratio using the official poverty line is 0%. This is significantly below the official head-count ratio of 8.3% in 1999–2000 (Planning Commission 2002). Furthermore, this is much higher than the rest of India, with Haryana being one of the richest states in the country. Figure 5 sets out the calculated individual income distribution before the project was implemented.

As discussed in chapter 4, absolute poverty lines can be supplemented using a relative poverty measure. The *relative* poverty line for this group (measured as half the median income) is Rs1,837 per month. Using this relative poverty line, 138 individuals were living below the poverty line before the project was implemented. The corresponding Gini coefficient is 40.9.

Post-zero-tillage incomes and poverty measures

Comparing the poverty and income measures above with the post-project measures in chapter 4 provides an indication of the direct household impacts of the project upon poverty and income within the region. Table 8 summarises the results.

As a result of the project:

- average per person monthly income increased by Rs24 per month (roughly $0.70), or 0.5%

Table 7. Cost and revenue impacts of zero tillage—the zero-tillage premium

	Without zero tillage (rupees per acre)	With zero tillage (rupees per acre)	Change (rupees per acre)
Benefit			
Value of wheat output	11 012.0	11 216.5	204.5
Cost			
Herbicide expenditure	60.1	65.5	5.4
Tillage expenditure	1 255.8	1 279.4	23.6
Net benefit from zero tillage			175.5

Source: CIE

Table 8. Pre- and post-project income and poverty measures

Measures of poverty	Pre-project levels	Post-project levels	Change (absolute)
Mean monthly net income per person (rupees)	4,774	4,798	24
Gini coefficient	40.9	40.8	−0.1
Planning Commission poverty line			
Absolute monthly poverty line (rupees)	390	390	
Number of people under absolute poverty line	0	0	0
Head-count ratio (%)	0	0	
Half median poverty line			
Relative monthly poverty line (rupees)	1,837	1,837	
Number of people under relative poverty line	138	138	0
Head-count ratio (%)	26.6	26.6	

Source: CIE calculations

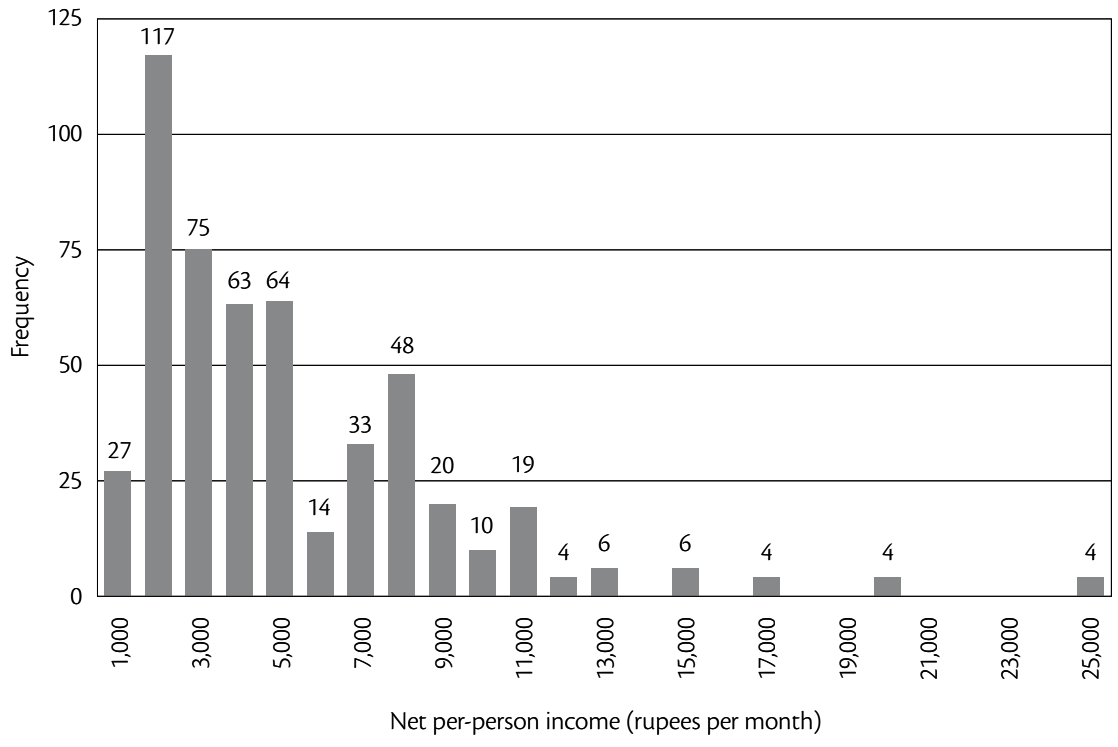

Figure 5. Calculated pre-project income distribution. Data source: CIE

- the number of people living in absolute poverty did not change, with all individuals pre and post the project living above the poverty line
- the number of people living in relative poverty did not change.

Comparing the distribution of pre- and post-project incomes (Figures 5 and 3, respectively), the level of income distribution has changed only slightly, with a relatively small number of individuals moving between income brackets.

Interestingly, however, while all individual incomes pre and post the project exceed the official poverty line, the degree of income inequality is significantly higher that the country-wide measure of 32.5 in 2000 (World Development Indicators 2005). Even after the project's benefits are distributed, the measured degree of income inequality is 40.8.

From the above, it is clear that the ACIAR-funded project has had a minor impact on poverty levels and incomes within the sampled households. This is in part due to the existing relative wealth of the farms sampled.

Broader economy-wide impacts

The broader economy-wide impacts of the weed-control package come about through a number of mechanisms.

- One such mechanism is through the impact of the weed-control package on commodity prices and hence the expenditures and living standards of domestic purchasers. By improving the productivity of these 100 farms, and other farms across the region, output will rise, resulting in either (or both) increased consumption or decreased prices for the commodities from these farms.
- Another broad impact of the project is through the potential flow-on effects of increased expenditures of the more profitable and productive farms adopting the ACIAR package on the profitability of industries supplying goods and services to farmers and hence the incomes of participants in these industries.
- A third broad impact relates to the associated environmental benefits from reduced diesel consumption and herbicide usage. Furthermore, zero tillage, by not tearing up the soil by ploughing, also helps to maintain soil moisture levels, thereby reducing the need for water. By reducing the demand for these inputs in the production process, there will be broader environmental impacts that will benefit, even slightly, rural communities in the immediate area.
- A fourth impact relates to the potential benefits from the flow-on of increased productivity on broader groups. With the income of relatively wealthy farmers increased, the demand for unskilled labour, both on and off-farm, may increase. Additionally, the increased wheat productivity may increase the supply of wheat, which may slightly lower its price. The more broadly the zero-tillage techniques are used, the larger these impacts.

It is, however, impossible to quantify any of these broader benefits using the data available, except to say that improvements in any one and all four together will have broader impacts upon poverty levels and the quality of life across the country to some degree.

6 Conclusion

This report has described a low-cost foray into the kind of research required to generate original information suitable for use in poverty and income impact analysis.

Using the survey data collected by the team at Haryana Agricultural University, the direct farm benefits from using zero-tillage technology were calculated. Specifically, a zero-tillage premium of Rs175 per acre was determined. That is, where zero tillage was implemented, farmers received on average Rs175 more per acre from that land than from land otherwise managed.

With the vast majority of farms in the region using zero-tillage technology on at least half their property, average per capita incomes increased by around 0.5% as a result of the project. There was, however, no impact on absolute or relative poverty levels of the households within the dataset given the relative wealth of the regions and the relatively small impact on overall per-person incomes. The increase in wheat production may lower overall wheat prices. This may have second-round impacts on poverty levels, with urban and rural poor benefiting from lower prices. It is, however, impossible to quantify any benefit from this using the data available.

This highlights a key issue with the project. On average, the Haryana region is one of India's richest and, within the state, the farmers surveyed are towards the top end of the state's income bracket. Thus, while a number of farmers have benefited from the project, the project has not had an impact on poverty levels, particularly within the poorer states of India.

A number of lessons can be drawn from this experience.

- Good quality data are expensive to obtain. While three of the components identified by Vincent and Quirke (2002) could be identified and quantified, the remaining five could not be assessed. Additionally, the poorer the quality of data, the weaker the results become. The two examples of farms with significantly negative per-acre net income highlight this problem.
- Poverty analysis should be integrated into the impact analysis. Ideally, the poverty impact analysis should be planned in advance of the project, which would provide the following benefits:
  - establish a baseline against which future surveys can be compared
  - identify early on and correct any data collection problems
  - ensure that the target group and the impact of the project on them fit within any overarching goals of the project.
- Ex-post surveys inevitably have problems. Undertaking the analysis ex post necessitates assumptions about what individuals and firms were doing before the project. Without a clear picture being available ex ante, the results rely on assumptions and are thus open to question. Furthermore, nonsensical results such as ex-ante negative incomes may be calculated.

The failure of the project to affect poverty also raises the question of the relationship between poverty measures and other measures of the net benefit of a project. Clearly, the project was valuable: it increased incomes and (according to Vincent and Quirke) yielded a positive benefit–cost ratio. It just didn't change poverty.

Whether this is an issue depends on the implicit social welfare function that ACIAR uses to evaluate its projects. As Angus Deaton (1997) has argued: 'poverty measures [are] likely to be an inadequate guide to policy' and 'a Pareto-improving project is surely socially desirable even when it fails to reduce poverty…it makes no sense to ignore policies that would improve the lot of those who are poor by many definitions, but whose incomes place them just above some arbitrary poverty line'.

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IMPACT ASSESSMENT SERIES

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1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
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