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# Rice–wheat cropping systems in India and Australia, and development of the 'Happy Seeder'

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# Rice–wheat cropping systems in India and Australia, and development of the 'Happy Seeder'

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Centre for International Economics

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2012

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Saunders C., Davis L. and Pearce D. 2012. *Rice–wheat cropping systems in India and Australia, and development of the 'Happy Seeder'*. ACIAR Impact Assessment Series Report No. 77. Australian Centre for International Agricultural Research: Canberra. 48 pp.

ACIAR Impact Assessment Series – ISSN 1832-1879 (print); ISSN 1839-6097 (online)

ISBN 978 1 921962 41 7 (print)
ISBN 978 1 921962 42 4 (online)

Editing and design by Clarus Design
Printing by Elect Printing

Cover: A progressive farmer in the Indian Punjab displaying his tractor-towed Happy Seeder to other farmers and project staff. The seeder sows wheat into the unploughed stubble of the previous rice crop. Photo: Simrat Labana

# Foreword

The expansion of India's rice–wheat cropping system during the green revolution was vital in lifting the country's harvests of staple cereals. But concerns are now being expressed about the sustainability of the system. The growth in yields that generated this expansion has slowed, while India's population continues to grow. This means demand for food keeps increasing at a time when the area of arable land is decreasing, through rising urbanisation and environmental damage that is emerging as the country strives to lift production.

In line with the mission to achieve more productive and sustainable agricultural systems, the Australian Centre for International Agricultural Research (ACIAR) has invested A$2.3 million (in nominal terms), around 43% of a total A$5.2 million (nominal) budget, across three projects to solve some of the problems in rice–wheat cropping that have arisen in northern India, and undertaken complementary research in south-eastern Australia, where a reappraisal of the practices associated with irrigated rice growing is needed. The initial project researched permanent beds for irrigated rice–wheat, and alternative cropping systems in north-western India and south-eastern Australia. This research increased scientific understanding and improved the capacity to research rice–wheat cropping on raised beds. It also helped to refine the modelling of the rice–wheat cropping system.

While researchers concluded that raised (permanent) beds are not suitable for rice–wheat cropping, their field experiments to evaluate the practices of soil tillage versus zero till led to the development of the 'Happy Seeder', an implement that attaches to the back of a tractor and facilitates the direct seeding of wheat into rice stubble. Measuring the benefits delivered by the Happy Seeder, which are both environmental and economic, is the focus of this impact assessment.

In addition to providing evidence of significant potential returns to the investment in the rice–wheat cropping projects, this impact assessment found many challenges to the Happy Seeder's early adoption. Dedicated extension programs may promote this promising farm implement, leading to greater acceptance and more widespread adoption. Farmers need comprehensive information and training to show them firsthand the benefits of introducing the Happy Seeder into their cropping systems.

**Nick Austin**
Chief Executive Officer, ACIAR

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# Acknowledgments

The authors thank those who assisted in the preparation of this impact assessment, particularly those who participated in the consultation undertaken in Punjab, India, during 16–20 November 2009.

For presentations provided by project researchers at the Punjab Agricultural University (PAU) in Ludhiana, India, we thank:

- Dr H.S. Dhaliwal, Additional Director, Extension Education
- Dr S.S. Kukal, Professor of Soil Conservation, Department of Soils
- Dr Yadvinder-Singh, Senior Soil Chemist, Department of Soils
- Dr H.S. Sidhu, Hub Coordinator, Cereal Systems Initiative for South Asia (CSISA)
- Dr Kulvir Singh Saini, Professor of Agronomy, Department of Agronomy, Agrometeorology and Forestry
- Dr Hari Ram, Wheat Agronomist, Department of Plant Breeding and Genetics
- Er Manpreet Singh, Assistant Engineer, Department of Farm Machinery and Power
- Professor John Blackwell, Agricultural Engineer, Charles Sturt University.

We especially thank Dr Yadvinder-Singh for arranging these presentations and, along with Manpreet Singh, for arranging and hosting our field visits. And, of course, this thanks extends to the farmers and PAU extension officers with whom we consulted during our field visits. They included:

*Village Kattu, District Barnala*

- Mr Gulzara Singh

*Village Kinoi, District Sangrur*

- Mr Jagdu Singh
- Mr Sukhoin Singh

*PAU Farm Advisory Services, Patiala*

- Dr Jaswinder Singh, District Extension Specialist
- Ms Gurpreet Kaur, District Extension Specialist (farm management)

*Village Shambhu, District Patiala*

- Dr Kulvinder Singh

*Village Kang, District Nawan Shahar*

- Mr Harijit Singh

*New Delhi*

- Dr Raj Gupta, International Maize and Wheat Improvement Centre.

We also wish to thank those who provided valuable input and comments on earlier drafts of this report:

- Dr Elizabeth Humphreys of the International Rice Research Institute
- Dr Rajinder Pal Singh of Industry & Investment NSW, Australia
- Maurice ‘Rip’ Landes of the United States Department of Agriculture
- Professor John Blackwell of Charles Sturt University, Australia
- Dr H.S. Sidhu of CSISA.

# Summary

Saving India from the brink of famine, the green revolution delivered substantial improvements in productivity and an expansion of cultivated lands. Under the green revolution, running from the 1960s all the way through to the 1990s, India's production of rice and wheat expanded enormously, leading to it now being the world's second-largest producer of rice and wheat. Within India, the state of Punjab is one of the most productive states for rice and wheat cropping, contributing 12% and 20%, respectively, to India's rice and wheat production, from only 1.5% of the geographical area (Mira Kamir, quoted in Kang 2010).

The expansion of rice–wheat cropping that occurred under the green revolution, and turned Punjab and surrounding states into the food bowl of India, has led to degradation of the natural environment. Falling groundwater, with pockets of rising groundwater and salinity,[1] is threatening the sustainability of rice–wheat cropping. Furthermore, the practices used to grow rice, including puddling, burning rice stubble, and the high usage of fertilisers and pesticides, are leading to degradation of air, soil and water quality.

The Australian Centre for International Agricultural Research (ACIAR) project LWR/2000/089, 'Permanent beds for irrigated rice–wheat and alternative cropping systems in north-western India and south-eastern Australia', was undertaken in both Punjab, India, and New South Wales, Australia, by CSIRO[2] Land and Water. The project was implemented in collaboration with Punjab Agricultural University in India, and Industry & Investment NSW (formerly New South Wales Department of Primary Industries) in Australia. It ran from January 2002 until the end of 2006. The primary output from this project, the 'Happy Seeder' implement, is being built upon by another ACIAR project, CSE/2006/124, 'Fine-tuning the Happy Seeder technology for the adoption in north-western India', undertaken by Charles Sturt University in collaboration with the International Rice Research Institute, Punjab Agricultural University and Industry & Investment NSW.

The total budget for the initial project on permanent beds for irrigated rice–wheat and alternative cropping systems was close to A$4 million (nominal). ACIAR contributed A$1.7 million to the initial project, then invested a further A$410,000 in the follow-on project, CSE/2006/124, to improve the design of the Happy Seeder.

In recognition of the policy issues and barriers to adoption of the Happy Seeder, ACIAR funded a policy-linkages scoping study (LWR/2006/132) to the amount of A$150,000.

This brings the total ACIAR investment to A$2.3 million (in nominal terms), forming around 43% of the A$5.2 million (nominal) budget of these three projects. In real present-value terms, total project costs were A$5.6 million, of which ACIAR contributed A$2.4 million.

## Outputs and adoption

The outputs of the two related projects can be grouped as:

- increased scientific understanding and improved research capacity, particularly in relation to rice–wheat cropping on raised beds

1 Mostly in non-rice–wheat areas (E. Humphries, pers. comm., 8 March 2011)

2 Commonwealth Scientific and Industrial Research Organisation

- refined modelling of the rice–wheat cropping system
- development and refinement of the Happy Seeder package (the machine and management practices for its use).

The Happy Seeder is an implement that attaches to the back of a tractor and facilitates the direct seeding of wheat into rice stubble. Although direct seeders have existed for some time, the innovation of the Happy Seeder is that it can seed directly into combine-harvested rice stubble, which includes a mix of anchored and loose straw. It thus removes the need to burn the rice stubble before planting the wheat crop.

Despite the benefits of the Happy Seeder, it faces considerable barriers to adoption. These include its cost, the risk aversion of farmers, and the subsidisation of herbicides and electricity. The subsidies diminish the incentive to adopt the Happy Seeder because a primary benefit of this technology is the reduced need for these inputs. To overcome these barriers, subsidies are currently available for purchase of Happy Seeders. Also, extension programs are being implemented by the Government of Punjab, together with field days, to demonstrate to farmers how to implement and gain the benefits of this technology. The Happy Seeder is also being heavily promoted in north-western India through the Cereal Systems Initiative for South Asia project supported by the Bill and Melinda Gates Foundation and the United States Agency for International Development.

## Benefits

The benefits delivered by the Happy Seeder are both environmental and economic. By removing the need to burn rice stubble, significant air pollution is avoided, soil nutrients are retained and soil organic matter is increased, leading to improved soil physical properties (e.g. water retention and nutrient cycling). The economic benefits are generated from the smaller number of field operations required (in comparison with conventional tillage or incorporation of residues), which reduces fuel (diesel) costs, and saves wear and tear on the tractor, and time (labour). Reduced water, fertiliser and herbicide inputs are also expected, although further studies are being undertaken to determine under what conditions these are most likely to be obtained.

By reducing the field operations, and labour, water and other inputs, the cost of production falls, directly benefiting farmers.

It is estimated that, in constant 2009 dollars, the project will deliver gross benefits of around A$96 million in present-value terms, using a discount rate of 5%. Of these benefits, A$41 million can be attributed to ACIAR on the basis of its contribution to the funding of this and associated projects.

These benefits far exceed the costs associated with the three projects, which were A$5.6 million (expressed in comparable terms). The net benefit of the research is A$90.4 million, representing a return of A$17.20 for every A$1 spent on this project. The internal rate of return is estimated to be 20%.

These estimated benefits are subject to significant uncertainty since most of them will occur in the future, and are highly dependent upon further developments in policy and technology that may affect the level of adoption.

## Conclusions

Despite the uncertainties associated with estimating the benefits from this project, the broad conclusion that this project is likely to deliver significant benefits is plausible in light of the examination of a range of assumptions undertaken as part of this assessment.

# 1 Introduction and overview

## Rice and wheat production in India

As staples of the Indian diet, rice and wheat are crucial to the food security of India. In response to the Bengal famine of 1943 and the subsequent and sustained period of food shortage, over the period 1967–78,[3] the green revolution saw production of rice and wheat expand rapidly across India. Expansion of the farming area, double cropping, improved genetics and increased inputs (water, nutrients, biocides) have seen production of rice increase almost three-fold from 53 million tonnes (Mt) in 1961 to 144 Mt in 2007, and wheat production from 10 Mt to 75 Mt over the same period (Figure 1).

This growth in production has led to India now being the world's second-largest producer of rice and wheat (Figure 2).

Within India, the states of Punjab and Haryana are considered to be the home of the green revolution. These states used high-yielding, short-duration cultivars, extensive fertilisers and pesticides, and irrigation, to increase their contribution to the total national food grain production from 3% before the green revolution to 20% in 2000.[4] However, the growth in yields that generated this expansion in production has since slowed. Moreover, with India's population currently growing at an annual rate of 1.34% (World Bank 2009), demand for food is increasing, the area of arable land is decreasing due to urbanisation and the pressure to increase production is ever growing.

## Rice–wheat cropping in Punjab, India

Rice and wheat grown in rotation is the most productive cropping system in India, covering approximately 10–12 million hectares (Mha).[5] The majority of the rice–wheat area is in the Indo-Gangetic Plain, which runs from west to east across northern India. Of the areas where rice and wheat are grown, Punjab is one of the most productive, with a cropping intensity of 189% vis-à-vis the national rate of 134% (H.S. Sidhu, pers. comm., 16 November 2009), facilitating its contribution to the central pool; Punjab contributes 40–50% of the rice and 50–70% of the wheat in the central pool, from only 1.5% of the land (E. Humphreys, pers. comm., 2 March 2011).

Rice is a summer crop, conventionally grown in fields (paddies) that are puddled and flooded. It is typically grown first in nurseries, then transplanted into the paddies in June. The paddy field usually remains flooded until the rice is almost ready to be harvested, when it is then drained. After combine harvesting of the rice, crop residues remain (anchored stubble and loose straw), making it difficult to seed the wheat crop to follow. Because there are limited options for managing the rice stubble, the most common approach adopted is to burn it.

3 While effort was made before 1967 to improve food self-sufficiency, it was not until the practices and policies embodied in the green revolution were introduced that India had any success at improving domestic food supply.

4 Proposal by CSIRO Land and Water to ACIAR for project LWR/2000/089 (2001, p. 9)

5 Proposal by CSIRO Land and Water to ACIAR for project LWR/2000/089 (2001, p. 9)

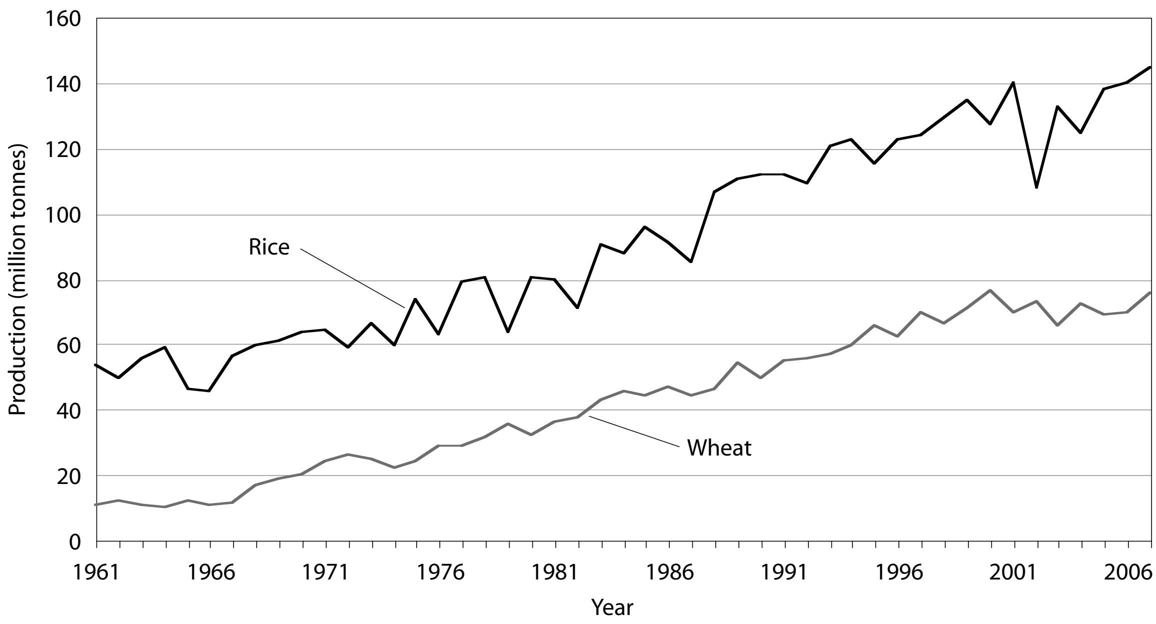


**Figure 1.** Production of rice and wheat in India, 1967–2007. Source: FAOSTAT at <http://fao.stat.org>

Unless the farmer intends to use zero tillage to sow the wheat, the field is typically prepared for planting wheat with one discing, two tine harrowings, two plankings[6] and an irrigation (Singh et al. 2008), although the number of tillage passes can exceed this (Gajri et al. 2002). Wheat is typically sown on the flat and, depending on seasonal conditions, with 2–6 irrigations, but many less than rice. After the wheat crop has been harvested, the field lies fallow for about 2 months before it is time to begin the cycle again and plant rice.

### The problem

While the expansion of the rice–wheat cropping system under the green revolution was important in terms of providing food, concerns have developed over the sustainability of rice–wheat cropping. In expanding the rice–wheat cropping area, production has also moved onto soils less suitable for flooded rice cultivation.

In the drier rice–wheat cropping areas of northern India, substantial irrigation is required, contributing to the depletion of groundwater. In Punjab and Haryana, approximately 95–98% of the rice–wheat cropping area is irrigated, with over 90% of water requirements sourced from groundwater (Ambast et al. 2006). This has contributed to a fall in watertable levels in central Punjab (the main area for rice–wheat cropping) by more than 33 centimetres per year from 1979 to 1994 in 46% of the area.[7]

The conventional method of puddling rice is also damaging the soil. In puddling the soil for rice, a thick hardpan can develop, which restricts root growth in crops grown in rotation with rice. The constant flooding of the soil also leads to greater losses of soil and fertiliser nitrogen.

The practice of burning the rice stubble has a substantial negative effect on the environment. More than 90% of the 17 Mt of rice stubble in Punjab are burnt each year, resulting in thick smoke blanketing the region, since the burn-off occurs over a short period (Singh et al. 2008, p. 3). The air pollution caused by this burn-off has serious adverse health effects on humans and animals; it has been blamed for causing road accidents and the closing of airports due to poor visibility (Singh et al. 2008, p. 14). Furthermore, the burning results in the loss of nutrients and organic matter from the soil.

6 Planking is a process applied to level and slightly compact the soil.

7 Proposal by CSIRO Land and Water to ACIAR for project LWR/2000/089 (2001, p. 11)

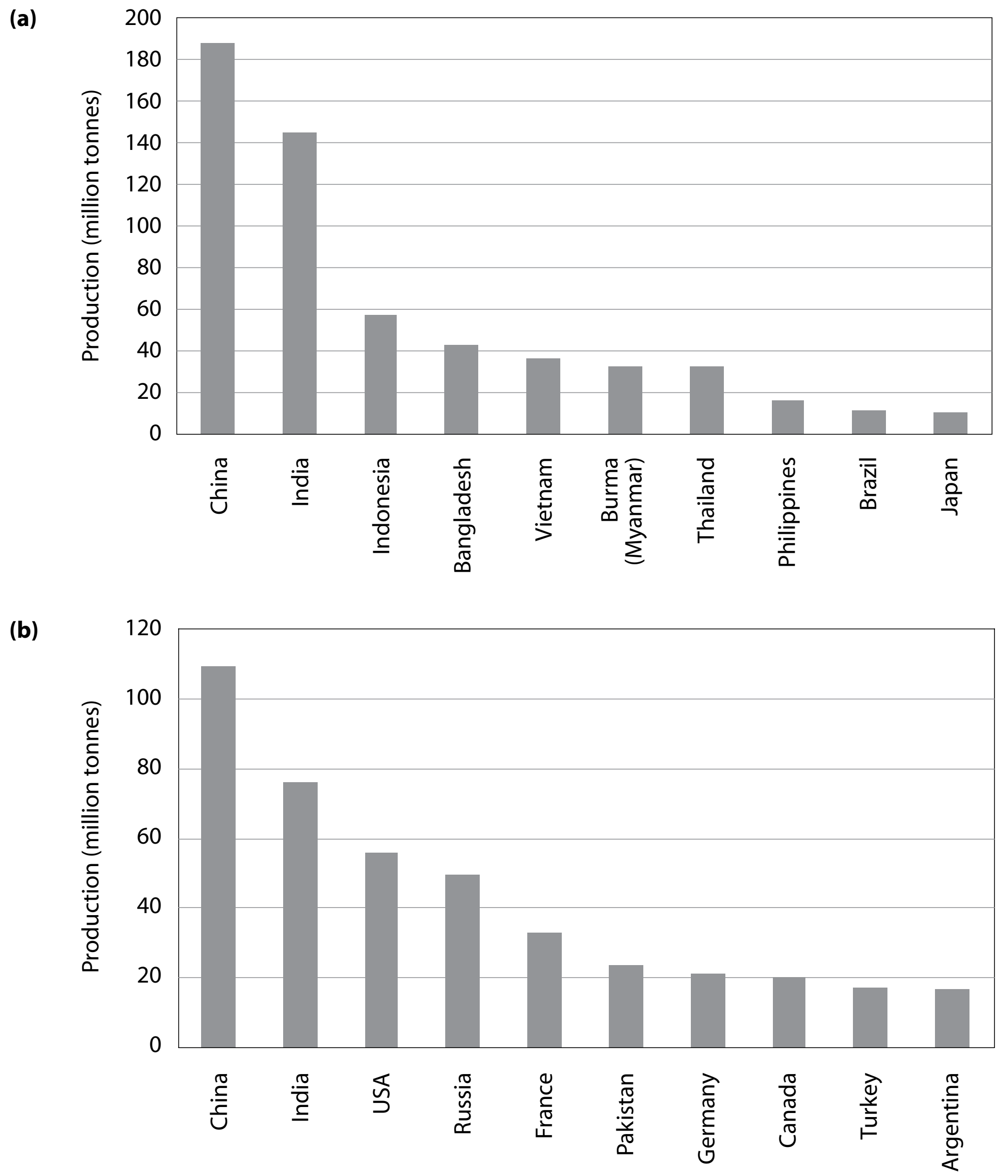


**Figure 2.** The world's top 10 producers of (a) rice and (b) wheat in 2007. Source: FAOSTAT at <http://fao.stat.org>

## Rice cropping in New South Wales, Australia

Rice is grown in the southern region of New South Wales (NSW), over an area that has gradually increased to around 150,000–180,000 hectares (ha) annually.[8] The initial expansion of the rice-growing region occurred in response to deregulation of rice production and the increasing availability of irrigation water. However, the water has now become less available due to decreasing rainfall and increasing allocation of water to industry and the environment.

### The problem

Despite good management of disease and water, which delivers single-crop rice yields among the highest in the world, at the time of commencement of the project the sustainability of irrigated agriculture in rice-growing areas of southern Australia was being threatened by salinisation caused by rising watertables. Before the

8 Grains Research and Development Corporation (2006), project number DAN00002, 'Permanent beds for sustainable cropping systems on irrigated farms'

onset of prolonged drought in 2002 (Humphreys et al. 2008), large portions of the irrigation areas and districts had a watertable within 2 metres of the surface, with 40–50% of the problem attributed to ponded rice growing.[9]

With the current practice of ponded rice on contoured layouts, problems of soil degradation (especially in wet years), poor water management and waterlogging of crops grown in rotation with rice (using the rice layout) are emerging. Furthermore, conversion from the contoured layouts for rice to contours better suited to non-rice crops is inconvenient and expensive, limiting the non-rice crop to relatively low-value crops (winter cereals) and annual pastures.[10]

## The projects

In light of the declining sustainability of the current rice-cropping practices, the Australian Centre for International Agricultural Research (ACIAR)-supported project LWR/2000/089, 'Permanent beds for irrigated rice–wheat and alternative cropping systems in north-west India and south-east Australia', was developed to assess alternative practices for growing rice sustainably, with a focus on growing it and alternative crops on raised beds.

Raised beds are those where the cropping zones sit above the furrows, and are constructed by moving the soil from the furrows and adding it to the zones where the crops are planted. The furrows serve as irrigation channels, drains and traffic zones. The raised beds can be semi-permanent, where they are left in place for several years at a time, or constructed for each crop rotation.

Extensive research and numerous field studies have been undertaken on raised beds across different countries, climates, soils and crops, with the general results showing environmental benefits and cost savings (and sometimes both). The benefits from raised beds include irrigation water savings, improved soil structure from reduced compaction, less waterlogging and improved horizontal infiltration of water.[11]

However, given the number of different variables across these studies, the evidence on the suitability for permanent raised beds for rice–wheat cropping in north-western India and south-eastern Australia was not clear. The ACIAR-supported project was undertaken to fill this gap in collective understanding. In the previous studies and farmer field trials in India, wheat (or another interchangeable crop) had been grown on the raised beds, which were then dispersed before puddling the soil for rice. Then, after harvesting the rice, the beds were re-formed. The ACIAR raised-bed project differed in that it assessed *permanent* raised beds, investigating the feasibility of achieving the additional gains for rice–wheat cropping that permanent beds had been hypothesised to provide. Permanent beds reduce the number of machinery operations (from many tillage and levelling passes for each crop, to simply direct seeding and occasionally reshaping the beds/furrows), fuel costs and greenhouse gas emissions, as well as time savings in land preparation. They can also greatly reduce the turnaround time between crops, providing greater flexibility in crop rotation and enhanced capacity to respond rapidly to market opportunities.

The ACIAR project initially comprised six subprojects focused on different aspects of the use of permanent raised beds in rice–wheat cropping systems. Four subprojects were field experiments used to compare different layouts and agronomic options for permanent raised beds. The first field experiments, in subproject one, were used as preliminary experiments to guide the design of subsequent field activities, evaluating the planting, and water, nitrogen and stubble management options.

Building upon subproject one, subproject two was a 4-year field experiment on two soil types, comparing rice–wheat on permanent beds, fresh beds and conventional layouts/tillage in Punjab, India, and NSW, Australia.

Subproject three comprised medium-term (3-year) field experiments to evaluate soil tillage versus zero till, beds versus flats and wheat residue management options for maize–wheat and soybean–wheat systems in Punjab.

9 Proposal by CSIRO Land and Water to ACIAR for project LWR/2000/089 (2001, p. 11)

10 Proposal by CSIRO Land and Water to ACIAR for project LWR/2000/089 (2001, p. 12)

11 Proposal by CSIRO Land and Water to ACIAR for project LWR/2000/089 (2001, p. 17–21)

The initial work also produced an implement that could be attached to a tractor and which was effectively a seed drill attached to a forage harvester, with the capability of direct drilling wheat into rice residues on the flat or on beds. Because the implement showed potential, a request for additional funding was made, and granted, with an additional subproject added to this project (ACIAR 2002).

Subproject four evaluated different nitrogen application rates and residue management for rice and wheat on permanent raised beds and with conventional tillage.

Subproject five focused upon the calibration, evaluation and refinement of a computer model to help identify management options for maximising the productivity of rice–wheat cropping systems.

Subproject six was an economic assessment of permanent raised beds, which drew heavily upon the field experiments undertaken in the other subprojects.

As mentioned above, the initial work undertaken in subproject three, looking at stubble management options, produced a combined mulcher and planter, which became known as the 'Happy Seeder'. Under an additional subproject, subproject seven, this initial work was extended through research, experimentation and design development, resulting in the production of several versions of the Happy Seeder. An economic evaluation of the Happy Seeder was also undertaken as part of this subproject.

## Project funding

There were numerous contributors to the funding of the ACIAR raised-beds project, LWR/2000/089, with ACIAR being the largest single funder, contributing over A$1.7 million of the A$4.0 million budget. CSIRO and NSW Agriculture also made substantial contributions. Funding details are given in Table 1.

ACIAR project CSE/2006/124, 'Fine-tuning the Happy Seeder technology for the adoption in northwest India', followed on from the ACIAR raised-bed project. The aim of the follow-on project was to further refine the Happy Seeder, to increase the likelihood of its adoption. Consequently, the cost of the follow-on project (Table 2) is included in this impact assessment. Again, ACIAR

**Table 1.** Funding of ACIAR project LWR/2000/089, 'Permanent beds for irrigated rice–wheat and alternative cropping systems in north-west India and south-east Australia'

| Organisation | 2002[a] | 2002–03 | 2003–04 | 2004–05 | 2005–06 | 2006[b] | Total |
|---|---|---|---|---|---|---|---|
| | A$ | A$ | A$ | A$ | A$ | A$ | A$ |
| ACIAR | 183,732 | 387,988 | 310,236 | 346,937 | 300,287 | 183,811 | 1,712,991 |
| CSIRO Australia | 68,271 | 143,976 | 153,934 | 159,967 | 166,365 | 86,179 | 778,692 |
| NSW Agriculture | | 206,978 | 209,137 | 211,173 | 213,398 | | 840,686 |
| Rice Cooperative Research Centre | 50,000 | | | | | | 50,000 |
| Punjab Agricultural University | 8,650 | 17,300 | 17,300 | 20,600 | 20,600 | 8,650 | 93,100 |
| International Atomic Energy Agency | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | | 90,000 |
| INCITEC (fertiliser company) | | 5,000 | 5,000 | 5,000 | 5,000 | | 20,000 |
| Grains Research and Development Corporation, Australia | 210,933 | | | | | | 210,933 |
| Rural Industries Research and Development Corporation, Australia | 201,108 | | | | | | 201,108 |
| Total | 740,694 | 779,242 | 713,607 | 761,677 | 723,650 | 278,640 | 3,997,510 |

Source: Proposal by CSIRO Land and Water to ACIAR for project LWR/2000/089 (2001, p. 5)

a Refers to the second half of the 2001–02 financial year

b Refers to the first half of the 2006–07 financial year

**Table 2.** Funding of ACIAR Project CSE/2006/124, 'Fine-tuning the Happy Seeder technology for the adoption in northwest India'

| Organisation | 2007–08 | | 2008–09 | | 2009–10 | | Total |
|---|---|---|---|---|---|---|---|
| | 1 October | 1 April | 1 October | 1 April | 1 October | 1 April | |
| | A$ | A$ | A$ | A$ | A$ | A$ | A$ |
| ACIAR | 74,472 | 64,352 | 75,046 | 67,146 | 81,025 | 48,089 | 410,130 |
| Charles Sturt University | 36,900 | 36,900 | 36,900 | 36,900 | 36,900 | 36,900 | 221,400 |
| NSW Department of Primary Industries | 4,851 | 4,851 | 4,851 | 4,851 | 4,851 | 4,851 | 29,106 |
| Punjab Agricultural University (funds distributed through IRRI) | 13,027 | 13,027 | 13,027 | 13,027 | 13,027 | 13,027 | 78,162 |
| International Rice Research Institute (IRRI) | 10,550 | 10,550 | 10,852 | 10,852 | 11,162 | 11,162 | 65,128 |
| Dasmesh Mechanical Works, Amagah | 20,000 | | 20,000 | | 20,000 | | 60,000 |
| National Agro Engineering | 20,000 | | 20,000 | | 20,000 | | 60,000 |
| Total | 179,800 | 129,680 | 180,676 | 132,776 | 186,965 | 114,029 | 923,926 |

Source: ACIAR project documents

was the largest single contributor to project funding, committing A$410,130, approaching half of the total budget of A$923,926.

Finally, a third ACIAR project, LWR/2006/132, 'The Happy Seeder: policy barriers to its adoption in Punjab, India', has been undertaken to assess the range and scale of policy related issues relevant to the adoption of the Happy Seeder. This too has been incorporated into the impact assessment, with ACIAR providing close to 80% of the A$188,148 budget (see Table 3).

In addition to the costs associated with the implementation of these projects, the extension officers within Punjab promote the Happy Seeder and assist with its adoption. Based upon one extension officer for each of the central rice–wheat growing districts (12 in total), the total cost was A$130,363 for the 3 years to 2009 (R.P. Singh, pers. comm., 29 June 2010).

**Table 3.** Funding of ACIAR project LWR/2006/132, 'The Happy Seeder: policy barriers to its adoption in Punjab, India'

| Organisation | 2007–08 | 2008–09 | 2009–10 | Total |
|---|---|---|---|---|
| | A$ | A$ | A$ | A$ |
| ACIAR | 80,000 | 64,494 | 5,000 | 149,494 |
| NSW Department of Primary Industries | 21,401 | 17,253 | | 38,654 |
| Total | 101,401 | 81,747 | 5,000 | 188,148 |

Source: Budget for ACIAR project PLIA/2006/132, which became project LWR/2006/132

# 2 Project outputs

ACIAR project LWR/2000/089, 'Permanent beds for irrigated rice–wheat and alternative cropping systems in north-west India and south-east Australia', focused on researching and evaluating different methods of rice–wheat cropping, particularly the use of raised beds. This project was undertaken as seven subprojects with the outputs corresponding to these smaller subprojects. The follow-on project, CSE/2006/124, focused on enhancing the Happy Seeder technology for adoption in north-western India. Cumulatively, the outputs of the projects can be grouped as:

- increased scientific understanding and improved research capacity, particularly in relation to rice–wheat cropping on raised beds, and residue retention
- refining modelling of the rice–wheat cropping system
- development and refinement of the Happy Seeder package (the machine and management practices for its application).

## Scientific understanding and research capacity

Through the field experiments, further insights were gained into how crop performance varies across different layouts, establishment methods, amounts and frequency of irrigation, fertiliser application and mulching. These field evaluations were carried out across different sites in Punjab, India, and NSW, Australia. Different soil types were accounted for in analysing the results of the field experiments.

The main output from the field experiments was an increase in understanding of the potential applicability of raised beds under different cropping and agroclimatic conditions.

Much of this knowledge has been documented in 'Permanent beds and rice residue management for rice–wheat systems in the Indo-Gangetic Plain', the proceedings of a workshop organised by the project team at Ludhiana in September 2006 (Humphreys and Roth 2007). By the end of 2007, the project team had also had published 14 papers in peer-reviewed scientific journals and books, presented 35 conference and workshop papers, written 13 articles in farmer publications and prepared a range of other papers (Humphreys et al. 2008). Since then it has added a further five papers to the scientific literature.

To elucidate the financial drivers of adopting permanent raised beds, an analysis of the costs and benefits of permanent raised beds for rice–wheat, maize–wheat and soybean–wheat cropping systems in Punjab was undertaken. It was hypothesised that permanent raised beds could generate cost savings through:

- yield increases
- reduced labour costs through shorter irrigation times and fewer irrigations
- reduced tillage costs in comparison with conventional tillage.

The financial analysis showed that, while permanent raised beds were more profitable than other layouts for soybean–wheat and maize–wheat rotations, fresh beds were a more profitable layout for rice–wheat cropping because of yield decline of rice on permanent beds (Dhaliwal et al. 2007). While rice–wheat cropping remains, overall, the most profitable crop to harvest, maize and soybean, with their lower irrigation requirements, provide greater environmental benefits than rice–wheat cropping in the form of reduced energy consumption for pumping and *possibly* reduced water depletion (Humphreys et al. 2010).

Furthermore, in undertaking this project, the capacity of the researchers and scientists has been greatly improved. The skills and capacity of Punjab Agricultural University (PAU) researchers in particular, have been enhanced through multidisciplinary, cross-department teams, an exception to the normal mode of within-department conduct of research at PAU. Four of the projects' research fellows have also completed, are in the latter stages of, or have been enrolled in PhD programs (three in Australia), and one of the field coordinators has completed a Bachelors degree in agricultural economics as a result of the project, and is now doing a Masters degree. Furthermore, at least one of the investigators from the PAU team greatly benefited from exposure to international project management training through ACIAR's John Dillon Fellowship program and is now playing a leading management role in the dissemination of technologies in Punjab in the large Cereal Systems Initiative for South Asia project. The skills and capacities of the Australian scientists to undertake international collaborative research were also greatly enhanced and this has led to many new developments (E. Humphreys, pers. comm., 9 March 2011).

### Modelling of the rice–wheat cropping system

Data from the field experiments were used to calibrate and validate existing crop models for raised-bed and conventional rice–wheat cropping systems.

Building on the existing DSSAT[12] crop-modelling software, this project developed routines that allow the selection of automatic irrigation management that more closely reflects recommended or farmer practice for both rice and wheat. The code has been provided to the maintainers/developers of DSSAT, but has yet to be incorporated into the standard version (Humphreys et al. 2008).

The modelling studies have informed and validated several of the practices for rice–wheat cropping:

- the optimal date for planting wheat (variety PBW343), in terms of yield and water productivity, is late October to mid November
- changing from continuous flooding to the recommended water management practice for puddled, transplanted rice reduces irrigation input, but does not 'save' water
- the recommended irrigation management for puddled, transplanted rice is optimal in terms of maximising yield and irrigation water
- the recommended transplanting date for rice has been reconfirmed, although this may lead to later harvest (and later wheat sowing) with the long-duration variety of rice in some years.

### Development of the Happy Seeder

The process of developing the Happy Seeder involved three major prototypes in the original project, with further refinements funded through the follow-on project. The first version of the Happy Seeder, the Trailing Happy Seeder, consisted of a zero-till seed drill behind a forage harvester with a modified chute. It had flexibility, but poor manoeuvrability and visibility of the seed drill. This was followed by the Combo+ Happy Seeder, which was developed in collaboration with Dasmesh Mechanical Works. It combined the forage harvester and seed drill into a single, lightweight and compact machine. The Combo+ Happy Seeder also included strip tillage in front of the sowing tines. As with the first version, the Combo+ Happy Seeder generated considerable dust, making it difficult, due to the inability to see the sowing lines under the mulch, to line up adjacent passes. The third prototype, the Turbo Happy Seeder, eliminated the chute by chopping the straw finely in front of the tines and feeding it past them, reducing the dust and making it easier to see the sowing lines.

To establish the cost-effectiveness of the Happy Seeder, a financial gross-margin analysis (see Box 1) was undertaken on the Combo+ Happy Seeder as part of project LWR/2000/089.[13] While this analysis

[12] Decision Support System for Agrotechnology Transfer; details at <icasa.net/dssat>

[13] Cost-effectiveness refers to the comparison of the relative costs of multiple activities. This is particularly appropriate in the context of the Happy Seeder, since there are multiple methods for rice–wheat cropping and the financial analysis allows the comparison of the costs of these different options.

relies on some assumptions, the results confirm that the Happy Seeder can be cost-effective for farmers (Singh et al. 2008).

By facilitating direct seeding into the rice stubble, the Happy Seeder reduces the number of field operations required to prepare the field for planting wheat. This has the benefit of saving fuel and labour, and the rice stubble need not be burned. Retaining the straw as mulch reduces the need for herbicide and, in the medium term, should also reduce the amounts of nitrogen and potassium fertiliser needed. Furthermore, sowing wheat immediately after the rice harvest reduces the need for a pre-irrigation, which saves energy (electricity for pumping water) and reduces the loss of water by evaporation between rice harvest and wheat establishment (a real water saving).

**Box 1.** Gross-margin analysis

Gross-margin analysis looks at the return from a particular crop (yield multiplied by the farm-gate price) less the variable costs of production (non-variable costs are not considered).

This analysis facilitates comparison of the profitability of rice–wheat cropping using the Happy Seeder and the conventional practice of establishing wheat after the rice harvest.

Because the Happy Seeder technology is new and emerging, there are uncertainties associated with the cost of operating the equipment (particularly in a commercial sense) and the change in the inputs as a consequence of adopting the technology.

# 3 Adoption of project outputs

Adoption of each of the three primary outputs—improved understanding of permanent raised beds, rice–wheat cropping model, and the Happy Seeder—is discussed in turn.

## Permanent raised beds

While the experiments and activities of this project have helped improve knowledge and understanding of growing crops on permanent raised beds, it is the performance of crops on raised beds that ultimately determines whether they will be adopted.

Field experiments on the suitability of permanent raised beds for rice–wheat, maize–wheat, soybean–wheat and other rice-based cropping systems were undertaken in Punjab and NSW. The results of these experiments, and their implications, differ between the locations, so they are discussed separately.

### Punjab, India

Previous experiments have shown that continuous ponding, as is the conventional practice for growing rice, was not necessary, and that yields could be sustained while reducing irrigation input. Studies have also shown that tillage is not necessary for growing wheat. The results of the ACIAR project confirmed these findings on two soil types.

However, the experiments undertaken as part of this project showed that the yield of transplanted rice on permanent beds declined with the age of the bed (Yadvinder-Singh et al. 2009), and that the yield decline was even greater when rice was dry-seeded on beds. Furthermore, there was no irrigation water saving on the permanent beds (and an increase in water use on one soil type due to the development of macropores). However, the yield of transplanted rice on fresh beds was similar to that of puddled transplanted rice with the same water management (irrigation 2 days after the ponding of the soil surface/furrow has ceased).

Wheat, on the other hand, grew well when direct-drill planted on the raised beds. Despite the fact that wheat performs well on the raised beds, the poorer performance of rice on older beds has led scientists to conclude that *permanent* raised beds are not suitable for rice–wheat cropping with current rice varieties and under the soil and climatic conditions of the north-western Indo-Gangetic Plain (IGP), where rainfall is lower than in the eastern IGP (Yadvinder-Singh et al. 2009). In the eastern IGP countries of Bangladesh and Nepal, rice and wheat transplanted on permanent raised beds have performed better than when grown under conventional tillage (Humphreys et al. 2008).

While there is the possibility of the use of fresh raised beds for wheat in rotation with puddled transplanted rice, this practice requires that the beds be made and dismantled for each crop.

The project findings led to PAU's decision to recommend against permanent raised beds for rice–wheat systems, but to favour transplanted rice on fresh beds in rotation with wheat, a system in which the beds are made once a year.

Fresh and permanent beds were also evaluated for soybean–wheat and maize–wheat systems. These crops are generally better suited than rice to coarser textured soils, which make up about 5% of Punjab soils. Furthermore, permanent raised beds were the most profitable of the layouts trialled (but only marginally more so than double zero tillage on the flat), reducing the costs of tillage, labour and wheat seed (Dhaliwal et al. 2007). However, this work was done on a coarse-textured soil with no history of rice culture. Other studies have shown that beds can make the difference between a failed and a good crop on fields with a history of rice growing and which have a well-developed hard pan that can lead to waterlogging problems during the rainy season (Ram et al. 2005). Thus, diversification from rice–wheat cropping to soybean–wheat or maize–wheat requires more research and extension effort, and new marketing arrangements to enable soybean and maize to be able to compete with the existing guaranteed minimum support price and procurement scheme for rice. Consequently, adoption is unlikely, with no evidence to date of adoption occurring outside the extension program.

**New South Wales, Australia**

The field experiments in Australia, conducted on a much heavier (clay) soil, showed that the yield of direct-seeded rice on permanent raised beds is comparable with the yield on flat beds, provided the furrow gap is not too wide and the crop is protected by deep water during the pollen microspore growth stage. Other crops (wheat, barley and soybean) were also successfully grown in rotation with rice. Yields of wheat on the beds were comparable with yields on the flat, although past studies in the region had shown higher yields of wheat on beds, due to reduced waterlogging. However, the rains were well distributed with below-to-average totals, therefore waterlogging was not a problem in the flat plots.

This work was undertaken in Australia at a time when the region was entering a prolonged drought, which meant that farmers had to greatly reduce their rice area, and ultimately cease rice cropping altogether (until the drought broke in late 2010). Conditions were therefore not conducive for farmers to be investing in new layouts and methods of rice production.

Further evaluation and demonstration of the concept needs to be undertaken under a variety of different conditions (especially soil type) before there will be significant adoption. Growing rice on raised beds in rotation with other crops is currently feasible for farmers who have developed terraced layouts, with beds running on the flat within each irrigation bay, for growing a range of crops. Such layouts offer many advantages, including rapid irrigation and drainage of the beds, a minimal amount of drainage water leaving the bottom of the field and requiring recycling, and the ability to pond water on the beds if needed (e.g. to achieve complete soaking of the beds or to pond water for protection of rice from cold damage).

The extent of adoption is likely, however, to be constrained by existing land slope, since it may not be economical to develop the necessary terraces on very flat land. Furthermore, a lack of district infrastructure may inhibit the provision of irrigation flow rates sufficient to deliver the volume required by the irrigation layouts. Raised beds are also unlikely to be suitable for farmers who have mixed livestock and cropping enterprises, because of the risk that the beds pose to the animals (Humphreys et al. 2008), although opinion is divided on this.

**Happy Seeder**

The response to the Happy Seeder has been positive and, as discussed in the second section of this report, several iterations of the implement have been developed. There has also been a rollout of the Happy Seeders to farmers through the trial and farm extension programs.

Cooperative societies hold the largest number of Happy Seeders, with around 180 machines. More than 20 farmers also have the latest version of the machine, with another 20 held by PAU, the Cereal Systems Initiative for South Asia project and government departments (H.S. Sidhu, pers. comm., 13 April 2011). This is an increase from roughly 50–70 machines in late 2009 (Y. Singh, pers. comm., 16 November 2009). These machines were used to sow an estimated 2,000 ha in the 2010–11 season (H.S. Sidhu, pers. comm., 13 April 2011).

To encourage adoption of the Happy Seeder, a government subsidy is provided to purchase the machine. The initial subsidy was 25% of the cost, increasing to 33%, and by 2009, to 50% (H.S. Sidhu, pers. comm., 16 November 2009). More recently, on 29 March 2011, officials from the Punjab state government announced at a farmer gathering that they will provide a 60% subsidy to all the farmers or operators in the coming season (H.S. Sidhu, pers. comm., 13 April 2011).

While the field experiments and extension efforts show that the Happy Seeder has the potential to change the ways in which rice residues are managed and wheat is sown, there are some potential constraints to its adoption. They have been identified in ACIAR project LWR/2006/132, 'The Happy Seeder: policy barriers to its adoption in Punjab, India', as:

- engineering design issues
- agronomic issues
- financial viability of the technology
- distorted price signals
- government policies
- manufacture of the implement
- training and extension issues
- purchase price.

We deal with each of these in turn.

**Engineering design issues**

Refinements to the Happy Seeder have continued to be made throughout the course of project LWR/2000/089, as well as in follow-on project CSE/2006/124. A major focus was the development of a Happy Seeder that could be powered by a 35 hp (26 kW) tractor. The latter project also investigated how to best manage nitrogen fertilisation and irrigation for crops sown into rice residues with the Happy Seeder, and the development of a low-cost straw spreader for combine harvesters. These refinements continue to improve the performance of the implement and increase the likelihood of its adoption.

**Agronomic issues**

Many of the field experiments investigated the agronomic constraints associated with the use of the Happy Seeder. The investigation needs to continue so as to determine, for example, the effect of straw mulch on soil moisture and irrigation requirements, and to refine nitrogen management across different sites and climatic conditions.

As with the engineering design issues, further research will provide better understanding of the farming practices that will yield the best results from the use of the Happy Seeder.

**Financial viability**

The financial viability assessment (see Box 2) of the Happy Seeder used a partial budgeting approach in which the foregone annual costs and benefits associated with the Happy Seeder were compared with the estimated net gains from adopting it.

This analysis showed that, over a 20-year period (the life of a Happy Seeder), the Happy Seeder generated net present value benefits of rupees (Rs) 31,910/ha over the practice of tillage after burning rice stubble, and Rs9,420/ha over the practice of burning stubble and zero tillage (Singh et al. 2008).

While the financial analysis indicates that the Happy Seeder will provide financial benefits to farmers and is more profitable than conventional alternatives, the evaluation was restricted by shortages of time and data, and was undertaken under assumptions of contract provision of Happy Seeder sowing services for an 'average' farm. Consequently, the implications of uncertainty in some of the key variables in the analyses have yet to adequately assessed, and investigations for a range of farm circumstances have not yet been undertaken. Given the expected sensitivity of the financial viability of the technology to these factors, firm conclusions about financial viability cannot yet be made (Pagan and Singh 2006).

**Box 2.** Economic versus financial assessment—what is the difference?

In undertaking a financial evaluation, financial values are used for all the relevant inputs and outputs, which refer to the actual prices, revenue received by farmers for outputs, and the actual costs paid by farmers for inputs used or losses suffered. In an economic evaluation, inputs and outputs are priced at the value placed on them by society, which can include environment and amenity values, as well as opportunity cost.

#### Distorted price signals

Building the case for economic feasibility, as opposed to financial viability, is complicated by price-distorting government policies. The Government of India provides subsidies for several of the inputs used in agricultural production, including irrigation water, electricity for pumping water, petroleum products, fertiliser, herbicides and pesticides (Singh et al. 2008).

In pricing the inputs too low, the incentive for using resources sustainably is impaired. For example, because there is no marginal cost associated with pumping water, there is minimal financial incentive for farmers to reduce water consumption. This is in spite of the fact that watertables have fallen considerably in the rice–wheat cropping areas of Punjab (Humphreys et al. 2008). Furthermore, this water source is being contaminated by the use of fertilisers, which are leaching into the groundwater. The need for fertilisers is increased by the practice of burning rice stubble, since nutrients are thereby lost to the atmosphere and subsequently need to be replaced.

Electricity is used for pumping the water used to irrigate crops, but because there is no marginal cost associated with pumping water, there is minimal financial incentive to reduce energy consumption. Furthermore, the externalities associated with the degradation of the environment accrue to the community as a whole, with the solution requiring collective action from farmers. Individual farmers, however, have no incentive to avoid burning rice stubble.

#### Government policies

While the government has a ban on the burning of rice stubble, it is not enforced, because of the perception that there is no suitable alternative to burning (Pagan and Singh 2006). However, the reality of this is challenged, with the Punjab Science and Technology Council, the Punjab Pollution Control Board and the Punjab Farmers Commission identifying the Happy Seeder as providing one of several options that could be phased in if the ban on residue burning were to be enforced (Pagan and Singh 2006).

#### Manufacture of the implement

There are currently four manufacturers commercially selling the Happy Seeder, with Dashmesh and Kamboj mechanical works being the major suppliers (H.S. Sidhu, pers. comm., 13 April 2011). While Dasmesh is a relatively small operator, it has the capacity to produce up to five 'turbo' Happy Seeders per day. Furthermore, there is no patent over the intellectual property of the Happy Seeder, which will enable other suppliers to enter the market if demand increases.

#### Training and extension issues

While there is a role for better pricing of inputs to create a greater incentive for adoption of the Happy Seeder, participatory farmer evaluation, and demonstration and communication of the benefits of the Happy Seeder, continue to play important roles in facilitating the uptake of the new technology. An example that illustrates this particularly well is the story of a farmer replanting his wheat after initially using the Happy Seeder. Because the Happy Seeder plants into the rice stubble, the wheat shoots take longer to appear—10–15 days as opposed to 4–5 days using the conventional method. When the shoots were not visible after 4–5 days, the farmer replanted his wheat using the conventional method. This time lag associated with emergence through the mulch can cause anxiety to farmers, and distrust of the practice. To alleviate concerns and facilitate practice change, extension activities, including field days and demonstrations, are continuing. Care is taken to select fields in highly visible areas, such as along the sides of main roads and intersections so that as many farmers as possible can see the new practice in action. Furthermore, the Happy Seeder has been included in the recommended practice guidebook produced by PAU (H.S. Sidhu, pers. comm., 16 November 2009). In addition to the follow-up ACIAR project, the Happy Seeder is now being widely promoted in north-western India through the large Cereal Systems Initiative for South Asia project funded by the Bill and Melinda Gates Foundation and the United States Agency for International Development (E. Humphreys, pers. comm., 9 March 2011).

#### Purchase price

A Happy Seeder costs up to around Rs115,000 (H.S. Sidhu, pers. comm., 16 November 2009[14]). The financial analysis estimated that the net present

14 Also, an article at <http://www.business-standard.com/india/news/happy-seeder-machines-by-govt-to-tackle-paddy-problem/399106/>

value of use of the Happy Seeder is Rs9,420/ha (Singh et al. 2008). This shows that the cost savings associated with its adoption are expected to outweigh its cost. To be able to maximise the cost-effectiveness of the Happy Seeder, it should be used to its maximum capacity of 2–3 ha/day or 100 ha/season (H.S. Sidhu, pers. comm., 16 November 2009). Because of the small size of holdings, most farmers who buy the Happy Seeder will need to be sufficiently entrepreneurial to hire it out to surrounding farmers to ensure its cost-effectiveness. Consequently, potential contracting options affect the financial viability of the Happy Seeder for an individual farmer (Pagan and Singh 2006).

## Potential adoption

The rice–wheat cropping area of Punjab is 2.61 Mha with 2,000 ha sown using the Happy Seeder in the most recent 2010–11 season. This equates to just 0.077% of the total rice–wheat cropping area.

Using this observation to calibrate a standard S-shaped adoption curve, total adoption is estimated to be 3.7%. It should be noted, however, that should the ban on burning rice stubble be enforced, the actual adoption of the Happy Seeder could be much higher. The adoption profile is illustrated in Figure 3 and detailed in Table 4.

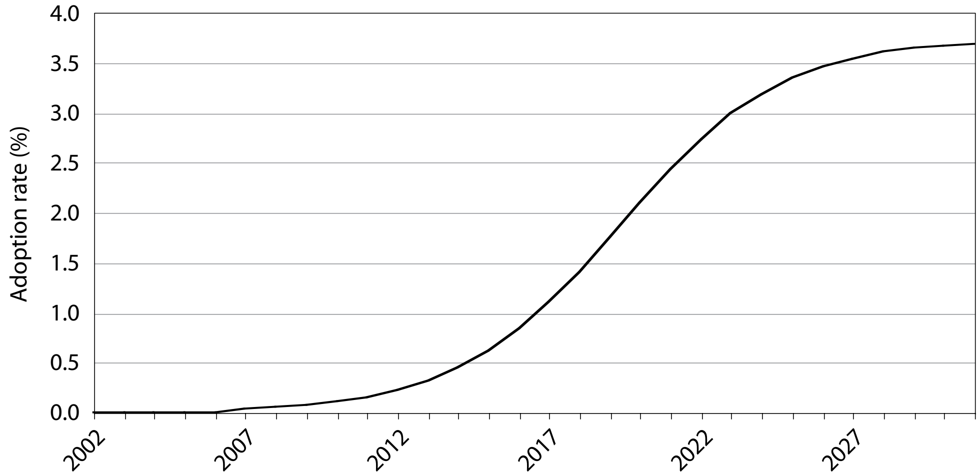


**Figure 3.** Estimated adoption profile for the Happy Seeder, 2002–31. Source: Centre for International Economics

**Table 4.** Adoption rate details for the Happy Seeder, 2002–31

| Year | Adoption rate | Year | Adoption rate | Year | Adoption rate | Year | Adoption rate |
|---|---|---|---|---|---|---|---|
| 2002 | 0.0 | 2010 | 0.1 | 2018 | 1.4 | 2026 | 3.5 |
| 2003 | 0.0 | 2011 | 0.2 | 2019 | 1.8 | 2027 | 3.5 |
| 2004 | 0.0 | 2012 | 0.2 | 2020 | 2.1 | 2028 | 3.6 |
| 2005 | 0.0 | 2013 | 0.3 | 2021 | 2.4 | 2029 | 3.6 |
| 2006 | 0.0 | 2014 | 0.4 | 2022 | 2.7 | 2030 | 3.7 |
| 2007 | 0.0 | 2015 | 0.6 | 2023 | 3.0 | 2031 | 3.7 |
| 2008 | 0.1 | 2016 | 0.8 | 2024 | 3.2 | | |
| 2009 | 0.1 | 2017 | 1.1 | 2025 | 3.3 | | |

Source: Centre for International Economics

# 4 Outcomes

The Happy Seeder is the primary adopted output from the projects being assessed. The benefits of adopting the Happy Seeder are environmental and economic. Its adoption facilitates:

- a reduction in air pollution and improved soil fertility due to a shift away from burning rice stubble
- a reduction in production costs, from a decrease in the quantity of inputs required for production.

These outcomes are discussed below and the economic benefits quantified.

## Reduction in pollution, and soil improvement

As already discussed, currently the most common way of removing rice stubble is to burn it, with more than 90% of the 17 Mt of rice stubble in Punjab being burned each year (Singh et al. 2008). Burning rice straw emits a range of harmful emissions and particulate matter into the atmosphere.

After burning the stubble, there are typically about six tillage passes in preparation for planting wheat. Using the Happy Seeder enables farmers to cut down on the number of field operations required in preparation for planting wheat, thereby reducing diesel consumption.[15] For each hectare of wheat sown using the Happy Seeder, 45 litres of diesel are saved over the conventional method, which is the equivalent of 121.5 kg of emitted carbon dioxide ($CO_2$) greenhouse gas.

In the Punjab, the majority of farmers use an electric motor for pumping groundwater for irrigation. With around 60% of total electric power in the Punjab generated in coal-fired thermal power stations, a reduction in the volume of irrigation required leads to a decrease in $CO_2$ emissions. The Happy Seeder may reduce the amount of irrigation needed by up to 30%,[16] which corresponds to an energy saving of 168 kW and a 161 kg/ha reduction in $CO_2$ emissions (Table 5).

While the extent of the uptake of the Happy Seeder ultimately determines the size of the reduction in $CO_2$ emissions, considering that 2.7 Mha of rice was cultivated in Punjab alone, there is significant potential to reduce emissions. In addition to the 282 kg/ha saved from changes in operations (see Table 5), each tonne of stubble not burned avoids around 1,700 kg of emissions of a range of pollutants (mostly $CO_2$ and ash; see Singh et al. (2008)).

**Table 5.** Carbon dioxide ($CO_2$) emissions avoided by using the Happy Seeder rather than conventional planting

| Activity | $CO_2$ (kg/ha) |
|---|---|
| Pumping water | 161 |
| Tillage | 121 |
| Total | 282 |

Source: Singh et al. (2008)

The process of burning stubble also degrades soil quality by driving off nutrients (Table 6) and organic matter, which ultimately have to be replaced using comparatively expensive fertilisers.

15 An operation in this context refers to driving the tractor over an entire field, usually row by row, and can include activities such as slashing, seeding, hoeing and tining.

16 In about 50% of years (Balwinder-Singh, P.L. Eberbach, E. Humphreys and S.S. Kukal, unpublished data)

**Table 6.** Soil nutrient losses due to burning rice residues, Punjab, India, 2001–02

| Nutrient | Nutrient loss | | |
|---|---|---|---|
| | Concentration in straw | Loss in burn | Loss |
| | (g/kg) | (%) | (kg/ha) |
| Carbon | 400 | 100 | 2,400 |
| Nitrogen | 6.5 | 90 | 35 |
| Phosphorus | 2.1 | 25 | 3.2 |
| Potassium | 17.5 | 20 | 21 |
| Sulfur | 0.75 | 60 | 2.7 |

Source: Singh et al. (2008, table 1)

**Social externalities from burning rice stubble**

The practice of burning the rice stubble causes serious problems for people and livestock in the region. Burning the rice stubble reduces visibility and increases harmful fine particulate matter in the atmosphere.

Regional studies have shown that there are increased road accidents and traffic delays because of the poor visibility, and that airports and roads have needed to be closed. There is also accidental burning of natural vegetation and infrastructure. More seriously, preliminary studies are showing increased numbers of people attending hospital with respiratory problems during the burn-off period (Singh et al. 2008, pp. 14–15).

While the social benefits from reduced burning due to use of the Happy Seeder are important, their value is difficult to estimate. Consequently, they are not included in the economic evaluation of this project, but provide additional support for the adoption of the Happy Seeder.

## Change in production costs

Adoption of the Happy Seeder changes the cost of producing wheat. The first and most significant obstacle to overcome is the capital cost of the implement itself which, at Rs90,000–100,000 (H.S. Sidhu, pers. comm., 16 November 2009), is a significant investment, particularly for a smallholder. In recognition of this, and to encourage its adoption, the Punjab Government is currently subsidising 50% of the cost of its purchase (H.S. Sidhu, pers. comm., 16 November 2009).

Offsetting this significant capital cost is the Happy Seeder's capacity to reduce the cost of production through:

- reduced operations on the field, saving time, labour and fuel costs
- direct seeding immediately after harvesting, allowing earlier planting, which reduces the number of irrigations required, saving water (and pumping costs)
- lower water requirements, avoiding the costs of using and/or switching to a submersible pumping system[17]
- not having to burn the rice stubble, so the nutrients that would have been lost in the burn-off are retained, eventually reducing the need to apply fertilisers (or at least the quantity required)
- reduced weed establishment and growth, and hence reduced quantity of herbicides used because the straw mulch suppresses weed populations.

The value of each of these benefits is quantified below.

[17] Recent research indicates that the net water loss from the system as evapotranspiration may not be much different with Happy Seeder planting; i.e. there is no effect on watertable decline (Balwinder-Singh, P.L. Eberbach, E. Humphreys and S.S. Kukal, unpublished data).

**Reduced field operations**

As discussed above, using the Happy Seeder to direct-seed wheat into rice stubble reduces the number of operations on the field and, consequently, the amount of fuel consumed. Furthermore, in reducing the number of operations, so also is the amount of labour needed reduced. Labour in Punjab can be hired from the open market at Rs10/hour or Rs80/day (Singh et al. 2008, p. 8). With a saving in time of 7.5 hours/ha, the labour saving equates to Rs75/ha.

**Reduced water consumption**

If wheat is sown directly after harvesting the rice, the residual moisture in the soil negates the need for a pre-irrigation. Using the rice straw as mulch for the wheat reduces evaporation, further lowering the amount of water required in the first few irrigations. A farmer has no need to irrigate before sowing and can save around 15% on the first irrigation after sowing and 10% on the second, equating to an overall saving of 30% (Table 7).

A reduced number of irrigations translates into savings in the labour required to undertake the irrigations. Each irrigation requires 15 hours of labour to apply 7.5 cm/ha, which equates to 0.5 cm/hour/ha. Ordinarily, 40 cm/ha are applied in a season, at Rs10/hour, costing the farmer Rs800 in labour for irrigating. With the volume of irrigation required with the Happy Seeder estimated to be 30% lower than under conventional cropping, labour requirements are also scaled back by 30%, saving farmers Rs238/ha.

If water consumption is reduced, then the cost of irrigation should fall. However, in Punjab, water and the electricity required to pump it are freely provided to the farmers. This undermines one of the incentives to adopting the Happy Seeder. Furthermore, by undervaluing water, groundwater has been used excessively for rice–wheat cropping, with the watertable declining at the rate of 70–80 cm per year (Singh et al. 2008, p. 16).

As the groundwater level falls, farmers are shifting from centrifugal pumps to submersible pumps. While submersible pumps are more efficient at pumping groundwater, they are more expensive to buy and maintain (Table 8).

If the current trend continues, this will lead to an increase in the cost of production and a contraction in supply. Given the area fed by groundwater, and the current trend towards submersible pumps, these avoided costs could be significant: 95–98% of the rice–wheat area is irrigated, with around 60–65% of the total irrigation requirement coming from groundwater. This means that approximately 2.4 Mha of the rice–wheat cropping area is irrigated from tube wells (Table 9).

**Retaining stubble and mulching**

In using the rice straw as mulch for the wheat crop, weed establishment and growth are suppressed. Consequently, farmers can reduce the amount of herbicides typically used by an estimated 50%. These figures are costed in Table 10, and are similar to the estimate of Rs750 provided during consultation (H.S. Sidhu, pers. comm., 16 November 2009).

**Table 7.** Irrigation for wheat under different treatments

| Irrigation | Conventional | Happy Seeder | Change in water consumption |
|---|---|---|---|
| | (cm/irrigation) | (cm/irrigation) | (%) |
| Pre-sowing | 10 | 0 | −100 |
| First | 7.5 | 6.38 | −15 |
| Second | 7.5 | 6.75 | −10 |
| Third | 7.5 | 7.5 | 0 |
| Fourth | 7.5 | 7.5 | 0 |
| Total | 40.0 | 28.1 | −30 |

Source: Singh et al. (2008, table 4)

**Table 8.** Annual costs (Rs/ha) of pumping groundwater using submersible versus centrifugal pumps

| | Centrifugal | Submersible |
|---|---|---|
| Motor | 550 | 1,250 |
| Repairs and maintenance (10%) | 1,100 | 2,500 |
| Pipes, fittings and structure | 700 | 2,500 |
| Total cost[a] | 587.5 | 1,562.5 |

Sources: Singh et al. (2008, table 2) and Centre for International Economics' calculations

[a] Based upon the assumption that each farm has its own pump, and that the average farm is 4.0 ha

**Table 9.** Area covered by tube wells in Punjab, India, 2001–02

| | Area | |
|---|---|---|
| | (%) | (ha) |
| Farms | 100.0 | 4,022 |
| Irrigated | 96.5[a] | 3,881 |
| Groundwater pumps | 62.5[a] | 2,425 |

Source: Singh et al. (2008, p. 29); ACIAR project documents

[a] Mid-point of range

**Table 10.** Cost savings from retaining rice stubble for mulching

| Input | Change in inputs | Change in cost |
|---|---|---|
| | (%) | (Rs/ha) |
| Fertiliser | −10 | −133 |
| Herbicide | −50 | −908 |

Source: Singh et al. (2008, p. 11)

### Summarising production cost savings

There are several methods of establishing wheat after rice, most notably the conventional method of burning stubble and zero-till drilling following full residue removal. While zero till is an important alternative to the conventional tillage, in 2007–08 it accounted for only approximately 10% of the rice–wheat cropping area (R.P. Singh, pers. comm., 14 April 2011). Consequently, in this impact assessment we compare the costs of using the Happy Seeder with those of the conventional method.

Table 11 summarises the key cost elements of the conventional and Happy Seeder approaches to rice–wheat cropping, and shows the magnitude of the cost difference between the two.

The total cost saving is estimated to be Rs2,163/ha, or Rs800/tonne, which is equivalent to a 9.4% cost saving.

**Table 11.** Cost savings: rice–wheat growing using the Happy Seeder versus conventional cultivation with rice-stubble burning

| Cost item | Conventional (Rs/ha) | Happy Seeder (Rs/ha) | Happy Seeder saving (Rs/ha) |
|---|---|---|---|
| **Key operations** | | | |
| Stubble shaving | 519 | 0 | 519 |
| Straw burning | 37 | 0 | 37 |
| Tillage | 2,224 | 0 | 2,224 |
| Straw spreading | 0 | 49 | −49 |
| Sowing | 494 | 2,001 | −1,507 |
| Bund making | 124 | 185 | −61 |
| Rodent control | 0 | 49 | −49 |
| **Other costs** | | | |
| Capital cost | 0 | 230 | −230 |
| Irrigation | 800 | 562 | 238 |
| Fertiliser | 1,330 | 1,197 | 133 |
| Herbicide | 1,816 | 908 | 908 |
| Other costs | 15,606 | 15,606 | 0 |
| Total cost | 22,950 | 20,787 | 2,163 |
| Implied cost per tonne | 8,500 | 7,700 | 800 |
| **Percentage saving** | | | **9.4** |

Source: Centre for International Economics’ estimates based on Singh et al. (2008)

# 5 Impacts

To understand the impact of adopting the Happy Seeder it is important to comprehend how relevant markets are affected. Markets are shaped by a range of factors, including government policies and regulations, the technology used in production, and demand and supply from both domestic and international markets. To account for these factors and their influence on the impact of adopting the Happy Seeder, a partial equilibrium economic surplus framework is used.

To model the impact of adopting the Happy Seeder, the focus is on the wheat market, despite the fact that the Happy Seeder relates to rice–wheat cropping more generally. This is because the cost savings generated by the use of the Happy Seeder are reflected in the production of wheat.

Furthermore, the model of the wheat market is restricted to that of Punjab, India, which contributes around 20% of India's wheat production. As discussed earlier, we are looking only at adoption of the Happy Seeder in the state of Punjab, India, and therefore only at the impact that the adoption of the Happy Seeder has upon the wheat market there. This also reflects the segmentation of the domestic market, brought about through the difference in timing of supply, and implementation of government policy.

## The market for wheat

Constructing a model of the market for wheat requires definition of functions for supply and demand. We assume linear supply and demand curves, which take the form:

$$\text{Supply:} \quad P = a + bQ \qquad\qquad (1)$$
$$\text{Demand:} \quad P = a - bQ$$

where *P* is price, *Q* is the quantity supplied or demanded, and *a* and *b* are the intercept and slope terms, respectively.

To construct the supply and demand curves, the intercept and slope terms have been derived by using the elasticity of supply and demand, drawing on estimates taken from external research.[18] A value of 0.09 was used for the long-run elasticity of supply, implying that supply of wheat is price inelastic. Likewise, with a value of 0.5, demand is also inelastic. This is to be expected, given that wheat is a staple in the Indian diet.

Using these values of elasticity, we can rearrange for the slope term, *b*, using the equation for elasticity (e) and the fact that the slope term is the change in price divided by the change in quantity:

$$\mathrm{e} = \frac{\Delta Q}{\Delta P} \times \frac{p^*}{q^*} \qquad (2)$$

$$\mathrm{e} = \frac{1}{b} \times \frac{p^*}{q^*} \qquad (3)$$

$$b = \frac{1}{\mathrm{e}} \times \frac{p^*}{q^*} \qquad (4)$$

where $p^*$ and $q^*$ are the equilibrium price and quantity supplied for wheat in Punjab. Since the Indian (and therefore Punjab) wheat market is relatively closed to the international market, with only sporadic international trade, we have modelled a closed domestic market.

Given the relationship between the slope term, *b*, and the intercept, *a*, given by the supply and demand functions in equation (1), we can solve for the intercept term.

18 The value of the elasticity of supply was sourced from Jha et al. (2007, appendix table 1.10), and that for demand from Mullen et al. (2005, table 10).

These calculations provide the basic parameters for the market for wheat in Punjab, which we use to estimate the impact of adopting the Happy Seeder technology. Discussion of further details and characteristics of the market follows.

### Pricing policy

To provide stability in prices for farmers, and encourage investment in agriculture, the Government of India (GOI) operates a minimum support price (MSP) policy for many agricultural products, including wheat. Initially implemented as a market stabilisation tool, the MSP is increasingly becoming an income-support policy for farmers in Punjab, Haryana and Western Uttar Pradesh.

The MSP acts as a price floor, setting the minimum price at which wheat can be traded. For a floor price to be effective it must be higher than the equilibrium price. The effect of this higher price upon the market is that consumers demand less of the good and producers supply more, the net effect being that the quantity supplied is greater than the quantity demanded. This is illustrated in Figure 4. At a price ($p_{MSP}$) above the market-clearing equilibrium $p_{eq}$, consumers demand only $q_d$, while farmers supply $q_s$, creating a surplus of supply, $q_s - q_d$.

There are different instruments that government can use to implement a price floor, including regulation and direct market intervention. To support the MSP for wheat, the GOI intervenes directly in the market, paying the MSP directly to farmers in the primary grain markets (Jha et al. 2007, p. 4). The GOI procurement ranges from 8 to 20 Mt, accounting for around 15–20% of the total wheat produced.[19] However, in Punjab, a major surplus state, roughly 50–60% of production is procured by government at the MSP (M.R. Landes, United States Department of Agriculture, pers. comm., 21 May 2010). The grain procured in price support operations is stored by the Food Corporation of India, a government-owned corporation, which either makes the grain available to state governments for subsidised distribution, holds it in storage or, when conditions permit, allocates surplus grain for export (Jha et al. 2007, p. 4).

In India, the MSPs are largely based on the costs of production, as estimated by the Commission on Agricultural Costs and Prices (CACP) using a 'full cost' measure that includes the costs of variable inputs, the rental value of the land, an imputed value of family labour and a 10% return on management (Jha et al. 2007). Basing the MSP upon the cost of production ensures that farmers receive an income that covers the cost of production and facilitates continued production of wheat (and other supported products). While the CACP develops an estimate for the MSP based upon the full cost of production, these estimates are provided only as a recommendation to government on the determination of the MSP. From 1995–96 to 2001–02, the government set MSPs above the recommendations of the CACP in 5 of the 7 years.

Where the MSP is binding (that is, above the market equilibrium price), it has the effect of increasing the income to farmers at the expense of consumers. Furthermore, the procurement of the surplus by the government is done so with government funds, at a cost to the economy as a whole. The impact of the price floor on economic welfare is illustrated in Figure 5.

The consumer surplus is the triangle 'abc', while the producer surplus is the larger triangle 'bdg'. The government procures the surplus wheat at a cost of the rectangle 'cdef'. Part of this cost is offset by the producer surplus, reducing the net cost of this policy to 'defh'. However, the government may recover some the cost of this policy through the disbursement of wheat through its food distribution policy.

### Trade and trade policy

In an open economy, excess supply, as can accrue under the MSP policy, is typically exported to the international market. However, India has restrictions upon the export of wheat, historically having exported only sporadically and even then under strict conditions (such as stipulation of the country or trading agent).

In the mid 1990s, India shifted to tariffs, from its previous policy of quantitative restraints upon imports, initially setting the tariff at zero but raising it to 50% in 1999 (with a bound rate of 100%). Export restrictions were implemented through state trading, quotas and minimum export prices, but have been progressively liberalised. In fact, in 2000, India began to provide export subsidies in light of the higher domestic prices

[19] Commodity online 2010, Wheat, available at <www.commodityonline.com/commodities/cereal/wheat.php>, accessed 10 May 2010

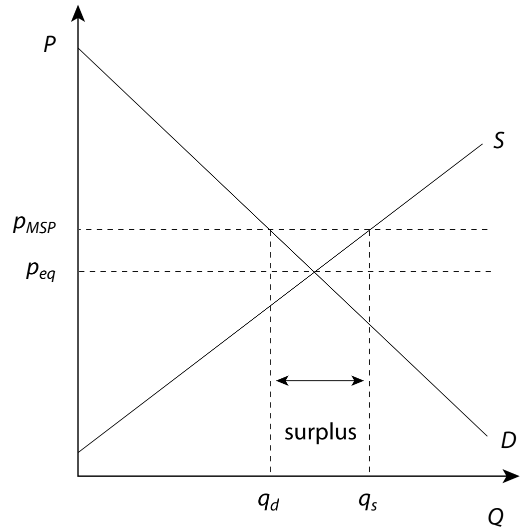


**Figure 4.** Price floors and impact on markets. Source: Centre for International Economics

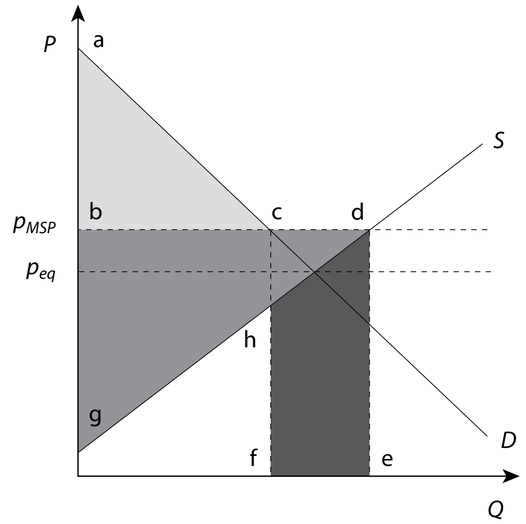


**Figure 5.** Economic welfare from the minimum support price (MSP) policy. Source: Centre for International Economics

and declining world prices, making India's wheat uncompetitive in the international market. In 2005, these export subsidies were halted in response to tightening domestic supply (Jha et al. 2007, p. 13). In 2007, the GOI went further, halting the export of wheat altogether, to ensure smooth domestic supply at reasonable rates.

Surplus is usually not exported, but placed into storage, such that supply can be supplemented during years of lower production. However, excellent crops over consecutive seasons saw the accumulation of huge surpluses. Consequently, pressure was placed on the government to lift the ban on exports, which happened in 2009 with limited exports permitted to neighbouring countries. Further pressures have been placed on the government to completely remove the ban, and allow broader exporting, particularly in light of the fact that space for storing the surplus wheat is running out.

### Impact of government policies

In addition to price supports for the production of wheat, many agricultural inputs are partially or completely subsidised by the government. The most important of these is the supply of free electricity for the purposes of agricultural production in Punjab. This is used for pumping water. In addition, purchases of diesel, herbicides and pesticides are subsidised.

The subsidisation of inputs means a weakening of incentives to adopt new practices or technology that would reduce the consumption of electricity (and subsequently water), diesel, herbicides and pesticides. Overuse of these inputs is harmful to the environment and, in the case of water, is depleting a natural resource, which access to is becoming increasingly difficult as watertables fall.

Furthermore, the intervention and subsidisation of the inputs distort the market signals about the true cost of rice–wheat cropping relative to other crops, particularly those that use less water.

The government has made the burning of rice stubble illegal. However, because until now there has been no satisfactory alternative practice for dealing with the rice stubble, the law has not been enforced. Its enforcement would provide support for the adoption of the Happy Seeder.

An alternative to enforcing the rule against burning rice stubble would be to construct a mechanism, such as a pollution tax, to factor the externalities into the price of wheat.

## The impact of adopting the Happy Seeder

The impact of the Happy Seeder is estimated in a partial equilibrium framework, looking at the costs and benefits of its adoption and, using an economic surplus framework, the effect that these have upon the market for wheat. This approach enables us to measure the total change in welfare from the adoption of the Happy Seeder, as well as how these changes in welfare are distributed between consumers and producers.

When looking at the impact that adopting the Happy Seeder has upon the market for wheat, it is necessary that we view this in the context of what would have happened, over the same period, in the absence of the Happy Seeder technology. This is our base-case, or counterfactual, scenario.

### Base-case scenario

Under the base-case scenario, we modelled that supply would contract by a small amount over time. This reflects the declining condition of the natural environment, which would make it difficult to reap the same returns from the land and other inputs. Furthermore, as watertables continue to deepen, farmers will need to shift from centrifugal pumps to the more expensive submersible pumps, raising production costs and contracting supply. While it is likely that there are other research and development activities that are currently working to increase supply (most likely in terms of yields) these are unquantifiable.

Conversely, demand is expected to increase. India is soon set to take over from China over as the world's most populous country, so population growth continues to place upward pressure on demand for many things, including wheat. We also assessed the relationship between wheat consumption and income growth, since India is becoming wealthier over time. However, no strong relationship was found. Consequently, the increase in demand was based upon the average annual population growth rate of 1.48%.[20]

The contraction in supply and expansion in demand are illustrated in Figure 6, where the MSP is binding (above the market-clearing price). If the MSP is maintained at its current price, as is presented below, the contraction in supply from *S* to *S'*, and increase in demand from *D* to *D'* will result in a smaller surplus. Over time, as supply continues to contract, and demand continues to expand, the surplus originally generated by the MSP will be eroded.

However, the government may choose to change the MSP in response to changing supply and demand. As discussed earlier, the GOI has previously set MSPs to reflect (and usually exceed) the production costs faced by farmers. Consequently, it is likely that an increase in production costs over time will be met by an increase in the MSP. However, in raising the MSP further, and continuing to support surplus production, the cost of the policy will increase. Furthermore, with the MSP

20 Taken as the average growth in population over 2000–08.

above the market clearing price, the GOI will continue to fund surplus production of wheat.

Because the government does not have endless capacity to store the surplus, or an endless capacity to fund it, it is likely that they will allow the surplus to fall a little over time (although this may fluctuate significantly due to domestic and global conditions). So it is expected that the MSP would increase slightly, such that the surplus is not completely eroded over time, but not maintained at its original level. This is illustrated in Figure 7, where the new MSP, $p'_{MSP}$, and surplus are represented by the blue lines.

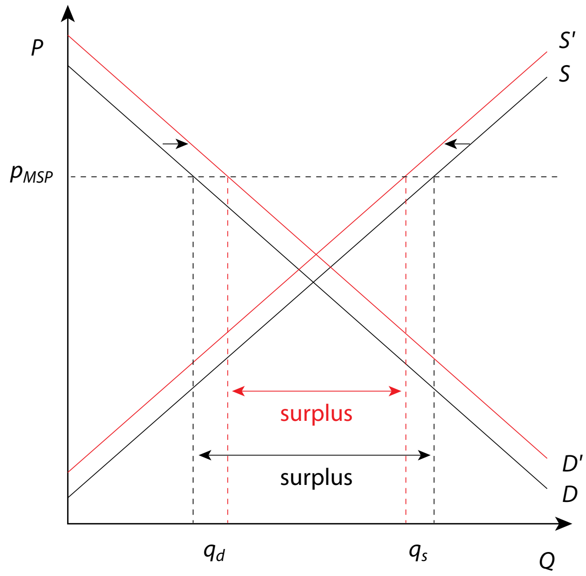


**Figure 6.** Changes in supply (*S*) and demand (*D*) over time with a fixed minimum support price (MSP): base-case scenario. Source: Centre for International Economics

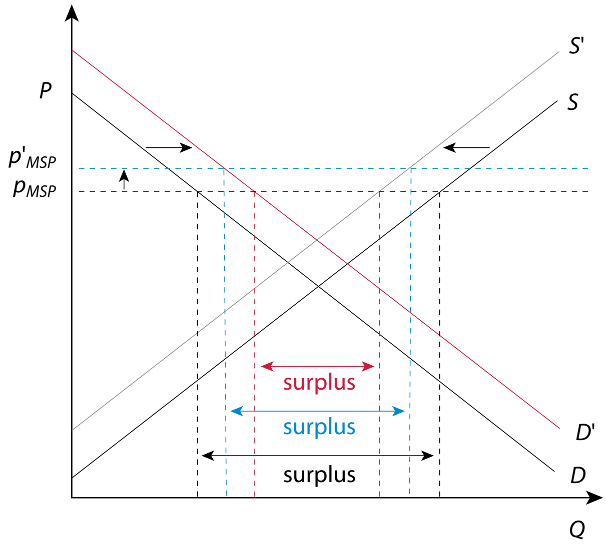


**Figure 7.** Changes in supply (*S*) and demand (*D*) over time with changed minimum support price (MSP): base-case scenario. Source: Centre for International Economics

#### Adopting the Happy Seeder scenario

Adopting the Happy Seeder reduces the cost of producing wheat; the Happy Seeder not only helps to avoid some of the sources of rising costs (groundwater access) but also reduces the input costs. This cost reduction is depicted in the partial equilibrium framework as an increase in supply, which is represented as a shift in the supply curve from *S* to *S′*. The shift in the supply curve is substantially larger than that in demand, which is, as in the base-case scenario, expected to increase from *D* to *D′*. Figure 8 illustrates the shifts in supply and demand, and shows that, with no change in the MSP, the surplus of wheat will increase.

As the surplus is procured by the GOI, a larger surplus will accrue if the MSP is not changed, and will be costly to the government, which is also responsible for the storage costs of wheat that is not sold-on as part of its food distribution policy. Consequently, it is expected that the GOI would reduce the MSP from $p_{MSP}$ to $p'_{MSP}$. This is illustrated in Figure 9.

How much would the MSP fall by? While it is difficult to forecast how the MSP policy will be implemented over the long time horizon of this study, we have conservatively modelled that the MSP will be reduced by an amount sufficient to hold constant the cost of the policy between the base-case scenario and the adopting the Happy Seeder scenario. Holding constant the cost of the MSP policy between the base-case and Happy Seeder scenarios enables us to look at only the impact of adopting the Happy Seeder on the economic welfare of producers and consumers.

Under the adoption of the Happy Seeder, there is now a greater quantity of wheat supplied, at a lower (MSP) price to consumers, and at no extra cost to the government. This reinforces the importance of productivity improvements to the objective of food security.

#### Welfare effects from adoption of the Happy Seeder

As discussed above, as a result of lower production costs from adopting the Happy Seeder, the GOI is modelled as responding by lowering the MSP for wheat. As the MSP is implemented by direct market intervention, this price is for all producers, not just those who use the Happy Seeder, with the low-cost producers (Happy Seed adopters) driving the market price through a perfecty competitive market.[21] This means that those producers who do not adopt the Happy Seeder are faced with a

21 It should be noted that although the government intervenes with the pricing in this market, because wheat is a homogenous product, and there is a large number of producers, the market is perfectly competitive.

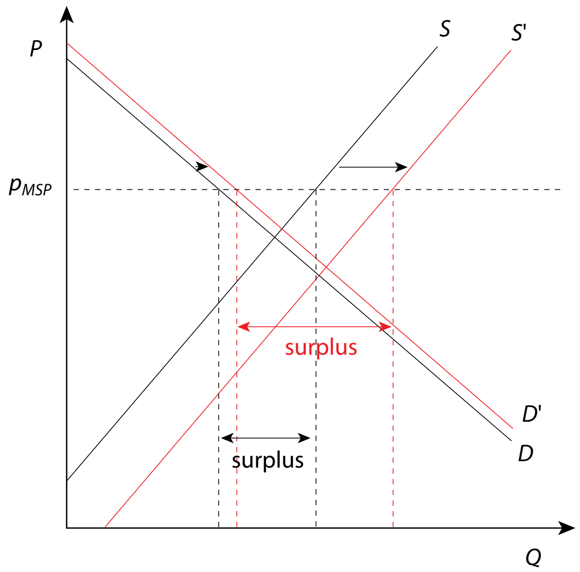


**Figure 8.** Changes in supply (*S*) and demand (*D*) over time, with the Happy Seeder. Source: Centre for International Economics

lower MSP but still have the same production costs as under the base-case scenario. The impact of this on the different producers (adopters and non-adopters) is illustrated in Figure 10.

The consequence of this is that the economic welfare rises for producers who adopt the Happy Seeder technology but falls for those who do not. This is illustrated in Figure 11.

Consumer surplus is represented by the area above the price line and below the demand curve, while the producer surplus is represented by the triangle under the price line and above the supply curve. The black area represents the consumer and producer welfare before the adoption of the Happy Seeder, while the red areas represent consumer and producer surplus after adoption. As can be seen in the left panel of Figure 11, the producer and consumer surpluses are both

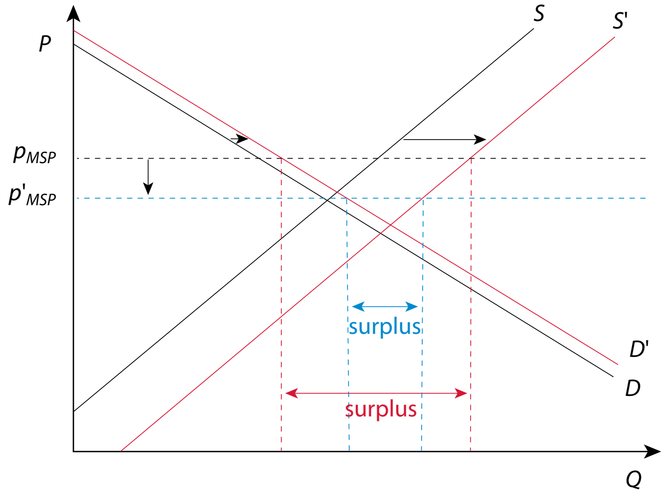


**Figure 9.** Changes in supply (*S*), demand (*D*) and minimum support price (MSP) over time, with the Happy Seeder. Source: Centre for International Economics

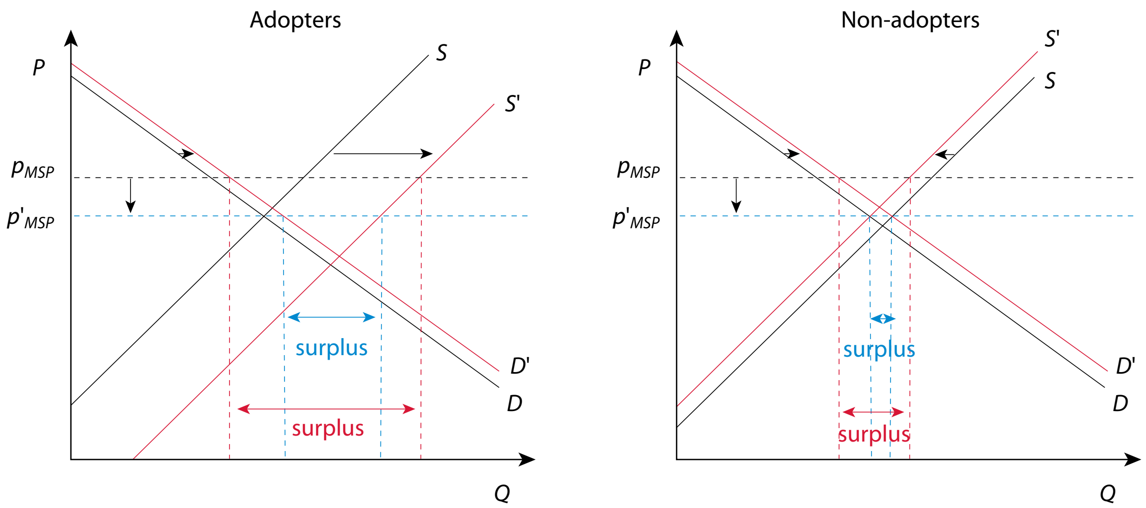


**Figure 10.** Impact of a lower minimum support price on adopting and non-adopting producers. Source: Centre for International Economics

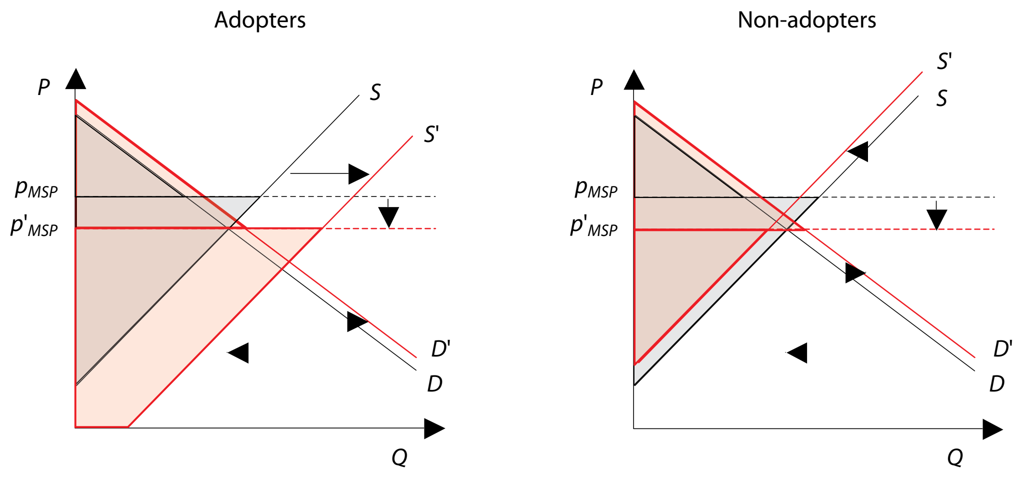


**Figure 11.** Welfare effects on adopters and non-adopters. Source: Centre for International Economics

substantially larger after adoption of the Happy Seeder. On the right panel of Figure 11, the consumer surplus is similarly enlarged, but the producer surplus of the non-adopters has been reduced. The net effect upon economic welfare is an increase, because the losses of non-adopters are outweighed by the gains in welfare from consumers and adopters. Furthermore, this gain in economic welfare increases across time as more producers become adopters of the technology. This is discussed further in the next section.

# 6 Net benefits

This section brings together the estimated benefits and costs associated with the project in a cost–benefit analysis framework. We also discuss the risk surrounding the estimates and test how robust the conclusions drawn from this analysis are to changes in these assumptions.

## Benefits

The estimated benefits of adopting the Happy Seeder technology for the 30-year period from 2002 to 2031 (inclusive) are presented in Table 12. The benefits are estimated in Indian rupees and converted to Australian dollars using historical annual special drawing rights (SDR) exchange rates up to 2009, with the 2009 exchange rate used for all future periods.

The benefits delivered from adopting the Happy Seeder continue to increase over time as more farmers purchase or hire the Happy Seeder. Once maximum adoption is reached in 2031, the project is estimated to deliver ongoing annual benefits of around A$24 million (in nominal terms).

## Costs

The nominal research costs, which include all cash and in-kind contributions, are converted to real 2009 dollars using the Australian gross domestic product (GDP) deflator. The nominal and real (in 2009 dollars) project costs for ACIAR and other contributors are presented in Table 13.

## Summary measures

Over the 30-year period from 2002 to 2031, it is estimated that the project will deliver benefits of A$73 million plus an additional A$23 million in perpetuity, yielding total benefits worth A$96 million (Table 14) (expressed in 2009 dollars and in present value terms using a discount rate of 5%). The estimated benefits significantly exceed the cost of the projects, which were A$5.6 million (expressed in comparable terms). The project is therefore expected to produce net benefits of A$90.4 million, equivalent to around A$17.20 for every A$1.00 spent. The internal rate of return on the research is estimated at 20%. From these figures it is clear that the adoption of the Happy Seeder has the potential to deliver substantial benefits to farmers in the Punjab region.

## Attribution of benefits

Benefits from this project are attributed among the project contributors on a cost-share basis. Using a discount rate of 5%, ACIAR contributed A$2.4 million, or 42.7% of the total cost of the project. Consequently, benefits of A$41 million can be attributed to ACIAR (Table 15).

**Table 12.** Benefits from adopting the Happy Seeder, 2002–31

| Year | Producer surplus | Consumer surplus | Exchange rate | Total surplus[a] | |
|---|---|---|---|---|---|
| | (Rs million) | (Rs million) | (Rs/A$) | (Rs million) | (A$ million) |
| 2002 | | | 26.85 | – | – |
| 2003 | | | 23.98 | – | – |
| 2004 | | | 23.83 | – | – |
| 2005 | | | 24.86 | – | – |
| 2006 | | | 29.96 | – | – |
| 2007 | 0 | 2 | 30.88 | 1.9 | 0.1 |
| 2008 | 0 | 3 | 31.26 | 3.1 | 0.1 |
| 2009 | 1 | 5 | 29.10 | 5.1 | 0.1 |
| 2010 | 2 | 7 | 37.82 | 8.1 | 0.2 |
| 2011 | 3 | 9 | 38.30 | 12.8 | 0.3 |
| 2012 | 7 | 13 | 38.30 | 19.9 | 0.5 |
| 2013 | 12 | 19 | 38.30 | 30.6 | 0.8 |
| 2014 | 20 | 26 | 38.30 | 46.3 | 1.2 |
| 2015 | 33 | 36 | 38.30 | 68.6 | 1.8 |
| 2016 | 51 | 48 | 38.30 | 99.4 | 2.6 |
| 2017 | 77 | 63 | 38.30 | 140.1 | 3.7 |
| 2018 | 111 | 80 | 38.30 | 191.2 | 5.0 |
| 2019 | 153 | 98 | 38.30 | 251.7 | 6.6 |
| 2020 | 202 | 117 | 38.30 | 319.1 | 8.3 |
| 2021 | 255 | 135 | 38.30 | 389.7 | 10.2 |
| 2022 | 310 | 150 | 38.30 | 459.9 | 12.0 |
| 2023 | 365 | 162 | 38.30 | 526.6 | 13.7 |
| 2024 | 417 | 171 | 38.30 | 588.0 | 15.4 |
| 2025 | 467 | 177 | 38.30 | 643.7 | 16.8 |
| 2026 | 513 | 181 | 38.30 | 693.9 | 18.1 |
| 2027 | 557 | 183 | 38.30 | 739.3 | 19.3 |
| 2028 | 598 | 183 | 38.30 | 780.9 | 20.4 |
| 2029 | 636 | 183 | 38.30 | 819.4 | 21.4 |
| 2030 | 674 | 182 | 38.30 | 855.5 | 22.3 |
| 2031 | 709 | 181 | 38.30 | 890.0 | 23.2 |
| Post-2031 | 744 | 179 | 38.30 | 923.2 | 24.1 |
| Total | | | | 9,508.4 | 248.3 |

Source: Centre for International Economics

[a] Total surplus represents the benefits of the projects

**Table 13.** Project costs[a]

| Year | ACIAR | | Other | | Total | |
|---|---|---|---|---|---|---|
| | Current A$m | 2009 A$m | Current A$m | 2009 A$m | Current A$m | 2009 A$m |
| 2002 | 0.38 | 0.50 | 0.75 | 1.00 | 1.13 | 1.50 |
| 2003 | 0.35 | 0.45 | 0.40 | 0.51 | 0.75 | 0.96 |
| 2004 | 0.33 | 0.41 | 0.41 | 0.51 | 0.74 | 0.92 |
| 2005 | 0.32 | 0.39 | 0.42 | 0.50 | 0.74 | 0.89 |
| 2006 | 0.33 | 0.38 | 0.31 | 0.35 | 0.64 | 0.74 |
| 2007 | 0.08 | 0.08 | 0.11 | 0.13 | 0.19 | 0.21 |
| 2008 | 0.21 | 0.22 | 0.23 | 0.24 | 0.44 | 0.46 |
| 2009 | 0.18 | 0.18 | 0.22 | 0.22 | 0.40 | 0.40 |
| 2010 | 0.09 | 0.09 | 0.12 | 0.12 | 0.21 | 0.21 |
| Total | 2.27 | 2.71 | 2.97 | 3.58 | 5.24 | 6.30 |

Source: Centre for International Economics

[a] This includes the costs identified in Tables 1–3 as well as the estimated $130,363 cost for an extension officer across 2007 to 2009.

**Table 14.** Summary measures

| Discount rate | Present value of benefits | Present value of costs | Net present value | Benefit:cost ratio | Internal rate of return |
|---|---|---|---|---|---|
| (%) | (A$m) | (A$m) | (A$m) | | (%) |
| 1 | 210.6 | 6.1 | 204.4 | 34.3 | 20 |
| 5 | 96.0 | 5.6 | 90.4 | 17.2 | 20 |
| 10 | 66.7 | 5.0 | 61.7 | 13.3 | 20 |

Source: Centre for International Economics

**Table 15.** Attribution of benefits to ACIAR

| Discount rate | Present value of ACIAR costs | Share of total costs | Present value of benefits attributable to ACIAR |
|---|---|---|---|
| (%) | (A$m) | (%) | (A$m) |
| 1 | 2.6 | 43.0 | 87.9 |
| 5 | 2.4 | 42.7 | 41.0 |
| 10 | 2.1 | 42.3 | 26.1 |

Source: Centre for International Economics

## Robustness of estimates

While the benefits of this project are expected to accrue into the future, there is significant uncertainty and risk associated with how the future will unfold. The estimated benefits are also critically dependent on a number of key parameters and assumptions provided by the researchers and other project stakeholders. We test the robustness of the conclusions drawn from the estimates by varying these assumptions.

### Break-even analysis

The estimated benefits presented in this impact assessment are based on a degree of subjectivity, particularly about the rate of adoption. Clearly, the project can deliver benefits only if the Happy Seeder is adopted, but there are some barriers to adoption, as discussed in the third section of this report.

In undertaking this assessment, we have estimated an adoption rate, and subsequently produced an estimate of the net benefits based upon that rate. An alternative approach is to reconfigure the analysis as: 'How low would adoption have to be to deliver no benefit?' Taking this approach, the analysis shows that to produce a net present value of 0 (or benefit:cost ratio of 1), the maximum adoption rate would need to fall to 0.2% of the rice–wheat cropping in Punjab (using a discount rate of 5%). An adoption of 0.2% translates to coverage of approximately 5,200 ha. Considering that each Happy Seeder has a maximum capacity of 100 ha, 52 Happy Seeders would need be adopted. Given that, in late 2009, approximately 70 Happy Seeders were in circulation and that the Punjab State Farmers Commission has recently distributed 200 Happy Seeders (Singh 2010), the level of adoption of the Happy Seeder is already above the minimum required for a positive return from this project. We can therefore be confident that the project will deliver positive benefits.

As noted above (Table 11), the cost saving attributable to the Happy Seeder is 9.4%. The cost saving required to cover all of the costs of the project (that is, to generate a net present value of zero, or a benefit:cost ratio of 1) is 0.55%.

### Sensitivity analysis

As with all impact analyses, measured results are clearly sensitive to the magnitude of a variety of input assumptions. The benefits from adopting the Happy Seeder arise from lowering the number of operations on the field required to plant wheat seed (net of some operational cost increases) along with reduced inputs costs.

In the case of the analysis presented here, seven sets of assumptions are particularly important:

- *Adoption parameters*, including the maximum adoption rate and the time needed to achieve that rate.
- *Capital costs* of the Happy Seeder.
- *Operational cost savings* associated with adoption of the Happy Seeder.
- *Sowing and related cost increases* associated with adoption of the Happy Seeder.
- *Irrigation savings*—the irrigation savings associated with the use of the Happy Seeder have been estimated at 30%.
- *Fertiliser savings*—the fertiliser savings generated from not burning the rice stubble have been estimated at 10%. However, research on this subject has yet to be completed, so there is still uncertainty about the magnitude of the saving. The benefits are also modelled without the fertiliser savings.
- *Herbicide savings*—the herbicide savings generated from not burning the rice stubble have been estimated at 50% per year.

Figure 12 reports the sensitivity of outcomes to a 10% change in key assumptions. It shows the percentage change in the net present value of the project (relative to base assumptions) as a consequence of a 10% change in the relevant assumption.

Not surprisingly, the most important assumptions are the operational cost savings and the adoption parameters. The cost increases associated with the Happy Seeder are also important, but the impacts of fertiliser savings, irrigation-related savings and capital costs are relatively small by comparison.

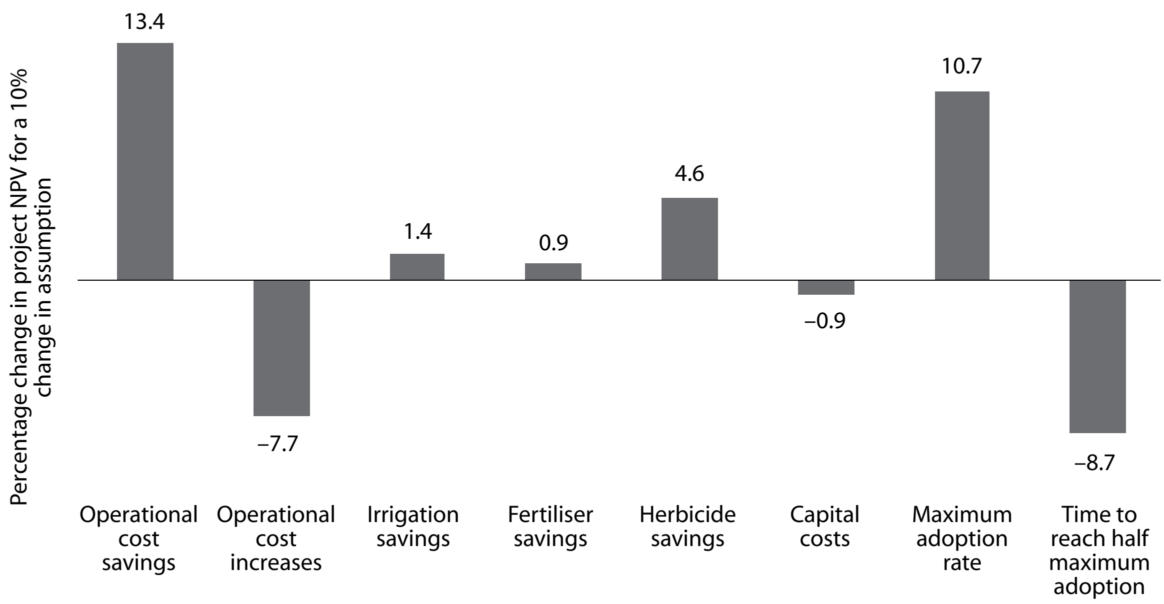


**Figure 12.** Sensitivity of project net present value (NPV) to a 10% change in various assumptions. Source: Centre for International Economics' estimates

# 7 Conclusions

While widespread benefits are yet to be realised, we estimate that the ACIAR-funded projects will eventually deliver significant benefits to Indian farmers growing rice and wheat in rotation.

This project included many different activities, undertaken as seven subprojects, contributing to the development of three main outputs:

- raised beds for rice–wheat, maize–wheat and soybean–wheat cropping
- a rice–wheat cropping model
- the Happy Seeder.

Of these three outputs, only the benefits of adopting the Happy Seeder have been modelled. This is because the rice yields on raised beds were found to fall, leading to the current conclusion that permanent raised beds are not suitable for rice–wheat cropping. While raised beds were also assessed for use in conjunction with maize–wheat and soybean–wheat cropping, these are relatively small systems in Punjab, and there was little evidence to suggest widespread adoption. The components of the rice–wheat cropping model were shown to have good predictive power, but more work is required to ascertain how this output can be transformed into a material outcome.

The Happy Seeder has the potential to deliver significant benefits to farmers. While we could model only the benefits deliverable to Punjabi farmers with any confidence, there is the long-term potential for much broader adoption of the Happy Seeder. Other ACIAR work has already been undertaken in Pakistan. Further development work is required for the Happy Seeder to be used in Australia, where the rice straw loads are heavier than in India.

However, adoption remains the primary area of uncertainty associated with the benefits from this project. The financial benefits of the Happy Seeder have been muted by the distortionary price signals in the market; farmers neither bear the full social cost of their practice of burning rice stubble, nor the full cost of the inputs of production, including irrigation water, electricity for pumping it, petroleum products, fertilisers, herbicides and pesticides. A change in government policy (or rather, implementation of current government policy) could see a change in these incentives for adoption. However, Indian farmers are very risk-averse, and still need to be convinced of the long-term benefits of adopting the Happy Seeder, including the long-term impact on soil fertility, crop yields and savings on machinery maintenance, labour, water and other inputs. This requires further research, as well as the continuation of extension programs communicating to farmers the use and benefits of the Happy Seeder.

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