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Two-stage grain drying in the Philippines

ACIAR IMPACT ASSESSMENT SERIES 59

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Two-stage grain drying in the Philippines

Agnes Chupungco, Elvira Dumayas and John Mullen

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Cover: Drying rice by the roadside, Luzon, Philippines. Photo: Debbie Templeton.

Foreword

This is the second Impact Assessment Series (IAS) report that the Australian Centre for International Agricultural Research (ACIAR) and the Philippine Council for Agriculture, Forestry and Resources Research and Development (PCARRD) have supported collaboratively as part of each organisation's impact assessment program. The first was published as IAS Report No. 57.

Grain drying is a major issue in all grain-producing countries and presents particular problems in humid, tropical climates. ACIAR and PCARRD, in association with other Philippine research organisations, supported a major effort in this area from the very early days of ACIAR's activities. In addition, similar research had been supported by ACIAR in several other partner countries in Asia.

It was decided that this was an important area for an impact assessment study.

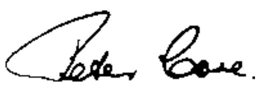
The initial review of the research, and discussions with industry stakeholders, indicated that the technologies developed in these projects had not been adopted and that little use was being made of them in the Philippines. Further investigation indicated that the same technologies had been adopted in other collaborating countries in the Asian region and in Australia.

Rather than report a zero return on investment and choose another research effort to assess, it was decided that the assessment resources should be used to look in detail at the reasons for this lack of adoption and impact.

This report presents the results of this assessment study. It found that the structure of the grain industry in the Philippines, and the policy and institutional environment there, are such that the grain-trading industry remains dominated by small-scale operators. As a consequence, economies of scale do not exist in grain trading, and the grain-drying technologies developed are therefore currently not profitable. There has thus been virtually no adoption of them.

The study provides some very useful lessons for guiding future investments in research, in particular the need to take local industry and policy conditions into account when developing research activities. The analysis undertaken suggests that, if the structure of the grain industry in the Philippines changes, application of the grain-drying technologies developed could yield returns as high as those gained in other countries.

We believe the collaboration between ACIAR and PCARRD in impact assessment studies is working very well, bringing benefits to both organisations from the activities conducted. We congratulate the assessment groups. Further collaborative assessments are planned in the coming years.



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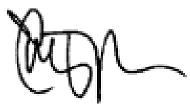

Patricio S. Faylon
Executive Director
PCARRD-DOST

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Abbreviations

ACIAR Australian Centre for International Agricultural Research

BPRE Bureau of Postharvest Research and Extension (Philippines), formerly NAPHIRE

DA Department of Agriculture (Philippines)

DA–BAR Bureau of Agricultural Research of the Department of Agriculture (Philippines)

m.c. moisture content

NAPHIRE National Post-Harvest Institute for Research and Extension (Philippines), now BPRE

PCARRD Philippine Council for Agriculture, Forestry and Natural Resources Research and Development

PHP Philippine pesos

R&D research and development

UNSW University of New South Wales (Australia)

Acknowledgments

The authors express their deepest gratitude to the Australian Centre for International Agricultural Research (ACIAR), the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) and the Bureau of Agricultural Research of the Department of Agriculture for providing financial assistance and for making this research undertaking possible; and to the University of the Philippines Los Baños (UPLB) and the UPLB Foundation, Inc., for serving as conduits for these funds and for other in-kind support.

For their valuable insights and suggestions, special acknowledgment is due to Dr Jeff Davis, Research Program Manager, Policy Linkages and Impact Assessment, ACIAR; Dr Patricio Faylon, Dr Albert Aquino, Dr Ernesto Brown, Ms Rita Fabro and Ms Anita Tidon of PCARRD. A special note of thanks also goes to Dr Minda Mangabat of the Bureau of Agricultural Statistics in Quezon City for dealing with all our queries on rice prices.

Appreciation is also extended for the administrative support of Dr Agnes Rola, Dean of the College of Public Affairs; Dr Rogelio Tagarino, Director of the Institute of Strategic Planning and Policy Studies and his staff—Ms Rowena Noche, Mr Mario Tandang and Mr Virgilio Ativo; the research support contributed by Mr Mark Tañedo and Ms Macrina Umali; and administrative assistance provided by Mr Joe Marvin Alpuerto.

Several other individuals and institutions are to be thanked for their time and generosity in participating in our interviews and responding to our phone calls. They are Dr Dante de Padua, a retired UPLB professor and the first Executive Director of the National Post-Harvest Institute for Research and Extension (NAPHIRE), now the Bureau of Postharvest Research and Extension (BPRE); BPRE officials and personnel, especially Director Raul Paz, Ms Isis Davalos, Engr. Robelyn Daquila, Engr. Allan Bermundo, and Engr. Reagan Pontawe; the Agricultural Credit and Policy Council; KATO International and the officials of farmer-cooperatives and some municipal agriculturists and respondents in Nueva Vizcaya, Kalinga, Nueva Ecija, Tarlac, Laguna, Marinduque, South Cotabato and Zamboanga del Sur.

Finally, the authors wish to thank Dr Robert Driscoll and Dr George Srzednicki from the University of New South Wales and Engr. Manolito Bulaong from BPRE who reviewed this paper and were participants in the grain-drying projects it assesses.

Summary

Between 1983 and 1997, ACIAR and its research partners in the Philippines, including the Bureau of Postharvest Research and Extension (BPRE) and its predecessor the National Post-Harvest Institute for Research and Extension (NAPHIRE), invested A$4.1m (Philippine pesos 159m) in research, extension and capacity building targeting the problems of drying grains such as rice, maize and peanuts after harvest in hot, humid climates and particularly during the wet season. The concept of two-stage grain-drying technology was developed, based on the use of a flash dryer or, in later projects, a fluidised-bed dryer, in the first stage, for grain with high moisture content (>18%), followed by slower, in-store drying to reduce the grain moisture content to a safe storage level. We focused on the use of the technology in the rice industry.

From a technical viewpoint, the program of research and development seems to have been successful, with the emergence of a technology that is close to being competitive on a cost basis, especially during the wet season, and delivers, in addition, a significantly higher proportion of rice meeting Grade 1 standards. The technology is reported to be widely adopted in Thailand and to be attracting growing interest in Vietnam and China (Pearce and Davis 2008), yet there has been no adoption in the Philippines of the two-stage drying strategy or either of its components.

Hence, from the suite of projects funded by ACIAR there are no positive changes in economic welfare in the Philippines that can be reported here. An earlier assessment by McLeod et al. (1999) reported positive benefits that arose largely from efficiency gains in Australia and further gains in Thailand where fluidised-bed first-stage drying was widely adopted. There have likely been important gains in capacity in Australian and Philippine agencies conducting research into grain handling, and this capacity has enabled the results of the research to be extended and adapted in other countries such as Thailand, China and Vietnam where there is some evidence of adoption.

Perhaps the potential benefits from adoption of this technology, which requires a significant change to the way small grain-trading firms operate, are not well known. Certainly, there have been criticisms of the government programs that were implemented to support the introduction of the technology. These focused mainly on an apparent lack of understanding of the two-stage nature of the technology, on the poor selection of firms to receive assistance and on the lack of training and ongoing support and maintenance for a technology that requires significant management skills. We are not aware of government policy that directly impinges on the adoption of two-stage drying technology, apart from past attempts to subsidise adoption. However, we have not attempted to assess the implications for adoption of more efficient grain-drying processes of general government policy relating to, for example, land reform and food security which may influence the rate of adjustment in the farm and processing sectors of the rice industry.

It is more likely that the economic incentives to adopt the technology are not strong even though, albeit simple, budgeting studies suggest that two-stage drying, while more costly, has a positive impact on profit, largely from quality improvement.[1] The Philippine rice-trading sector is characterised by many small traders turning over small volumes of rice in a few days. The two-stage technology requires significant investment in drying facilities (often including shed space) with a consequence that a larger throughput of rice is required to achieve per unit drying costs similar to traditional sun

1 The same can be said of drying in recirculating-type grain dryers.

drying. The adoption of two-stage drying technology (or of recirculating-type dryers) on a significant scale may require considerable structural adjustment within the Philippine rice industry, and likely needs to be aligned with other developments such as further movement from bagged to bulk handling of rice. We have not been able to assess the significance of these scale and adjustment issues to the adoption of the technology.

The technology would also be more attractive from an economic point of view if the premium for Grade 1 rice were larger. Rice is a staple in the Philippines, consuming a large share of family income in many households. Perhaps as households become wealthier through general economic progress in the Philippines, a stronger premium for quality will emerge.

These projects are likely to have delivered significant gains in capacity in the partner research organisations and in grain-processing firms that were engaged, in various ways, in the research process. Several research staff in the Philippines undertook postgraduate training in association with these projects. The staff of the cooperatives (technical and managerial) collaborating in the research received training in grain drying by NAPHIRE scientists. Other extension activities, including ACIAR's Postharvest Newsletter, which was disseminated throughout the Philippines, reached out to grain processors and others. It is highly likely that the knowledge acquired in these projects has been used in other BPRE research. We have not attempted the complex and time-consuming task of estimating the value derived from those potential gains in capacity.

1 Background to, and objectives of, the impact assessment study

The Australian Centre for International Agricultural Research (ACIAR) has had a strong culture of assessing the impact of its research investments to demonstrate to taxpayers in Australia and partner countries the value of these investments and to guide the allocation of research resources in the future to potentially high pay-off activities.

Peak agricultural research institutions in the Philippines, including the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) and the Bureau of Agricultural Research of the Department of Agriculture (DA–BAR) have been interested in applying ACIAR's experience to further develop their own capacity in impact assessment. In 2007, ACIAR, PCARRD and DA–BAR decided to jointly fund impact assessments of three areas of research and development (R&D) supported by ACIAR in the past. The partners agreed to conduct impact assessments in the following three areas:

- the control of endoparasites in goats
- the development of two-stage drying processes for grains, including rice
- pest management in grain storage in the context of developing pesticide-resistance problems.

A number of criteria guided the choice of research areas to be assessed. The research had to have been largely completed so that the industry had had time to adopt the technologies. In this first round of impact assessments there was a deliberate attempt to select research areas where at least the science was thought to have been successful, even if the level of adoption was uncertain. An attempt was made to assess different types of technologies in different industries at different links in the marketing chain. The interests, priorities and skills of the three partners influenced the choice. In each case, the program of research assessed consisted of a number of sequential research projects funded by ACIAR and sometimes projects funded by other agencies such as the International Fund for Agricultural Development and PCARRD that were inextricably linked to the ACIAR projects.

ACIAR commissioned Dr John Mullen from the New South Wales Department of Primary Industries to coordinate the assessments with Philippine collaborators. PCARRD and DA–BAR commissioned economists from the University of the Philippines Los Baños (UPLB), the Bureau of Agricultural Statistics (BAS) and the Philippine Rice Research Institute (PhilRice) to work with Dr Mullen. These organisations also provided in-kind support to the impact assessment process.

Here we report an assessment of the impact of research funded by ACIAR, PCARRD and DA–BAR into a two-stage drying technology for grains such as rice.

In the Philippines and other tropical countries, grains such as rice and maize are traditionally sun dried. While practical in the dry season, this technology is problematic in the wet season. Unless grain is properly dried, there can be severe losses in both quantity and quality during storage. These quality changes take the form of yellowing of paddy rice, lower milling yields and reduced content of lysine, an essential amino acid. In maize, improper drying can lead to greater problems with aflatoxins, toxic compounds of fungal origin. Double cropping has increased the production of grain in the wet season and hence the problem of grain drying.

ACIAR funded three projects in the Philippines (and other countries) over a 14-year period to research ways to overcome grain-drying problems. A two-stage drying technology for grains was developed after more than 10 years of collaborative R&D work between the National Post-Harvest Institute for Research and Extension (NAPHIRE) [now the Bureau of Postharvest Research and Extension (BPRE)] and the University of New South Wales (UNSW). This technology, which is suited to use by medium- and large-scale grain processors such as farmers' cooperatives and private millers, is composed of the NAPHIRE flash dryer or any efficient high-temperature dryer for the first-stage drying and an in-store dryer for the second stage drying. In the first stage of drying, newly harvested grains or grains with high moisture content (m.c.) (say about 24%) are dried rapidly to a more manageable level of about 18%. The second, slower stage of drying takes the grain to about 14% m.c., a safe storage level. The first stage provides uniform drying in a matter of minutes or a few hours, whereas the second stage proceeds gently, in order to minimise or prevent grain fissuring and breakage, which can occur using mechanical dryers unless the drying temperatures are carefully controlled (Tumambing et al. 1999).

The two-stage drying technology was expected to offer higher drying efficiency, lower drying cost and more operational flexibility than the existing fixed-bed or continuous-flow drying technologies for grains, particularly during the wet season. It was also expected that it would frequently yield grain of superior quality to that subjected to other drying methods.

Our overall objective in this impact assessment was to estimate the rate of return to ACIAR's investment in the Philippines on research into grain-drying technologies during three projects undertaken from 1983 to 1997. Mangabat et al. (2002) assessed these three projects but their analysis stopped short of estimating a rate of return on investment. McLeod et al. (1999) undertook a more complete assessment of the impact of the operations of these projects in Thailand. He found that, at the level of adoption at the time of his analysis, the benefit:cost ratio was about 3:1 but continuing adoption to 2020 implied that it might increase to 15:1. He also found that, at the time of his analysis, most of the benefits had accrued to Australian rice farmers.

Despite its technical promise, based on the investigations and a survey undertaken in this study, we found that the two-stage drying technology has never been widely adopted in the Philippines. The technology now promoted by BPRE entails retrofitting mechanical dryers with biomass furnaces, replacing oil-fired burners. At present, most private traders use oil-fuelled batch recirculating dryers but are switching to biomass-fuelled dryers due to the high cost of oil. The reasons for this are explained later in this report.

Specific aims of the assessment were to:

1. describe the objectives of the ACIAR-funded projects
2. determine the inputs, outputs, and outcomes of the R&D
3. describe adoption pathways and the extent of adoption
4. estimate potential and actual changes in welfare attributable to the technology
5. discuss why adoption of the technology has been so low in the Philippines.

Figure 1 summarises our approach to the impact assessment.

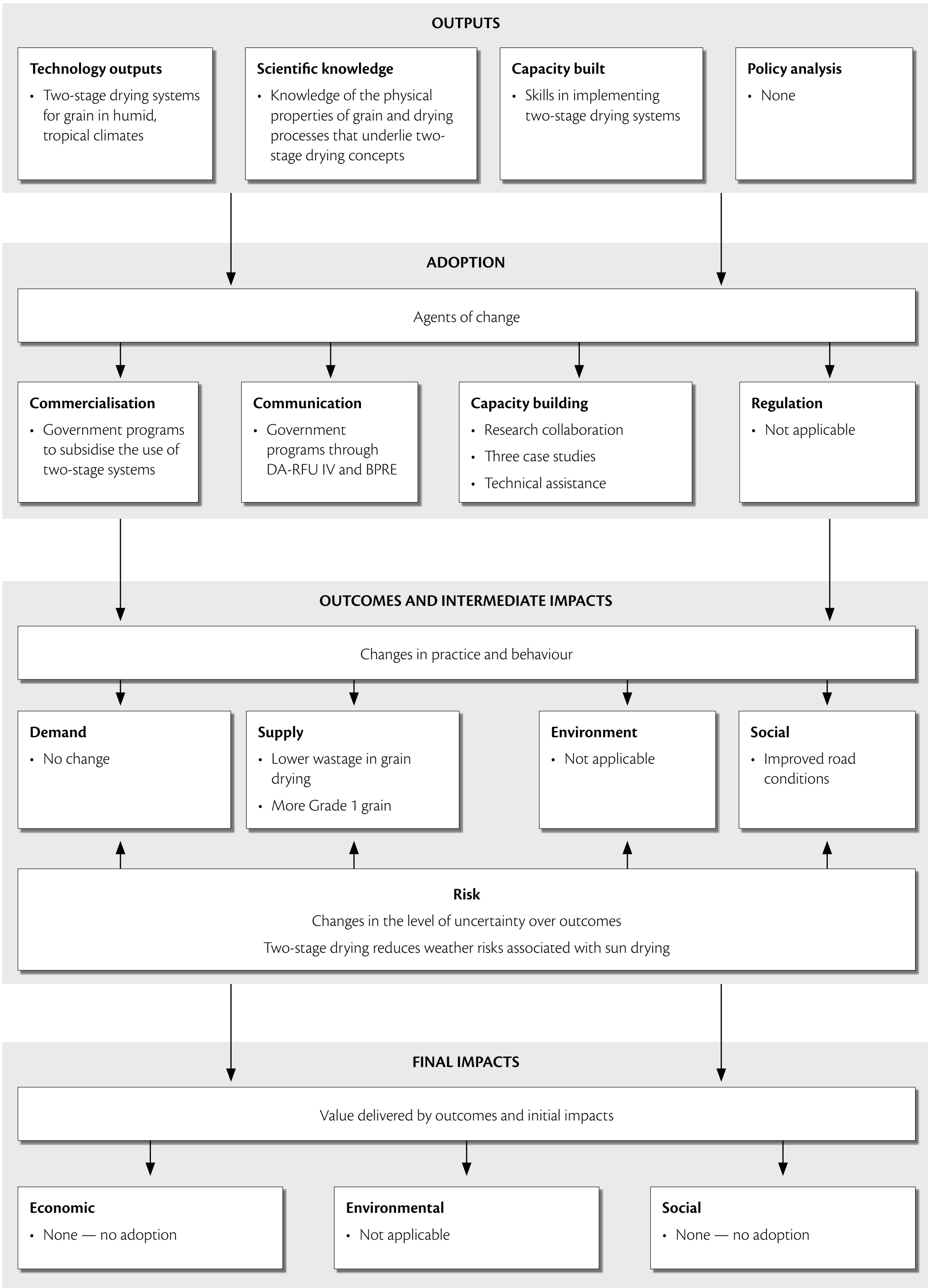

Figure 1. Summary of pathway to benefits for the two-stage drying technology

2 Grain-drying technologies in the Philippines

In 2007, palay (paddy, or unhusked (rough) rice) production in the Philippines reached 16,237,000 tonnes. After harvest, palay grown by farmers is either dried by the farmers themselves (using a solar pavement or the road) or sold to traders, farmers' cooperatives or grain processors/rice millers. Sales to the last-named group are either direct or through agents. Some of the palay harvested goes to Farm Level Grain Centers (FLGCs) in the rural communities. In the FLGCs, the grain is dried, stored and, as required, milled. In general, farmers need cash immediately so, especially during the rainy season when it is hard for them to dry their crop, they sell their palay wet and let the private traders, cooperatives or grain processors dry it. Farmers who are members of cooperatives sell their produce to either the cooperative (as some cooperatives extend production loans to farmers and farmer-members are required to sell their newly harvested palay to the cooperative) or to private traders who offer a higher price. Cooperatives also buy palay from non-members. Conversely, during times of oversupply and insufficient drying capacity some cooperatives will urge farmer-members to sell their wet palay to other players in the market.

There are also transactions in dry (14% m.c.) palay, which is sold to the marketing intermediaries mentioned above and to the National Food Authority, which buys dry palay to an average of about 4% of total production. There is a 2–5 pesos per kilogram difference in the buying price of dry palay and price of wet palay (Hughes and Daglish 2005).

Of the total production in the country only about 14% (2.2 million tonnes) is dried using mechanical dryers (Elepaño 2008); the rest (about 14 million tonnes) is sun dried. Table 1 describes the various methods of drying palay from field drying to use of mechanical dryers.

The Republic Act No. 7607, known as the 'Magna Carta of Small Farmers', provides for the provision of at least one storage facility and a multipurpose pavement in each of the nation's rural barangays/villages (Cabanilla et al. 2002). The intention is that these postharvest facilities be used by individual farmers and/or farmer cooperatives for various purposes, including drying of agricultural produce. The act was approved in 1992 and its enforcement is continuing.

Sun drying works well in the dry season when it takes about 1 day to get the moisture content of rice down to 14%. If the weather is cloudy, drying takes 2 days. When drying is delayed in the wet season, the value of the grain can fall by between 5 and 58% (Mendoza and Quitco 1984) unless it is sold wet to wholesalers with mechanical drying facilities at a discounted price. Delays in drying lead to grain discoloration, chalky kernels and decreased yields during grain handling and processing. De Padua (2007) pointed out that one of the key causes of the poor quality of milled rice produced in the Philippines is the lack of drying capacity, particularly for the wet-season harvest.

The introduction of the high-yielding seed varieties and the adoption of advanced production technology has created extra problems in drying grain in the wet season. Sun drying is no longer adequate to dry large quantities of wet palay especially at the peak of the harvest. In the 1990s, 58% of palay and 65% of maize were harvested in the wet season (Mangabat et al. (2002), from BAS sources).

The mechanical dryers used by cooperatives and grain processors are typically flat-bed dryers of 1–6-tonne capacity and batch-recirculating dryers of 6–10-tonne capacity. There are very few continuous-flow dryers in use. Somewhere between 50 and 90% of private traders use batch-recirculating dryers, more than half of which are oil-fired (M.C. Bulaong, pers. comm.). Private traders are now switching to biomass-fuelled dryers due to the high cost of oil.

After drying, a small number of traders or cooperatives store the palay (for up to 3 months) to wait for a higher price during lean months when supply of palay is low.

Before consumption, palay is dehusked and milled to produce white rice. Elepaño (2008) found that palay is milled using either kiskisan-type mills with a capacity of 0.1–0.3 tonnes per hour but with milling losses of 6–8%; cono-type mills with a capacity of 0.5–2 tonnes per hour; and rubber-roller mills with a capacity of 0.5–2.5 tonnes per hour. Of the total palay production about 56.1% is milled using rubber-roller mills, 33.2% with cono mills and 10.5% with kiskisan.

Almost all palay is stored in bags; only 1% is stored in bulk. More than 80% of palay is handled by private millers. De Padua (2007) reports that:

> …the urban areas are supplied primarily from the traditional rice granaries and processed by large capacity commercial millers, but the provincial communities are supplied by smaller entrepreneurs that depend on low efficiency service mills.

After milling, the rice is sold to traders, wholesalers, wholesaler–retailers or retailers. Farmers retain almost 25% of the palay crop for home consumption. It is dried but not milled until needed.

Table 1. The main methods of drying palay (paddy, rough rice) in the Philippines

Method	Description	Process	Additional information	Comments
Field drying	Cut panicles are either spread out in the field, or bundled and left standing, to dry for a few hours or days.	Sun or solar drying of unthreshed or uncut panicles in the field	Usually practised during the rainy season	Losses are incurred due to rats, birds and grain shattering. If the grain is left too long in the field, quality deteriorates due to overheating.
Shade drying	Bundled, cut panicles are placed in the shade to dry. Threshed palay is spread to dry on mats, the floor or other surfaces inside the house or in a shaded place outside.	Shade or air drying	Used for next season's seed Long drying time Sometimes, bundled panicles for seed are hung above the cooking area in the kitchen.	Subject to grain loss due to pests and spillage.
Sun drying	Threshed palay is spread out on mats, a pavement, the roadside or other surfaces to dry in the sun.	Sun or solar drying The palay needs to be stirred frequently, by hand or using the feet, a rake or other means.	This is the cheapest and most common method used by all sectors involved in palay production or processing.	Losses occur due to spillage, consumption by animals, or rain damage. Sun drying is labour intensive and is usually done by women or children on the farm.
Shallow-bed batch dryer	Grain is loaded at up to 40 cm thickness on a perforated floor and dried by forcing heated air through it.	The grain is dried in batches. For seed drying, the air is heated to 43 °C.	Because of the high temperature of the drying air used, manual stirring is needed to minimise uneven drying.	This is a simple but labour-intensive method in that loading and unloading is done manually. Small-scale palay processors are its most common users.
Deep-bed batch dryer	Grain is loaded at more than 40 cm depth on a perforated floor and dried by forcing ambient or slightly heated air through it.	Slow drying of grain while in storage	The method is applicable only to grain with a low moisture content (not more than 20%) at harvest. First-stage drying must be applied initially if the moisture content is above 20%.	The method has a low energy requirement and yields high quality grain due to the low temperature and gentle drying applied. It is used in large-scale processing plants.

Table 1. (continued)

Method	Description	Process	Additional information	Comments
Continuous-flow, non-mixing dryer	The grain is dried in a column about 30 cm thick supported by perforated screen walls, and with a feed hopper on top and a discharge mechanism at the bottom.	Air heated to up to 70 °C is forced across the column of grain to effect drying as it flows downward. Exposure time is 10–15 minutes.	After drying, grain is transferred to an aerated tempering bin to allow moisture in the grain to equilibrate.	The method is used in large commercial installations. Drying is uneven because only one side of the grain is exposed to heated air.
Continuous-flow, mixing dryer	The grain is dried in a column with perforated screen walls, mixing baffles, a loading hopper at the top and a discharge mechanism at the bottom. A variation, called the LSU-type (Louisiana State University), incorporates inverted V-ducts alternately arranged inside the bin. Heated air is forced into one layer of inverted Vs and discharged to the adjoining inverted Vs as the wet grain flows downward.	Grain zigzags downwards through the drying column, allowing mixing and resulting in more uniform drying. The LSU-type has no perforated screens; the drying air passes through the inverted V-ducts.	The LSU-type dryer is more adaptable to local conditions as it allows cleaning of grain during the drying—there are no screens to clog with dirt.	Mixing of the grain means that this type of dryer gives more uniform grain drying.
Batch recirculating dryers	These are column dryers as described above, using either perforated screens or LSU-type V-ducts, but grain is recirculated into the drying column until dry.	The process is the same as continuous-flow dryers but grain is recirculated into the drying column.	The grain is dried in batches, using either oil-based fuel or biomass fuel as the heat source.	This is a method commonly used by private grain traders.

Source: adapted from Andales (1996)

Notes:

For each type of mechanical dryer, power is required to drive the blower to move the air, to heat the drying air, and to operate elevators and other accessories. Power can be provided by petrol or diesel engines or electric motors, while the heat source could be from electricity, fossil fuel or biomass fuel, depending on the cost and availability in the area.

Other methods such as fluidised-bed, rotary and tray dryers are also available for drying palay, but they are seldom used because of unavailability of equipment, stringent technical requirements, critical operating conditions and a high risk of damaging the grain if they are not operated properly.

3 Research undertaken

3.1 Agencies and countries involved

ACIAR funded research to overcome wastage and quality problems associated with drying grains in humid, tropical climates, particularly in the wet season. The ACIAR grain-drying projects in the Philippines, which began in 1983 and finished in 1996, were PHT/1983/008, 'The drying in bulk storage of high-moisture grains in tropical climates—principles and application technology'; PHT/1986/008, 'Drying of high moisture grains in humid tropical climates'; and PHT/1990/008, 'Applications of in-store drying in the grain industry in Southeast Asia'. The research was conducted by UNSW and NAPHIRE (now BPRE). Other countries cooperating in the grain-drying research were Vietnam, Thailand and Malaysia.

3.2 Total expenditure on research

The data on investment in this set of research projects came from a variety of sources. The data pertaining to the ACIAR projects were largely derived from ACIAR project submissions and subsequent revisions. A proportion of the total expenditure by ACIAR on each project was attributed to research in the Philippines and this estimate is used here.

Investment data for project PHT/1983/008 were taken from McLeod et al. (1999). ACIAR sources were used for later projects. They suggested that, for project PHT/1986/008, 40% of total expenditure went to work in the Philippines and this proportion was also applied to the earlier project. The Philippine contribution to project PHT/1986/008 was estimated from the ACIAR project data to be A$13,700. That estimate was applied also to project PHT/1983/008. For both of these projects the UNSW contribution was judged to be the same as the Philippine contribution. For project PHT/1990/008 the proportion of total funding attributed to the Philippines increased to 50% and data became available on the in-kind contributions from the Philippine and the Australian partners.

The investments, in Australian dollars, by the three partners were totalled for each year and then converted to 2007 Australian dollars using the Australian GDP deflator (Appendix 1). This 2007 Australian dollar series was converted to a series in 2007 Philippine pesos (PHP) using the exchange rate in 2007. Both series were compounded forward to 2007 at a rate of 5% (analogous to discounting a stream of future investments or benefits).

Following this approach, the net present value in 2007 of the investment in these three projects in the Philippines by ACIAR and its partners amounts to A$4.1m or PHP159m (Table 2). The ACIAR contribution was A$2.5m, giving it a share in the total investment of just over 60%, with the shares to BPRE and UNSW being about 20% each.

3.3 New technology and knowledge developed, and capacity built

The ACIAR projects led to the development of a two-stage drying process. The first project provided the basic information about drying grain (rice, maize and peanuts) in humid, tropical climates such as that in the Philippines. Computer models of mill drying systems

Table 2. Investment by ACIAR, BPRE and partners in two-stage grain drying research and development in the Philippines, 1983–1997

	Real investment (2007 values)					Present value in 2007 (5% compound)				
	ACIAR	**Philippine partners**	**UNSW**	**Total**		**ACIAR**	**Philippine partners**	**UNSW**	**Total**	
	A$ 2007	A$ 2007	A$ 2007	A$ 2007	PHP million 2007				A$	PHP million
1983	77,018	33,475	33,475	143,968	5.56	248,390	107,961	107,961	464,312	17.94
1984	42,615	31,045	31,045	104,704	4.05	130,893	95,354	95,354	321,601	12.43
1985	31,515	29,572	29,572	90,659	3.50	92,189	86,506	86,506	265,201	10.25
1986	44,334	28,021	28,021	100,377	3.88	123,512	78,067	78,067	279,645	10.81
1987	20,231	26,206	26,206	72,642	2.81	53,678	69,532	69,532	192,742	7.45
1988	70,882	24,135	24,135	119,151	4.60	179,115	60,987	60,987	301,089	11.63
1989	108,154	22,038	22,038	152,229	5.88	260,286	53,036	53,036	366,358	14.16
1990	93,828	20,899	20,899	135,625	5.24	215,054	47,900	47,900	310,855	12.01
1991	16,486	–	–	16,486	0.64	35,988	–	–	35,988	1.39
1992	–	–	–	–	–	–	–	–	–	–
1993	108,616	12,583	28,518	149,717	5.79	215,053	24,914	56,463	296,430	11.45
1994	175,296	24,939	28,259	228,494	8.83	330,547	47,026	53,287	430,860	16.65
1995	163,731	24,652	27,934	216,317	8.36	294,037	44,271	50,166	388,474	15.01
1996	147,131	12,049	27,306	186,486	7.21	251,645	20,607	46,702	318,954	12.32
1997	54,562	–	26,935	81,497	3.15	88,876	–	43,875	132,750	5.13
Total present value in 2007 (5% compound)						**2,519,263**	**736,161**	**849,836**	**4,105,259**	**159**
Share of total cost:						**61.4%**	**17.9%**	**20.7%**		

Notes: ACIAR, Australian Centre for International Agricultural Research; BPRE, Bureau of Postharvest Research and Extension; UNSW, University of New South Wales; PHP, Philippine pesos using flat-bed dryers were developed, and studies on a rice-hull gasifier and supplemental heating energy undertaken. The information collected was used in later projects. In particular, the key concepts associated with two-stage drying were developed during this project; later projects were designed to make these concepts 'operational'.

The second project developed a mobile flash dryer. The flash dryer is used to pre-dry wet season palay to 18% m.c. at which level it can be stored for 3 weeks without deterioration in quality. The technology was also extended to drying of maize and peanuts. Parallel research in Thailand led to the development of the fluidised-bed dryer as a first-stage dryer. Fluidised-bed drying has been widely adopted in Thailand and there is growing interest in its use in Vietnam and China, but only a few of the dryers were imported into the Philippines by private millers.

McLeod et al. (1999) observed that the development of fluidised-bed drying, which was finally preferred over flash drying, was a significant outcome from the ACIAR projects. According to their study, the chief advantages of the technology were perceived to be the speed of drying and lower costs, although more labour was required.

The third project developed the in-store drying technology, using the information from the second project to design a low airflow dryer to dry the grain to 14% m.c. It likewise conducted field trials using a two-stage drying system: first-stage flash drying followed by second-stage in-store drying (Mangabat et al. 2002).

BPRE (2000) enumerated the advantages of in-store dryer use as follows:

- Depending on the initial grain quality, in-store drying yields high-quality dried grain producing up to 99% head (unbroken) rice at milling.
- It has a relatively low energy cost of PHP1.00–3.00 per cavan (50 kg) depending on the season.
- Grain handling is minimised in that drying and storage can be done in the same bin.
- Drying efficiency is high: even unheated air can at times be used.
- There is less dependence on oil-based fuels.
- The drying bin can be divided into several independent compartments for flexibility of operation.
- In-store drying is competitive with sun drying in terms of operating costs.

The method does, however, also have several limitations:

- When used as a second-stage dryer during the wet season, the grain inloaded needs to have an initial moisture content of no more than 18%.
- Supplemental heating (1–5 °C temperature rise) of the drying air is required during the wet season or at times when the average daily relative humidity is greater than 75%.
- Drying of each batch of grain takes a few days—up to 3 days per metre depth of grain.
- A three-phase electricity supply is needed, and this is not always available.

The in-store dryer had been developed in Australia as a slow drying process based largely on use of ambient air. This process was not directly applicable in the Philippines because of the high humidity, and the dryer was therefore adapted to heat ambient air by several degrees to reduce its humidity to a level suitable for grain drying. This also proved a useful innovation in more humid parts of Australia.

As for every R&D project funded by ACIAR, the grain-drying projects included a capacity-building component. The Philippines project leader, Justin Tumambing, undertook and completed PhD studies at UNSW, and Manolito Bulaong an MSc. Both were working on topics focusing on grain drying. Technical and managerial staff of the cooperatives collaborating in the research received training on grain drying by the NAPHIRE scientists, and other extension activities—including ACIAR's Postharvest Newsletter, which was disseminated throughout the Philippines—reached out to grain processors.

We have not attempted to quantify the benefits flowing from these capacity-building activities.

4 Outcomes

4.1 Adoption pathway

The in-store dryer was designed to operate in combination with the flash dryer or any suitable pre-dryer as part of a two-stage drying system during the wet season and frequently as a single-stage drying system during the dry season (Tumambing et al. 1999). The intention was that rice handlers of sufficient scale, such as cooperatives, would own both in-store and flash dryers, and would sell rice in milled form to take advantage of the high quality of the dried product (BPRE 1999).

Recognising the potential gains from reduced wastage and improved quality, the Philippine Government introduced a number of schemes to subsidise the cost of adoption of improved grain-drying technology.

Mangabat et al. (2002) noted that the Philippine Department of Agriculture (through its Post Harvest Facility Program under the Grains Production Enhancement Program (GPEP) (1993–96)) developed a mechanical dryer assistance project to help farmer organisations adopt the technologies developed in the ACIAR projects. Other programs followed, including the *Gintong Ani* program (1996–98), the *Agrikulturang Makamasa* program (1998–99) and the *Ginintuang Masaganang Ani* program during 2000–03 (Calica 2006).

During 1993–95, 777 mechanical dryers, or 94% of the targeted 830 mechanical dryers under the GPEP, were distributed nationwide to farmer organisations. They were mostly flash dryers, either mobile or stationary.

As part of the ACIAR projects, in-store dryers were installed in three farmer cooperatives: the Dayap Development Cooperative in Dayap, Calauan, Laguna, Southern Tagalog Region; the Christian Farmers Cooperative in Talavera, Nueva Ecija, Central Luzon; and the Tupi Integrated Agricultural Cooperative in Tupi, South Cotabato, Mindanao. These in-store dryers were assessed in the pilot study discussed in Tumambing et al. (1999).

Mangabat et al. (2002) reported that, as of December 1999, 206 mobile flash dryers from a total of 257 units procured for six regions, and 47 in-store dryers from a total of 48 units procured for two regions, were distributed as part of the *Agrikulturang Makamasa* program. All 47 in-store dryers were distributed in Southern Tagalog by the Department of Agriculture (DA)-Regional Field Unit IV. In 1999, as part of the *Gintong Ani* program, 12 in-store dryers from BPRE funded by the DA were donated to cooperatives in various regions. Calica et al. (2006) reported that 27 in-store dryers (a lower estimate than above) and 1,329 other mechanical dryers costing PHP13m and PHP181m, respectively, were distributed during the 1993–2004 period.

Sixty-two in-store dryers have been distributed to farmer organisations:

- 3 ACIAR-funded units went to demonstration sites in cooperatives in Dayap, Calauan, Laguna; Talavera, Nueva Ecija; and Tupi, South Cotabato
- 12 units were distributed to 12 beneficiaries by BPRE for the *Gintong Ani* program
- 47 units were distributed in Southern Tagalog.

From the interviews with BPRE and officials of some cooperatives, it was found that the cooperatives in Dayap, Calauan and Talavera, Nueva Ecija that had received the ACIAR-funded units had gone bankrupt and had not been using the in-store dryer. Of the 12 recipients of dryers from BPRE, it seems that only one has been continuously using the dryer. This is the SAVACOMFAS Multipurpose Cooperative (previously called the Salug Valley Compact Farms Association, Inc.) located in Zamboanga del Sur, Mindanao. Currently, it has two in-store dryers, one acquired from BPRE in 1998, the second from another cooperative in Surigao del Norte in 2003. The cooperative has been using both dryers since the times of their acquisition.

Davalos (2006) noted complaints from the 12 recipients of the dryers from BPRE. They included slower drying and higher labour costs than anticipated, mechanical failure and lack of after-sales service. Similarly, there is little evidence of adoption of the in-store dryers distributed under the *Gintong Ani* program in 1996–98 and the *Agrikulturang Makamasa* program in 1998. Some of the reasons for non adoption, elicited in interviews conducted as part of this study and from information in Davalos (2006), are given in Appendix 2.

Studies by Mangabat et al. (2002) and Calica et al. (2006), and findings from a survey conducted as part of this impact assessment, confirmed problems with the subsidised distribution of dryers, including that selection criteria were not strictly followed by implementing agencies, that there was financial and management incapacity within some cooperatives, that about 43% of respondents complained of poor quality machinery parts and engines, and that the majority did not receive after-sales service from the manufacturer.

Because they were designed to be used in combination with in-store dryers rather than as stand-alone units, mobile flash dryers are no longer being used.

4.2 Previous impact assessments of the ACIAR grain-drying projects

McLeod et al. (1999)

The impact assessment by McLeod et al. (1999) of the three ACIAR projects focused on benefits to Australia and Thailand. Most benefits accrued in Australia and arose from improved in-store drying technology. In Thailand the major outcome was the development of the fluidised-bed dryer for first-stage drying. The technology was commercialised there. McLeod et al. noted that there was strong interest in the fluidised-bed dryer technology in Vietnam but seemed to imply that there was little interest in it in the Philippines (although large private millers are reported to have bought several units). They estimated that the projects delivered a benefit:cost ratio of 3:1 and an internal rate of return of 27.

Mangabat et al. (2002)

Another assessment of the grain-drying projects was made by Mangabat et al. (2002). They reported two surveys of 161 farmer cooperatives in 30 provinces in 1997 and 1998. Between 1991 and 1997, 161 flash dryers had been distributed to these cooperatives but very few had in-store dryers to enable them to implement the two-stage drying process. The surveys were conducted at the time of an El Niño event and so the traditional sun-drying technology was attractive. Only two of the cooperatives were recipients of both a flash dryer and an in-store dryer, the components of the two-stage drying technology. The findings of the Mangabat et al. (2002) study were as follows:

- Some 86% of surveyed cooperatives utilised the flash dryers. At the time of survey, 35% of flash dryers were not being used. Reasons given for this were: cooperatives were resorting to sun drying during the El Niño phenomenon; dryers were defective when delivered; some were damaged during use; dryers were laborious to operate; dryer operating costs were high; limited capacity of the dryer per batch; the limited volume of palay harvested by cooperative members did not maximise dryer utilisation; the dryer produced unevenly dried and discoloured palay; there was a taint in palay dried using kerosene as fuel; there was an increase in broken rice when flash-dried palay was milled.
- While most cooperatives found the flash dryer useful, they were unhappy that the machine had to lie idle during the dry season.
- There was no nationwide drive to provide information and technical assistance, and to monitor use of the dryers.

Using data from 26 cooperatives, Mangabat et al. (2002) compared the costs of flash drying and sun drying. Two scenarios were compared: one in which the wet-season palay was first dried in a flash dryer then further dried in the sun; in the other, sun drying was used for the whole process. Postharvest losses were reduced from 8% for sun drying to 2.4% for the flash-drying technology. However, the costs of flash drying were higher—PHP21.8 versus PHP19 per 50 kg bag. Mangabat et al. expressed concern about the low level of adoption of both the flash dryer and two-stage drying. They did not conduct a financial impact assessment of the project.

Tumambing et al. (1999)

Tumambing et al. (1999) conducted an economic analysis of grain drying at the three sites for which ACIAR had provided in-store dryers to demonstrate two-stage drying—the Dayap Development Cooperative at Calauan, Laguna, the Christian Farmers Cooperative in Talavera, Nueva Ecija, both handling rice, and the Tupi Integrated Agricultural Cooperative in Tupi, South Cotabato, which handled maize. Under the two-stage technology, sun drying was still used whenever the weather permitted. The cost comparison between two-stage drying and traditional methods is complicated in that, for both rice and maize, the two-stage drying process allowed the cooperatives to almost double the amount of grain they could handle. Nevertheless, the researchers estimated that the two-stage technology was marginally cheaper (PHP0.86 versus PHP1.24 per cavan) than previous drying processes using sun drying and a recirculating batch dryer. They observed also that the two-stage drying process might yield a price premium for milled rice of PHP100 per cavan (PHP2 per kg).

4.3 Changes in costs and returns at the trader level

Although the adoption of two-stage drying technology has been negligible in the Philippines, we have made an analysis of costs and returns associated with alternative grain-drying technologies, partly to gain an appreciation of the potential welfare gains from adoption of the technology and partly to gain an understanding of why adoption has been so low.

It is very difficult to compare the costs and returns associated with the alternative technologies. The three major factors that contribute to this difficulty are the variable scales at which the technologies are most efficient, the weather-related risks associated with drying and the differences in grain quality associated with the application of each technology.

Much of the rice entering the commercial sector is accumulated by small rice handlers and millers, sun dried on a concrete apron and stored for a matter of only days or weeks. Ignoring weather risks, this technology is low cost because it is labour intensive and uses little energy, although wastage is likely to be higher. There would appear to be few economies of scale associated with this technology. Larger firms might use mechanical dryers during the wet season, requiring energy.

The cost structure associated with two-stage drying is much different. The capital investment is significant and the technology, especially the in-store dryer, is ‘lumpy’, which means that the cost of drying falls until throughput reaches the capacity of the dryer. This optimal throughput may be much larger than the scale of many small traders. Widespread adoption of the technology may require substantial adjustment within the processing sector.

Drying costs are clearly weather-related. In dry times, sun drying is the least expensive option, but dry times also mean that less energy is also required for mechanical drying because the initial moisture content of grains is lower and hence drying costs are also lower. When the grain is wet, costs rise for all technologies, but the risk of adverse quality changes is higher for sun drying and some high-temperature mechanical dryers. Hence, the choice between drying technologies is also influenced by the impact of quality changes on revenue and by the firm’s perception of weather risk and the degree of its aversion to such risk. While the two-stage technology is unlikely to show large cost advantages over other technologies, it may be a more profitable technology if revenue increases as grain quality improves. The impact on revenue and profit depends not only on the change in quality but also on the extent of the premium paid for higher quality grain.

A thorough comparison of the revenue and costs associated with alternative grain-drying technologies would therefore require consideration of the impact on the optimal scales of a number of demand and supply factors under uncertain weather conditions. We have not attempted such an analysis. Rather we have tried to estimate differences in profit between alternative technologies for some tightly constrained scenarios that should not be construed as arising from any optimising process.

In particular, our analysis focuses on the wet season, when the advantages of the two-stage technology are likely to be at a maximum. Cost estimates are based on the capacity of each technology being fully utilised. The 'ACIAR' two-stage technology is compared with traditional sun-drying technology. We also present some information about recirculating drying technology, which is presently preferred to the two-stage drying technology. Many other combinations of sun drying and mechanical drying are ignored in this analysis but, in our judgment, the key elements of the debate are captured in the scenarios we examine here.

Our analysis is based on operating an in-store dryer of 30 tonnes capacity, the smallest configuration, which allows an annual throughput of 900 tonnes. We compare this with a sun-drying facility with the same throughput. The capital and annual overhead costs associated with these facilities are given in Table 3. The overhead costs of the two-stage process, PHP0.17 per kg, are much higher than those associated with sun drying. These unit overhead costs would be much higher again were the capacity of the dryer not fully utilised because, unlike the concrete apron for sun drying, there is no scope for scaling down the two-stage drying facility. The overhead costs associated with a recirculating dryer at PHP0.10 per kg are midway between the two alternatives. A qualification is that the recirculating dryer considered here has a much larger annual throughput than the two-stage configuration.

Estimates of the differences in profit when 1,000 kg of palay are dried using various processes are presented in Tables 4 and 5. These budgets are based on current prices and costs, and technology coefficients are derived from research conducted during the projects, from current industry expertise and from interviewing a firm that is still using the two-stage process. The overhead costs are those presented in Table 3.

Our baseline scenario compares the two-stage process developed during the projects with traditional sun drying. The benefits of the two-stage process are likely to be more important for rice harvested during the wet

Table 3. Overhead costs (in Philippine pesos (PHP)) for two-stage drying compared with sun drying and drying in a biomass-fuelled recirculating dryer, December 2007

	Two-stage drying	Sun drying only	Recirculating biomass
Capital investment			
Mobile flash dryer	400,000	0	
In-store dryer	500,000	0	
Solar		433,000	
Biomass-fuelled recirculating dryer			950,000
Total	900,000	433,000	950,000
Fixed annual expenses			
Depreciation	81,429	12,990	85,500
Interest on investment	24,750	11,908	26,125
Repairs and maintenance	30,000	6,495	28,500
Taxes and insurance	18,000	8,660	14,250
Total	154,179	40,053	154,375
Annual capacity (kg)	900,000	900,000	1,560,000
Fixed annual costs (PHP per kg)	0.17	0.04	0.10

season, when sun drying becomes more risky, and hence we have focused on that season. The costs and returns associated with this scenario are detailed in Table 4.

Critical parameters in estimating the cost of alternative drying processes are the weight losses during the process, from drying itself and other causes. As explained in the notes to Table 4, the weight loss in reducing moisture content from 24% to 18% is 7.3% and from 18% to 14% a further 4.7%. Other losses in using the flash dryer and the in-store dryer are a further 0.5% each. Additional losses associated with sun drying, particularly from rain damage, are most uncertain. Maranan (1996) reported average losses of 4.5% over the year. The average losses do not include quality deterioration, which is higher in the wet season than in the dry season (M.C. Bulaong, pers. comm.). We have followed Mangabat et al. (2002) in setting these losses at 8%. Using these parameters and a milling yield of 65%, 1,000 kg of palay yields 568 kg milled rice following two-stage drying and 545 kg of milled rice if sun dried.

The total cost of all steps from buying 1,000 kg of wet palay to selling milled rice at the wholesale level was estimated to be PHP8,670 for two-stage drying and PHP7,855 for sun drying. This estimate was for Luzon, the chief island of the Philippines. Under the scenario described here, the two-stage drying technology is more expensive than traditional sun drying even in the wet season, despite a marked reduction in wastage (with 23 kg more rice being available for sale). The two-stage drying process adds PHP0.62 per kg to the cost of drying rice.

Note that for sun drying the difference between the cost of purchasing palay and selling milled rice at wholesale, i.e. the price of processing services, or the price spread, is PHP7.3 per kg. If the price of palay (24% m.c.) were as high as PHP10.2 per kg then the price spread would narrow to PHP2.4 per kg.

This higher cost is ameliorated by the improved quality of rice delivered by the two-stage drying process. If the proportion of rice meeting Grade 1 standards increases from 21% to 79% and there is a PHP2 per kg premium for Grade 1 rice then the two-stage process becomes more profitable by PHP0.59 per kg.

The difference in net returns is sensitive to the price differential for quality. If the premium were PHP3 instead of PHP2, then the incremental profit is PHP1.2 per kg (and the price spread is PHP7.5 per kg). It is also sensitive to the shift in quality between the two technologies. If all sun-dried rice is Grade 2 and all two-stage dried rice is Grade 1 then the incremental profit is more than double at PHP1.45 per kg.

As we have already noted, most private grain traders use batch recirculating dryers fired by oil-based fuels but some are now switching to biomass furnaces due to the high cost of oil. A comparison of the costs and returns of two-stage drying technology with batch recirculating dryer technology is set out in Table 5. This budget is prepared under the assumption that there is a premium of only PHP2 for Grade 1 rice and that, in terms of quality, half the rice from recirculating drying is Grade 1 and half is Grade 2, an improvement on sun drying but not as great as that from two-stage drying technology.

Under these conditions the two-stage technology is less profitable than the recirculating technology by something less than PHP1 per kg. The profit disadvantage would be even smaller were the price premium to be PHP3. The comparison is not entirely fair in that the two-stage technology is based on the use of electricity rather than biomass. Nevertheless, the difference in profit is likely to be small, and while recirculating technology has the advantage of being quicker, it would also seem to share the disadvantages of large investment in 'lumpy' capital.

The key differences in costs and net revenues are summarised in Table 6.

Table 4. Costs in taking 1,000 kg of wet (24% moisture content, m.c.) palay (paddy, rough rice) to wholesale level in milled rice form using two-stage drying technology (flash dryer plus in-store dryer) versus use of sun drying

Item	Without price premium		With price premium	
	Two-stage drying	Sun drying	Two-stage drying	Sun drying
Farm-gate price of palay (PHP/kg)	7.5	7.5	7.5	7.5
Quantity of palay to be dried (kg)	1,000	1,000	1,000	1,000
Total revenue if palay is sold wet (PHP)	7,500	7,500	7,500	7,500
Using flash dryer				
Drying cost from 24% to 18% m.c. (PHP)	420		420	
Weight of palay after drying (kg)	922		922	
Using in-store dryer				
Drying cost from 18% to 14% m.c. (PHP)	387.24		387.24	
Weight of palay after drying (kg)	874.06		874.06	
Using sun drying				
Drying cost from 24% to 14% m.c. (PHP)		130.00		130.00
Weight of palay after drying to 14% m.c. (kg)		839.00		839.00
Depreciation cost and other fixed costs (PHP)	170.00	40.00	170.00	40.00
Storage cost	26.22	25.17	26.22	25.17
Milling cost (PHP)	166.07	159.41	166.07	159.41
Weight of rice after milling (kg)	568.14	545.35	568.14	545.35
Wholesale price of milled rice (PHP/kg)	21.01	21.01	22.17	21.01
Total revenue for selling milled rice (PHP)	11,936.55	11,457.80	12,595.58	11,457.80
Total cost from buying wet paddy to selling milled rice wholesale (PHP)	8,669.53	7,854.58	8,669.53	7,854.58
Net revenue (PHP)	3,267.01	3,603.22	3,926.05	3,603.22

Table 4. (continued)

Item	Without price premium		With price premium	
	Two-stage drying	Sun drying	Two-stage drying	Sun drying
Incremental profit (PHP)	−336.21		322.83	
Incremental profit per kg of milled rice (PHP/kg)	-0.62	–	0.59	–
Price spread per kg of milled rice				7.26

Notes based on interviews with Dr M.C. Bulaong of the Bureau of Postharvest Research and Extension and three cooperatives officials during 2007–08:

1. The farm-gate price of palay for newly harvested grains (with 24% m.c.) was PHP7.50 per kg based on interviews with the three cooperatives officials. The average price of grain at 14% m.c. is PHP11.50 per kg (Bureau of Agricultural Statistics, December 2007).
2. The drying cost to take grain from 24% to 18% m.c. using a flash dryer is PHP0.42 per kg
3. The equation for calculating palay shrinkage is:
   Fw = Iw (1 – [IMC/100]) / (1 – [FMC/100])
   where Fw = final weight of palay, Iw = initial weight of palay, IMC = initial moisture content, FMC = final moisture content.
   Hence, the weight loss during drying from 24% to 18% m.c. is 7.3%.
4. Other drying losses arising from use of the flash dryer amount to 0.5%.
5. The drying cost to take grain from 18% m.c. to 14% m.c. using the in-store dryer is PHP0.42 per kg.
6. The weight loss during drying from 18% m.c. to 14% m.c. is 4.7%.
7. Other drying losses from use of the in-store dryer amount to 0.5%.
8. The drying cost to take grain from 24% m.c. to 14% m.c. using sun drying is PHP0.13 per kg.
9. The weight loss during sun drying from 24% to 14% m.c. is 11.6%.
10. Other losses during sun drying amount to 4.5%.
11. The depreciation cost and other fixed costs are estimated to be PHP0.17 per kg in two-stage drying and PHP0.04 per kg in sun drying.
12. The storage cost for palay is estimated to be PHP0.03 per kg for storage of up to 2 months.
13. The milling cost is PHP0.19 per kg of palay after deducting income from selling by-products of milling. If the by-products of milling were not considered, the milling cost would be PHP0.75 per kg of palay.
14. Milling recovery is 65%.
15. The transport cost is zero as it is borne by the buyer.
16. The average wholesale price was PHP22.59 per kg for well-milled rice (considered as Grade 1 rice in this study) and PHP20.59 per kg for regular milled rice (considered here as Grade 2 rice). Tumambing et al. (1999) noted that there was a PHP2.00 per kg price premium when palay was dried using the two-stage drying technology rather than sun drying. Interviews with BPRE officials in December 2007 claimed a PHP3.00 per kg price premium in 2007.

Table 5. Costs in taking 1,000 kg of wet (24% moisture content, m.c.) palay (paddy, rough rice) to wholesale level in milled rice form using two-stage drying technology (flash dryer plus in-store dryer) versus use of a recirculating dryer

Item	Without price premium		With price premium	
	Two-stage drying	Recirculating dryer	Two-stage drying	Recirculating dryer
Farm-gate price of palay (Philippine pesos (PHP)/kg)	7.5	7.5	7.5	7.5
Quantity of palay to be dried (kg)	1,000	1,000	1,000	1,000
Total revenue if palay is sold wet (PHP)	7500	7500	7500	7500
Using flash dryer				
Drying cost from 24% to 18% moisture content (m.c.) (PHP)	420		420	
Weight of palay after drying (kg)	922		922	
Using in-store dryer				
Drying cost from 18% to 14% m.c. (PHP)	387.24		387.24	
Weight of palay after drying (kg)	874.06		874.06	
Using recirculating dryer				
Drying cost from 24% to 14% m.c. (PHP)		240		240
Weight of palay after drying to 14% m.c. (kg)		879		879
Depreciation cost and other fixed costs (PHP)	170.00	100	170.00	100.00
Storage cost	26.22	26.37	26.22	26.37
Milling cost (PHP)	166.07	167.01	166.07	167.01
Weight of rice after milling (kg)	568.14	571.35	568.14	571.35
Wholesale price of milled rice (PHP/kg)	21.59	21.59	22.17	21.59
Total revenue for selling milled rice (PHP)	12,266.06	12,335.45	12,595.58	12,335.45
Total cost from buying wet paddy to selling milled rice wholesale (PHP)	8,669.53	8,033.38	8,669.53	8,033.38
Net revenue (PHP)	3,596.53	4,302.07	3,926.05	4,302.07

Table 5. (continued)

Item	Without price premium		With price premium	
	Two-stage drying	Recirculating dryer	Two-stage drying	Recirculating dryer
Incremental profit (PHP)	−705.53		−376.01	
Incremental profit per kg of milled rice (PHP/kg)	−1.23	–	−0.66	–
Price spread per kg of milled rice				8.46

Notes based on interviews with Dr M.C. Bulaong of the Bureau of Postharvest Research and Extension and three cooperatives officials during 2007–08:

1. The farm-gate price of palay for newly harvested grains (with 24% m.c.) was PHP7.50 per kg based on interviews with the three cooperatives officials. The average price of grain at 14% m.c. is PHP11.50 per kg (Bureau of Agricultural Statistics, December 2007).
2. The drying cost to take grain from 24% to 18% m.c. using a flash dryer is PHP0.42 per kg
3. The equation for calculating palay shrinkage is:
   Fw = Iw (1 – [IMC/100]) / (1 – [FMC/100])
   where Fw = final weight of palay, Iw = initial weight of palay, IMC = initial moisture content, FMC = final moisture content.
   Hence, the weight loss during drying from 24% to 18% m.c. is 7.3%.
4. Other drying losses arising from use of the flash dryer amount to 0.5%.
5. The drying cost to take grain from 18% m.c. to 14% m.c. using the in-store dryer is PHP0.42 per kg.
6. The weight loss during drying from 18% m.c. to 14% m.c. is 4.7%.
7. Other drying losses from use of the in-store dryer amount to 0.5%. They are also 0.5% for the recirculating dryer.
8. The drying cost to take grain from 24% m.c. to 14% m.c. using sun drying is PHP0.13 per kg. For the recirculating dryer the cost is PHP0.24 per kg.
9. The weight loss during sun drying from 24% to 14% m.c. is 11.6%.
10. Other losses during sun drying amount to 4.5%.
11. The depreciation cost and other fixed costs are estimated to be PHP0.17 per kg in two-stage drying and PHP0.04 per kg in sun drying. They amount to PHP0.10 per kg for the recirculating dryer.
12. The storage cost for palay is estimated to be PHP0.03 per kg for storage of up to 2 months.
13. The milling cost is PHP0.19 per kg of palay after deducting income from selling by-products of milling. If the by-products of milling were not considered, the milling cost would be PHP0.75 per kg of palay.
14. Milling recovery is 65%.
15. The transport cost is zero as it is borne by the buyer.
16. The average wholesale price was PHP22.59 per kg for well-milled rice (considered as Grade 1 rice in this study) and PHP20.59 per kg for regular milled rice (considered here as Grade 2 rice). Tumambing et al. (1999) noted that there was a PHP2.00 per kg price premium when palay was dried using the two-stage drying technology rather than sun drying. Interviews with BPRE officials in December 2007 claimed a PHP3.00 per kg price premium in 2007.

Table 6. Costs and returns associated with alternative drying technologies

Price premium—PHP per kg:	2		3	
Farm price—PHP per kg:	7.50	10.16	7.50	10.16
Differences in processing costs				
Two-stage versus sun drying	−0.62	−0.62	−0.61	−0.61
Two-stage versus recirculating drying	−1.23			
Differences in net returns				
Two-stage versus sun drying	0.59	0.59	1.20	1.20
Two-stage versus recirculating drying	−0.66			
Price spread for sun drying	7.26	2.38	7.47	2.59
Processing supply shift—k%				
Two-stage versus sun drying	9		19	
Total welfare gains—PHP per 1,000 kg palay				
Two-stage versus sun drying	373		761	

5 Impact assessment

5.1 Methodology

The potential benefits from the two-stage grain-drying technologies were estimated using standard welfare analysis (as described in detail in, for example, Alston et al. (1995)). New grain-drying technology can be thought of as reducing costs or improving profits in the grain handling and processing sector. The impact of new processing technology can only be represented graphically in a heuristic manner. The market for processing inputs is shown in Figure 2. Initially, equilibrium is at price W_{20} and quantity X_{20}. If new grain-drying technology results in a cost saving of *vz* pesos for all units of production, the supply curve shifts from S_{20} to S_{21}, the price of processing inputs falls to W_{22} and the quantity increases to X_{22}. The suppliers of these inputs enjoy a gain in economic surplus of area *wxzy*.

The impact of new processing technology on the producers and consumers of rice is illustrated in Figure 3, which is drawn under the assumptions that palay, milled rice and processing inputs must be used in fixed proportions (there is no input substitution, in other words), and that the processing sector is competitive and inputs are perfectly elastic in supply. Under these assumptions, a reduction in processing costs results in the price spread between palay and milled rice shrinking by the amount of the cost reduction and this is represented by a shift in the derived demand curve for palay to D_{X11}. The production and price of palay increase to X_{11} and W_{12} and the price of milled rice falls to P_1.

The consumers of milled rice benefit to the extent of area *jihg*. Palay producers benefit by the extent of the area *abdc*. All benefits are shared by producers of palay and consumers of milled rice. If processing inputs are less than perfectly elastic in supply, some of the benefits of this technology can now be captured by the suppliers of processing inputs (as in Figure 2).

Input substitution in rice processing makes the derived demand for palay more elastic, and therefore increases the benefits to rice farmers from an increase in farm-level productivity. However, in the case of new rice-processing technology, substitution that makes the demand for palay more elastic also reduces the increase in derived demand arising from a rise in processing efficiency. The substitution effect works in the opposite direction to the scale effect, rather than complementing it as is the case for new farm technology. With large substitution possibilities, rice producers could lose from greater processing efficiency (i.e. derived demand for palay could fall) but because the opportunities for substituting processing inputs for rice are likely to be limited (and less than the elasticity of demand for milled rice), the demand for palay is likely to increase with the increased use of processing inputs, although to a lesser extent than with fixed factor proportions.

Empirical welfare analysis of the impact of new technologies in processing has often been evaluated using a ‘Muth’ model in which a farm input and non-farm inputs are used to produce a processed product for sale in a wholesale or retail market (Muth 1964; Mullen et al. 1988, 1989). This model is described in detail in Alston et al. (1995, pp. 253–264).

The solution in terms of relative changes in the prices and quantities of processed rice (P, Q) and the palay (X_1, W_1) and processing (X_2, W_2) inputs for a reduction in the cost of grain drying (a shift in the supply of processing inputs) is described in the following set of equations from Alston et al. (1995, p. 261) (note that for simplicity of presentation here, other supply and demand shifters have been set to zero) which have been

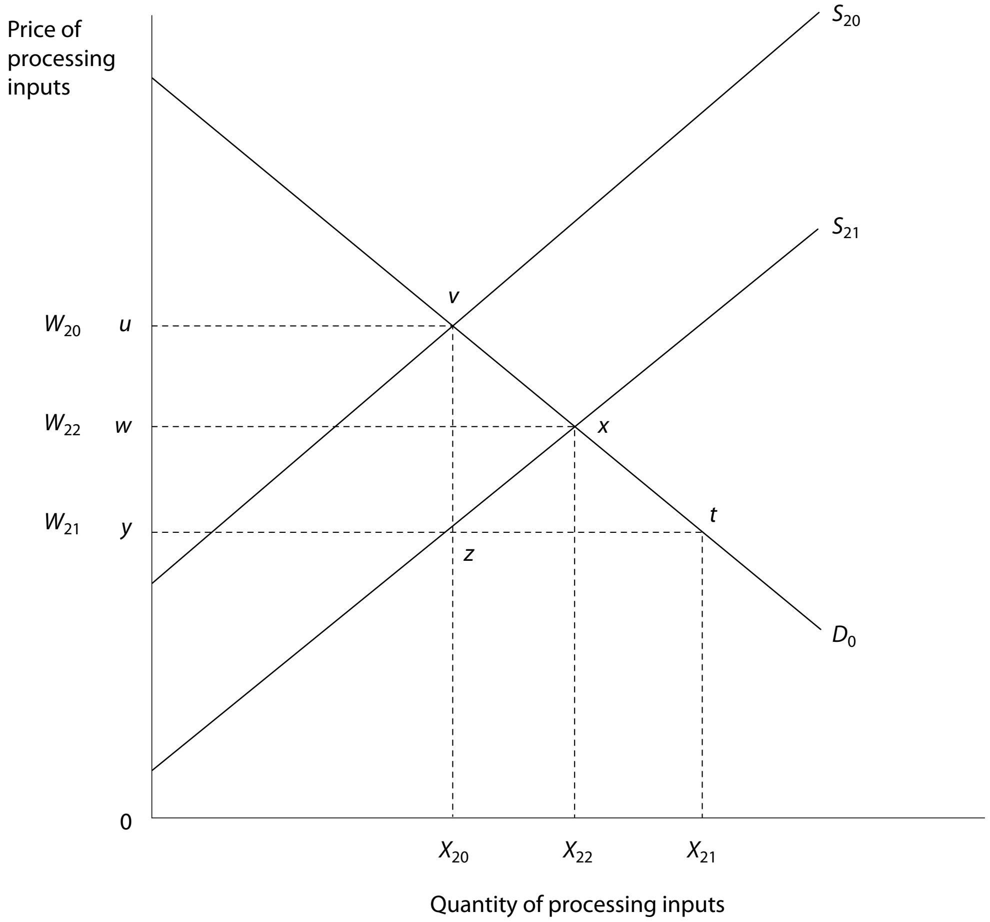

Figure 2. New processing technology and the market for processing inputs

derived by totally differentiating a set of general supply and demand equations for inputs and outputs and a market equilibrium condition:

$$EQ = s_2 \varepsilon_2 \eta (\sigma + \varepsilon_1) \beta_2 / D$$

$$EP = -s_2 \varepsilon_2 (\sigma + \varepsilon_1) \beta_2 / D$$

$$EX_1 = -s_2 (\sigma - \eta) \varepsilon_1 \varepsilon_2 \beta_2 / D$$

$$EX_2 = \{\eta \sigma + (s_1 \sigma + s_2 \eta) \varepsilon_1\} \varepsilon_2 \beta_2 / D$$

$$EW_1 = -s_2 \varepsilon_2 (\sigma - \eta) \beta_2 / D$$

$$EW_2 = -(s_2 \sigma + s_1 \eta + \varepsilon_1) \varepsilon_2 \beta_2 / D$$

where

$$D = \sigma (\eta + s_1 \varepsilon_1 + s_2 \varepsilon_2) + \eta (s_2 \varepsilon_1 + s_1 \varepsilon_2) + \varepsilon_1 \varepsilon_2$$

and where β_2 is the downward shift in the supply of processing inputs relative to the price of processed rice, s_1 and s_2 are the shares of expenditure on farm rice (W_1X_1) and processing inputs (W_2X_2) relative to total revenue (PQ), ε_1 and ε_2 are the elasticities of supply of farm rice and processing inputs, η is the absolute value of the elasticity of demand for processed rice and σ is the elasticity of substitution between farm rice and processing inputs. Note that efficiency gains in processing encourage firms to use more processing inputs and less farm inputs and, if $\sigma > \eta$, then farmers can lose from the technology.

The gains to input suppliers (including farmers and grain dryers) and consumers (including processors and traders) are given by (Alston et al. 1995, p. 256):

$$\Delta PS_i = W_i X_i (EW_i + \beta_i)(1 + 0.5E(X_i))$$

$$\Delta CS = -P_0 Q_0 EP (1 + 0.5EQ)$$

Total industry gains are the sum of the changes in producer and consumer surplus.

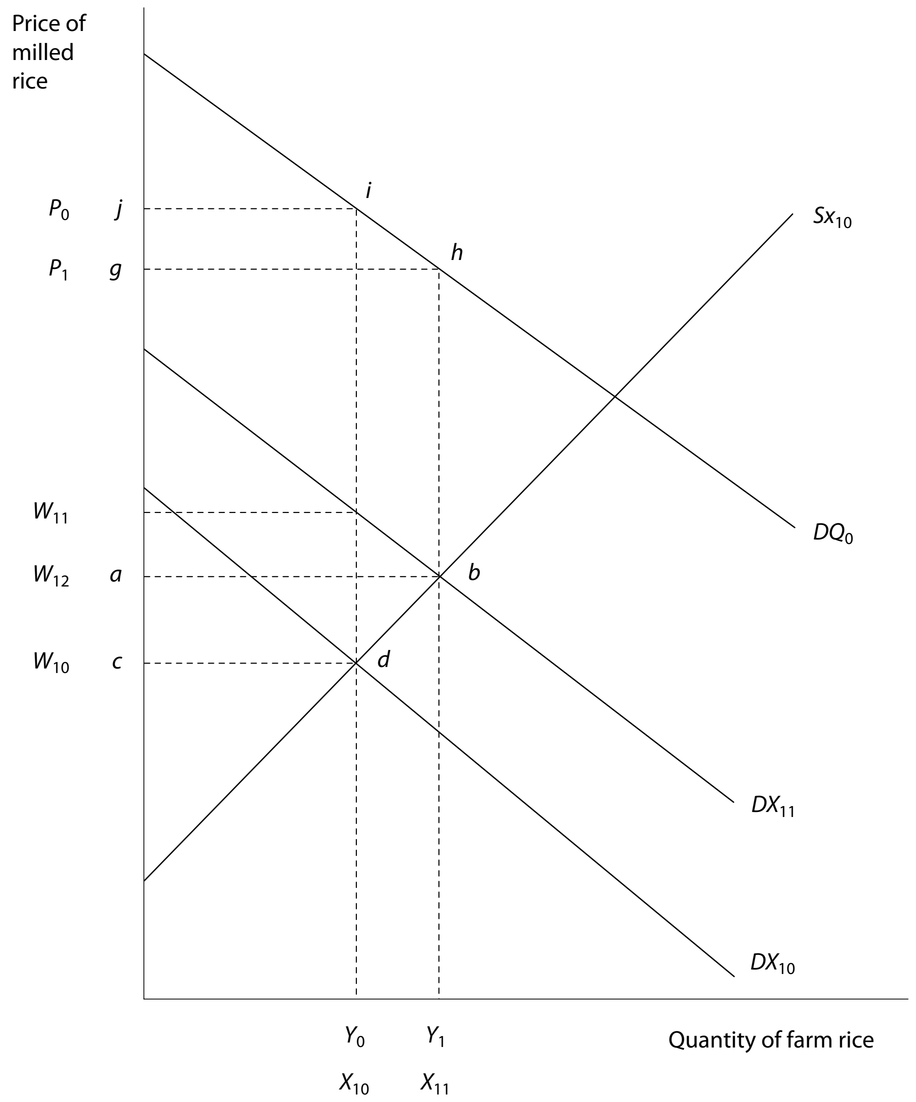

Figure 3. New processing technology in a multi-stage model

The demand and supply elasticity values used here, which are based on limited econometric estimates and the judgment of industry experts, are:

elasticity of demand, η	–0.39
elasticity of supply of palay, ε_1	0.33
elasticity of supply of processing inputs, ε_2	5.0
elasticity on substitution between inputs, σ	0.2

Input shares and the supply shift were estimated in the course of constructing budgets comparing the technologies.

There are two further issues to be confronted in applying this model. The first concerns the estimation, from budget analyses of processing costs, of the shift in the supply of processing inputs. Because budget analyses already reflect the impact of the technology on the input mix and input prices, the change in processing costs has to be adjusted to arrive at a 'pure' estimate of the supply shift in a manner suggested by Mullen et al. (1988):

$$\beta_2 \quad = \quad E(CMI) / (1 - (1 - s_2)\,\sigma)$$

where $E(CMI)$ is the relative change in the cost of processing inputs estimated from the budgeting studies.

The second issue concerns the treatment of quality change. Welfare analysts have found it difficult to assess the impact of research that alters the quality characteristics of a product such as rice. A common pragmatic approach has been to reflect quality change as a demand shift. More fundamentally, however, quality grades of a product can be thought of as separate goods, with research leading to relative shifts in the supply of the different grades. What is required from a methodological viewpoint is a generalisation of the approach taken by Mullen and Alston (1994) who assessed the impact of a change in the proportion of different grades of Australian lamb.

In evaluating the impact of farm technology that has impacts on more than one enterprise, a common approach has been to estimate the change in farm profit—the incremental profit approach—and scale this up to an industry estimate of the impact of the new technology. A variant of that approach has been used here. The price spread budgets for the alternative grain technologies that have been prepared accommodate both cost changes in the form of waste reduction offset by drying costs and revenue changes from changes in the proportion of rice classified as Grade 1 or 2. These budgets were presented earlier. The difference in profit between two technologies relative to the price of processing services, W_2, has been treated as an estimate of the relative change in the cost of processing inputs, $E(CMI)$, in the set of equations given earlier.

Had there been adoption of the two-stage drying technology, the model above could have been used to estimate the potential changes in welfare for the industry as a whole and, using an adoption profile, the actual changes in welfare through time. The net present value of this stream of welfare gains could then have been compared with the present value of the investment in R&D to provide the usual criteria for assessing the efficiency of the investment, including the net present value, the benefit:cost ratio and the internal rate of return.

5.2 Estimates of welfare changes

The incremental profit in the scenarios considered above was negative when there was no price premium for Grade 1 rice. When the price premium was PHP2 per kg, the incremental profit was PHP0.59 per kg, increasing to PHP1.2 per kg when the premium was PHP3. When the farm price for palay was PHP7.5 per kg, the price spread was about PHP7.3 per kg, giving a shift in the supply of processing inputs of either 9% when there was a PHP2 premium for Grade 1 rice or 19% when the premium was PHP3. For these two scenarios, the total welfare gains to the Philippines were PHP373 or PHP761 for every 1,000 kg of palay dried using the two-stage drying technology. Welfare gains were less sensitive to the farm price. The results from these scenarios are summarised in Table 6.

An analysis of recirculating drying technology would show similar welfare gains over sun drying but little difference from the two-stage drying technology.

The present value of an annuity at a discount rate of 5% of PHP373 is PHP7,460. The present value of the investment in developing these technologies has been PHP158.6m and hence the technology has to be applied to about 21,260 tonnes of palay a year to show a return on the investment. This is only about 0.35% of the palay entering the commercial sector in the wet season. Annual palay production is about 16 million tonnes, of which about 58% is produced during the wet season. Some 64%, or about 6 million tonnes, of wet-season production enters the commercial sector to be dried.

While there seems little incentive to adopt the two-stage technology in favour of recirculating-dryer technology, it is not clear why neither of these technologies has been adopted in place of sun drying. This issue is discussed further in the context of the two-stage technology in the next section.

6 Why has two-stage grain drying not been adopted in the Philippines?

The lack of adoption within the Philippines of the two-stage grain-drying process as a whole or even of flash dryers (or alternatively fluidised-bed dryers) and in-store dryers separately is somewhat a puzzle. McLeod et al. (1999) pointed to the success of the technology in Thailand and the early interest in it in Vietnam. There are reports of continuing interest in Vietnam and growing interest in China also (Pearce and Davis 2008). The technology has also been used extensively in Australia. It is beyond the scope of this study to revisit these earlier assessments and identify whether ACIAR funded R&D into grain drying has delivered significant benefits in countries other than the Philippines.

Factors that may explain the lack of adoption in the Philippines include:

- poor extension of the technology to users
- the technology is more expensive than the trial results suggested
- the technology is not relevant to the small scale of Philippine rice trading
- the price premium for higher quality rice is smaller in the Philippines than in other countries.

Each of these factors is discussed below but it is beyond the scope of this report to assess their relative significance in any depth. Their interdependence must be recognised in seeking to explain the poor adoption of two-stage grain-drying technology in the Philippines.

Was the technology poorly extended to users?

The process whereby public funds were used to subsidise the adoption of two-stage drying was described above. Several analysts, including Mangabat et al. (2002) and de Padua (2007), have observed weaknesses in the process. There has also been criticism of the way the two-stage technology has been 'extended'. Responsibility for extension was taken from BPRE and transferred to DA, where there was less appreciation that the technology required both flash and in-store drying facilities. Apparently, cooperating firms rarely received both pieces of technology, hence precluding capture of the full benefits of the two-stage drying strategy.

Other criticisms were that the procedure used to select who would receive the postharvest facilities, especially the flash dryer and the in-store dryer, did not follow criteria identified as essential for successful adoption: some cooperatives were already in financial difficulty and subsequently went bankrupt; some dryers were in poor mechanical condition at installation; and most recipients received no technical assistance or after-sales service from the manufacturer.

De Padua (2007) noted that much of the grain-drying machinery was imported by public authorities, and that servicing and access to spare parts were problems. He argued that a better result could have been achieved if a local industry to manufacture grain-drying equipment had been encouraged, as happened in other countries such as Thailand. He further asserted that providing postharvest capability in the countryside using the concept of integrated grain centres provided with dryers, storage and more efficient mills owned and operated by farmer groups, and piloted in several provinces by the DA, had demonstrated its potential to service small farmers. In addition, he recommended the need for continuous training of professionals in the country's academic institutions; training of technicians for the industry; engineering development, testing and certification for local manufacturers of postharvest equipment; computer automation of the operation of dryers and mills to remove dependence on illiterate operators; studies to gain a deeper understanding of the causes of the rice grain discoloration and breakage; development of business systems and procedures, and 'how-to' manuals for grain business people; development of a system for the efficient handling, storage, and utilisation of the renewable rice hull mass for grain dryers; and, finally, studies to develop further integrated farm production – processing systems that are sustainable.

Is the technology more expensive than trial results suggested?

The basis for comparing the costs of alternative drying technologies is quite limited. With only one firm in the Philippines actually using in-store dryers and that firm not using flash dryers, there are very few firm-level cost data. We have had to rely on the judgment of the engineers who have conducted the research and a limited number of case studies comparing alternative technologies.

While some studies have suggested that the two-stage process is a low-cost technology, our budgeting analyses suggest that to dry a kilogram of grain using two-stage drying costs a little more than if traditional sun drying is used.

The two-stage drying technology distributed by DA had three-phase electric motors, which are 50% cheaper than single-phase motors. However, there are many areas in the Philippines, especially more remote rural communities, where three-phase power is not available.

A common criticism of two-stage drying was its high labour requirement for loading and unloading the flash dryer (perhaps twice for palay of high moisture content), and for subsequently transferring palay to the in-store dryer. Another common complaint was that in-store drying is too slow, requiring up to 3 days per metre depth of grain, according to BPRE (2000). This is often too long for small traders, who need rapid turnover rates, especially when there is a high demand for grain drying during the peak wet-season harvest, and who may have limited working capital. As long as grain quality remains within limits acceptable to the target market, high-speed, high-temperature drying is preferred by such traders.

Issues of scale are further discussed below, but clearly annual overhead costs associated with the larger capital investment in two-stage drying technology are dependent on the firm's throughput of palay.

Another limitation of in-store drying is that during times when the average daily relative humidity exceeds 75%, a circumstance more common during the wet season, supplemental heating is required, adding to energy costs. The relative increase in the cost of energy since the development of the technology has no doubt eroded costs savings and favoured sun drying. There is ongoing research into alternative sources of energy.

On the positive side of the ledger, the chief attraction of the flash-drying process is that it reduces the risks of weather damage to the grain associated with sun drying in the wet season. Our static approach of using a higher wastage rate for sun drying may not adequately reflect wet-season risks. Nevertheless, the low level of adoption of flash drying suggests that this may not be the issue.

Is the technology relevant to small-scale rice traders in the Philippines?

Comparing the costs of two-stage drying with sun drying is made complex because capital investment and hence fixed costs are much higher for the two-stage drying technology. The result is that much higher throughput is required to get to the point where the average total cost of drying per kilogram of rice is at a minimum, or even to the point where it is comparable to the average total cost per kilogram of sun drying. Changes in scale are also likely to influence procurement and distribution costs, and whether rice is handled in bulk or bags.

We have already noted that much of the rice entering the commercial sector is accumulated by small rice handlers and millers, and is stored for a matter of only days or weeks. Many of these rice handlers operate at too small a scale to be able to achieve the lower drying costs associated with high-throughput drying systems.

Hence, adoption of the technology may depend on the firm's expectations about its ability to capture larger procurement and distribution markets. It seems likely that the efficiencies associated with this two-stage process will be captured only if the rice processing system in the Philippines moves to fewer, larger firms perhaps based on bulk handling. An increase in farm size would also likely be associated with greater adoption of these technologies. Government policy can hasten or impede such adjustments.

The degree of significance of these structural and economies of scale issues is not clear to us. It would seem that the use of other mechanical dryers, such as recirculating dryers, is not uncommon, suggesting that they are either not very significant or that adjustment is occurring.

Is there only a small price premium for higher quality rice in the Philippines?

Use of the in-store dryer, rather than other types of mechanical dryers or sun drying, results in better quality milled rice (fewer broken grains). Drying the palay using the in-store dryer protects the grain from breakage. The cost comparison given earlier is based on a judgment that the proportion of Grade 1 rice will increase from 21% for sun drying to 79% for two-stage drying.

When cost savings are small or even negative, then the size of the price premium for higher quality rice is crucial as an incentive to adopt the two-stage technology. The existing premium of PHP2 per kg is not large enough to generate a strong economic incentive to switch to two-stage drying.

Some suggest that, as a statutory authority largely focusing on food security, the National Food Authority (NFA) has little incentive to reflect consumer preferences in market intervention activities. However, NFA's average procurement for the period 1974–2004 was only 4% of the total production, too insignificant to make an impact on the market (Sombilla et al. 2006).

Alternatively, PhilRice (2005, cited in Manalili et al. 2006) reported that rice accounts for as much as 30% of family food expenditure and almost twice this proportion in the low-income brackets. Hence, increasing the price of rice will reduce household disposable income. Manalili et al. (2006) therefore deduced that there is no incentive to adopt quality enhancements or product differentiation, except for those traders catering to a market niche that is willing to pay the increase in price for grain with particular characteristics. Some express the view that there are not strong economic incentives in the Philippines to produce high quality rice because average household incomes are not yet high enough for a price differential to emerge.

7 Conclusions and lessons

Between 1983 and 1997, ACIAR and partners including BPRE invested A$4.1m (PHP159m) in research, extension and capacity building addressing the problems of drying grains such as rice, maize and peanuts after harvest in humid, tropical climates, particularly during the wet season. The concept of two-stage grain-drying technology was developed based on the use of a flash dryer or, later in the project, a fluidised-bed dryer, in the first stage for grain of high moisture content (>18%), followed by slow, in-store drying to take the grain to a safe storage moisture content of 14%.

From a technical viewpoint the program of R&D seems to have been successful, with the development of a technology that is close to being competitive on a cost basis, especially during the wet season, and delivers a marked improvement in the proportion of rice meeting Grade 1 standards. It is reported that this technology has been widely adopted in Thailand and that there is growing interest in it in Vietnam and China (Pearce and Davis 2008), yet there has been no adoption in the Philippines of the two-stage process as a whole or of either of its components.

Perhaps the benefits of this technology, which requires a significant change to the way small grain-trading firms operate, are not well known. Certainly, there have been criticisms of the government programs to subsidise the introduction of the technology. These focus mainly on an apparent lack of understanding of the two-stage nature of the technology, the poor selection of firms to receive assistance, and the lack of training and ongoing support and maintenance for a complex technology more demanding of management.

It is, however, more likely that the economic incentives to adopt the technology are not strong, even though budgeting studies, albeit simple, suggest that two-stage drying technology (and recirculating dryer technology), while more costly, has a positive impact on profit, largely from quality improvement. No doubt the increase in energy prices has made the technology less attractive than when it was first developed. More importantly, the Philippine rice-trading sector is still characterised by many small traders turning over small volumes of rice at time scales of a few days. The two-stage technology requires significant investment in drying facilities (often including shed space) with the consequence that a larger throughput of rice is required to achieve per-unit drying costs similar to those for traditional sun drying. The adoption of two-stage drying technology (and recirculating-dryer technology) on a significant scale may require considerable structural adjustment within the Philippine rice industry and likely needs to be aligned with other developments such as greater implementation of bulk handling of rice.

The technology would also be more attractive from an economic point of view if the premium for Grade 1 rice were larger. Rice is a staple, consuming a large share of family income in many Philippine households. Perhaps as households become wealthier through economic development, a stronger premium for quality will emerge. We are not aware of government policy that directly impinges on the adoption of two-stage drying technology, apart from past attempts to subsidise adoption. However, we have not attempted to assess the implications for adoption of more efficient grain-drying processes of more general government policy related, for example, to land reform and food security.

These projects are likely to have delivered significant gains in capacity in the partner research organisations and in grain-processing firms that were engaged in the research process in some way. Several research staff in the Philippines undertook postgraduate training in association with these projects. The staff of the cooperatives (technical and managerial) collaborating in the research received training on grain drying by the NAPHIRE scientists, and other extension activities reached out to grain processors in the Philippines. These included ACIAR's Postharvest Newsletter, which was disseminated throughout the Philippines. It is highly likely that the knowledge gained in these projects has been used in other BPRE research. We have not attempted the complex and time-consuming task of estimating the value derived from these gains in capacity.

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Appendix 1

Exchange rates, deflators and interest rate used in computing the total research investments that led to the development of the in-store drying technology

	Exchange rates			Australian GDP deflator	Philippine deflator		Interest rate 0.05
	A$:PHP[a]	US$:A$	US$:PHP				
1983	10.01	1.11	11.11	40.9	11.4	24	3.23
1984	14.65	1.14	16.70	44.1	17.5	23	3.07
1985	12.99	1.43	18.61	46.3	20.6	22	2.93
1986	13.63	1.50	20.39	48.9	21.2	21	2.79
1987	14.40	1.43	20.57	52.3	22.8	20	2.65
1988	16.48	1.28	21.09	56.8	25.0	19	2.53
1989	17.19	1.26	21.74	62.2	27.3	18	2.41
1990	18.98	1.28	24.31	65.6	30.7	17	2.29
1991	21.40	1.28	27.48	67.9	35.8	16	2.18
1992	18.74	1.36	25.51	69.2	38.7	15	2.08
1993	18.44	1.47	27.12	70.1	41.4	14	1.98
1994	19.31	1.37	26.42	70.8	45.5	13	1.89
1995	19.06	1.35	25.71	71.6	49.0	12	1.80
1996	20.52	1.28	26.22	73.2	52.7	11	1.71
1997	21.87	1.35	29.47	74.3	56.0	10	1.63
1998	25.69	1.59	40.89	75.2	61.9	9	1.55
1999	25.22	1.55	39.09	75.3	66.8	8	1.48
2000	25.62	1.72	44.19	76.8	71.1	7	1.41
2001	26.37	1.93	50.99	80.5	75.6	6	1.34
2002	28.04	1.84	51.60	82.8	79.0	5	1.28
2003	35.15	1.54	54.20	85.2	81.9	4	1.22
2004	41.21	1.36	56.04	88.1	87.0	3	1.16
2005	42.07	1.31	55.09	91.6	92.6	2	1.10
2006	38.64	1.33	51.31	96.0	97.1	1	1.05
2007	38.64	1.20	46.55	100.0	100.0	0	1.00

Source: Gordon and Davis (2007)

[a] Philippine peso

Appendix 2

Recipients of the in-store dryers distributed under the *Gintong Ani* program in 1998–99 and the *Agrikulturang Makamasa* program in 1998

Recipient	Address/location	Remarks
Gintong Ani program		
1. Tabuk Multipurpose Cooperative, Inc.	Tabuk, Kalinga	Never used the dryer; transferred the unit to Alay Kapwa Multipurpose Cooperative in Nueva Vizcaya in 2007
2. Claveria Grassroots Multipurpose Cooperative, Inc.	Claveria, Cagayan	Used the dryer only once during the dry season (for 1,300 bags); stopped using for drying because of high operating cost; have been using it for storage purposes
3. San José Multipurpose Cooperative, Inc.	San José, Tarlac	Used the unit from 1999 to 2002; had dried a total of 1,200 bags during dry season and 2,400 bags during wet season; coop went bankrupt in 2002
4. Matungao Multipurpose Cooperative	Matungao, Oriental Mindoro	Used the dryer from 1998–2000; had dried a total of 1,800 bags each during dry season and wet season; but became bankrupt; another coop took over but did not know how to operate; dryer no longer functional
5. Sta. Barbara Multipurpose Cooperative	Sta. Barbara, Iloilo	Had dried a total of 300 bags each during dry season and wet season; stopped using the dryer in 2001 because of high operating cost
6. Alegria, Surigao	Alegria, Surigao del Norte	Had no record of using the dryer; unit transferred to SAVACOMFAS Multipurpose Cooperative in Molave, Zamboanga del Sur in 2003
7. Balongating, Guipos	Guipos, Zamboanga del Sur	Had dried a total of 2,400 bags each during dry season and wet season; stopped using the dryer in 2002 as it needed repair; coop closed shop later
8. Managok Multipurpose Cooperative, Inc.	Managok, Bukidnon	Had dried a total of 200 bags during dry season only; used only once during the dry season; stopped using because of absence of elevator
9. Banaybanay Multipurpose Cooperative, Inc.	Banaybanay, Davao Oriental	Never used the unit; closed shop; transferred the unit to Sto. Nino MPC in Manolo Fortich, Bukidnon but was never used
10. Tullunan, Cotabato	North Cotabato	Coop has gone bankrupt; no record of using the dryer

Appendix 2. (continued)

Recipient	Address/location	Remarks
11. Sto. Nino Multipurpose Cooperative	Butuan City, Agusan del Norte	Used the unit only for one dry season; dried only 300 bags in 2000; unit no longer functional
12. SAVACOMFAS Multipurpose Cooperative	Culo, Molave, Zamboanga del Sur	Has been using the dryer since 1998 and acquired another dryer from Surigao del Norte in 2003; has been drying an average of 15,000 bags during the dry season and 18,000 during the wet season
Agrikulturang Makamasa program		
Mimaropa district		
1. Silangan Sta. Cruz MPCI	Malaon, Sta. Cruz, Marinduque	
2. c/o Hon. Roberto Madia	BOAC, Marinduque	Never used the dryer as it was never installed properly; dryer currently rusting
3. PADECO	Mamburao, Occ. Mindoro	
4. CAFARMCO	Pob., Calintaan, Occ. Mindoro	
5. First Mindoro Feedmillers MPCI	Pob., San José, Occ. Mindoro	
6. Central D MPCI	Central, San José, Occ. Mindoro	
7. PAKIKBAGAI	Magsikap, Rizal, Occ. Mindoro	
8. Kaakibat	Labangan, San José, Occ. Mindoro	
9. Kayagawan MPCI	Sablayan, Occ. Mindoro	
10. ALDECO	Sta. Cruz, Occ. Mindoro	
11. Biga FA	Calapan, Or. Mindoro	
12. Mabini Cooperative	Victoria, Or. Mindoro	
13. Matungcal MPCI	Socorro, Or. Mindoro	
14. Municipality of Socorro	Socorro, Or. Mindoro	
15. NAGEMCO	Naujan, Or. Mindoro	
16. MAPARBECO	Naujan, Or. Mindoro	
17. Sto. Nino MPCI	Naujan, Or. Mindoro	
18. Sta. Rita MPCI	Pinamalayan, Or. Mindoro	
19. Camburang MPCI	Bulalacao, Or. Mindoro	

Appendix 2. (continued)

Recipient	Address/location	Remarks
20. Or. Mindoro Seed Growers Association	Bulalacao, Or. Mindoro	
21. El Nido Cashew MPCI	Sibaltan, El Nido, Palawan	
22. Paglaum MPCI	Paglaum, Taytay, Palawan	
23. New Covenant MPCI	New Covenant, Roxas, Palawan	
24. Iraray Community MPCI	Iraray, Espanola, Palawan	
25. San Vicente Seed Growers Assoc	Alimangan, San Vicente, Palawan	
26. Quezon Seven Star MPCI	Pob., Quezon, Palawan	
27. Pangobilian MPCI	Pangobilian, Brookespoint, Palawan	
28. Bonobono Gintong Butil MPCI	Bonobono, Bataraza, Palawan	
29. Lapulapu MPCI	Lapulapu, Narra, Palawan	
30. Taritien MPCI	Taritien, Narra, Palawan	
31. Sicud MPCI	Candawa, Rizal, Palawan	
32. Sinaka MPCI	Iraganan, Puerto Princesa, Palawan	
33. Piat-nga MPCI	Kamuning, Puerto Princesa, Palawan	
Calabarzon district		
1. Lucban Federation of Farmers Association	Lucban, Quezon	Never used the unit; 3-phase power not available
2. c/o City Government	Lucena City, Quezon	Two units acquired were never used; 3-phase power not available
3. Paleta MPCI	Lopez, Quezon	Three-phase power not available in the area; tried using engine of tractor to run the unit; tested drying some palay twice but did not like it because of slow drying; unit now left idle in the warehouse
4. Sangguniang Bayan	Halayhangin, Siniloan, Laguna	Never used the unit; 3-phase power not available in the area
5. Sangguniang Barangay	Talangka, Sta. Maria, Laguna	Never used the unit; 3-phase power not available in the area; no shed

Appendix 2. (continued)

Recipient	Address/location	Remarks
6. Ramiro Herradura	Nanhaya, Victoria, Laguna	Used the dryer for only 1 month because of high operating cost, laboriousness to operate and slow drying
7. SL-Agritech	Oogong, Sta. Cruz, Laguna	Person who received the dryer had resigned; person interviewed did not know whether or not the dryer was utilised but operators of the dryer were said to have not been properly trained

Sources: Davalos (2006) and assessment team interviews with BPRE and DA-RFU IV officials and some recipients of the in-store dryers.

Note: Recipients of in-store dryers with no comments were not further visited or interviewed as revelations of BPRE (including the first Executive Director of NAPHIRE, Dr Dante de Padua and developers of the in-store dryer) and DA-RFU IV officials indicated minimal or no adoption of the in-store dryer. This was confirmed in interviews made with officials of farmer cooperatives in Calabarzon and Marinduque in Mimaropa, Region IV.

IMPACT ASSESSMENT SERIES

No.	Author(s) and year of publication	Title	ACIAR project numbers
1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
2	George, P.S. (1998)	Increased efficiency of straw utilisation by cattle and buffalo	8203, 8601 and 8817
3	Centre for International Economics (1998)	Establishment of a protected area in Vanuatu	9020
4	Watson, A.S. (1998)	Raw wool production and marketing in China	8811
5	Collins, D.J. and Collins, B.A. (1998)	Fruit fly in Malaysia and Thailand 1985–1993	8343 and 8919
6	Ryan, J.G. (1998)	Pigeon pea improvement	8201 and 8567
7	Centre for International Economics (1998)	Reducing fish losses due to epizootic ulcerative syndrome—an ex ante evaluation	9130
8	McKenney, D.W. (1998)	Australian tree species selection in China	8457 and 8848
9	ACIL Consulting (1998)	Sulfur test KCL–40 and growth of the Australian canola industry	8328 and 8804
10	AACM International (1998)	Conservation tillage and controlled traffic	9209
11	Chudleigh, P. (1998)	Post-harvest R&D concerning tropical fruits	8356 and 8844
12	Waterhouse, D., Dillon, B. and Vincent, D. (1999)	Biological control of the banana skipper in Papua New Guinea	8802-C
13	Chudleigh, P. (1999)	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
14	McLeod, R., Isvilanonda, S. and Wattanutchariya, S. (1999)	Improved drying of high moisture grains	PHT/1983/008, PHT/1986/008 and PHT/1990/008
15	Chudleigh, P. (1999)	Use and management of grain protectants in China and Australia	PHT/1990/035
16	McLeod, R. (2001)	Control of footrot in small ruminants of Nepal	AS2/1991/017 and AS2/1996/021
17	Tisdell, C. and Wilson, C. (2001)	Breeding and feeding pigs in Australia and Vietnam AS2/1994/023	
18	Vincent, D. and Quirke, D. (2002)	Controlling *Phalaris minor* in the Indian rice–wheat belt	CS1/1996/013
19	Pearce, D. (2002)	Measuring the poverty impact of ACIAR projects—a broad framework	
20	Warner, R. and Bauer, M. (2002)	*Mama Lus Frut* scheme: an assessment of poverty reduction	ASEM/1999/084
21	McLeod, R. (2003)	Improved methods in diagnosis, epidemiology, and information management of foot-and-mouth disease in Southeast Asia	AS1/1983/067, AS1/1988/035, AS1/1992/004 and AS1/1994/038
22	Bauer, M., Pearce, D. and Vincent, D. (2003)	Saving a staple crop: impact of biological control of the banana skipper on poverty reduction in Papua New Guinea	CS2/1988/002-C
23	McLeod, R. (2003)	Improved methods for the diagnosis and control of bluetongue in small ruminants in Asia and the epidemiology and control of bovine ephemeral fever in China	AS1/1984/055, AS2/1990/011 and AS2/1993/001
24	Palis, F.G., Sumalde, Z.M. and Hossain, M. (2004)	Assessment of the rodent control projects in Vietnam funded by ACIAR and AUSAID: adoption and impact	AS1/1998/036

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26	Mullen, J.D. (2004)	Impact assessment of ACIAR-funded projects on grain-market reform in China	ANRE1/1992/028 and ADP/1997/021
27	van Bueren, M. (2004)	Acacia hybrids in Vietnam	FST/1986/030
28	Harris, D. (2004)	Water and nitrogen management in wheat–maize production on the North China Plain	LWR1/1996/164
29	Lindner, R. (2004)	Impact assessment of research on the biology and management of coconut crabs on Vanuatu	FIS/1983/081
30	van Bueren, M. (2004)	Eucalypt tree improvement in China	FST/1990/044, FST/1994/025, FST/1984/057, FST/1988/048, FST/1987/036, FST/1996/125 and FST/1997/077
31	Pearce, D. (2005)	Review of ACIAR's research on agricultural policy	
32	Tingsong Jiang and Pearce, D. (2005)	Shelf-life extension of leafy vegetables—evaluating the impacts	PHT/1994/016
33	Vere, D. (2005)	Research into conservation tillage for dryland cropping in Australia and China	LWR2/1992/009, LWR2/1996/143
34	Pearce, D. (2005)	Identifying the sex pheromone of the sugarcane borer moth	CS2/1991/680
35	Raitzer, D.A. and Lindner, R. (2005)	Review of the returns to ACIAR's bilateral R&D investments	
36	Lindner, R. (2005)	Impacts of mud crab hatchery technology in Vietnam	FIS/1992/017 and FIS/1999/076
37	McLeod, R. (2005)	Management of fruit flies in the Pacific	CS2/1989/020, CS2/1994/003, CS2/1994/115 and CS2/1996/225
38	ACIAR (2006)	Future directions for ACIAR's animal health research	
39	Pearce, D., Monck, M., Chadwick, K. and Corbishley, J. (2006)	Benefits to Australia from ACIAR-funded research	FST/1993/016, PHT/1990/051, CS1/1990/012, CS1/1994/968, AS2/1990/028, AS2/1994/017, AS2/1994/018 and AS2/1999/060
40	Corbishley, J. and Pearce, D. (2006)	Zero tillage for weed control in India: the contribution to poverty alleviation	CS1/1996/013
41	ACIAR (2006)	ACIAR and public funding of R&D. Submission to Productivity Commission study on public support for science and innovation	
42	Pearce, D. and Monck, M. (2006)	Benefits to Australia of selected CABI products	
43	Harris, D.N. (2006)	Water management in public irrigation schemes in Vietnam	LWR2/1994/004 and LWR1/1998/034
44	Gordon, J. and Chadwick, K. (2007)	Impact assessment of capacity building and training: assessment framework and two case studies	CS1/1982/001, CS1/1985/067, LWR2/1994/004 and LWR2/1998/034
45	Turnbull, J.W. (2007)	Development of sustainable forestry plantations in China: a review	
46	Monck M. and Pearce D. (2007)	Mite pests of honey bees in the Asia–Pacific region	AS2/1990/028, AS2/1994/017, AS2/1994/018 and AS2/1999/060

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54	Monck M. and Pearce D. (2008)	Impact of improved management of white grubs in peanut-cropping systems	CS2/1994/050
55	Martin G. (2008)	ACIAR fisheries projects in Indonesia: review and impact assessment	FIS/1997/022, FIS/1997/125, FIS/2000/061, FIS/2001/079, FIS/2002/074, FIS/2002/076, FIS/2005/169 and FIS/2006/144
56	Lindner, B. and McLeod, P. (2008)	A review and impact assessment of ACIAR's fruit-fly research partnerships – 1984 to 2007	CS2/1983/043, CS2/1989/019, CS2/1989/020, CS2/1994/003, CS2/1994/115, CS2/1996/225, CS2/1997/101, CS2/1998/005, CS2/2003/036, CP/2007/002, CP/2007/187, PHT/1990/051, PHT/1994/133, PHT/1993/87, CP/1997/079, CP/2001/027 and CP/2002/086
57	Montes N.D., Zapata Jr N.R., Alo A.M.P. and Mullen J.D. (2008)	Management of internal parasites in goats in the Philippines	AS1/1997/133
58	Davis J., Gordon J., Pearce D. and Templeton D. (2008)	Guidelines for assessing the impacts of ACIAR's research activities	
59	Chupungco A., Dumayas E. and Mullen J. (2008)	Two-stage grain drying in the Philippines	PHT/1983/008, PHT/1986/008, PHT/1990/008

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