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International Rice Research Institute's contribution to rice varietal yield improvement in South-East Asia

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International Rice Research Institute's contribution to rice varietal yield improvement in South-East Asia

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Cover: Dr Darshan Brar, International Rice Research Institute plant breeder, working on a rice plant in an IRRI greenhouse. Photo: IRRI

Foreword

Ever since the Australian Centre for International Agricultural Research (ACIAR) was founded in the early 1980s, it has supported the research activities of the International Rice Research Institute (IRRI)—not surprising, given that rice is the most significant crop in ACIAR's mandated regions. Today IRRI remains a vital entity in the network of partner organisations working to deliver research results that bring benefits to many millions of people.

ACIAR is committed to the ongoing process of mapping the impacts of its funding for international research. In this instance, a study was undertaken to assess the impact of IRRI on rice production in ACIAR's mandated regions, concentrating solely on varietal improvement. Three countries in South-East Asia in which IRRI and ACIAR have maintained a particular interest were involved—the Philippines, Indonesia and Vietnam. A vital factor in choosing them for case studies was the availability of data on germplasm pedigree and release, and varietal adoption.

The study, which involved individual in-depth impact assessments of IRRI's germplasm improvements for each of these countries between 1985 and 2009, has revealed that, since 1985, significant and sustained yield gains have flowed to countries in South-East Asia from IRRI's work on varietal improvement. The gains between 1985 and 2009 ranged from 1.8% in northern Vietnam to 9.8% in southern Vietnam, 6.7% in the Philippines and 13.0% in Indonesia and, in 2009, averaged 11.2% across the three countries studied. There were changes in those gains over time. In southern Vietnam, for example, they were substantial in the 1990s, while gains in Indonesia were low in that period but have been more substantial in the period since 2000.

It became apparent from this study that, while benefits to farmers of increased yields have been large and ongoing since 1985, IRRI's role in those gains has changed since the years when it first developed and released the early modern rice varieties directly for use by farmers in these countries. Rather than direct IRRI crosses being released as varieties, the lines developed by IRRI have increasingly been used as parents or other ancestors to the recent varieties, consistent with a move towards more specific adaptation to local production circumstances.

The change in IRRI's role may also be associated with the decline in IRRI's core funding that started in the early 1990s. This decline has been reversed since 2006, and there is expectation that the downward trend in IRRI's contribution to germplasm improvement may already be showing some reversal.

Economic analysis reveals very high returns on the investment made in IRRI's research to develop high-yielding, modern rice varieties. The funds invested have yielded an internal rate of return of 28%, a level of return that can be expected to apply similarly to Australia's investment in IRRI.

Nick Austin
Chief Executive Officer, ACIAR

Contents

Figures

Tables

Acknowledgments

In assembling the data for this study, we have approached many people from a number of organisations in the countries involved. In addition, draft copies of the report were circulated to a number of people, and comments and suggestions were received from many of them. We are grateful to all these people for their contribution to our study. Those approached for data and/or comments, or who were involved in meetings related to this project are as follows:

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
AGI	Agricultural Genetics Institute [Vietnam]
ARMM	Autonomous Region in Muslim Mindanao [Philippines]
BAS	Bureau of Agricultural Statistics [Philippines]
BPI	Bureau of Plant Industry [Philippines]
BPTP	Balai Pengkajian Teknologi Pertanian (Assessment Institute for Agricultural Technology) [Indonesia]
CALABARZON	Cavite, Laguna, Batangas, Rizal and Quezon [Philippines]
CAR	Cordillera Administrative Region [Philippines]
CLRRI	Cuu Long Delta Rice Research Institute, Can Tho [Vietnam]
FAOSTAT	Food and Agriculture Organization of the United Nations Statistical Service
FCRI	Field Crops Research Institute [Vietnam]
ha	hectares
IAARD	Indonesian Agency for Agricultural Research and Development
IAS	Institute of Agricultural Science of South Vietnam
ICFORD	Indonesian Center for Food Crops Research and Development
ICRR	Indonesian Center for Rice Research
INGER	International Network for Genetic Evaluation of Rice
IR	prefix in rice variety name designating IRRI variety
IRG	International Rice Genebank
IRIS	International Rice Information System
IRRI	International Rice Research Institute
IVI	index of varietal improvement
MIMAROPA	Occidental Mindoro, Oriental Mindoro, Marinduque, Romblon and Palawan [Philippines]
MVs	modern rice varieties
NARES	national agricultural research and extension systems
NCPFT	National Centre for Plants and Fertilizer Testing [Vietnam]
NCT	National Cooperative Tests [Philippines]
NSIC	National Seed Industry Council [Philippines]
NSIC Rc	prefix in rice variety name designating variety released by the National Seed Industry Council [Philippines]
NSQCS	National Seed Quality Control Services [Philippines]

PhilRice	Philippine Rice Research Institute, Nueva Ecija
PPI	Plant Protection Institute [Vietnam]
PSB	Philippine Seed Board
PSB Rc	prefix in rice variety name designating variety released by Philippines Seed Board
R&D	research and development
SeedNet	National Rice Seed Production Network [Philippines]
SOCCSKSARGEN	South Cotabato, Cotabato, Sultan Kudarat, Sarangani and General Santos City [Philippines]
t	tonnes
TBSC	Thai Binh Seed Company
UPCA	University of the Philippines College of Agriculture
UPLB	University of the Philippines Los Baños
VAAS	Vietnam Academy of Agricultural Sciences

Executive summary

As part of the process of mapping the impacts of Australian Centre for International Agricultural Research (ACIAR) funding for international research, a study has been undertaken to assess the impact of the International Rice Research Institute (IRRI) on rice production in ACIAR's mandated regions. Primarily because of data availability, the analytical approach used in this study was to assess the impact of improvements in rice varietal yields since 1985 in three key rice-growing countries: the Philippines, Indonesia and Vietnam. The aim was to carry out in-depth individual impact assessments of IRRI's germplasm improvements for each selected country, for the period from 1985 to 2009.

Only varietal yield improvement was measured in this study. Thus, other potential impacts of IRRI activities such as capacity building and improvements in non-yield traits including eating quality, resistance and tolerance to pests, diseases and other production constraints have not been included, although they are likely to have produced further significant benefits.

Data on the share that each variety has in the rice area each year were combined with data on varietal yields to obtain a measure of the yield gains resulting from varietal change. IRRI's contribution to those gains was then calculated by examining the pedigree of each variety and the contribution of IRRI lines to that pedigree. From that, it was possible to get an annual estimate, for each region, of the varietal gains and IRRI's contribution to those gains.

The analysis undertaken in this study shows that there have been significant and sustained gains since 1985 flowing from IRRI's work on varietal improvement to countries in South-East Asia. The yield gains from IRRI's contribution to varietal improvement between 1985 and 2009 have ranged from 1.8% in northern Vietnam to 9.8% in southern Vietnam, 6.7% in the Philippines and 13.0% in Indonesia and, in 2009, averaged 11.2% across the three countries studied. The yield gains vary between countries in both their size and how they vary over time. For example, in southern Vietnam the gains were substantial in the 1990s, while in Indonesia the gains were low in that period but have been more substantial in the period since 2000.

It is apparent from this study that rice breeders in South-East Asia have continued to produce higher yielding varieties in the period since 1985. The benefits to farmers of those increased varietal yields have been large and ongoing. However, IRRI's role in those gains has changed since the early years when IRRI developed and released the early modern rice varieties directly for use by farmers in these countries. Since IRRI ceased directly releasing varieties for farmers in 1975, increased testing and evaluation and release activities have been transferred to the national agricultural research and extension systems (NARES), rather than being undertaken by IRRI. This reflects a maturing of the roles of IRRI and NARES, and is a sign that NARES in these countries have developed into productive and effective organisations.

The principal level on which IRRI's contribution has changed, and the one that has been measured in this study, has been a decline in the direct genetic contribution to the pedigree of the varieties that are being released to farmers. While lines developed by IRRI feature prominently in the genetic composition of the varieties, they have increasingly become used as parents or other ancestors to the recent varieties, rather than being direct releases of IRRI crosses. This is consistent with a move towards more specific adaptation to overcome local production constraints rather than the more general adaptation that was evident in the earlier varieties produced and released by IRRI.

The change towards a more significant NARES contribution may also be associated with the decline in IRRI's core funding that started in the early 1990s and which mainly affected activities that did not attract restricted grants, particularly the mainstream irrigated breeding programs. That decline has been reversed since 2006, and there is expectation that the downward trend in IRRI's contribution may already be showing some reversal.

When the economic value of that yield improvement is calculated using constant prices, the economic benefits averaged $1.46 billion per year across the three countries. Over 44% of those benefits occurred in Indonesia, while a further 38% occurred in southern Vietnam, 14% in the Philippines and 4% in northern Vietnam. In all cases, the increase in rice prices in 2008 and 2009 has lifted the benefits significantly in the most recent years. If rice prices fall back from those peak levels, then the value of future yield increases may decline.

The average benefits per hectare (ha) for the Philippines ($52/ha) and Indonesia ($76/ha) are less than the benefits that have been identified for southern Vietnam ($127/ha). Benefits for northern Vietnam ($26/ha) are at a lower level, reflecting the lower adaptation of IRRI-related varieties in that environment compared with the others in this study, and also the extent to which that area relies more on germplasm from China than on germplasm from IRRI for its varieties. Across the three countries, the benefits have averaged $88/ha for the period since 1985 and, in recent years, have reached over $200/ha.

An economic analysis based on IRRI's total costs and only the benefits from varietal yield improvement in the three selected countries reveals an internal rate of return of 28% on IRRI's total investment in rice improvement, a benefit:cost ratio of 21.7 and a net present value of US$97 billion. By any standards, these are high levels of return from the investment in IRRI. The returns would be even higher if the benefits of all IRRI's activities were included.

While the best available data have been used in this study, caution is needed in interpreting the results, as there are several limitations to the data and the approach used. The key limitations of the study are: (a) the varietal yield data are drawn from trials and may be influenced by changes in trial management that would obscure the changes in relative varietal yields; (b) the varieties may be grown in environments different from those where they were tested; (c) the relative improvements in varietal yields in trials may not accurately reflect the relative varietal yield improvements in farmers' fields; (d) the benefits measured here do not include some non-yield improvements such as host plant resistances, abiotic stress tolerances and maintenance of yield potential; and (e) the method of attributing IRRI's share of the benefits of varietal improvement used in this study is based on IRRI's contribution to the pedigree, and does not reflect the value of the particular traits incorporated in the different varieties. These limitations and caveats need to be borne in mind when using and interpreting the results of this study, as they may have affected the findings.

Nevertheless, the results of this study lead to a general conclusion that broad benefits from IRRI reflect strong benefits from continuing investment in IRRI, and that that investment is likely to produce benefits that are appropriate to ACIAR and its mandate.

PART I
Introduction and methodology

1 Introduction

1.1 International Rice Research Institute

Rice is the most important food crop in South-East Asia. Rice is a staple food of the people of this region, with average annual consumption per person in 2007 of 131 kg (FAOSTAT 2011). Rice provided 49% of the calories and 39% of the protein in their diet in 2007 (FAOSTAT 2011).

The International Rice Research Institute (IRRI) has been a key player in the development of rice production in the Philippines for over 50 years, through the provision of breeding lines and varieties, and capacity-building activities. IRRI has been at the forefront of the improvements in rice productivity flowing through the green revolution period and in more recent decades.

IRRI was established in 1960 through funding from the Ford and Rockefeller Foundations. It is an autonomous, non-profit, agricultural research and training organisation. Its mission is to reduce poverty and hunger, improve the health of rice farmers and consumers and ensure that rice production is sustainable (IRRI 2010).

IRRI was established to help poor rice farmers in developing countries grow more rice on less land using less water and labour, and fewer chemical inputs. By helping to greatly boost production and ease the use of farm chemicals, IRRI clearly showed the importance of rice and agricultural research in helping poorer nations develop. The Institute's importance has been further reinforced by the low level of interest in rice research traditionally shown by the private sector.

IRRI's research activities began in 1962 at Los Baños in the Philippines, and are now estimated to have touched the lives of almost half the world's population (IRRI 2010). IRRI played a major role in sparking the green revolution in rice when it developed its first new modern variety of rice in the 1960s. Since that time, IRRI varieties and IRRI germplasm have spread across rice-producing countries, especially in Asia. Genetic improvement of rice, the developing world's most important agricultural product, is the largest single documented source of international agricultural research benefits to date (Raitzer and Kelley 2008).

Most of IRRI's research is carried out in cooperation with the national agricultural research and development (R&D) institutions, farming communities and other organisations of the world's rice-producing nations. IRRI has developed highly effective cooperative and collaborative relationships with national agricultural research and extension service (NARES) scientists throughout rice-growing countries, especially in South-East Asia.

1.2 ACIAR relationship with IRRI

As rice is the most significant crop in the mandated region of the Australian Centre for International Agricultural Research (ACIAR), since its inception in 1982 the Centre has been contributing to IRRI activities. IRRI remains vital to ACIAR's efforts to deliver research results that improve the livelihoods of the people most in need (Core 2005).

ACIAR works with IRRI in two ways: by providing Australia's core funding contribution to Consultative Group on International Agricultural Research (CGIAR) centres, and by commissioning IRRI to undertake special projects (Core 2005). In 2008–09, Australia contributed US$1.16 million in core funds to IRRI, from a total of US$50.1 million allocated in core funding for CGIAR centres. ACIAR's project activities, and its support for IRRI and other CGIAR centres, are based on both formal and informal consultations with partner countries.

1.3 Outline of the report

In Section 2 of this report, the study undertaken is detailed, the approach taken is outlined and the data availability discussed. The remainder of the report is in four parts. Parts II–IV are the case studies of the three selected countries: the Philippines, Indonesia and Vietnam. For each country, there are sections on the rice industry, rice research institutions, rice varieties and sources, the impact of rice varieties since 1985 and an analysis of the impact of IRRI in those varietal changes. In Part V, the results from the three countries are combined and an economic analysis of the impact of IRRI since 1985 is carried out, and some conclusions are drawn in the final section.

2 A study of IRRI impacts on rice varietal yields in South-East Asia

2.1 The study defined

As part of the process of mapping the impacts of ACIAR funding for international research, a study has been undertaken to assess the impact of IRRI on rice production in the regions in which ACIAR operates. The outcome of the study will be improved knowledge of the impact of IRRI's development of improved rice varieties in ACIAR's mandated countries.

The resources were not available in this project for a complete study for all countries within ACIAR's sphere of operations. The focus has been on selected countries in South-East Asia in which there is an important IRRI impact and in which ACIAR has a particular interest. Following consideration of the level of rice production, the significance of the use of IRRI-linked germplasm and the significance of funding from ACIAR, the countries selected for focus in this study were the Philippines, Indonesia and Vietnam. IRRI germplasm development, release and uptake is considerable in these three countries, which all have significant rice industries and strong linkages to IRRI and ACIAR funding. In addition, the necessary germplasm pedigree, release and varietal adoption data for these countries were largely available in sufficient detail to enable the study to take place.

As well as the varietal yield impacts, IRRI has strong relationships with the three selected countries in terms of capacity building. Since 1965, over 3,600 people from these countries have received training at IRRI, indicating the important role of capacity building provided to those NARES by IRRI (Table 2.1).

The analysis undertaken in this study focuses only on the varietal improvement from IRRI germplasm. As such, it excludes non-yield impacts of IRRI germplasm (such as eating quality and resistances and tolerances) and non-varietal impacts such as capacity building.

The analysis was disaggregated within each selected country to a regional level, based on regions or provinces and production environments (e.g. irrigated or rainfed) as appropriate. The extent of the disaggregation was determined by the availability of the required data in each country. In some cases, data at a more localised level were obtained and then aggregated into regions to provide a workable set of regions for analysis.

New rice varieties are being released continually in rice-producing countries. Estudillo and Otsuka (2006) defined the following phases of modern rice varieties (MVs):

- MV1—varieties released mid 1960s to mid 1970s, requiring high inputs
- MV2—varieties released mid 1970s to mid 1980s, with resistances to major pests and diseases
- MV3—varieties released mid 1980s to mid 1990s, with improved resistances and higher grain quality
- MV4—varieties released after 1995, targeting more difficult production environments.

The time period of the analysis in this study is from 1985 to the present. The 1985 start date coincides with the start of the third phase of MVs, as defined by Estudillo and Otsuka (2006). Thus, the focus of this study is to assess the impact of phases MV3 and MV4 in the selected countries.

Table 2.1 Capacity building provided by IRRI for selected countries, 1965–2008

Country	MS + PhD	Fellowships + internships	Non-degree training	Total
Philippines	266	184	1,509	1,959
Indonesia	70	119	798	987
Vietnam	78	170	457	705
Total	414	473	2,764	3,651

Source: S. Mohanty, Social Sciences Division, IRRI

The availability of data determined that the ex-post analysis ends in 2009. Benefits have been projected into the future beyond 2009, to allow for lags in benefits from current investments in new varieties.

2.2 Analytical approach

The analytical approach used in this study was to assess the spread and impact of MVs since 1985 in the selected countries. The aim was to carry out in-depth individual impact assessments of IRRI's germplasm improvements in each selected country, from 1985 to the present, then project benefits from current investments into the future as appropriate.

Some caution is required in estimating the impact of higher yielding rice varieties. Acknowledging that, the study compares the progress in yield that has actually occurred in the presence of the IRRI material with that which would have occurred without the IRRI material.

The improved varieties can lead to a permanent shift to a higher yield potential, or the gain can be a 'one-off' increase that is eroded over time. The analysis used in this study is based on the proposition that the higher yielding varieties have led to a permanent upward shift in yield potential over what would have occurred otherwise. Given that that is the case, the important question is the size of that upward shift in yield potential.

If IRRI's rice breeding program were to cease, the advantages of its lines would be likely to decline over time until, at some future point, the 'with-IRRI' and 'without-IRRI' yield would be the same. However, for the foreseeable future, the proposition that, with continued investment, IRRI research results in a permanent upward shift in yields seems to most suitably reflect its impact on the world rice industry.

The economic approach was to assess the welfare impacts of the new varieties, under a restrictive set of assumptions. The approach is represented in Figure 2.1, where the impact of higher yielding varieties on the supply curve is illustrated. A genetic improvement in yield means an increase in productivity, in the sense that there is higher output for each level of input. Thus, higher yielding varieties lead to a downward shift in the supply curve, equivalent to a reduction in costs per tonne of production (Alston et al. 1995). Following Edwards and Freebairn (1984), the increase in productivity is defined as a parallel vertical shift in the supply curve through a lowering of the production costs per tonne (Figure 2.1). Economic benefits can flow to both producers and consumers from such a cost reduction.

It is possible that the increased supply resulting from the higher yielding varieties has affected the world price received for rice. The analysis in this study is based on the assumption that the demand is perfectly elastic, and that world rice prices have not measurably fallen because of the additional rice production from the varietal change measured here. If the market were less than perfectly elastic, the increased supply would have reduced the price, and the gains indicated by this analysis would be overstated. For example, if the estimated export elasticity were –10, the gains indicated by this analysis would be overstated by approximately 10%.

Thus, the large shifts in world rice supply (measured as increases in world production) attributed to varieties emanating from IRRI could have had a substantial impact on the world price for rice (see, for example, Evenson and Rosegrant (2003)). These price-spillover effects would

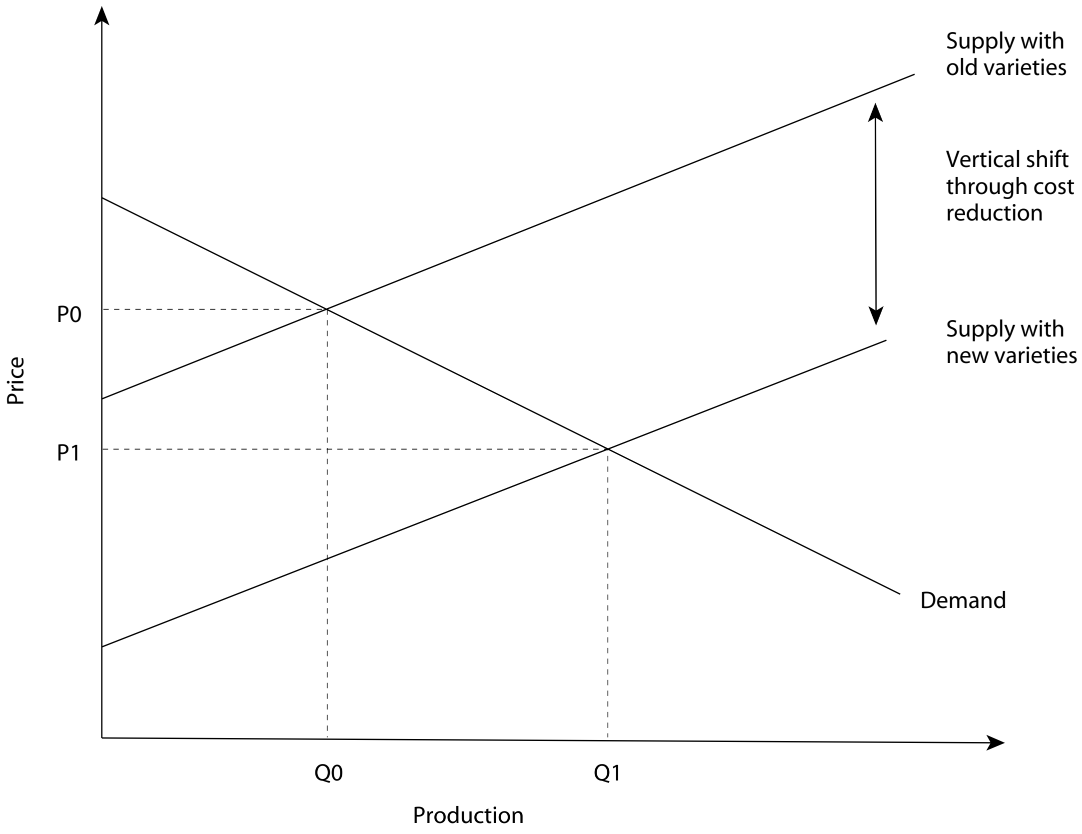

Figure 2.1 Economic framework for analysis of impacts of higher yielding varieties

reduce the magnitude of the change in producers' welfare, while increasing the benefits for consumers. Their influence is not estimated in this report.

Underlying or embodied in the increase in yield changes through varietal change are improved management techniques, seed production and distribution, collection and maintenance of genetic materials, and other capacity-building approaches. At the same time, some of the ongoing research on pest and disease resistance, for example, represents 'maintenance research' rather than yield-enhancing research. Hence, a true measure of the economic benefits of the germplasm will, in part at least, be a measure of not only the traits of the improved germplasm, but also the management technologies and the enabling institutional structures accompanying the improved varieties. Such complexities are, of course, extremely difficult to quantify, and have not been included in this study, although they need to be recognised as playing an important role.

While the precise approach in each country varied slightly with the availability of data, the general approach was approximately as follows:

(a) Within each region

- Compile a list of the varieties released in the selected time period.
- For each variety, determine its relationship to IRRI.
- Obtain data on percentage of area planted or harvested to individual varieties each year.
- Obtain data on average yield for each variety, based on yields in comparative varietal trials.
- Calculate an index of varietal improvement, whereby the yield of each variety grown each year is weighted by its area share, to provide a measure of the yield gain from varietal improvement each year.
- Obtain data on area, production and yield of rice in the region each year.

- Combine the index of varietal improvement with yield data to calculate the gains in yield in the region from the new varieties.
- Obtain data on annual rice prices common to all countries.
- Combine the yield gains from varieties, area data and the price to calculate the value of additional yields in the region each year.
- Using data on IRRI's contribution to each variety, calculate the value of IRRI's contribution to the total gains for each year.

(b) Within each country

- Calculate aggregate benefits for the country by aggregating across regions.

(c) Aggregate analysis

- Calculate total benefits by aggregating the benefits from the three selected countries, including projected future benefits.
- Project the benefits into the future to allow for the research and adoption lags involved.
- Obtain data on costs from IRRI's budget.
- Using a discount rate, discount future benefits and costs and compound past benefits and costs to develop estimates of the present value of benefits and costs.
- Calculate the rate of return on IRRI's investment.
- Consider returns to ACIAR's investment in IRRI.

2.3 Data availability

Data were obtained for each of the selected countries on the area, yield and production of rice for regions/provinces in each year since 1985.

The International Rice Genebank (IRG), which is located at IRRI, contains pedigree information that can be readily accessed, so that the pedigree of the varieties released is generally readily available. From those pedigrees, varieties could be classified as to their origins and their relationship to IRRI, with assistance from IRRI breeders.

The International Network for the Genetic Evaluation of Rice (INGER) holds information on the movement of breeding lines and on the varieties released in each country. Data contained in the IRG and INGER are available through the International Rice Information System (IRIS) at IRRI.

There is no central database providing data on the area planted to each variety, or each variety's percentage share of the total area planted. Therefore, these data needed to be gathered separately from the countries themselves. Because of differences between countries in the availability of varietal share data, the level and form of the data collected varied between countries.

Similarly, there is no central database where data on the yield of each variety are available, and these data needed to be gathered separately from the countries themselves. Because of differences between countries in the availability of varietal yield data, there were differences between countries in the form of the data collected. In some countries, only national average varietal yields were available, while in others there were average yields available for each region or province. In each case, however, data were available on average yields only, not annual varietal yields. Thus, the analysis carried out here is based on the premise that each variety has an identifiable average yield in each production environment, and that comparing those yields provides a measure of varietal yield improvement over time.

There is evidence from trials (e.g. Flinn and De Datta 1984; Cassman and Pingali 1995) of downward creep in yields of rice varieties over time. Peng et al. (2010) found that the yield of the variety IR8 had declined by 15% from the 1960s to about 2000, and that the decline was the result of changing environmental conditions. The best of more recently released varieties had higher yields than IR8 in comparable conditions, but were no higher than those found for IR8 in the 1960s. If the decline is similar in both older and newer varieties, then the differences between yields at any one time will be consistent. However, if the yields are measured at the time of release for each variety, this may understate the gains that are made through varietal replacement, as it will tend to make the release yields more similar even though the performance in the field will be greater because the yield of older varieties declines over time. In this study, the implicit assumption is that all varieties follow similar paths in yield decline over time, and that the yields used represent the average relativities between them over their productive lives.

2.4 Index of varietal improvement

Given the average varietal yields for each region and the data on adoption of the varieties, it is possible to calculate a relative yield index or 'index of varietal improvement' (Silvey 1978; Brennan 1984). This index combines the yields obtained in trials with data on the share of varieties being grown by farmers, to provide a measure of the contribution that new varieties make to increasing yields.

The index of varietal improvement (IVI) is used to measure the increase in yield due to changes of varieties grown. This index is calculated by taking the percentage area share for each variety and using that as a weight for the yield of each variety. For example, if, in one year, 80% of the area is planted to one variety with a yield of 4.0 tonnes (t)/ha, and 20% to one with a yield of 5.0 t/ha, then the weighted average is (4.0 × 80%) + (5.0 × 20%) = 4.20 t/ha. If, in the following year, 50% is planted to each variety, then the weighted average becomes 4.50 t/ha. Therefore, we can measure the progress over time from changes in variety as the difference in this index of weighted varietal yields. In the case above, the change leads to an increase in varietal yields from 4.20 to 4.50 t/ha, or 7%, so the IVI has increased by 7% in that year.

Algebraically, for a given region, the index of varietal improvement is calculated as follows:

$$I_t = \Sigma(v_i\, p_{it})/100 \qquad (1)$$

where I_t is the index in year t, v_i is the yield of variety i and p_{it} is the proportion of the area planted to variety i in year t. Note that vi remains constant over time in this analysis.

Using the IVI, a measure of the progress of changes in varieties is obtained that can then be used in estimating the total economic benefits of changes in varieties over time. To then determine what proportion of those benefits is attributable to IRRI, a measure of IRRI's contribution to new varieties is required.

2.5 IRRI contribution to varieties released

Once the gains from MVs have been estimated, the proportion of those gains that could be attributable to IRRI, based on parentage or pedigree, needs to be estimated. However, the issue of the IRRI contribution to each variety is a vexed and complex one (see, for example, Alston and Pardey (2001)).

Previous studies, such as that of Hossain et al. (2003), have classified varieties into:

- IRRI crosses released as varieties
- varieties (released by NARES) with an IRRI parent
- varieties (released by NARES) with IRRI materials among previous ancestors
- other varieties without IRRI connection.

The sum of the first three categories can be classified as 'released varieties linked to IRRI'.

As a quantitative measure of IRRI's contribution to new varieties, a rule of thumb based on attribution for the parentage and pedigree is used in this study (see Table 2.2). Varieties with two IRRI lines as parents have 100% IRRI contribution, while with one IRRI parent the contribution is 50%. Where there is IRRI ancestry but not IRRI parents, the contribution is taken as 25%.

As this approach attributes benefits on the basis of the lines that make up each variety's pedigree, it can measure the contribution of IRRI where IRRI breeders develop a variety that is then formally released by authorities in another country. In that case, all of the breeding operations have been carried out by IRRI, so 100% attribution to IRRI is reasonable. However, this approach gives no recognition to the institution that bred and/or released the variety, but only to the source of the parent material. It is therefore likely to overstate the contribution of IRRI to varieties that were developed by NARES from crosses they made using IRRI lines as parents. For example, where NARES take two IRRI lines and use them as parents to develop a new variety, in that case all the breeding operations are carried out in NARES, but the variety (by the above attribution method) would give 100% attribution to IRRI, understating the contribution of the activities of the breeding process. Thus, while this approach can

Table 2.2 IRRI contribution to varieties released

Origin of variety	IRRI contribution (%)
IRRI cross with two IRRI lines as parents	100
IRRI cross with one IRRI line as a parent	50
IRRI crosses with no IRRI lines as parents	0
NARES cross with two IRRI lines as parents	100
NARES cross with one IRRI line as a parent	50
NARES cross with other IRRI ancestry	25
NARES cross without IRRI connection	0

lead to errors, and may provide an upper limit to IRRI's contribution to the varieties, the cases of rice varieties in the three countries studied are likely to be relatively well defined by this approach, and only rarely would we expect that the IRRI contribution would be overstated.

Alternative approaches where the contribution of the institution making the cross and undertaking the early-generation selection processes are given higher weighting require more information about each variety than was available for this study. The key issue is which organisation did the crossing, and the breeding operations up to the stage where the variety was ready for release. If lines were obtained from early generations, then the organisation that carried out the crossing and early-generation stages needs some attribution, while if the line was obtained when virtually ready for release, then NARES would have contributed very little in terms of resources and expenditure into that variety. We do not have the necessary data to attribute the contribution to each variety on that basis in this study, so the simpler rule-of-thumb approach has been used. While there are limitations to the interpretation of such a simple and arbitrary rule, it is a useful, practical and consistent way to determine the contribution of IRRI to changes that have taken place in the genetic make-up and the release processes for each variety.

An alternative approach to this IRRI attribution was also to examine the pedigree of each variety available in IRIS, and to assess the percentage of the pedigree that was comprised of 'IR' lines named by IRRI. With the assistance of William Eusebio of IRRI, this approach was tested for varieties found in the Philippines. The results of a preliminary assessment for the Philippines based on Mendelgram analysis of IRRI's contribution revealed that the results were very similar to those given in this report. This gives confidence that the more basic analysis used here provides essentially the same overall outcome as that provided by the more sophisticated analysis. For the Philippines, if the alternative analysis had been used, the total benefits for IRRI would have been within 1% of the benefits estimated here using the above rule of thumb. Since there were insufficient data in the IRIS database to enable a similar analysis for varieties from Indonesia and Vietnam, for consistency across all three countries the simpler classification approach was used in this study.

Data were obtained from the variety database in IRIS, with assistance from William Eusebio and Florita Rañeses at IRRI, and from contacts in each of the countries studied, to enable the 'IRRI contribution' to each of the varieties grown in the countries included in this study to be calculated using the rule of thumb. The percentage of varieties released in different time periods (1980s, 1990s etc.) that fall into each category can be determined, to detect any trends.

2.6 Rice prices

To provide consistent prices across years and countries, the additional rice production has been valued at a representative export price for rice. The price series selected was Vietnam export prices (rough rice, 5% brokens) from 1985 to 2009, converted to real 2009 dollars. In the analysis, the nominal price of rice was converted to constant 2009 dollars using the United States (US) consumer price index to determine a real price to use to value the gains in productivity over the period. From 1985 to 2007, the average real price (in 2009 dollars) was US$418/t (Figure 2.2). The real price fell from around US$500/t in the late 1980s to close to US$200/t in the early 2000s, and then recovered to over US$300/t by 2007. In 2008, the export price more than doubled, so that in 2008 and 2009 additional production is valued much more highly than in earlier years, although only marginally higher than that in the late 1980s.

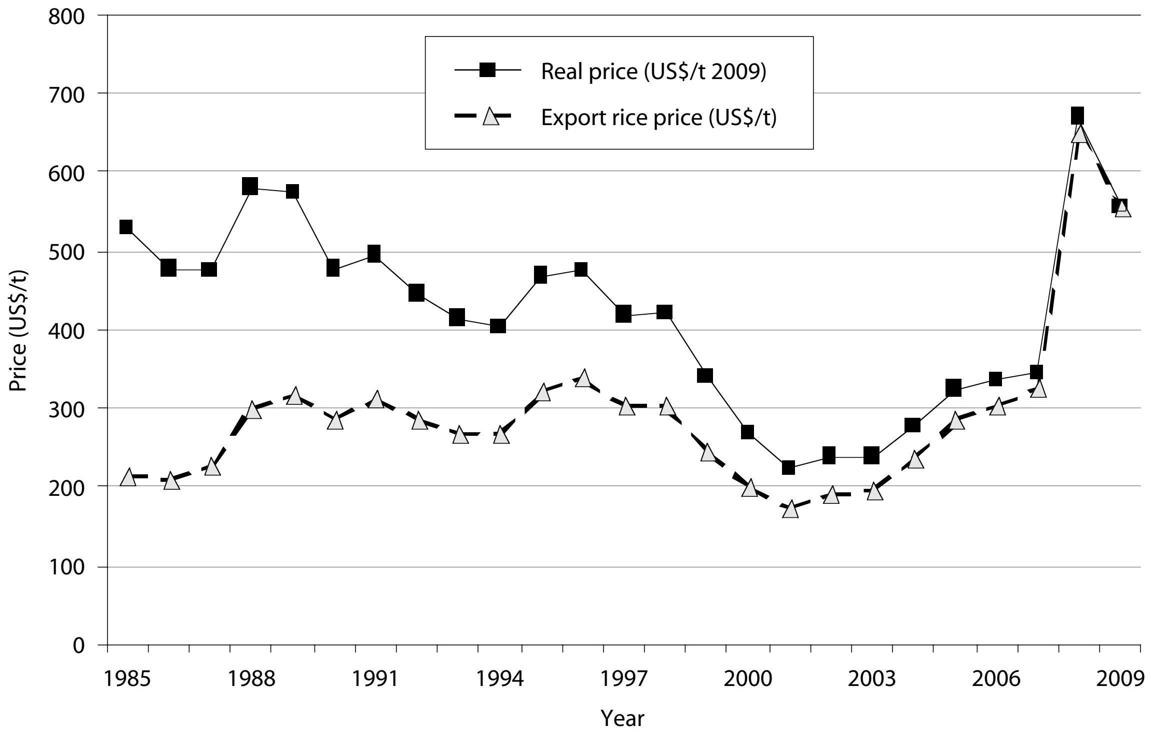

Figure 2.2 Export rice prices, 1985–2009. Source: IRRI

PART II
Impacts of IRRI germplasm on the Philippines since 1985

3 Philippine rice industry

3.1 Rice industry trends in the Philippines

Rice is the most important food crop in the Philippines. Rice is a staple food of the Philippine people, with average annual consumption per person (milled equivalent) in 2007 of 129 kg (FAOSTAT 2011). Rice provided 50% of the calories and 37% of the protein in their diet in 2007 (FAOSTAT 2011).

Data on area planted, production and yield of rice in the Philippines are summarised in Table 3.1. From the 1980s to 2009, production increased by 73% as a result of a 25% increase in area planted and a 39% increase in yields per hectare. The area and yield increases occurred in both the 1990s and the 2000s. The annual changes since 1985 are illustrated in Figure 3.1. Farm yields showed slow growth during the 1990s, followed by rapid growth from 1999 to 2007, with declines in the most recent 2 years.

3.2 Rice production systems in the Philippines

Rice production in the Philippines is predominantly on small landholdings averaging 1.7 ha, most commonly operated under owner cultivation (Estudillo and Otsuka 2006). Estudillo and Otsuka (2006) indicate that use of elemental fertiliser on rice crops has been increasing over time, and has been associated with the increased yields from the adoption of MVs, which respond favourably to higher fertiliser application.

Rice is grown in a wide range of production environments throughout the Philippines, which lies within the tropics (5–22°N). There are three main rice ecosystems (Estudillo and Otsuka 2006): (a) irrigated lowland, (b) rainfed lowland and (c) upland. The irrigated rice system is increasingly dominant, and accounted for 76% of total rice production in the period 2000–09. This share increased from 56% in 1970, because of the increased adoption of high-yielding and shorter MVs that thrive well in irrigated environments (Estudillo and Otsuka 2006). The rainfed ecosystem's share of rice production fell from 37% in 1970 to 23% in 1997, while the upland system's share fell from 7% to 2% in the same period (Estudillo and Otsuka 2006).

3.3 Previous studies of the impact of modern rice varieties in the Philippines

The green revolution in rice had its origins in Central Luzon in the Philippines (Herdt and Capule 1983), and MVs were adopted more quickly in the Philippines than in any other country. The adoption of MVs from 1966 in the Philippines was rapid and widespread (Hossain et al. 2003), and reached over 90% of the crop area by the mid 1980s. The rapid rate of adoption of new varieties has been maintained during the 1990s, indicating continuing varietal improvement (Launio et al. 2008).

The green revolution was the result of many forces coming together to provide an environment in which high-yielding varieties could be developed and utilised to provide large and lasting increases in rice production in Asian countries (Hazell 2010). Hossain et al. (2003) also found that the initial replacement of traditional varieties with MVs was estimated to provide a net gain of US$170/ha in the Philippines.

Table 3.1 Area, production and yield of rice in the Philippines since the 1980s

	1980–89	1990–99	2000–09	Increase 1980s–2000s (%)
Area (million ha)	3.3	3.6	4.2	25
Production (million t)	8.4	10.2	14.6	73
Yield (t/ha)	2.52	2.88	3.49	39

Hossain and Pingali (1998) demonstrated the rapid rate of rice yield improvement associated with the green revolution period. Between 1966 and 1986, rice yields in the Philippines grew at 3.59% per year, while from 1986 to 1996 they grew at a markedly lower rate of 0.76%. Estudillo and Otsuka (2006) found that, up until 1997, MVs had contributed to significant yield increases in the irrigated ecosystem in the Philippines, to a lesser extent in the rainfed ecosystem but not at all in upland areas. They indicated that the major yield gains in Central Luzon had come through the second phase of MVs (MV2 in Section 2.1), where varieties had resistances to major pests and diseases, rather than through the initial (MV1) varieties with high yield potential and high input requirements.

3.4 Philippine rice production regions for analysis

The Philippines has well-defined regions for which area, yield and production data were obtained for the period since 1985. The regions are:

- Region I – Ilocos
- Region II – Cagayan Valley
- Region III – Central Luzon
- Region IV – Cavite, Laguna, Batangas, Rizal and Quezon (CALABARZON)/Occidental Mindoro, Oriental Mindoro, Marinduque, Romblon and Palawan (MIMAROPA)

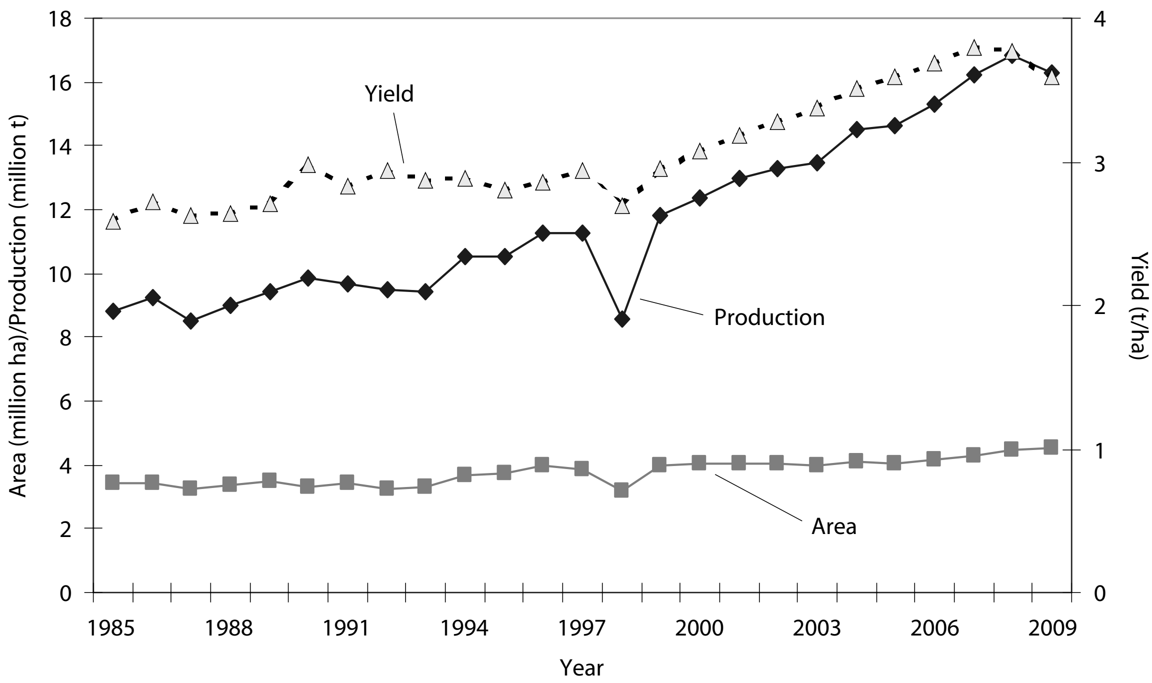

Figure 3.1 Area, production and yield of rice in the Philippines since 1985

- Region V – Bicol
- Region VI – Western Visayas
- Region VII – Central Visayas
- Region VIII – Eastern Visayas
- Region IX – Zamboanga Peninsula
- Region X – Northern Mindanao
- Region XI – Davao
- Region XII – South Cotabato, Cotabato, Sultan Kudarat, Sarangani and General Santos City (SOCCSKSARGEN)
- Caraga
- Cordillera Administrative Region (CAR)
- Autonomous Region in Muslim Mindanao (ARMM)

Of the major production regions, Ilocos, Cagayan Valley, Central Luzon and CALABARZON/MIMAROPA have well-developed systems of irrigation infrastructure, while Bicol and Western Visayas have favourable rainfall patterns (Estudillo and Otsuka 2006). The average area, production and yield of rice in each of these regions for the period 2000–09 are shown in Table 3.2.

Because only annual data on varieties were available for the Philippines, that is the basis on which the analysis in this study is carried out. The study takes no separate account of the seasons; nor is there any account taken of differences between lowland and upland or irrigated and dryland production systems—all are aggregated in this analysis. This is an important limitation of this study, but is supported by the finding of Estudillo and Otsuka (2006) that there were no significant differences in yields of MVs between wet and dry seasons in the Philippines.

Table 3.2 Average area, production and yield of rice by region in the Philippines, 2000–09

Region		Area ('000 ha)	Production ('000 t)	Yield (t/ha)
I	Ilocos	367	1,395	3.80
II	Cagayan Valley	494	1,885	3.81
III	Central Luzon	594	2,522	4.25
IV	CALABARZON/MIMAROPA	367	1,209	3.29
V	Bicol	291	874	3.01
VI	Western Visayas	601	1,874	3.12
VII	Central Visayas	95	238	2.49
VIII	Eastern Visayas	241	765	3.18
IX	Zamboanga Peninsula	151	520	3.44
X	Northern Mindanao	136	508	3.73
XI	Davao	105	439	4.17
XII	SOCCSKSARGEN	324	1,118	3.45
	Caraga	124	379	3.07
	CAR	103	360	3.48
	ARMM	185	503	2.72
Total Philippines		4,178	14,586	3.49

Source: Bureau of Agricultural Statistics, 2009

Notes: CALABARZON/MIMAROPA = Cavite, Laguna, Batangas, Rizal and Quezon / Occidental Mindoro, Oriental Mindoro, Marinduque, Romblon and Palawan; SOCCSKSARGEN = South Cotabato, Cotabato, Sultan Kudarat, Sarangani and General Santos City; CAR = Cordillera Administrative Region; ARMM = Autonomous Region in Muslim Mindanao

Because area and production data have been rounded, some yield values and totals may appear to be slightly inconsistent.

4 Rice research in the Philippines

4.1 Key rice institutions in the Philippines

The key institutions involved in rice research and in developing improved varieties for rice farmers in the Philippines are:

- IRRI
- Philippine Rice Research Institute (PhilRice)
- University of the Philippines Los Baños (UPLB)
- National Seed Quality Control Services (NSQCS)
- INGER.

Because of its location at Los Baños in the Philippines, IRRI has always had a special relationship with the Philippines and its rice-growing environments. Philippine institutions and farmers have been in a strong position to be at the forefront of improvements made by IRRI. The benefits of that position are evident in the close relationship between IRRI and the other Philippine rice research institutions, particularly PhilRice.

4.2 Philippine Rice Research Institute

PhilRice, based at Muñoz in Nueva Ecija, was established in 1985 to provide the necessary national focus for rice R&D to adapt and localise IRRI's technologies to Philippine farms. Its aims include operation of a national R&D program for rice and rice-based farming systems, and a national network of rice R&D stations to ensure the Philippines has 'economically viable, socially acceptable and environmentally efficient' rice technologies (PhilRice 2010).

4.3 University of the Philippines Los Baños

UPLB is located at Los Baños in the province of Laguna, and was established in 1909. The university has played an influential role in Asian agriculture and biotechnology due to its pioneering effort in plant breeding and bioengineering, focusing on the development of high-yielding and pest-resistant crops (Wikipedia 2010). UPLB, through its University of the Philippines College of Agriculture (UPCA), has been at the forefront of agricultural research, experimenting and generating knowledge on tropical agriculture since its foundation. UPCA administers more than half of the country's total agricultural research, and conducts extension programs that aim to transfer technology and information to the farming and food production sectors (UPLB 2010). UPLB has a close relationship with IRRI, which is enhanced by both being located at Los Baños.

4.4 National Seed Quality Control Services

The NSQCS section of the Bureau of Plant Industry (BPI) is responsible for seed certification in the Philippines. To oversee seed production and to ensure that there is adequate quality assurance and control in the production, storage and distribution of high-quality rice seed, it has offices in each of the regions. NSQCS also supports seed research and training in seed quality control with the aims of ensuring sustainable agriculture and environmental protection (BPI 2010).

4.5 International Network for Genetic Evaluation of Rice

INGER is a global model for the exchange, evaluation, release and use of genetic resources. It functions under the International Treaty on Plant Genetic Resources for Food and Agriculture, which uses the Standard Material Transfer Agreement to facilitate access and benefit sharing. INGER represents a long-established partnership among NARES of rice-growing countries and international centres including IRRI. INGER is a repository of detailed information on the genetic make-up of rice varieties.

4.6 Pathway from germplasm research to farmer impact in the Philippines

The structure of the varietal development process in the Philippines is illustrated in Figure 4.1, where the pathway from rice germplasm research to farmer impact is shown. The role of each of the contributing agencies is indicated.

IRRI produces germplasm that is made freely available to breeding programs operated by PhilRice, UPLB and BPI, which are the rice-breeding centres for the Philippines. In more recent years, private companies have also bred new varieties (Launio et al. 2008).

It normally takes 7 years to develop a new rice variety through the conventional breeding process. The breeder purifies the lines up to year 4 when the promising lines are turned over to the advanced observational nursery for the preliminary yield trial. The superior lines or selections are then entered in the national cooperative tests (NCT) in which they are tested in 20 major rice-growing areas of the country (PhilRice 2010).

By year 7, a superior line identified in these trials is recommended to the National Seed Industry Council (NSIC) for approval as a commercial variety. The members of the NSIC are (a) the Secretary of Agriculture, (b) the Director of Bureau of Plant Industry, (c) the Dean of the UPLB College of Agriculture, (d) the Director of the Institute of Plant Breeding, (e) the Director of the Crops Research Division of the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development, (f) the Executive Director of PhilRice, (g) representatives of accredited farmers' organisations and (h) a representative from the seed industry (PhilRice 2010).

Breeders' and foundation seeds of approved varieties are distributed to members of the National Rice Seed Production Network (SeedNet) for faster multiplication and accessibility to seed growers and farmers. The SeedNet has 85 members nationwide (PhilRice 2010). The members include state universities and colleges, Department of Agriculture research outreach stations, farmers' cooperatives or associations, and non-government organisations. Seed of new and current varieties is produced through this system.

From the SeedNet, seeds are submitted to NSQCS for seed certification. Once certified, seed is ready for distribution to accredited seed growers and seed companies for farmers' use (PhilRice 2010).

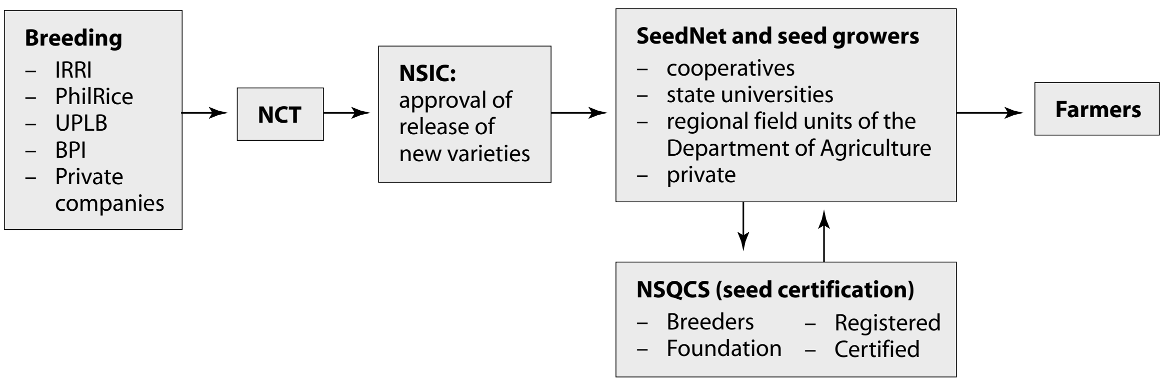

Figure 4.1 Pathway from rice germplasm research to farmer impact in the Philippines

5 Data on varieties and sources in the Philippines

5.1 Varietal release and pedigree data in the Philippines

In the Philippines, IRRI lines were initially released directly as varieties. In 1975, IRRI decided not to name any varieties but to continue to freely share breeding lines and to let national programs release the IRRI-bred lines as varieties (Khush and Virk 2005). The Philippine Seed Board (PSB) continued to release IRRI-bred lines as IR varieties until 1988, at which time PhilRice assumed the responsibility for testing improved germplasm.

Varieties were then released with the prefix 'PSB Rc' (Philippine Seed Board—Rice) until 2002, when a new prefix 'NSIC Rc' (National Seed Industry Council—Rice) was used for all new varieties. The numbering of the varieties has continued sequentially, so that PSB Rc varieties are from 1 to 102, and NSIC Rc are from 104 to 222 by 2009. From the release of IR20 in 1969, even numbers have been used for general-purpose varieties and odd numbers for special purpose varieties (Khush and Virk 2005).

Data on the varieties released in the Philippines since 1985 have been obtained from the IRG, INGER and IRIS. For each variety, this list includes:

- variety name
- pedigree
- year of release
- institution that released the variety
- classification of IRRI contribution to the variety.

A rich dataset was compiled to provide the basis for the analysis of varietal origins used in this study. Where there were gaps in the data on year of release and classification, they were estimated based on related and similar varieties. Because these data were available for all varieties grown on significant areas, these estimated data had minimal effect on the results obtained.

5.2 Relative yields of varieties in the Philippines

For each variety, yield data from variety trials at time of release were obtained from PhilRice. The statistic obtained for all varieties for the Philippines was the average yield from consolidated results of NCT trials across seasons and locations. These are research-managed trials. The yield data were based on results from five seasons, with the first three seasons being on-station trials and the last two on farm. Where there were gaps in the yield data, they were estimated based on related and similar varieties. Because yields were obtained for all varieties grown on significant areas, these estimated yields had minimal effect on the results obtained.

5.3 IRRI contribution to varieties in the Philippines

From the information on varieties, they were classified by their relationship to IRRI, using the rule of thumb developed in Section 2.5 (see Table 2.2). The percentage

IRRI contribution to each variety was used to assess the weighted IRRI contribution to overall variety yield improvement (see Section 6.2).

5.4 Data on varietal share of area planted in the Philippines

The only data on the proportion of the area planted to different rice varieties ('varietal share') in the Philippines that were comprehensive enough for our analysis were seed certification data from NSQCS. PhilRice conducted socioeconomic surveys of farmers in some regions in some years and obtained data on the leading varieties grown on farms (Mr Ronell Malasa, Science Research Specialist, PhilRice, pers. comm., September 2010). Those data are available for 12 regions, but only for the years 1996, 1997, 2001, 2002, 2006 and 2007, and so were too limited to provide the basis for the comprehensive analysis required in this study.

Seed data were extracted from the seed certification reports compiled in NSQCS's central office. These were hard-copy annual reports, mostly handwritten. The annual summaries (where the seed data were extracted) by the central office staff were prepared manually by summarising the handwritten monthly reports coming from the 13 NSQCS centres located in different regions.[1]

The seed share data extracted from the seed certification reports were taken to represent the share of varieties grown by farmers. For any given region, the total amount of seed for use by farmers (registered, certified or 'good' seed) produced in a region was calculated, then the percentage share of the seed produced of each variety was used to represent the percentage share of each variety grown on farms in that year. The process involves the following assumptions:

- All seed produced in a year is used on farms in that year. The extent of seed retained and not sold to farmers until the following year, if any, is not known.
- The percentage mix of varieties in the seed retained by farmers is the same as the percentage mix of varieties found in seed production. Farmers retain seed on farm for use in the following season. As much as 75% of seed used can be retained on farms or purchased on the informal seed market, and is therefore not included in the formal seed production data (Dr Stephan Haefele, IRRI, pers. comm., August 2010).
- The seed produced in one region is representative of the seed used on farms in a region, and inter-region trade in seed is not significant.

These are restrictive assumptions that demonstrate the difficulty of relying on seed share data, but there was no other basis for determining the varietal share data required for this study. Nevertheless, the use of seed data may well lead to an overestimate of the importance of new varieties, and therefore may exaggerate the rate of varietal yield improvement.

We have collected data on varieties grown, by region, in the Philippines since 1985 (based on seed production data). This list includes many varieties that were released before 1985, and so provides a strong base from which to calculate changes in yield attributable to varietal change since 1985.

Unfortunately, data were not available for every year since 1985. No records were available for 1990 and 1992, and data for 2001 could not be compiled for this study. For the missing years, in the calculation of yield gains and benefits (see Section 7), the gaps in the intervening years were filled by linear interpolation between the neighbouring years for which we have data, to provide a full annual estimate of the yield gains and welfare benefits.

Using the seed production shares by region, we were able to estimate the aggregate varietal share in the Philippines as a whole. That was done by using the varietal share in each region, weighted by the area planted in each region, to give the aggregate share of varieties across the Philippines as a whole.

1 Much of the seed data were painstakingly and meticulously extracted and compiled from the handwritten reports by Ms Florita Rañeses from IRRI.

6 Rice varieties in the Philippines

6.1 Rice varieties released in the Philippines

New rice varieties have been released for farmers in the Philippines regularly over recent decades (Table 6.1). Between 1980 and 2009, 148 improved rice varieties were released. The number of releases has grown throughout the period, from 22 in the 1980s to 83 in the 2000s. Hossain et al. (2003) found that the average number of improved varieties released per million hectares of rice by 1999 in the Philippines was high compared with several other countries they examined, and that is confirmed here for the most recent decade. Over the 30-year period, there were 39 releases per million hectares of rice, or 1.3 varieties released per year per million hectares.

Of those 148 varieties released, 37 were released between 1985 and 1995 (that is, in Phase MV3 defined in Section 2.1), and 111 in the period from 1996 (Phase MV4).

6.2 IRRI contribution to varieties released in the Philippines

The varieties released since 1980 in the different classifications discussed in Sections 2.5 and 5.3 are shown in Table 6.2. Hossain et al. (2003) found that the Philippines' proportion of varieties with some IRRI link was the highest among the countries they examined. That trend has continued to the current period. In the 1980s, 64% of varieties were direct IRRI crosses, while in the 2000s, only 40% were IRRI crosses. However, the IRRI link to varieties was strong throughout the period, averaging 70% of all varieties released. Of the 83 varieties released in the decade to 2009, 52 were connected to IRRI in some way.

6.3 Adoption of modern rice varieties in the Philippines

Adoption of MVs in the Philippines was very rapid, reaching 40% by 1968 and over 80% by 1980, due in part to large irrigation infrastructure projects in the 1950s and 1960s (Hossain et al. 2003). In the 1990s, adoption had reached over 90% of the rice area.

Estudillo and Otsuka (2006) showed that, by 1985, adoption of MVs in the Philippines was already 93% of the area planted in the irrigated ecosystem, 86% in the rainfed ecosystem and 17% in the upland systems. These had changed little by 1997, although the proportion of the area under MVs in the uplands had declined to 6% by that time.

We do not have the data to assess whether MVs have spread further since that time. As the only comprehensive data on varieties grown is from seed production data for purchase by farmers, there is likely to be a strong bias towards MVs in the data and away from traditional varieties that are more likely to have the seed retained on farm from one harvest to the next. Therefore, we are not able to directly compare with previous data to determine the extent to which MV adoption has or has not increased in the past decade or so.

However, we are able to examine which of the MVs have been grown. The 50 most widely grown varieties in the period 1985 to 2009 are shown in Table 6.3. The varieties that reached the largest area planted were IR64, IR60, IR36, IR66 and IR74, all released by 1988, and PSB Rc18 (Ala, released in 1994), PSB Rc82 (Peñaranda,

Table 6.1 Number of rice varieties released in the Philippines since 1980

	1980–89	1990–99	2000–09	Total 1980–2009
No. of improved varieties released	22	43	83	148
Average area (million ha)	3.3	3.6	4.2	3.8
Releases/million ha	6.6	12.1	19.9	39.0

Table 6.2 IRRI contribution to varieties released in the Philippines, 1980–2009

	1980–89	1990–99	2000–09	Total 1980–2009
Total number of varieties released	22	43	83	148
IRRI releases	14	22	33	69
IRRI parent	1	13	11	25
IRRI ancestor	1	0	8	9
Total IRRI link	16	35	52	103
Percentage of varieties released				
IRRI releases	64	51	40	47
IRRI parent	5	30	13	17
Other IRRI ancestor	5	0	10	6
Total IRRI link	73	81	63	70

Table 6.3 Leading rice varieties in the Philippines, 1985–2009

Rice variety	Release name	Year released	Released by	Years grown		Total area (million ha)[a]
				First	Last	
IR36	IR36	1976	IRRI	1985	2007	3.9
IR42	IR42	1977	IRRI	1985	2009	2.4
IR54	IR54	1980	IRRI	1985	2006	0.2
IR56	IR56	1982	IRRI	1985	1999	0.2
BPI Ri-10	BPI Ri-10	1983	BPI	1985	2008	1.8
IR58	IR58	1983	IRRI	1985	1991	0.1
IR60	IR60	1983	IRRI	1985	2009	4.8
IR62	IR62	1984	IRRI	1985	2003	1.7
IR64	IR64	1985	IRRI	1985	2009	8.8
IR66	IR66	1987	IRRI	1987	2009	3.6
IR70	IR70	1988	IRRI	1988	2004	0.9
IR72	IR72	1988	IRRI	1988	2008	2.1
IR74	IR74	1988	IRRI	1988	2009	3.3
PSB Rc2	Nahalin	1991	IRRI	1991	2003	0.7
PSB Rc4	Molawin	1991	IRRI	1991	2009	1.0
PSB Rc10	Pagsanjan	1992	IRRI	1993	2009	4.3

Table 6.3 (continued)

Rice variety	Release name	Year released	Released by	Years grown		Total area (million ha)[a]
				First	Last	
PSB Rc12	Caliraya	1992	UPLB	1993	2006	0.3
PSB Rc14	Rio Grande	1992	UPLB	1993	2009	3.3
PSB Rc6	Carranglan	1992	PhilRice	1993	2002	0.6
PSB Rc8	Talavera	1992	PhilRice	1993	2009	0.8
PSB Rc18	Ala	1994	IRRI	1994	2009	9.2
PSB Rc20	Chico	1994	IRRI	1994	2008	0.6
PSB Rc28	Agno	1995	IRRI	1995	2009	3.7
PSB Rc30	Agus	1995	IRRI	1996	2005	0.4
PSB Rc32	Jaro	1995	UPLB	1995	2004	0.4
PSB Rc34	Burdagol	1995	PhilRice	1996	2008	0.6
PSB Rc52	Gandara	1997	IRRI	1997	2009	0.7
PSB Rc54	Abra	1997	IRRI	1997	2009	1.2
PSB Rc64	Kabacan	1997	IRRI	1998	2009	0.6
PSB Rc66	Agusan	1997	PhilRice	1998	2009	0.3
PSB Rc72H	Mestizo 1	1997	IRRI	1999	2009	0.9
PSB Rc74	Aklan	1998	UPLB	1997	2009	0.9
PSB Rc80	Pasig	2000	IRRI	2000	2009	0.7
PSB Rc82	Peñaranda	2000	IRRI	2000	2009	6.1
NSIC Rc110	Tubigan 1	2002	IRRI	2003	2009	0.3
NSIC Rc112	Tubigan 2	2002	IRRI	2003	2009	1.0
NSIC Rc116H	Mestizo 3	2002	IRRI	2003	2009	0.6
NSIC Rc120	Matatag 6	2003	PhilRice	2002	2009	0.4
NSIC Rc122	Angelica	2003	IRRI	2003	2009	1.0
NSIC Rc128	Mabango1	2004	PhilRice	2004	2009	1.3
NSIC Rc130	Tubigan 3	2004	PhilRice	2004	2009	0.8
NSIC Rc132H	Mestizo 6	2004	SL Agritech	2003	2009	0.5
NSIC Rc134	Tubigan 4	2005	PhilRice	2004	2009	0.6
NSIC Rc138	Tubigan 5	2006	PhilRice	2006	2009	0.6
NSIC Rc142	Tubigan 7	2006	PhilRice	2007	2009	0.3
NSIC Rc146	PJ7	2006	PhilRice	2006	2009	0.7
NSIC Rc150	Tubigan 9	2007	PhilRice	2007	2009	0.3
NSIC Rc152	Tubigan 10	2007	PhilRice	2008	2009	0.4
NSIC Rc158	Tubigan 13	2007	IRRI	2008	2009	0.3
NSIC Rc160	Tubigan 14	2007	PhilRice	2008	2009	0.6

[a] Total area planted from 1985 to 2009, excluding area grown in 1990, 1992 and 2001, for which years no data are available.
Note: Some varieties were grown by farmers before being officially released.

released in 2000), PSB Rc10 (Pagsanjan, released in 1992) and PSB Rc28 (Agno, released in 1995). Of the leading varieties released before 1990, almost all were released by IRRI, while in more recent years PhilRice has released most of the leading varieties. However, both PSB Rc18 and PSB Rc82 are crosses between IRRI lines and were developed by IRRI.

The pattern of usage of the most widely grown varieties is illustrated in Figure 6.1. In the 1980s, a smaller number of varieties was grown in larger proportions each year, while in more recent years the larger mix of varieties grown each year, and hence the lower level of dominance of the leading varieties, is evident.

6.4 Yield progress through rice varietal change in the Philippines

The ongoing and continued improvement in varietal yields through time is illustrated in Figure 6.2, where the yields of the leading 50 varieties are shown by year of release. Before 1990, varietal yields tended to be approximately 5.0 t/ha, while in recent years varietal yields from on-farm trials have been mainly in the range 5.5–6.0 t/ha. This increase in varietal yields through time demonstrates the continuing improvements made by breeders through varietal improvement. As outlined in Section 2.1, this study measures increases in varietal yields only. Other improvements brought about by breeders, such as improved pest and disease tolerance, abiotic stress tolerance and shorter maturity, have not been included except to the extent that they have improved varietal yields.

6.5 IRRI contribution to varietal improvement in the Philippines

Using the rule of thumb about IRRI's contribution to new varieties (Sections 2.5 and 5.3), the IRRI contribution to varieties released has changed over time (Table 6.4), as the varieties were initially released by IRRI but are now more commonly released by PhilRice. Only 26 of the 83 new varieties released in the 2000s were classified as 100% IRRI, while 14 of the 22 varieties released in the 1980s were 100% IRRI. In addition,

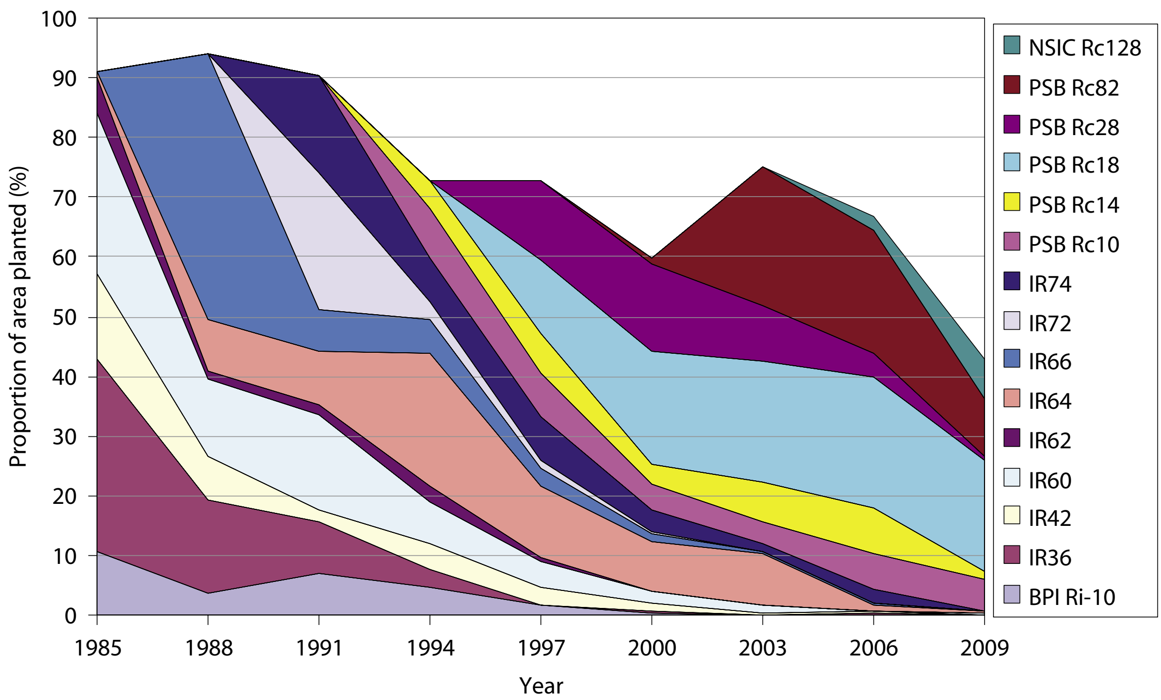

Figure 6.1 Pattern of use of leading rice varieties in the Philippines, 1985–2009

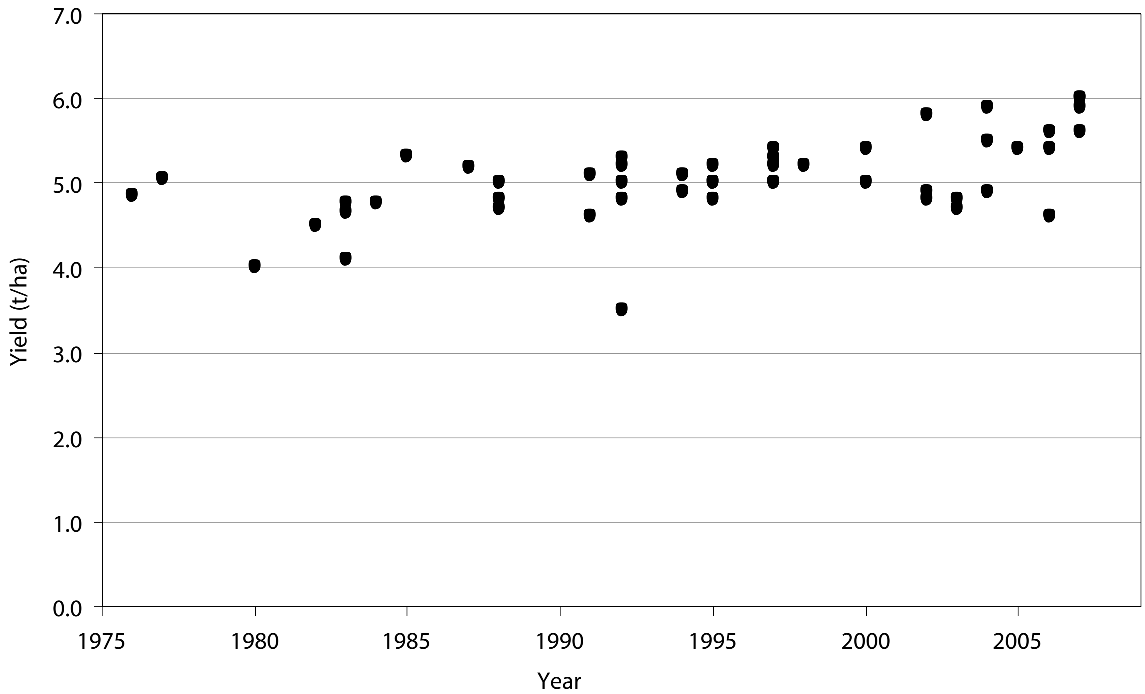

Figure 6.2 Rice varietal yield in the Philippines, by year of release

Table 6.4 IRRI contribution to Philippine rice varieties, by year of release

IRRI contribution (%)	Number of varieties released			
	1980s	1990s	2000s	Total
0	6	8	31	45
0–25	1	0	8	9
26–50	1	14	18	33
51–99	0	0	0	0
100	14	21	26	61
All varieties	22	43	83	148

IRRI made no contribution to the parentage of 31 of the varieties released in the 2000s. It is apparent that the contribution from IRRI to the pedigrees of recently developed varieties in the Philippines has been lower than for earlier varieties.

7 Analysis of the impact of IRRI in the Philippines

7.1 Varietal yield increases in the Philippines

From the regional data on percentage variety share, the analysis of varietal change was undertaken at the regional level in the Philippines. For each region, the data on varietal area share were combined with varietal yields to give the IVI for each year (Section 2.4). The index gives a weighted (weighted by area share) varietal yield measure for each year. This provides a measure of the yield improvement attributable to varietal change between 1985 and 2009. Where there were missing years in the data (1990, 1992 and 2001), the index was interpolated between neighbouring years to provide an annual series from 1985 to 2009.

The analysis using the IVI shows that rice varietal yields in the Philippines increased 11% between 1985 and 2009 (Table 7.1). For the Philippines as a whole, there was an initial sharp increase with the adoption of the high-yielding, higher quality variety IR64 in the late 1980s, with little progress over the following 10 years (Figure 7.1). This reflects the fact that the varieties grown up to 2000 in many regions were varieties released in the 1980s, and farmers were slow to change from those earlier IR varieties such as IR36, IR60, IR64 and IR66. From around 2000 there has been solid progress in varietal yields, with a relatively sharp increase at the end of the period. The increase of 11% over 24 years is equivalent to an average of 0.46% per year.

There has been considerable variation around this average in the different regions in the period to 2009, with varietal yield increases ranging from 4% to 17% in the different regions. In addition, the pattern of change during the period was very different between regions. Some regions showed sharp increases when others were showing decreases. For example, Ilocos showed no improvement between 1985 and 1995 while Central Visayas had a 7% increase in the same period. There is no clear explanation for the different patterns of yield progress between regions, but they may be due, at least in part, to our use of national average yields rather than regional yields. These differences are not explored in this report.

7.2 IRRI contribution to yield increases in the Philippines

The percentage IRRI contribution to each variety, when combined with the varietal share data, gives a weighted measure of the contribution of IRRI to each year's improvement. Again, where there were missing years in the data, the index was interpolated between neighbouring years to provide an annual series.

When the contribution of IRRI to each variety is weighted by the variety's share of the area planted, an interesting picture of a change in IRRI's share of the yield gains is revealed (Figure 7.2). Over the period 1985–2006, the relative IRRI contribution to varieties grown on Philippine rice farms (as measured using the rule of thumb developed in Section 2.5), was more than 80%, falling to around 60% by 2009. This recent change in the IRRI contribution to pedigrees reflects the trend in recent years for Philippine breeders such as PhilRice, UPLB and private companies to be more likely to use IRRI lines as parents or other ancestors rather than releasing

Table 7.1 Rice yield increases (%) attributable to varietal change in the Philippines, by region

	Ilocos	Cagayan Valley	Central Luzon	CALABARZON/ MIMAROPA	Bicol	Western Visayas	Central Visayas	Eastern Visayas	Zambo-anga	Northern Mindanao	Davao	SOCCSK-SARGEN	Caraga	CAR	ARMM	Philipp-ines
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	3	7	6	5	3	2	2	7	3	1	1	–1	0	7	–5	4
1987	6	5	7	5	3	1	6	7	3	1	2	1	1	11	–2	4
1988	4	5	6	2	8	2	9	6	6	7	6	5	3	9	0	5
1989	1	4	4	1	7	2	6	2	2	2	3	1	0	8	–3	3
1990	1	4	4	1	6	2	4	2	2	4	2	0	1	8	–3	3
1991	1	3	4	1	5	1	3	2	2	6	1	0	1	7	–4	2
1992	1	4	5	2	4	2	4	2	1	5	1	–2	1	7	–7	2
1993	1	5	5	4	3	3	4	1	0	4	1	–5	1	7	–10	2
1994	2	6	6	3	5	3	5	1	1	4	3	0	2	8	–4	4
1995	0	4	7	5	4	3	7	2	2	3	5	1	4	6	–5	4
1996	4	5	6	5	6	3	3	5	1	1	6	2	5	9	–6	4
1997	3	6	6	5	6	3	7	6	1	3	4	2	3	8	–4	4
1998	4	6	7	5	7	3	6	3	3	–2	4	3	5	11	–2	5
1999	4	7	7	4	8	3	7	6	3	5	6	3	6	9	–6	5
2000	3	8	7	4	9	2	8	9	6	7	8	5	6	11	0	6
2001	4	9	9	5	10	3	8	9	6	6	9	4	7	12	0	6
2002	5	9	10	6	11	3	9	9	6	5	10	3	8	12	0	7
2003	7	11	10	5	10	2	5	5	3	6	14	4	4	11	1	7
2004	6	16	11	7	10	0	8	1	2	10	13	4	6	13	1	8
2005	6	14	10	9	8	2	5	10	–2	21	21	4	6	18	–5	8
2006	6	14	8	5	9	2	9	7	4	7	19	7	8	18	–5	8
2007	6	11	8	5	9	3	9	10	8	8	18	8	4	14	5	8
2008	7	11	12	7	9	3	10	11	9	11	16	7	10	16	3	9
2009	9	14	14	10	13	4	11	13	10	13	10	12	12	17	7	11

Note: CALABARZON/MIMAROPA = Cavite, Laguna, Batangas, Rizal and Quezon / Occidental Mindoro, Oriental Mindoro, Marinduque, Romblon and Palawan; SOCCSKSARGEN = South Cotabato, Cotabato, Sultan Kudarat, Sarangani and General Santos City; CAR = Cordillera Administrative Region; ARMM = Autonomous Region in Muslim Mindanao

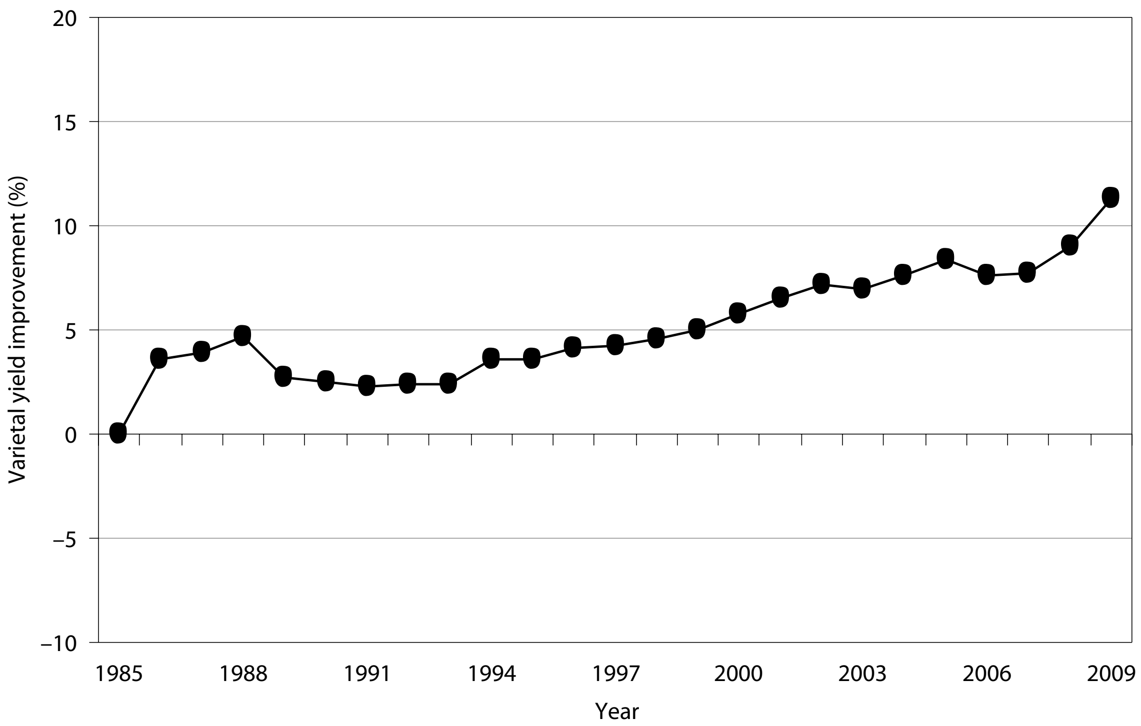

Figure 7.1 Rice varietal yield increases in the Philippines, 1985–2009

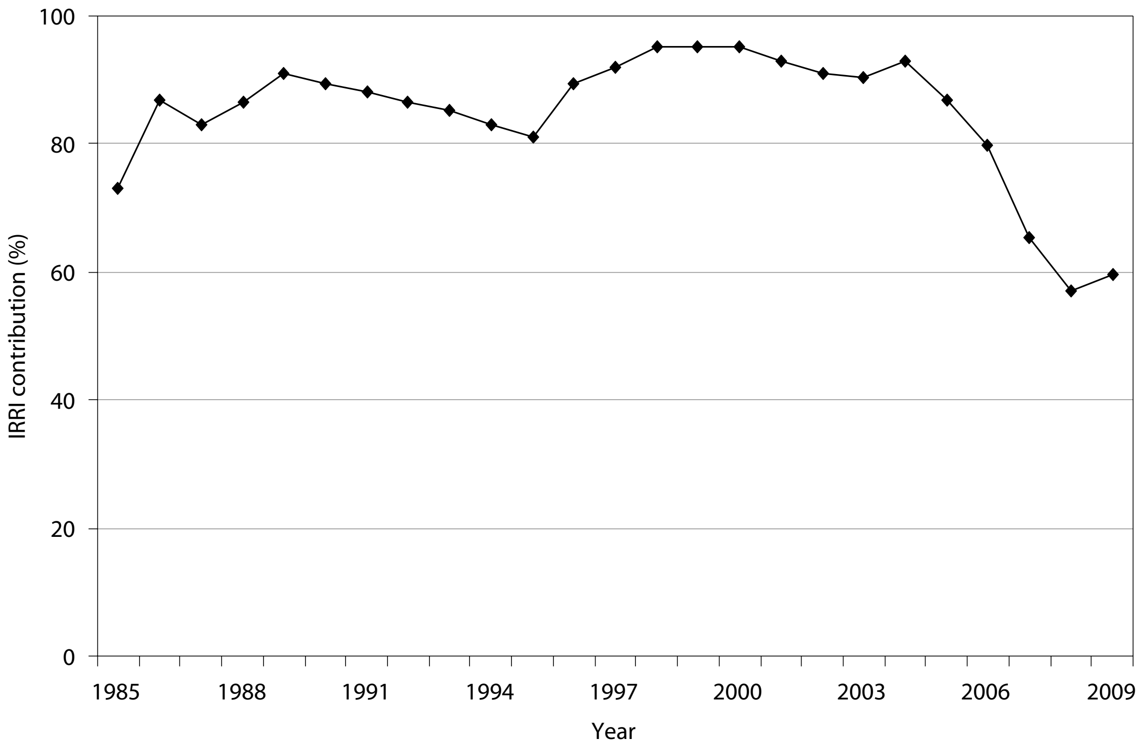

Figure 7.2 IRRI contribution to rice varieties grown in the Philippines, weighted by area planted

them directly as new varieties. Given that PhilRice was established in 1985, the change in the IRRI contribution, and the corresponding recent increase in that of PhilRice, is likely to reflect the growing achievements of PhilRice as it matured as an organisation.

These two measures, when combined, give a measure of the varietal yield improvement that is attributable to IRRI (Table 7.2). For the Philippines as a whole, gains attributable to IRRI were 6.7% by 2009. These gains had reached 4.1% by 1988, and then declined slightly until 1995. From that time, the increases attributable to IRRI increased steadily to 7.3% in 2005, before some decline in the past few years. These changes are a result of the varietal yield changes discussed above and the change in IRRI contribution to those changes.

Table 7.2 Rice varietal yield increases (%) attributable to IRRI in the Philippines, 1985–2009

Year	Increase in varietal yields	IRRI contribution (%)	Gains attributable to IRRI
1985	0.0	73	0.0
1986	3.6	87	3.2
1987	3.9	83	3.3
1988	4.7	86	4.1
1989	2.7	91	2.5
1990	2.5	90	2.3
1991	2.3	88	2.0
1992	2.4	87	2.0
1993	2.4	85	2.0
1994	3.6	83	3.0
1995	3.6	81	2.9
1996	4.1	89	3.7
1997	4.3	92	3.9
1998	4.6	95	4.3
1999	5.0	95	4.8
2000	5.7	95	5.5
2001	6.5	93	6.0
2002	7.2	91	6.6
2003	7.0	91	6.3
2004	7.6	93	7.0
2005	8.4	87	7.3
2006	7.6	80	6.1
2007	7.8	65	5.1
2008	9.1	57	5.2
2009	11.3	60	6.7

7.3 Value of IRRI contribution to yield increases in the Philippines

When the index measuring varietal improvement and the index measuring IRRI's contribution are combined, we are able to undertake an aggregate analysis across all regions of the economic benefits of the gains from varietal change. Using the real export price detailed in Section 2.6, the economic benefits each year from varietal improvement can be estimated, as well as IRRI's contribution to those benefits.

The total value of those increases in 2009 was US$1,017 million, or an annual average of US$265 million (in constant 2009 dollars) over the whole period (Table 7.3). The IRRI contribution to those gains in 2009 was valued at US$601 million, or an annual average of $204 million over the whole period.

The figures show that, in the late 1980s, there were substantial benefits from varietal improvement, with IRRI contributing the lion's share of those benefits. Between 1990 and 1993, there was a reduction in benefits. From the mid 1990s, benefits increased steadily, although with IRRI's share of the annual benefits declining in recent years, as shown in Figure 7.3.

There was a marked increase in benefits in the last 2 years (Figure 7.3). To 2007, the value of the IRRI contribution to varietal gains averaged $178 million per year. In 2008 and 2009, when the prices were historically very high and the yield increases were markedly higher, the average value was $588 million per year. As discussed above, it is unclear whether these levels of benefits will be sustained in future, as both prices and yield increases may be above trend in those 2 years.

To put the benefits from IRRI into a broader perspective, the IRRI contribution to the yield gains in the Philippines have been expressed on a per hectare basis (Table 7.3). The average annual value of the gains from IRRI since 1985 is equivalent to US$52/ha in 2009 values, with the average rice area in the Philippines over 3.7 million ha/year in that period.

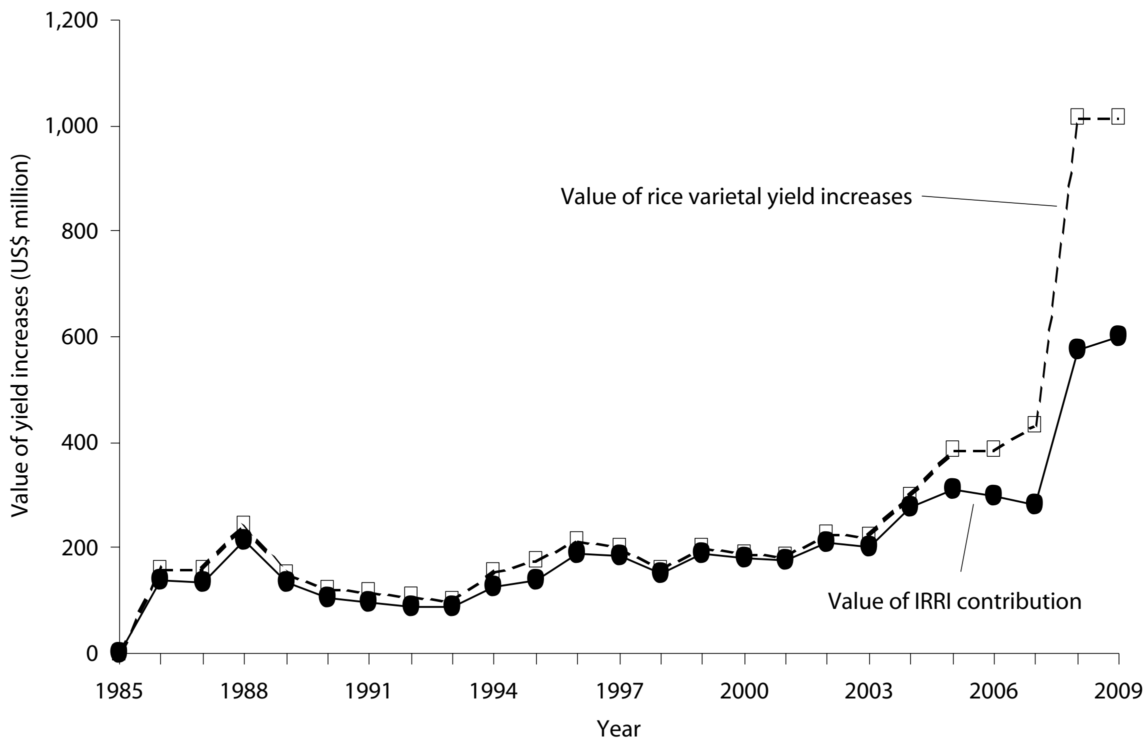

Figure 7.3 Value of rice varietal yield increases in the Philippines, 1985–2009

Table 7.3 Value of rice varietal yield increases in the Philippines (US$, 2009 values)

	Value of rice variety yield increases (US$ million)	Value of IRRI contribution (US$ million)	Value of IRRI contribution (US$/ha)
1985	0	0	0
1986	161	138	40
1987	160	134	41
1988	243	212	63
1989	151	135	39
1990	120	103	31
1991	117	98	29
1992	107	89	28
1993	101	87	27
1994	153	124	34
1995	178	140	37
1996	215	191	48
1997	203	186	48
1998	160	153	48
1999	200	190	48
2000	187	179	44
2001	186	175	43
2002	225	209	52
2003	222	203	51
2004	299	277	67
2005	384	311	76
2006	386	297	71
2007	431	281	66
2008	1,016	575	129
2009	1,017	601	133
Average per year	265	204	52

PART III
Impacts of IRRI germplasm on Indonesia since 1985

8 Indonesian rice industry

8.1 Rice industry trends in Indonesia

Indonesia is the third-largest producer of rice in the world, after China and India. Rice is the most important food crop in Indonesia. It is a staple food of the Indonesian people, and the Indonesian food system has a high dependence on it (Hariyadi 2010). Average consumption of rice (milled equivalent) in 2007 was 125 kg/head/year, and rice provided 49% of the calories and 40% of the protein in the Indonesian people's diet in 2007 (FAOSTAT 2011).

Data on area planted, production and yield of rice in Indonesia are summarised in Table 8.1. Since the 1980s, production has increased by 44%, as a result of a 22% increase in area planted and an 18% increase in yields per hectare. Between 1985 and 2008, total rice consumption increased by 23%, which was less than population growth (38%), so that rice consumption per head has fallen by 11%. The changes since 1985 are illustrated in Figure 8.1. Yields increased steadily from 1985 to 1991, followed by little growth up to 1997. Following a drop in yields in 1998 and 1999, yield growth has been steady since 2000.

8.2 Rice production systems in Indonesia

Rice is produced in irrigated, rainfed, upland and tidal swamp systems in Indonesia. Multiple cropping is widely practised, and rice is produced throughout the year. Rice farms in Indonesia are predominantly small landholder enterprises.

Fertilisers and pesticides are widely used, in conjunction with high-yielding varieties. Fertiliser levels have been increasing over time, and have been associated with the increased yields from the adoption of MVs, which respond favourably to higher fertiliser application. In more recent years, integrated pest management has been widely promoted, and pesticide subsidies removed to reduce the reliance on pesticides. Indonesian rice systems are productive, with national average yields per hectare among the highest in South-East Asia.

8.3 Previous studies of the impact of modern rice varieties in Indonesia

Indonesia was one of the key countries in the advances made during the green revolution in rice in Asia. MVs were introduced into Indonesia in the mid 1960s and, by 1970, there was rapid adoption of the new varieties (Herdt and Capule 1983). The ensuing green revolution resulted from many forces coming together to provide an environment in which high-yielding varieties were developed and utilised to provide large and lasting increases in rice production in Asian countries (Hazell 2010).

The adoption of MVs from 1966 in Indonesia was rapid and widespread (Hossain et al. 2003), and reached over 80% of the crop area by the mid 1980s. Hossain et al. (2003) also found that the initial replacement of traditional with MVs was estimated to provide a net gain of US$156/ha in Indonesia.

Hossain and Pingali (1998) documented the rapid rate of rice yield improvement associated with the green revolution period. Between 1966 and 1986, rice yields in Indonesia grew at 3.95% per year, while from 1986 to 1996 they grew at a markedly lower rate of 1.06%.

Table 8.1 Area, production and yield of rice in Indonesia since the 1980s

	1980–89	1990–99	2000–09	Increase (%) 1980s–2000s
Area (million ha)	9.7	11.1	11.8	22
Production (million t)	37.5	48.3	54.0	44
Yield (t/ha)	3.87	4.34	4.57	18

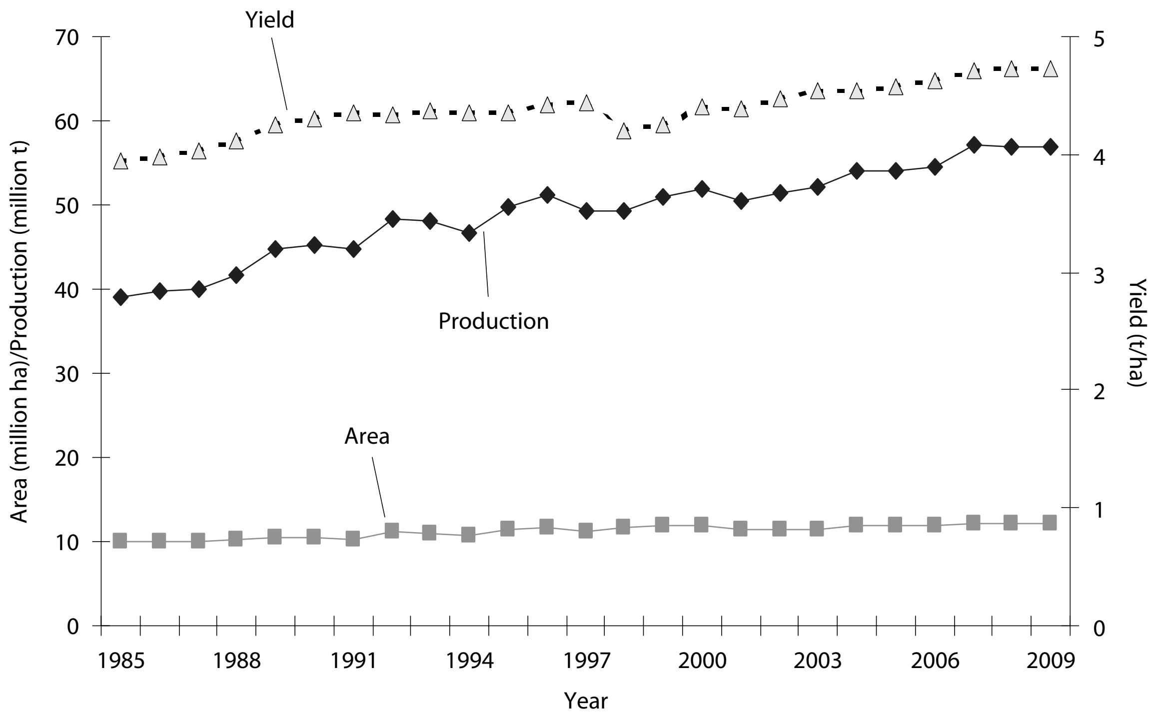

Figure 8.1 Area, production and yield of rice in Indonesia since 1985

8.4 Rice production regions for analysis in Indonesia

Indonesia has 33 rice-producing provinces for which area, yield and production data were obtained for the period since 1985. To make a manageable set of regions for the analysis, these provinces were grouped into five regions (see Table 8.2), four of them geographically defined, the fifth being comprised of the other provinces:

- Sumatra
- Java
- Sulawesi
- Kalimantan
- other provinces.

The average area, yield and production for rice in the period 2000–09 for each of these provinces and regions are shown in Table 8.2. Of the major production regions, Java is the largest producer (averaging over 29 million t/year since 2000), and three of its provinces have the largest production (West Java, Central Java and East Java). Sumatra is the second-highest rice-producing region, although Sulawesi and Kalimantan are also significant rice producers.

Table 8.2 Average area, production and yield of paddy rice in Indonesia, by region and province, 2000–09

Region	Province	Area ('000 ha)	Production ('000 t)	Yield (t/ha)
Sumatra	Aceh	341	1,451	4.26
	Bangka Belitung	7	16	2.47
	Bengkulu	113	418	3.71
	Jambi	156	569	3.64
	Lampung	496	2,111	4.26
	North Sumatra	784	3,290	4.19
	Riau	140	444	3.18
	Riau Islands	0.057	0.167	2.91
	South Sumatra	619	2,275	3.68
	West Sumatra	414	1,860	4.49
	Total Sumatra	3,069	12,436	4.05
Java	West Java (Jabar)	1,851	9,645	5.21
	Central Java (Jateng)	1,624	8,493	5.23
	East Java (Jatim)	1,722	9,117	5.29
	Jakarta (DKI)	2	11	4.82
	Yogyakarta (DIY)	133	681	5.12
	Banten	319	1,548	4.86
	Total Java	5,652	29,496	5.22
Kalimantan	Central Kalimantan	197	486	2.47
	East Kalimantan	144	488	3.38
	South Kalimantan	459	1,605	3.50
	West Kalimantan	372	1,067	2.87
	Total Kalimantan	1,172	3,647	3.11
Sulawesi	Central Sulawesi	184	733	3.99
	Gorontalo	37	159	4.30
	North Sulawesi	94	432	4.58
	South Sulawesi	780	3,643	4.67
	South-East Sulawesi	91	349	3.84
	West Sulawesi	66	300	4.53
	Total Sulawesi	1,219	5,466	4.48

Table 8.2 (continued)

Region	Province	Area ('000 ha)	Production ('000 t)	Yield (t/ha)
Other	Bali	148	815	5.51
	East Nusa Tenggara	171	492	2.88
	Maluku	13	41	3.31
	North Maluku	11	38	3.42
	Papua	22	72	3.31
	West Nusa Tenggara	326	1,469	4.51
	West Papua	9	28	3.14
	Total other	695	2,942	4.23
Total Indonesia		11,807	53,986	4.57

Source: IRRI Rice Statistics, 2009

Note: Because area and production data have been rounded, some yield values and totals may appear to be slightly inconsistent.

Because the data on varieties were available separately for both wet and dry seasons, the analysis for Indonesia in this study is carried out on that basis. The study takes no separate account of differences between lowland and upland, or irrigated and dryland production systems; all are aggregated into the two seasons in this analysis.

9 Rice research in Indonesia

9.1 Key rice institutions in Indonesia

There are several institutions involved in the scientific development of rice varieties and technologies, and science policy, in Indonesia, including: (a) the Indonesian Institute of Science; (b) the National Atomic Energy Agency; (c) Bogor Agricultural University; (d) Gadjah Mada University; and (e) the Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development. However, the key institutions involved directly in rice research and in developing and releasing improved rice varieties for farmers in Indonesia are:

- IRRI
- Indonesian Center for Rice Research (ICRR)
- Indonesian Center for Food Crops Research and Development (ICFORD)
- Committee for Variety Release.

From its earliest years, IRRI has had a close relationship with Indonesia and its rice research institutions. IRRI varieties have been popular in Indonesia and, at the scientist level, there has been close collaboration. This close level of interaction has led to nationally significant changes in rice productivity.

9.2 Indonesian Center for Rice Research

ICRR is an institution under the Indonesian Agency for Agricultural Research and Development (IAARD). It has a mandate to conduct rice research and is the principal organisation developing new rice varieties in Indonesia. ICRR has a strong working relationship with IRRI, and obtains a large proportion of breeding lines and varieties from IRRI. Many of the scientists at ICRR have been the beneficiaries of IRRI's on-the-job training and short courses. ICRR is a very significant player in getting improved rice varieties to farmers. Around 10,000 farmers visit ICRR each year to attend field days, so its role in increasing awareness and promoting new rice varieties is a critically important one.

As well as developing new rice varieties, ICRR plays a significant role in conservation of rice germplasm in Indonesia. Its focus in its breeding programs is the improvement of yield stability (by improving resistance and tolerance of varieties against biotic and abiotic threats) and yield potential (ICRR 2011). In addition, ICRR has important programs in areas such as agronomy, postharvest practices, pests and diseases, and seed management.

9.3 Indonesian Center for Food Crops Research and Development

ICFORD was established to formulate policies and programs and to conduct R&D on food crops (ICFORD 2011). In performing those tasks, ICFORD formulates food crop R&D policies and programs, undertakes food crop R&D and establishes institutional research collaborations. ICFORD has established close collaborative linkages with IRRI and ACIAR, among other international institutions.

9.4 Committee for Variety Release

The Committee for Variety Release comprises representatives from the private sector, scientists and the office of the Director-General for Food Crops. Its role is to make recommendations about the release of new varieties, based on the results of experiments and field trials undertaken by the relevant research institutions. The Committee presents its recommendations to the Department of Agriculture, on which basis varieties are released for seed multiplication, extension and use by farmers.

9.5 Pathway from germplasm research to farmer impact in Indonesia

The structure of the variety development process in Indonesia is illustrated in Figure 9.1, where the pathway from rice germplasm research to farmer impact is shown. The role of each of the contributing agencies is shown.

IRRI, through INGER, produces germplasm that is made freely available to breeding programs operated by ICRR which, as noted, is the principal rice-breeding centre for Indonesia. This germplasm is crossed or combined with traditional or popular varieties to produce the new varieties. The breeders make the appropriate crosses using these materials, then purify the lines over several years until the promising lines are sent for a series of comparative trials. The superior lines are then entered in the national multilocation trials. Once a superior line is identified in these trials, the Committee for Varietal Release assesses its suitability for release as a commercial variety. Once approved for release, seed is produced for distribution and promotion to farmers. The varieties are formally released under the banner of IAARD.

IRRI has also played a key role in the development of hybrid rice varieties for tropical conditions. In 2002, collaborative research between IAARD and IRRI identified promising hybrids that were subsequently released as Rokan and Maro. Since that time, more than 30 hybrids have been released in Indonesia, many sourced from China.

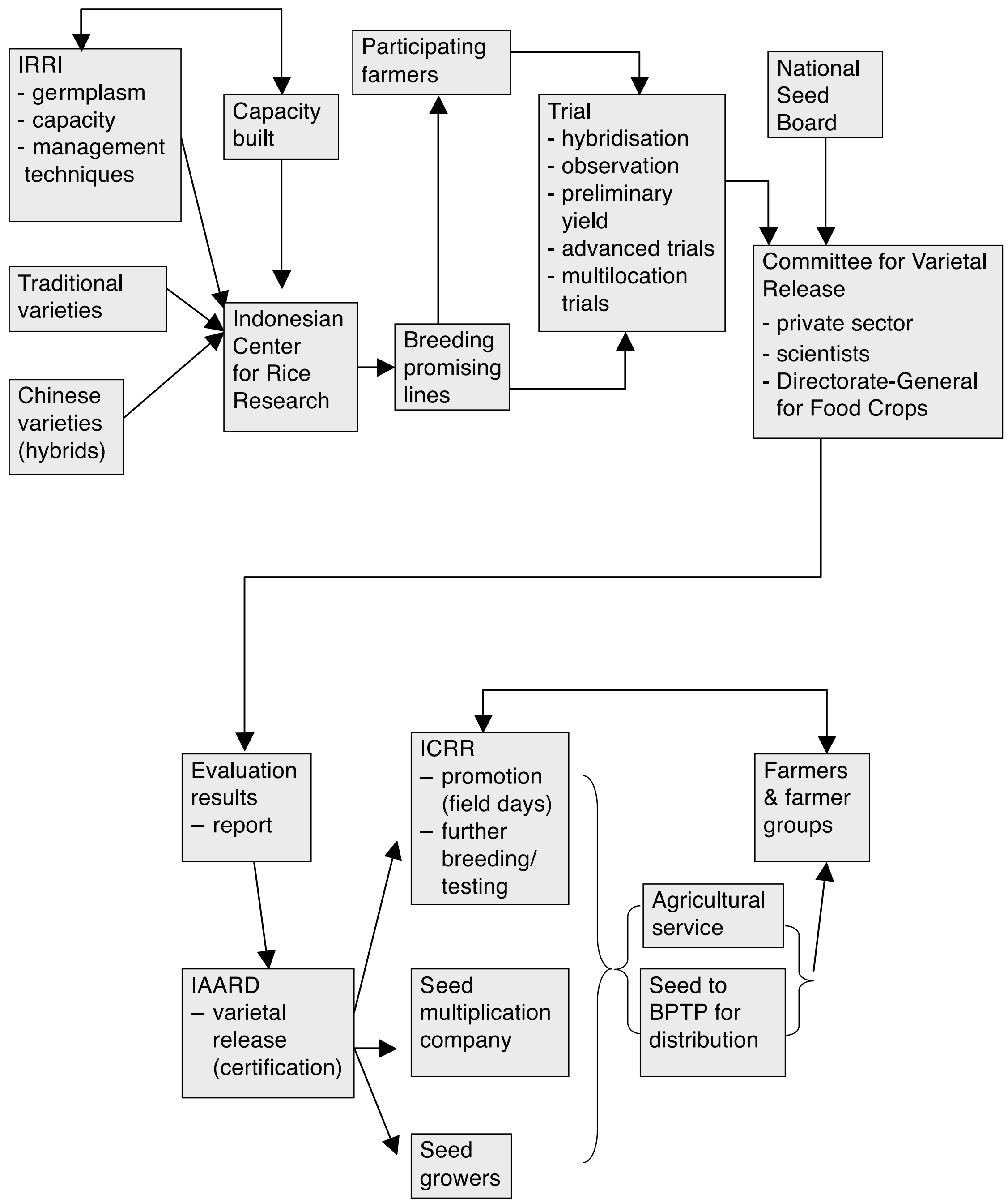

Figure 9.1 Pathway from rice germplasm research to farmer impact in Indonesia. Source: D. Templeton, ACIAR

10 Data on varieties and sources in Indonesia

10.1 Varietal release and pedigree data in Indonesia

An initial set of data on the varieties released in Indonesia since 1985 was obtained from IRG, INGER and IRIS. These data were verified and gaps filled by Dr Untung Susanto of ICRR (pers. comm., February 2011). For each variety, this list includes:

- variety name
- pedigree
- year of release
- institution that released the variety
- classification of IRRI contribution to the variety.

The list was expanded to include all varieties identified in the Indonesian statistics as having been grown in Indonesia. Where there were gaps in the data on year of release and classification, the missing data were estimated from related and similar varieties. Because these data were available for most varieties grown on significant areas, the estimated data had minimal effect on the results obtained.

In Indonesia, IRRI lines such as IR36 and IR64 were initially released directly as varieties. In 1975, IRRI decided not to name any varieties but to continue to freely share breeding lines and to allow national programs release the IRRI-bred lines as varieties (Khush and Virk 2005). ICRR has continued to release IRRI-bred lines since that time, along with varieties developed from local and imported materials by the Indonesian breeders.

10.2 Relative yields of varieties in Indonesia

For each variety, yield data from varietal trials at time of release were provided by Diah Wurjandari Soegondo of the IRRI Indonesia Office (pers. comm., February 2011), compiled from data gathered by the Directorate of Seeds (and its predecessors). The measure obtained for all varieties was the average yield in the trials across Indonesia at the time of release. Where there were gaps in the yield data, the missing data were estimated based on related and similar varieties. Because yields were not readily available for some varieties grown on significant areas, these estimates might have had some effect on the results obtained.

10.3 IRRI contribution to varieties in Indonesia

The information on varieties was used to classify them by their relationship to IRRI, using the rule of thumb developed in Section 2.5 (see Table 2.2). The percentage IRRI contribution to each variety was used to assess the weighted IRRI contribution to overall varietal yield improvement (see Section 11.2).

10.4 Data on varietal share of area planted in Indonesia

Detailed data on use of rice varieties were directly available for Indonesia from the Directorate of Seeds, and its predecessor, the Sub-directorate of Quality Control and Seed Certification in the Directorate General of Food Crop Production. The data were available separately for the wet season and the dry season each year. Thus, for crops harvested in 2007, for example, the wet season is shown as 2006–07, and the dry season as 2007.

We have assembled data on varieties grown in Indonesia, by region, since 1985. This list includes many varieties that were released before 1985, so it provides a strong base from which to calculate changes in yield attributable to varietal change since 1985.

Data are available for each season since 1985 except for 1991, 1991–92, 1992, 1992–93, 1997, 1997–98, 1998, 1998–99, 1999, 2000–01 and 2001. No attempt was made to directly fill in the varietal share data for the missing seasons. However, in the calculation of yield gains and benefits (see Section 12), so as to provide a full annual estimate of the yield gains and welfare benefits, the gaps in the intervening seasons were filled by linear interpolation between the neighbouring seasons for which we have data.

Using the varietal shares by province, we are able to estimate the aggregate varietal share in each of the regions defined above (Sumatra, Java, Kalimantan, Sulawesi and 'other'), and for Indonesia as a whole.

11 Rice varieties in Indonesia

11.1 Rice varieties released in Indonesia

New rice varieties have been released regularly for farmers in Indonesia over recent decades (Table 11.1). Between 1985 and 2009, 194 improved rice varieties were released in Indonesia. Although the rate of release was lower in the 1990s than in the 1980s, in the past decade the number of releases has continued at a high rate.

Over the 30-year period, there were 18 releases per million hectares of rice, or 0.6 varieties released per year for each million hectares of rice. The corresponding figures for the Philippines were 39 releases per million hectares of rice and 1.3 varieties released per year for each million hectares of rice (Section 6.1). Of the varieties released, 63 were released between 1985 and 1995 (that is, in Phase MV3 defined in Section 2.1), and 102 in the period from 1996 (Phase MV4).

11.2 IRRI contribution to varieties released in Indonesia

The varieties released since 1980 in the different classifications discussed in Sections 2.5 and 10.3 are shown in Table 11.2. In the 1980s, 24% of varieties were direct IRRI varieties, while in the 2000s none were IRRI releases. However, the IRRI link to varieties was strong throughout the period, averaging 89% of all varieties released. Of the 83 varieties released in the decade to 2009, 75 were connected to IRRI in some way.

11.3 Adoption of modern rice varieties in Indonesia

Adoption of MVs in Indonesia was rapid, reaching 40% by 1968 and over 80% by 1980, due in part to large irrigation infrastructure projects in the 1950s and 1960s (Hossain et al. 2003). In the 1990s, adoption had reached over 90% of the rice area.

Estudillo and Otsuka (2006) showed that, by 1985, adoption of MVs in Indonesia was already 93% of the area planted in the irrigated ecosystem, 86% in the rainfed ecosystem and 17% in the upland systems. These had changed little by 1997, although the proportion of the area under MVs in the uplands had declined to 6% by that time.

We were able to examine in detail which of the MVs have been grown. The 50 most widely grown varieties in the period 1985–2009 are shown in Table 11.3. The varieties that reached the largest area planted were IR64 (released 1987), Cisadane (1980), IR36 (1978), IR42 (1980), Ciliwung (1988) and Ciherang (2000). All of these varieties have IRRI lines in their parentage or other ancestry. Several of the leading varieties released before 1990 were released by IRRI, while in recent years ICRR/IAARD has released the leading varieties. However, both Ciliwung and Ciherang are crosses initially developed by IRRI.

The pattern of usage of the most important varieties is illustrated in Figure 11.1. From the 1980s until very recently, IR64 has had a dominant share of the area. In the past 5 years, Ciherang (released in 2000) has increased to also have a dominant share of the rice area. Other varieties have been important, but have mostly been dominated by IR64 and Ciherang overall, although in some provinces and regions they have played a more significant role.

Table 11.1 Number of rice varieties released in Indonesia since 1980

	1980–89	1990–99	2000–09	Total 1980–2009
No. of improved varieties released	70	41	83	194
Average area (million ha)	9.7	11.1	11.8	10.9
Releases/million ha	7.2	3.7	7.0	17.8

Table 11.2 IRRI contribution to varieties released in Indonesia, 1980–2009

	1980–89	1990–99	2000–09	Total 1980–2009
Total number of varieties released	70	41	83	194
IRRI releases	17	2	0	19
IRRI parent	34	25	49	108
IRRI ancestor	12	7	26	45
Total IRRI link	**63**	**34**	**75**	**172**
Percentage of varieties released				
IRRI releases	24	5	0	10
IRRI parent	49	61	59	56
Other IRRI ancestor	17	17	31	23
Total IRRI link	**90**	**83**	**90**	**89**

Table 11.3 Leading rice varieties in Indonesia, 1985–2009

Rice variety	Year released	Released by	Years grown		Total area (million ha)[a]
			First	Last	
C4-63	1969	IAARD	1985	2008	0.3
Pelita I-1	1971	IAARD	1985	2009	0.3
Adil	1976	IAARD	1985	2009	0.2
IR38	1977	IRRI	1985	2006	0.3
IR36	1978	IRRI	1985	2009	10.5
Cimandiri	1980	IAARD	1985	2009	0.2
Cisadane	1980	IAARD	1985	2009	13.7
IR42	1980	IRRI	1985	2009	6.4
Semeru	1980	IAARD	1985	2009	1.7
Barito	1981	IAARD	1985	2009	0.6
Cipunegara	1981	IAARD	1985	2009	0.4
IR50	1981	IRRI	1985	2003	0.2
IR52	1981	IRRI	1985	1997	0.2
Krueng Aceh	1981	IAARD	1985	2009	2.6
IR54	1982	IRRI	1985	2005	0.7
Bahbolon	1983	IAARD	1985	1997	0.4

Table 11.3 (continued)

Rice variety	Year released	Released by	Years grown		Total area (million ha)[a]
			First	Last	
IR46	1983	IRRI	1985	2009	2.1
IR56	1983	IRRI	1985	2002	0.2
Sadang	1983	IAARD	1985	2005	0.4
Kelara	1984	IAARD	1985	2008	0.6
Cikapundung	1985	IAARD	1985	2009	0.6
Citanduy	1985	IAARD	1985	2009	0.5
IR48	1985	IRRI	1985	2008	0.8
Cisanggarung	1986	IAARD	1986	2009	0.6
Cisokan	1986	IAARD	1986	2009	2.0
Dodokan	1987	IAARD	1986	2009	0.4
IR64	1987	IRRI	1987	2009	47.2
IR65	1987	IRRI	1987	2003	1.0
Ciliwung	1988	IAARD	1987	2009	4.8
IR66	1989	IRRI	1989	2009	2.6
IR70	1989	IRRI	1990	2009	0.5
IR72	1989	IRRI	1990	2009	0.3
Way Seputih	1989	IAARD	1990	2009	0.5
Atomita 4	1991	IAARD	1993	2009	0.2
IR74	1991	IRRI	1993	2009	1.0
Way Rarem	1994	IAARD	1994	2008	0.2
Membramo	1995	IAARD	1995	2009	1.9
Cilamaya Muncul	1996	IAARD	1996	2009	0.6
Digul	1996	IAARD	1996	2009	0.3
Way Apo Buru	1998	IAARD	1999	2009	2.5
Widas	1999	IAARD	1999	2009	0.9
Bondoyudo	2000	IAARD	2001	2009	0.2
Ciherang	2000	IAARD	2000	2009	19.1
Cisantana	2000	IAARD	2001	2009	0.6
Sintanur	2001	IAARD	2001	2009	0.3
Cigeulis	2002	IAARD	2004	2009	1.7
Cibogo	2003	IAARD	2002	2009	1.4
Pepe	2003	IAARD	2004	2009	0.3
Situbagendit	2003	IAARD	2001	2009	0.4
Mekongga	2004	IAARD	2005	2009	0.4

[a] Total area planted from 1985 to 2009, excluding area grown in 1991, 1991–92, 1992, 1992–93, 1997, 1997–98, 1998, 1998–99, 1999, 2000–01 and 2001, for which years no data are available.

Note: Some varieties were grown by farmers before being officially released.

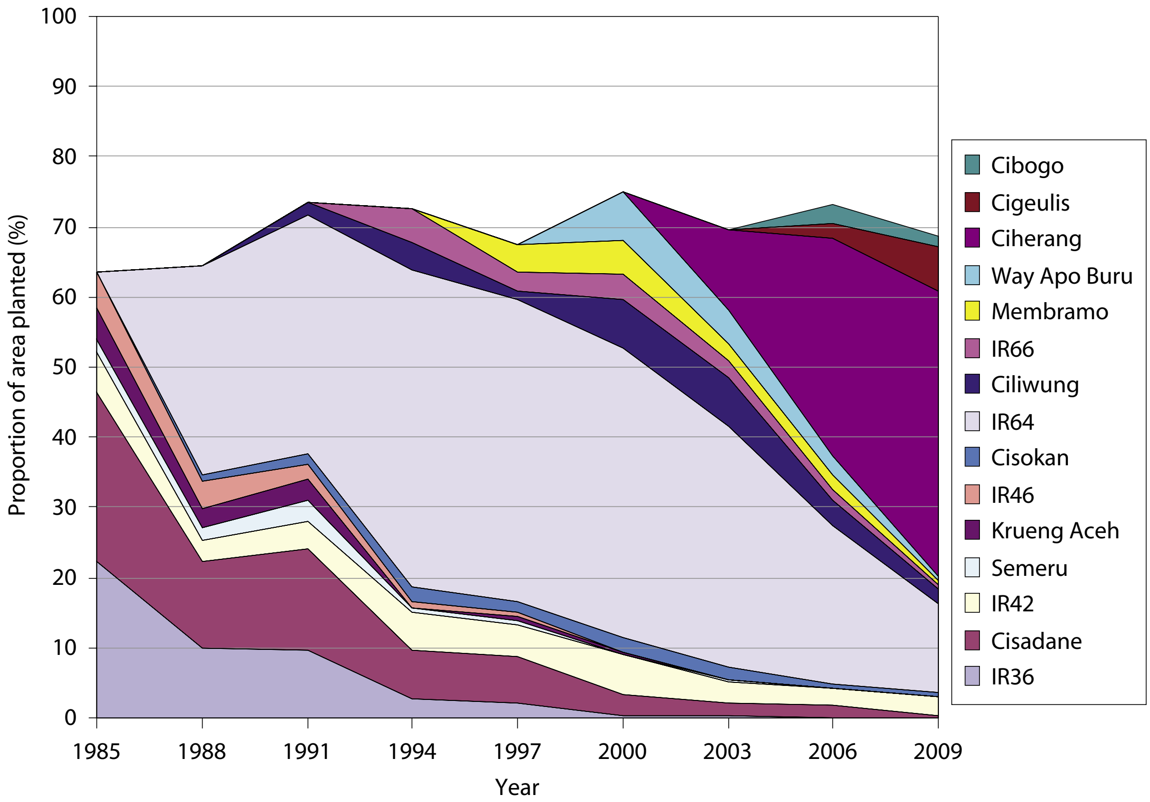

Figure 11.1 Pattern of use of leading rice varieties in Indonesia, 1985–2009

11.4 Yield progress through rice varietal change in Indonesia

The ongoing and continued improvement in varietal yields through time is illustrated in Figure 11.2, where the yields of the leading 50 varieties are shown by year of release. Before 1995, varietal yields tended to be mainly in the range 4.5–6.0 t/ha, while in recent years varietal yields from on-farm trials have been mainly in the range 5.5–7.0 t/ha. This increase in varietal yields through time demonstrates the improvements made by breeders through varietal improvement. As outlined in Section 2.1, this study measures only increases in varietal yields. Other improvements brought about by breeders, such as improved pest and disease tolerance, abiotic stress tolerance and shorter maturity, have not been included except to the extent that they have improved varietal yields.

11.5 IRRI contribution to varietal improvement in Indonesia

Using the rule of thumb about IRRI's contribution to new varieties (Sections 2.5 and 10.3), it is evident that the IRRI contribution to varieties released has changed over time (Table 11.4). This is because the varieties were initially released by IRRI but are now more commonly released by IAARD. Only 17 of the 83 new varieties released in the 2000s were classified as 100% IRRI, while 24 of the 70 varieties released in the 1980s were 100% IRRI. Only a small proportion (12%) of varieties have no IRRI linkage, while most (64% of releases) are classified as having between 25% and 50% IRRI contribution.

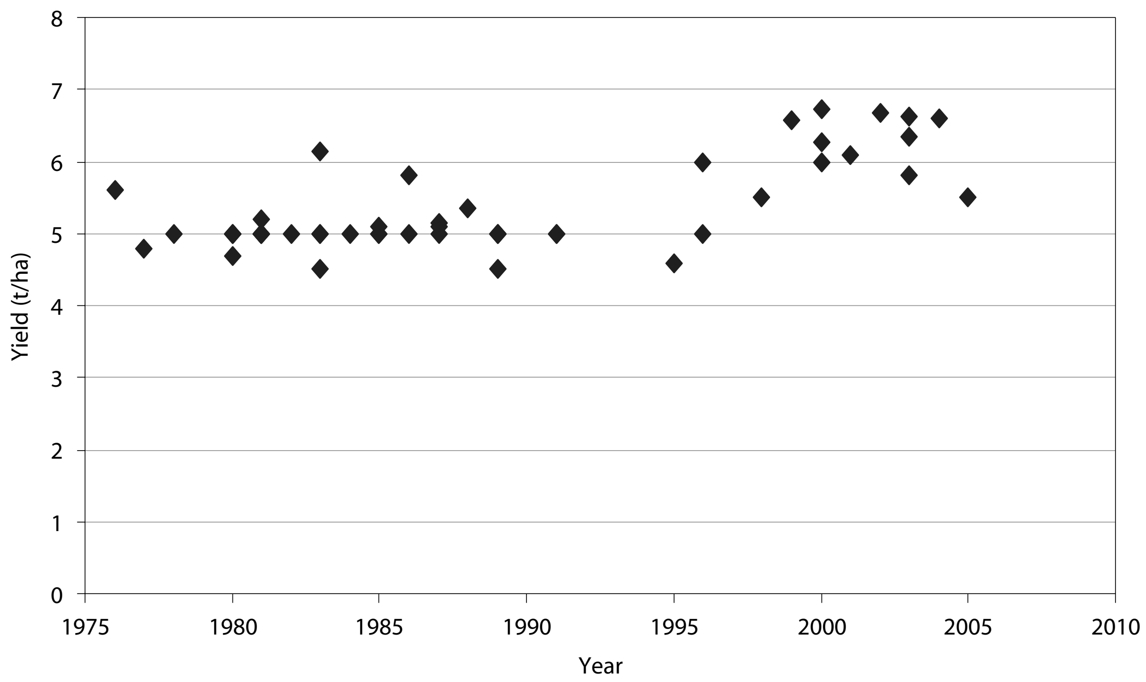

Figure 11.2 Rice varietal yield in Indonesia, by year of release

Table 11.4 IRRI contribution to Indonesian rice varieties, by year of release

IRRI contribution (%)	Number of varieties released			
	1980s	1990s	2000s	Total
0	8	7	8	23
0–25	12	7	26	45
26–50	26	21	32	79
51–99	0	0	0	0
100	24	6	17	47
All varieties	70	41	83	194

12 Analysis of impact of IRRI in Indonesia

12.1 Varietal yield increases in Indonesia

From the regional data on percentage varietal share, the analysis of varietal change was undertaken at the regional level in Indonesia. For each region, the data on varietal area share were combined with varietal yields to give the IVI for each year, as outlined in Section 2.4. The index provides a measure of the yield improvement attributable to varietal change between 1985 and 2009. Where there were missing seasons in the data (1991, 1991–92, 1992, 1992–93, 1997, 1997–98, 1998, 1998–99, 1999, 2000–01 and 2001), the index was interpolated between neighbouring seasons to provide a biannual series from 1985 to 2009.

The analysis using the IVI shows that rice varietal yields in Indonesia increased 19% between 1985 and 2009, ranging from 18% to 22% in the different regions (Table 12.1). The majority of those yield gains were achieved in the most recent 10 years, with only Java showing any improvement before 2000. For Indonesia as a whole, by 2001 the increase had been only 3% (Table 12.1). This reflects the fact that the varieties grown up to 2000 in many regions were varieties released in the 1980s, and farmers were slow to change from those earlier IR varieties such as IR36, IR42, IR64 and IR66, as well as Cisadane and Ciliwung. As those earlier varieties were replaced by more modern varieties such as Ciherang, the varietal yields increased sharply in the period after 2002.

For Indonesia as a whole, varietal yields increased from the late 1980s (Figure 12.1), then showed little progress until a sharp increase in 1996, then little further progress until 2001. From that time, there was rapid progress until 2008, although there was a slight fall in 2009.

12.2 IRRI contribution to yield increases in Indonesia

The percentage IRRI contribution to each variety is then combined with the varietal share data to give a weighted measure of the contribution of IRRI to each year's improvement. Again, where there were missing seasons in the data, the index was interpolated between neighbouring seasons to provide a complete series.

The contribution of IRRI to each variety, weighted by the variety's share of the area planted, is illustrated in Figure 12.2. From 1985 to 1993, the relative contribution of IRRI increased, particularly as IR64 became the dominant variety. Over the period since 1989, the relative IRRI contribution to varieties grown on Indonesian rice farms (as measured using the rule of thumb developed in Section 2.5) has remained around 70%. Unlike the Philippines, there is little evidence that breeders such as ICRR have become less likely to use IRRI lines as parents or other ancestors in the new varieties.

These two measures, when combined, give a measure of the varietal yield improvement that is attributable to IRRI (Table 12.1). For Indonesia, gains attributable to IRRI were 13.0% by 2009. The gains were less than 1.5% until 1995, and grew steadily from then, to 14.8% in 2008. There was a decline from that peak in 2009. The pattern of slow gains until around 2000 is consistent across all regions in Indonesia, as is the strong growth in more recent years.

Table 12.1 Rice yield increases attributable to varietal change in Indonesia by region, dry season, 1985–2009

Season	Increase in varietal yields (%)					IRRI contribution (%)	Gains attributable to IRRI (%)
	Sumatra	Java	Kalimantan	Sulawesi	Total Indonesia		
1985	0	0	0	0	0	47	0.0
1986	1	0	−2	1	0	52	0.0
1987	−2	0	−1	−1	−1	55	−0.4
1988	0	1	0	1	1	64	0.4
1989	−1	1	1	2	1	70	0.6
1990	2	1	−2	4	2	70	1.2
1991	2	1	−2	2	1	72	1.0
1992	1	1	−3	2	1	73	1.0
1993	1	1	−4	3	1	75	0.9
1994	2	2	2	1	2	73	1.3
1995	2	2	1	3	2	73	1.5
1996	3	2	2	3	2	65	1.4
1997	2	2	2	1	2	67	1.3
1998	2	2	2	2	2	69	1.3
1999	1	2	2	4	2	71	1.4
2000	1	2	2	5	2	73	1.5
2001	3	3	2	3	3	70	2.2
2002	4	5	3	8	5	68	3.2
2003	8	8	7	10	8	70	5.7
2004	7	11	8	11	10	71	7.1
2005	1	15	9	9	14	75	10.8
2006	15	15	18	14	15	74	11.1
2007	19	16	21	24	18	76	13.7
2008	16	20	23	20	20	74	14.8
2009	19	18	22	22	19	69	13.0

12.3 Value of IRRI contribution to yield increases in Indonesia

With the index measuring varietal improvement and the index measuring IRRI's contribution, we are able to undertake an aggregate analysis across all regions of the economic benefits of the gains from varietal change. Using the real export price detailed in Section 2.6, the economic benefits each year from varietal improvement can be estimated, as can IRRI's contribution to those benefits.

The total value of varietal yield improvement since 1985 in the 2008–09 wet and 2009 dry seasons was US$5,439 million, or an annual average of US$852 million/year (in constant 2009 dollars) over the whole period (Table 12.2). The IRRI contribution to those gains in those two seasons was valued at US$4,017 million, or an average of $644 million/year over the whole period since 1985.

The changes in varieties in the late 1980s led to negative varietal yield benefits[2] compared with 1985, which then from around 1988 became a steady flow of benefits of the order of US$100–$200 million/season. Since 2003, the value of IRRI's contribution to those gains has been more than US$500 million/year (from the two seasons), and has been more than US$1,000 million/year since 2005.

There was a marked increase in benefits in the last 3 years (Figure 12.3). To 2007, the average annual gain was $343 million, and in the past 2 years, when prices were historically very high and the yield increases were

2 See Section 18.1 for further discussion of the interpretation of negative yield gains found in some situations in this study.

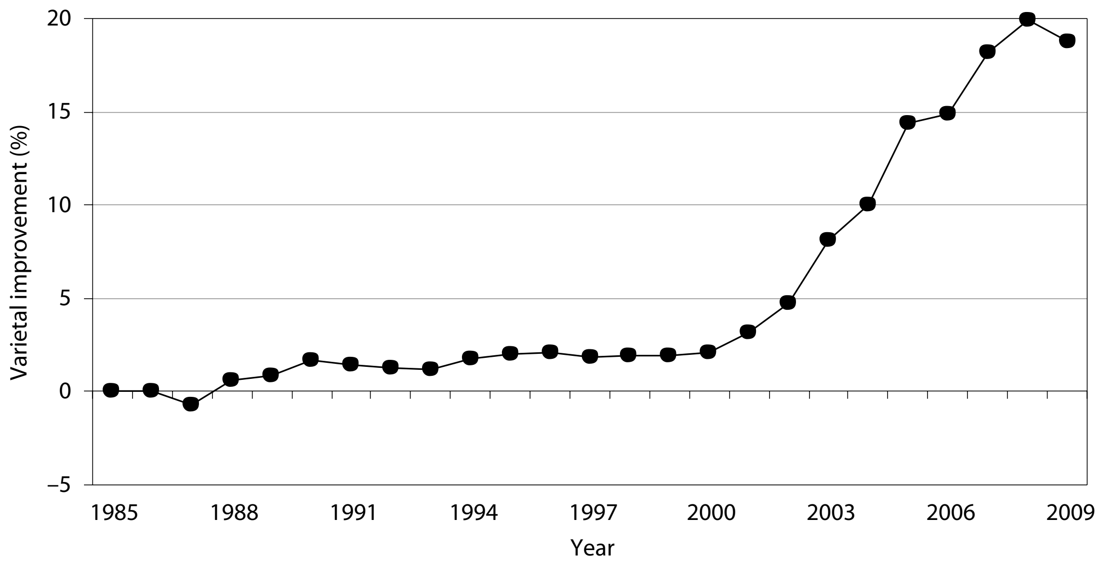

Figure 12.1 Rice varietal yield increase in Indonesia, from 1985

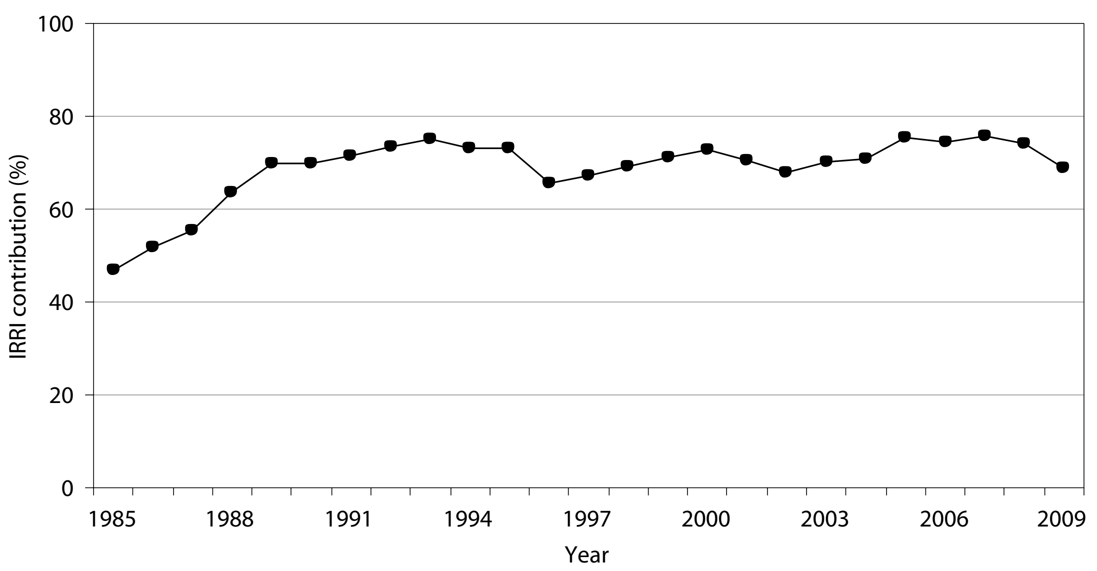

Figure 12.2 IRRI contribution to varieties grown in Indonesia, weighted by area planted

markedly higher, the average value of benefits was $4,107 million/year. As discussed above, it is unclear whether these levels of benefits will be sustained in future, as both prices and yield increases may have been above trend in those 2 years.

To put the benefits from IRRI into a broader perspective, the IRRI contribution to the yield gains in Indonesia have been expressed on a per hectare basis (Table 12.2). The average annual value of the gains from IRRI is equivalent to US$76/ha in 2009 values across the average rice area in Indonesia of over 9.2 million ha/year since 1985. This is higher than the average value for the Philippines (US$52/ha) (see Section 7.3).

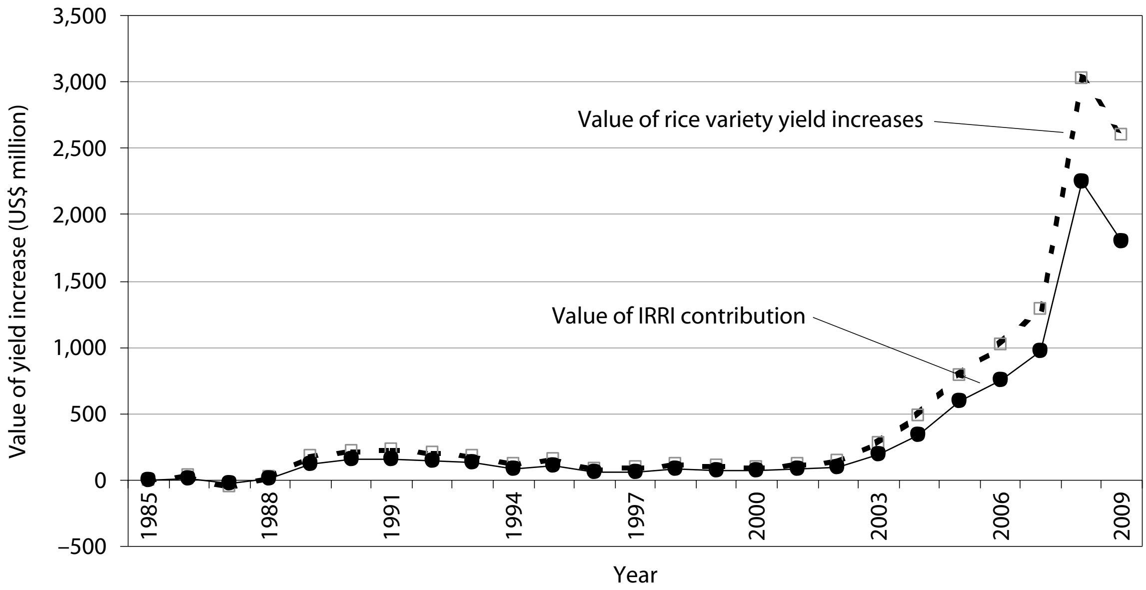

Figure 12.3 Value of rice varietal yield increases in Indonesia, 1985–2009

Table 12.2 Value of rice varietal yield increases in Indonesia (US$, 2009 values)

Season	Value of rice varietal yield increases (US$ million)	Value of IRRI contribution (US$ million)	Value of IRRI contribution (US$/ha)
1985	0	0	0
1985–86	–47	–25	–5
1986	4	6	2
1986–87	–71	–43	–8
1987	–46	–25	–8
1987–88	47	22	4
1988	47	35	11
1988–89	63	40	8
1989	68	51	15
1989–90	114	77	15
1990	112	84	27
1990–91	151	97	17

Table 12.2 (continued)

Season	Value of rice varietal yield increases (US$ million)	Value of IRRI contribution (US$ million)	Value of IRRI contribution (US$/ha)
1991	106	79	24
1991–92	164	117	18
1992	93	77	22
1992–93	181	142	20
1993	83	77	20
1993–94	215	177	22
1994	118	87	23
1994–95	209	160	26
1995	166	131	32
1995–96	221	158	24
1996	117	76	28
1996–97	78	54	17
1997	97	65	23
1997–98	118	84	21
1998	101	71	25
1998–99	128	93	20
1999	82	60	20
1999–2000	140	105	20
2000	72	57	18
2000–01	107	83	21
2001	96	72	23
2001–02	81	65	27
2002	153	110	36
2002–03	327	204	38
2003	327	238	62
2003–04	358	262	82
2004	524	390	93
2004–05	776	593	138
2005	594	498	193
2005–06	804	624	155
2006	925	706	175
2006–07	1,282	969	203
2007	1,151	890	224
2007–08	2,770	2,170	473
2008	2,659	2,028	496
2008–09	3,059	2,364	422
2009	2,380	1,653	344
Average per year	852	644	76

PART IV
Impacts of IRRI germplasm on Vietnam since 1985

13 Vietnamese rice industry

13.1 Rice industry trends in Vietnam

Rice is the most important food crop in Vietnam, and is a staple food of the Vietnamese people, with average consumption per person (milled equivalent) in 2007 of 166 kg/head/year (FAOSTAT 2011). Rice provided 58% of the calories and 45% of the protein in their diet in 2007 (FAOSTAT 2011).

Data on area planted, production and yield of rice in Vietnam are summarised in Table 13.1. Since the 1980s, production has increased by 111%, as a result of a 29% increase in area planted and a 64% increase in yields per hectare. Solid increases in both area and yield have occurred in both the 1990s and 2000s. The changes since 1985 are illustrated in Figure 13.1.

13.2 Rice ecosystems in Vietnam

Rice is grown throughout Vietnam, which lies within the tropics (8–23°N). In the southern delta, the climate is warm–humid all year round; the northern delta is in the tropical monsoon area with cold winters (Lang 2009). The highlands in the north have cool summers and cold winters, while the highlands in the central regions are cool all year round, with a long dry season. The central coast has a mixture of northern and southern climates. These characteristics create diversity in rice cultivation, with three distinct ecosystems definable: (i) irrigated and intensive, (ii) rainfed lowland and flood-prone and (iii) upland (Lang 2009).

Irrigated areas lie mainly in the Red River Delta in the north and the Mekong River Delta in the south (Lang 2009). In the Red River Delta, rice is cultivated with other upland crops in varying cropping patterns. In the lowland irrigated areas, two rice crops, possibly with one upland winter crop, are planted each year. In the Mekong River Delta, most irrigated areas are planted to two rice crops per year, with three crops per year grown in some places. The yield in irrigated systems reaches 6–7 t/ha in the dry season (spring) and 4–5 t/ha in the wet season (summer) (Lang 2009).

Since 1983, areas in the Mekong River Delta have converted from a floating rice system (with water as deep as 3 metres) to irrigated areas using a system of new canals and growing 2–3 crops per year (Lang 2009). There were parts of the region where water limitations prevented the change to irrigation, and there are still some 600,000 ha of rainfed rice grown where traditional varieties with photoperiod sensitivity are planted, and yields range from 2.5 to 4.5 t/ha. In the rainfed lowlands, improved varieties of medium duration (130–150 days) are planted, and yield levels of 5–6 t/ha can be obtained (Lang 2009). Yields decline as water depth increases.

Upland rice comprises about 8% of the total rice area in Vietnam (or 450,000 ha), and is cultivated mainly by minority ethnic groups who practise slash-and-burn shifting cultivation (Lang 2009). Almost no fertilisers or chemicals are used, and yields range from 0.6 to 2.0 t/ha. After 2–3 years, the farmers abandon the land and move to a new location for planting. The upland varieties grown are traditional, mostly sticky rice varieties, with a long maturity of 130–160 days. Land degradation and poor soil fertility are serious problems in the upland ecosystem (Lang 2009).

Table 13.1 Area, production and yield of rice in Vietnam since the 1980s

	1980–89	1990–99	2000–09	Increase (%) 1980s–2000s
Area (million ha)	5.7	6.8	7.4	29
Production (million t)	16.6	24.6	35.0	111
Yield (t/ha)	2.89	3.63	4.73	64

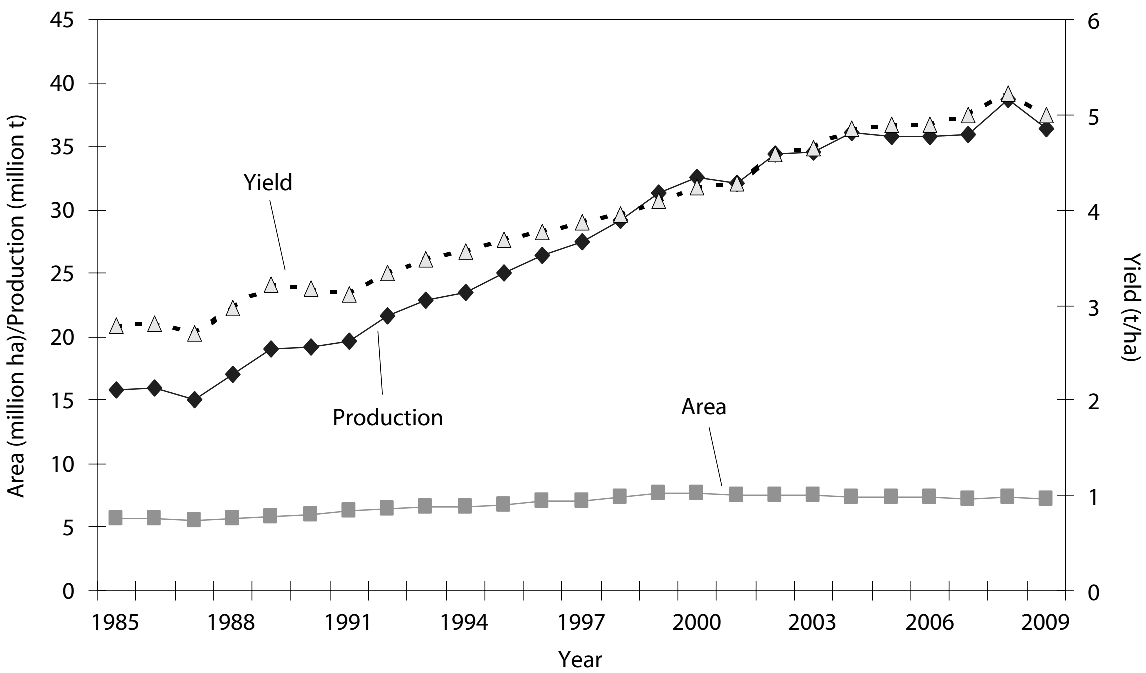

Figure 13.1 Area, production and yield of rice in Vietnam since 1985

13.3 Previous studies of the impact of modern rice varieties in Vietnam

The green revolution resulted from many forces coming together to provide an environment in which high-yielding varieties were developed and utilised to provide large and lasting increases in rice production in Asian countries (Hazell 2010). The green revolution was slower to begin in Vietnam because of the Vietnam War (Tran and Kajisa 2006). Although little progress had been made during the 1960s and 1970s, the growth in rice production in the 1980s and 1990s was 'truly remarkable' (Tran and Kajisa 2006). The yield increases began in the irrigated favourable areas and spread to less favourable areas over time (David and Otsuka 2006), assisted by an expansion in both the area under irrigation and the use of fertilisers.

Hossain and Pingali (1998) demonstrated the rate of rice yield improvement associated with the green revolution period and its aftermath. Between 1966 and 1986, rice yields in Vietnam grew at 1.85% per year, while from 1986 to 1996 they grew at a markedly high rate of 2.94%. This contrasts with both the Philippines and Indonesia, which had a higher rate of increase in the green revolution period to 1986, then a much lower rate of increase subsequently. The later impact of the MVs in Vietnam than in the other countries is clear from these figures.

Varieties associated with the green revolution in Vietnam came from two sources: the varieties in northern Vietnam, which were imported from China, and those developed by IRRI in southern Vietnam (Tran and Kajisa 2006). A key driving force for the yield improvements through new varieties has been the institutional structure of NARES, which has played a key role in selecting and promoting the imported technologies, and in developing appropriate technologies for the specific environments and constraints of the rice industry in Vietnam (Tran and Kajisa 2006).

The initial replacement of traditional varieties with MVs was estimated to provide a net gain of US$120/ha in Vietnam (Hossain et al. 2003). This was clearly a significant benefit, inducing the farmers to switch to the MVs in the favoured environments.

The consequences of the production increases resulting from the green revolution in Vietnam have been significant, as Vietnam became a rice exporter in 1988, following two decades as a rice importer.

13.4 Rice production regions for analysis in Vietnam

Rice in Vietnam is produced in the eight major regions of the country (Table 13.2), of which Mekong River Delta (which produces 52% of Vietnam's rice) in the south and Red River Delta in the north (18% of the total) have the most significant production. The eight regions comprise 62 separate provinces, with two other provinces outside these regions.

Data were collected at the provincial level, and were then aggregated into regions as appropriate. Where only some of the provinces within a region were covered by the data, the selected provinces were assumed to represent the other provinces in that region. Because only annual data on varieties in Vietnam were available, the analysis for the country in this study is carried out on that basis. The study takes no separate account of the seasons; nor is there any account taken of differences between lowland and upland or irrigated and dryland production systems: all are aggregated.

Table 13.2 Average area, production and yield of rice by region and province in Vietnam, 2000–09

Region	Province	Area ('000 ha)	Production ('000 t)	Yield (t/ha)
North East	Bac Giang	115	528	4.60
	Bac Kan	20	83	4.08
	Cao Bang	30	108	3.62
	Ha Giang	34	148	4.31
	Lang Son	49	185	3.79
	Lao Cai	31	121	3.86
	Phu Tho	72	332	4.60
	Quang Ninh	48	204	4.26
	Thai Nguyen	70	312	4.47
	Tuyen Quang	46	239	5.20
	Yen Bai	41	169	4.11
	Total North East	557	2,430	4.37

Table 13.2 (continued)

Region	Province	Area ('000 ha)	Production ('000 t)	Yield (t/ha)
Red River Delta	Bac Ninh	81	437	5.38
	Ha Nam	73	396	5.43
	Ha Noi	48	197	4.10
	Ha Tay	162	922	5.68
	Hai Duong	136	788	5.78
	Hai Phong	91	488	5.37
	Hung Yen	85	509	6.03
	Nam Dinh	159	933	5.86
	Ninh Binh	81	445	5.49
	Thai Binh	169	1,025	6.08
	Vinh Phuc	71	332	4.66
	Total Red River Delta	1,156	6,472	5.60
North Central Coast	Ha Tinh	103	442	4.28
	Nghe An	184	840	4.57
	Quang Binh	48	215	4.44
	Quang Tri	46	204	4.42
	Thanh Hoa	254	1,276	5.02
	Thua Thien Hue	51	235	4.62
	Total North Central Coast	687	3,212	4.68
South Central Coast	Binh Dinh	121	568	4.69
	Da Nang	9	48	5.22
	Khanh Hoa	44	190	4.32
	Phu Yen	58	310	5.31
	Quang Nam	87	371	4.28
	Quang Ngai	78	356	4.59
	Total South Central Coast	397	1,842	4.65
Central Highlands	Dak Lak	68	301	4.46
	Dak Nong	12	50	4.21
	Gia Lai	65	237	3.66
	Kon Tum	22	65	2.93
	Lam Dong	33	124	3.71
	Total Central Highlands	195	757	3.88

Table 13.2 (continued)

Region	Province	Area ('000 ha)	Production ('000 t)	Yield (t/ha)
South East	Binh Duong	20	57	2.90
	Binh Phuoc	15	36	2.42
	Binh Thuan	91	363	4.00
	Dong Nai	80	306	3.84
	Ninh Thuan	31	148	4.71
	Tay Ninh	155	600	3.87
	Total South East	392	1,511	3.85
Mekong River Delta	An Giang	502	2,788	5.55
	Bac Lieu	159	697	4.39
	Ben Tre	89	351	3.93
	Ca Mau	134	450	3.36
	Can Tho	310	1,524	4.92
	Dong Thap	440	2,325	5.28
	Hau Giang	127	600	4.72
	Kien Giang	575	2,685	4.67
	Long An	434	1,814	4.18
	Soc Trang	335	1,596	4.76
	Tien Giang	259	1,288	4.97
	Tra Vinh	233	997	4.28
	Vinh Long	201	943	4.70
	Total Mekong River Delta	3,798	18,059	4.75
North West	Dien Bien	25	78	3.17
	Hoa Binh	44	199	4.55
	Lai Chau	40	114	2.87
	Son La	40	128	3.21
	Total North West	148	520	3.51
Other	Ba Ria Vung Tau	24	75	3.12
	TP Ho Chi Minh	47	152	3.21
	Total other	72	227	3.18
Total		**7,401**	**35,030**	**4.73**

Source: IRRI Rice Statistics, 2009

Note: Because area and production data have been rounded, some yield values and totals may appear to be slightly inconsistent.

14 Rice research in Vietnam

14.1 Key rice institutions in Vietnam

The key institutions involved in rice research in Vietnam are:

- IRRI
- Agricultural Genetics Institute (AGI)
- Cuu Long Delta Rice Research Institute (CLRRI)
- Field Crops Research Institute (FCRI)
- National Centre for Plant and Fertilizer Testing (NCPFT).

Since the 1960s, IRRI has been a key player in the development of rice production in Vietnam through the provision of breeding lines and varieties, and capacity-building activities. Vietnam has benefited significantly from IRRI germplasm, training and know-how. The variety IR8 in the 1960s resulted in significant changes in not only yield but also the cropping system, as it was a relatively short-duration rice variety and hence enabled the growing of two crops a year. As a result of the large increase in rice production and the government agenda to ensure Vietnam was self-sufficient in food crops, by 1990 Vietnam had changed from being a net importer of rice to a net rice exporter. While government support waned once the threat of massive food shortages seemed no longer to be an issue, it was restored after the recent food price crisis.

14.2 Agricultural Genetics Institute

The focus of AGI research is on germplasm improvement for key crops. IRRI breeding lines with biotic (e.g. brown planthopper and blast) and abiotic (e.g. flood, drought and salinity) stress tolerance and resistance are used in the AGI breeding program to produce locally adapted varieties. AGI's breeding program develops varieties, and the promising lines are then forwarded to NCPFT for final testing and release (see Figure 14.1). NCPFT, seed companies/distributors, farmer groups/cooperatives and extension agencies are all involved in the varietal testing and development for farmers.

In the past, IRRI has also provided capacity building for AGI through on-the-job training, short courses and postgraduate studies.

14.3 Cuu Long Delta Rice Research Institute

CLRRI is located in the Mekong Delta, and its geographical focus is southern Vietnam. For use in its breeding and testing activities, CLRRI receives varieties and breeding lines from IRRI. Traditional varieties are also used in the breeding programs. Crop-management techniques received from IRRI are also included in the CLRRI research. Rice varieties developed by CLRRI based on IRRI lines have been dominant in the south, because those from other sources (e.g. China) have not been able to match their yields. IRRI also provides CLRRI with a significant amount of capacity building (e.g. on-the-job training and short courses).

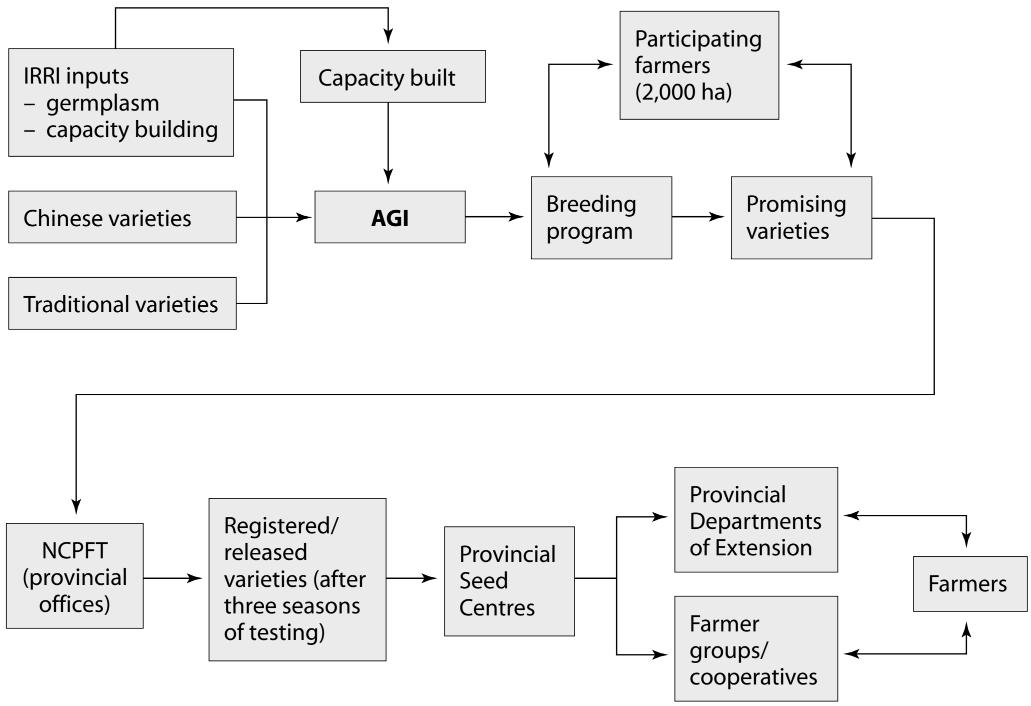

Figure 14.1 Agricultural Genetics Institute: pathway from rice germplasm research to farmer impact in Vietnam

The pathway from research to impact again incorporates the use of farmers' fields, and values farmers' feedback on varietal performance (Figure 14.2). Again, NCPFT, seed companies/distributors, farmer groups/ cooperatives and extension agencies are all involved in the varietal testing and development for farmers.

14.4 Field Crops Research Institute

FCRI is located in Hai Duong province in northern Vietnam. Varieties and lines from IRRI and China are used in the testing and breeding program at FCRI, as well as traditional varieties. In the breeding program, crosses are made within and between all of these varieties.

FCRI scientists have a strong relationship with IRRI scientists and have undertaken wide-ranging collaborative research with IRRI. IRRI has also provided training at FCRI through short courses, on-the-job training and postgraduate studies. In addition, IRRI has supported international workshops and meetings, and has provided in-country training. Many of FCRI's senior rice scientists have received some training from IRRI.

Varieties tested and/or used in the breeding program at FCRI include:

- IRRI varieties for their local suitability, stress-tolerant traits, and good eating and cooking quality
- Chinese varieties for their short-duration, high-yielding traits
- traditional varieties, which are highly adapted to local conditions and have a number of desirable traits.

In the breeding program, crosses are made within and between all of these varieties.

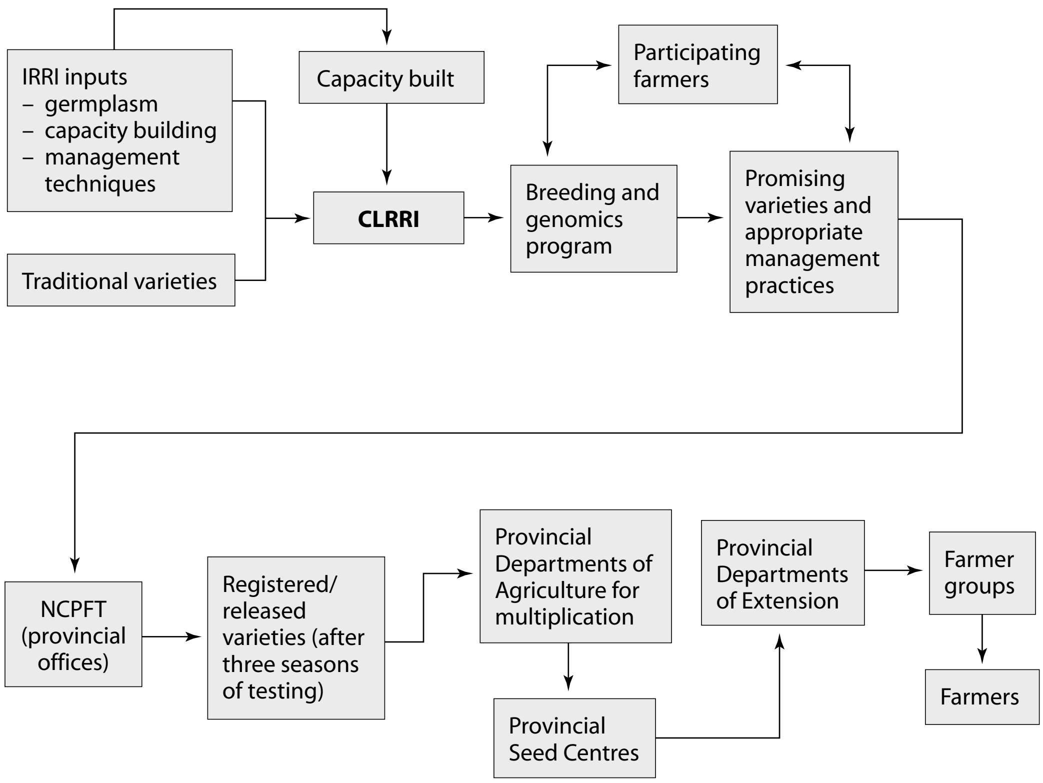

Figure 14.2 Cuu Long Delta Rice Research Institute: pathway from rice germplasm research to farmer impact in Vietnam

14.5 National Centre for Plant and Fertilizer Testing

The role of NCPFT is to test new varieties of crops, including rice, maize, legumes and vegetables, for registration and release. NCPFT has a network of testing stations throughout Vietnam. Once a promising line has been evaluated and released as a new variety, the seed is given to the seed companies for multiplication. The provincial extension departments have the role of promoting the new varieties and crop-management techniques.

15 Data on varieties and sources in Vietnam

15.1 Variety release and pedigree data in Vietnam

A list of varieties released in Vietnam since 1985 was compiled, drawing on data provided by CLRRI, NCPFT, IRG, INGER and IRIS. This initial list was then checked and some gaps filled by cooperators including Professor Nguyen Thi Lang of CLRRI and Nguyen Thi Duong Nga of the Hanoi University of Agriculture.

For each variety, the data obtained include:

- variety name
- pedigree
- year of release
- institution that released the variety
- classification of IRRI contribution to the variety.

Different approaches needed to be used in northern and southern Vietnam, because of differences in the availability of data. For southern Vietnam, data were collected for all varieties. However, for northern Vietnam, data related only to varieties that have some IRRI connection.

Where there were gaps in the data on year of release and classification, they were estimated based on related and similar varieties. Because these data were available for all varieties grown on significant areas, these estimated data had minimal effect on the results obtained.

15.2 Relative yields of varieties in Vietnam

The average yield of each important variety in each province, based on variety trials at time of release, has been obtained for southern Vietnam from Professor Nguyen Thi Lang of CLRRI and from Dr Nguyen Thi Duong Nga of the Hanoi University of Agriculture for northern Vietnam. Where there were gaps in the yield data, they were estimated based on related and similar varieties. Because yields were obtained for all varieties grown on significant areas, these estimated yields had minimal effect on the results obtained.

The average yield across all years in each province where it was grown is used for each variety, to enable the progress over time through varietal change to be assessed. However, varietal yields can vary from year to year, depending on the seasonal conditions. Thus, using average rather than annual varietal yields means that, while data for individual years can be unreliable, the trends through time can be clearly identified.

15.3 IRRI contribution to varieties in Vietnam

From the information on varieties, they were classified by their relationship to IRRI, using the rule of thumb developed in Section 2.5 (see Table 2.2). The percentage IRRI contribution to each variety was used to assess the weighted IRRI contribution to overall varietal yield improvement (see Section 16.2).

For southern Vietnam, data were available to enable such classification of all varieties grown. For northern Vietnam provinces, as noted above, the data related to only categories with IRRI lines as parents or ancestors.

15.4 Data on varietal share of area harvested in Vietnam

Data on spread and use of all rice varieties were not directly available for all of Vietnam, as slightly different data were available for northern and southern Vietnam. In southern Vietnam, data were available on the percentage share of each variety in the area harvested for all varieties. In northern Vietnam, data were available on the percentage share of each variety in the area harvested, but only for MVs. Within each of these geographical areas, data were available on the percentage share of each variety in the area harvested for each year from 1985 to 2009.

Data were collected at the provincial level, then aggregated into regions as appropriate. Where only some of the provinces within a region were covered by the data, those provinces were assumed to represent the other provinces in that region.

In southern Vietnam, data were available for 22 provinces, which represented 3 of the 4 regions. Data were not available for any provinces in the Central Highlands region. Within the 3 regions for which data were available, 6 of 6 provinces were included for the South East region, 3 of 6 for the South Central Coast region and all 13 in the Mekong Delta region (see Table 15.1). Given the Mekong Delta's predominance in rice production (see Section 13.4), this was important in providing an accurate assessment of the key impacts in southern Vietnam.

For northern Vietnam, data were available for 13 provinces, which represented 3 of the 4 regions. Data were not available for any provinces in the North East region. Within the 3 regions for which data were available, 6 of 11 provinces were included for the Red River Delta, 5 of 6 for the North Central Coast region and 2 of 4 for the North West region (see Table 15.1).

Table 15.1 Provinces and regions of Vietnam included in analysis

Regions	Provinces included	Provinces with insufficient data
North East		Bac Giang, Bac Kan, Cao Bang, Ha Giang, Lang Son, Lao Cai, Phu Tho, Quang Ninh, Thai Nguyen, Tuyen Quang, Yen Bai
Red River Delta	Ha Nam, Hai Duong, Hai Phong, Hung Yen, Nam Dinh, Thai Binh	Bac Ninh, Ha Noi, Ha Tay, Ninh Binh, Vinh Phuc
North Central Coast	Ha Tinh, Nghe An, Quang Binh, Quang Tri, Thanh Hoa	Thua Thien Hue
North West	Dien Bien, Hoa Binh	Lai Chau, Son La
South Central Coast	Binh Dinh, Khanh Hoa, Phu Yen	Da Nang, Quang Nam, Quang Ngai
Central Highlands		Dak Lak, Dak Nong, Gia Lai, Kon Tum, Lam Dong
South East	Binh Duong, Binh Phuoc, Binh Thuan, Dong Nai, Ninh Thuan, Tay Ninh	
Mekong River Delta	An Giang, Bac Lieu, Ben Tre, Ca Mau, Can Tho, Dong Thap, Hau Giang, Kien Giang, Long An, Soc Trang, Tien Giang, Tra Vinh, Vinh Long	
Other		Ba Ria Vung Tau, TP Ho Chi Minh

16 Rice varieties in Vietnam

16.1 Rice varieties released in Vietnam

New rice varieties have been regularly released for farmers in Vietnam over recent decades (Table 16.1). Between 1980 and 2009, 226 MVs were released for production in Vietnam. The rate of release of new varieties was especially high in the 1990s. In the past decade, the number of releases has continued at a high rate, although at a lower rate than in the 1990s. That may be because new varieties not related to IRRI have not been included in the data for northern Vietnam.

Over the 30-year period in Vietnam, there were 33 releases per million hectares of rice, or 1.1 varieties released per year for each million hectares of rice (Table 16.1). This is intermediate between the figures found for Indonesia (18) and the Philippines (39) (see Sections 6.1 and 11.1, respectively). Of those varieties released in Vietnam, 102 were released between 1985 and 1995 (that is, in Phase MV3 defined in Section 2.1), and 99 in the period from 1996 (Phase MV4).

16.2 IRRI contribution to varieties released in Vietnam

The IRRI-related varieties released since 1980 in the different classifications discussed in Sections 2.5 and 15.3 are shown in Table 16.2. In the 1980s, 47% of varieties were direct IRRI releases, whereas in the 2000s, only 12% were IRRI releases, but the use of IRRI lines as parents or as earlier ancestors increased correspondingly. Of the 226 varieties identified in this study, 173 (or 77%) had some IRRI link.

16.3 Adoption of modern rice varieties in southern Vietnam

IRRI varieties and varieties developed by CLRRI using IRRI genetic materials have been well suited to the climatic conditions of southern Vietnam, particularly the Mekong Delta, and have been widely adopted by farmers.

The 40 most widely grown varieties in southern Vietnam in the period 1985 to 2009 are shown in Table 16.3. The varieties that reached the largest area planted were OM89, the name for IR64 in southern Vietnam (released in 1987), OM576-18 (1990), OM2517 (1996), OMCS96 (1977), OMCS94 (1994), OMCS95-3 (1977), NN3B (1980) and IR50 (1979). The most widely grown variety released in more recent years has been OM4900 (released in 2002). Of the leading varieties released before 1988, many were direct IRRI releases, while in recent years CLRRI has released all of the leading varieties, although, as noted above, many have involved IRRI lines as parents or ancestors.

The pattern of usage of the most important varieties is illustrated in Figure 16.1. While in the 1980s the four leading varieties accounted for over 50% of the area planted, by the 1990s there was a much more even spread of varieties, and no single variety has accounted for more than 10% of the area in any one year since 1989. This reveals a high level of varietal diversity in the rice grown in southern Vietnam since that time. Since 1994, at least 56 separate varieties have been grown in the Mekong Delta each year, compared with less than 20 in the 1980s. Farmers are clearly growing a wide range of rice varieties and types in the Mekong Delta region. In the other regions of southern Vietnam, there are also high levels of varietal diversity.

Table 16.1 Number of rice varieties released in Vietnam since 1980

	1980–89	1990–99	2000–09	Total 1980–2009
No. of improved varieties released	60	98	68	226
Average area (million ha)	5.7	6.8	7.4	6.8
Releases/million ha	10.5	14.4	9.2	33.1

Table 16.2 IRRI contribution to varieties released in Vietnam, 1980–2009

	1980–89	1990–99	2000–09	Total 1980–2009
Total number of varieties released	60	98	68	226
IRRI releases	28	21	8	57
NARES release, IRRI parent	20	51	28	99
NARES release, IRRI ancestor	4	5	8	17
Total IRRI link	52	77	44	173
Percentage of varieties released				
IRRI releases	47	21	12	25
NARES release, IRRI parent	33	52	41	44
NARES release, IRRI ancestor	7	5	12	8
Total IRRI link	87	79	65	77

Table 16.3 Leading rice varieties in southern Vietnam, 1985–2009

Variety name	Year released	Released by	Years grown		Total area (million ha)[a]	Rank
			First	Last		
IR32	1975	IRRI	1985	1999	0.9	28
IR38	1976	IRRI	1985	2000	1.1	21
OMCS95-3	1977	CLRRI	1985	1999	2.2	6
OMCS96	1977	CLRRI	1985	2005	2.5	4
IR50	1979	IRRI	1985	2002	2.0	8
NN3B	1980	IRRI	1985	2000	2.1	7
OM33	1984	IRRI	1985	2001	1.8	13
NN4B	1985	IRRI	1986	2004	0.9	26
OM90	1986	CLRRI	1987	2001	1.3	19
OM91	1986	CLRRI	1987	2001	0.7	35
IR1820	1987	IRRI	1988	2006	0.7	36
Mot Bui	1987	Traditional	1988	2009	1.8	10

Table 16.3 (continued)

Variety name	Year released	Released by	Years grown		Total area (million ha)[a]	Rank
			First	Last		
Nang Thom Cho Dao	1987	IAS	1988	2009	1.4	18
OM88	1987	CLRRI	1988	2006	0.7	38
OM89	1987	IRRI	1988	2009	4.5	1
OM86	1988	CLRRI	1989	2002	0.7	37
OM86-9	1989	CLRRI	1990	2004	0.8	32
OM576-18	1990	CLRRI	1991	2009	3.1	2
IR50404	1992	IRRI	1993	2009	1.9	9
Jasmine 85	1992	IAS	1993	2009	1.8	12
OM987	1992	CLRRI	1993	2009	0.8	30
OM269	1993	CLRRI	1994	2008	0.6	39
OM723-11	1993	CLRRI	1994	2006	0.9	27
OM987-1	1993	CLRRI	1994	2008	0.9	25
Khao Dawk Mali 105	1994	CLRRI	1995	2009	0.9	29
OMCS94	1994	CLRRI	1995	2009	2.4	5
OM922	1995	CLRRI	1996	2008	0.7	34
OM992	1995	CLRRI	1996	2009	0.8	33
OM2517	1996	CLRRI	1997	2009	2.8	3
OMCS95-5	1997	CLRRI	1998	2009	1.5	16
Tai Nguyen DB	1997	CLRRI	1998	2009	1.1	22
Tep Hanh Db	1997	CLRRI	1998	2009	1.5	17
OM1490	1999	CLRRI	2000	2009	1.8	11
OMCS97	1999	CLRRI	2000	2009	1.7	14
AS996	2000	CLRRI	2001	2009	1.0	24
OMCS2000	2000	CLRRI	2001	2009	1.6	15
OM4900	2002	CLRRI	2003	2009	1.1	20
OM2395	2004	CLRRI	2003	2009	1.0	23
OM2717	2004	CLRRI	2005	2009	0.8	31
OM2718	2005	CLRRI	2006	2009	0.6	40

[a] Total area harvested from 1985 to 2009.

Note: Some varieties were grown by farmers before being officially released.

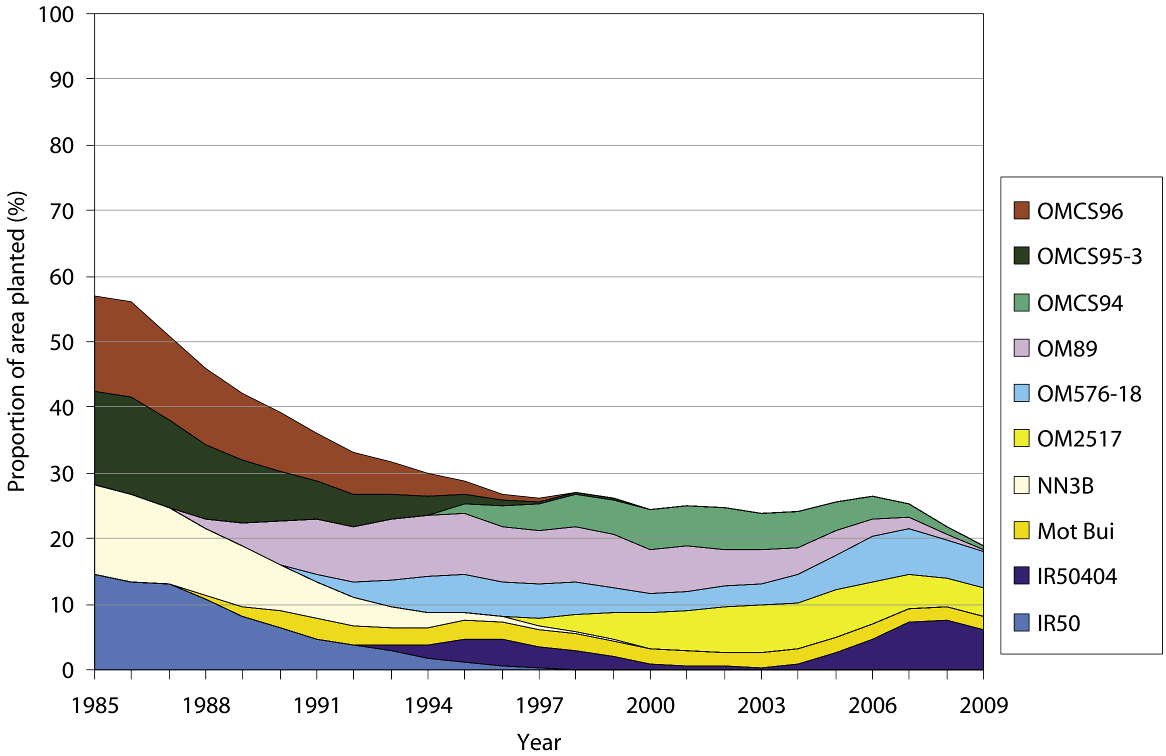

Figure 16.1 Pattern of use of leading rice varieties in southern Vietnam, 1985–2009

16.4 Adoption of modern rice varieties in northern Vietnam

IRRI varieties are less suited to the climatic conditions of northern Vietnam, although IR64 (named OM89 in the south) was widely grown in the north during the 1990s. In the late 1960s and early 1970s, IR8 was widely adopted because of its yield advantage, then IR8463 because of its resistance to brown planthopper, followed by IR64 in the 1990s. More recently, varieties developed in the south of China (especially hybrids) have become increasingly popular, surpassing IR64 in the north. Over 50% of the varieties grown in the north now come from China as these varieties are adapted to agroclimatic conditions similar to those in northern Vietnam.

In northern Vietnam, we were able to examine in detail only the IRRI-related MVs. IRRI-related varieties in northern Vietnam reached almost 50% of the area in 1989, and remained above 40% until 1997 (Figure 16.2). The share has generally declined since that time, to around 20% in 2008, although there was a small increase in 2009 related to the rapid adoption of the variety BC15. However, it is unclear if this is likely to lead to an ongoing increase in the area share of IRRI-related varieties in northern Vietnam in the coming years.

The 30 most widely grown IRRI-related varieties in the period 1985 to 2009 are shown in Table 16.4. The most widely grown varieties were CR203 (released 1985), IR17494 (1988), Xi23 (1995), IRI352 (1990), IR38 (1976), NN8A (1981) and X21 (1996). No IRRI-related variety released since 2002 has been grown on large areas.

The pattern of usage of the most important IRRI varieties or varieties with IRRI parentage grown in the north is illustrated in Figure 16.3 across the three regions analysed. The relative importance of IRRI-related varieties has never reached more than about 40% of the area across northern Vietnam, in contrast to the experience in southern Vietnam. Further, the relative importance of IRRI-related varieties in northern Vietnam has declined markedly since its peak in the

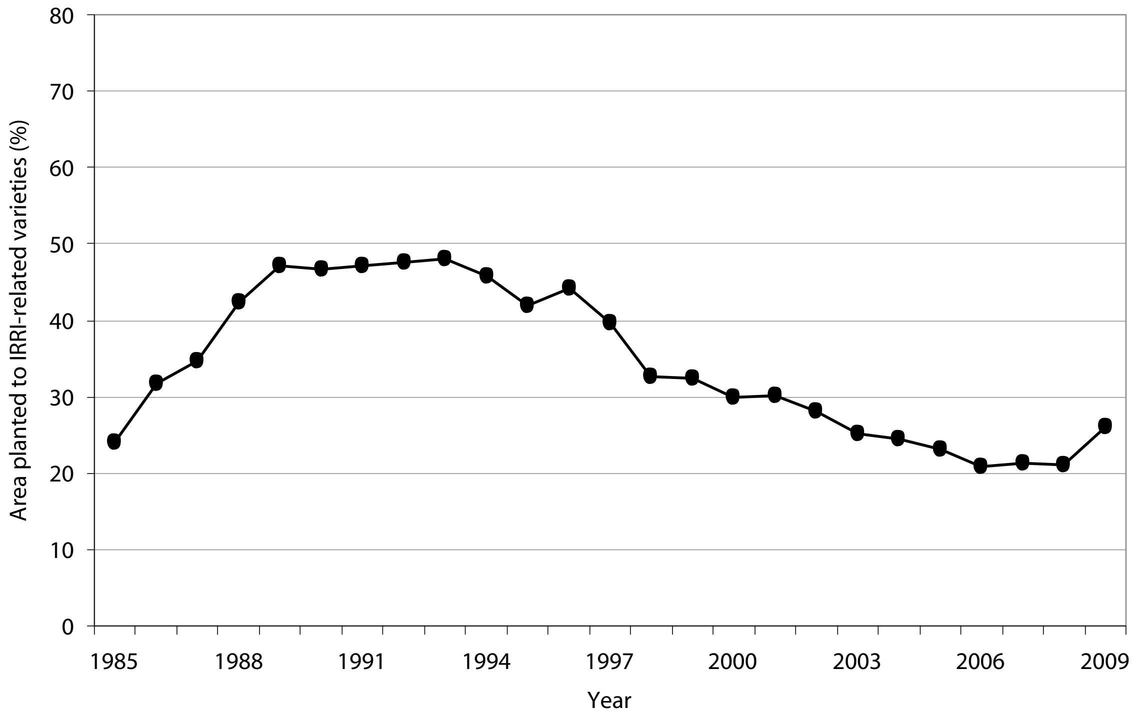

Figure 16.2 Share of area planted to IRRI-related varieties, northern Vietnam

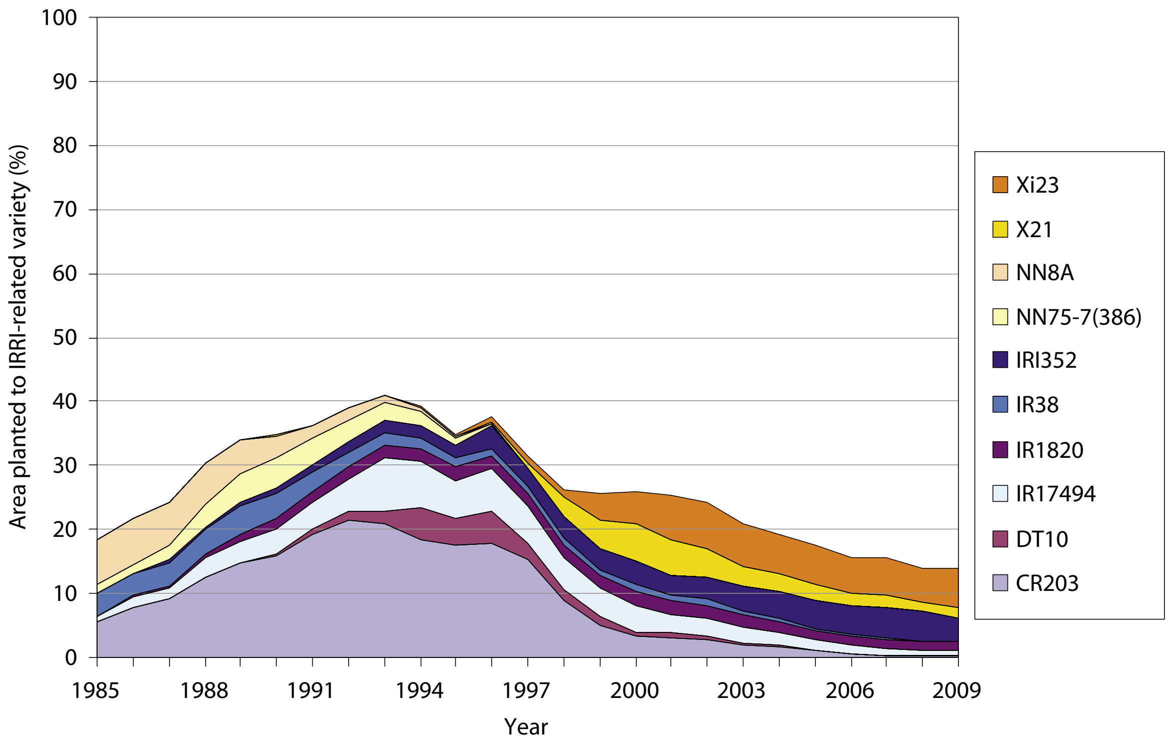

Figure 16.3 Pattern of use of leading IRRI-related varieties in northern Vietnam, 1985–2009

Table 16.4 Leading rice varieties in northern Vietnam, 1985–2009

Variety name	Year released	Released by	Years grown		Total area (million ha)[a]	Rank
			First	Last		
M2	1960	Traditional	1986	1992	0.26	12
IR38	1976	IRRI	1985	2009	0.59	5
NN75-2(424)	1979	IRRI	1985	1993	0.21	14
NN75-7(386)	1980	FCRI	1985	1996	0.45	9
NN8A	1981	IRRI	1985	1995	0.57	6
C22	1985	VAAS	1985	1989	0.07	21
CR203	1985	IRRI	1985	2009	3.17	1
NN4B	1985	IRRI	1985	1996	0.06	24
IR64	1986	IRRI	1985	2009	0.15	15
IR1820	1987	IRRI	1985	2009	0.54	8
Nếp415	1987	VAAS	1985	2009	0.07	22
OM80	1987	CLRRI	1989	1993	0.04	27
U17	1987	FCRI	1986	2006	0.08	20
IR17494	1988	IRRI	1985	2009	1.22	2
DT10	1990	AGI	1988	2004	0.37	10
IRI352	1990	IRRI	1989	2009	0.90	4
Xi12	1990	IRRI	1987	1997	0.11	16
C70	1993	PPI	1991	2009	0.27	11
C71	1993	PPI	1990	2007	0.09	19
CR01	1993	VAAS	1990	1999	0.06	23
Xi23	1995	VAAS	1994	2009	0.98	3
X21	1996	VAAS	1996	2009	0.56	7
IR1561-1-2	2000	IRRI	1998	2009	0.04	28
IR35366	2000	IRRI	1999	2009	0.10	18
N97	2002	VAAS	1997	2009	0.21	13
P6	2002	FCRI	2003	2009	0.05	25
AC5	2005	FCRI	2004	2009	0.05	26
BC15	2007	TBSC	2008	2009	0.10	17

[a] Total area harvested from 1985 to 2009.

Note: Some varieties were grown by farmers before being officially released.

mid 1990s, when CR203, a pest-resistant variety with short duration, was popular. In the 2000s, the two most prominent IRRI-related varieties have been IRI352, a sticky rice variety, and Xi23, which is tolerant to leaf blight.

16.5 Yield progress through rice varietal change in Vietnam

The ongoing and continued improvement in varietal yields through time is illustrated in Figures 16.4 and 16.5, where the yields of the IRRI-related varieties grown in southern and northern Vietnam, respectively, are shown by year of release. In southern Vietnam, the continual varietal yield improvement is striking. During the 1980s, the varieties released had yields of 3.5–4.5 t/ha, in the 1990s varietal yields were 4.0–5.0 t/ha, while since 2000 they have generally been between 4.5 and 5.0 t/ha. This demonstrates the progress made by breeders through varietal improvement, although some varieties grown for their special characteristics have lower yields than earlier varieties.

In northern Vietnam, the improvement in varietal yields until about 1990 is evident, but there appears to have been no progress in yields from IRRI-related varieties since that time (apart from BC15, released in 2007, which has a yield of 6.9 t/ha, well above any other variety). Clearly, IRRI-related material has performed differently in northern and southern Vietnam in recent years.

As outlined in Section 2.1, this study measures increases in varietal yields only. Other improvements brought about by breeders, such as improved pest and disease tolerance, abiotic stress tolerance and shorter maturity, have not been included except to the extent that they have improved varietal yields.

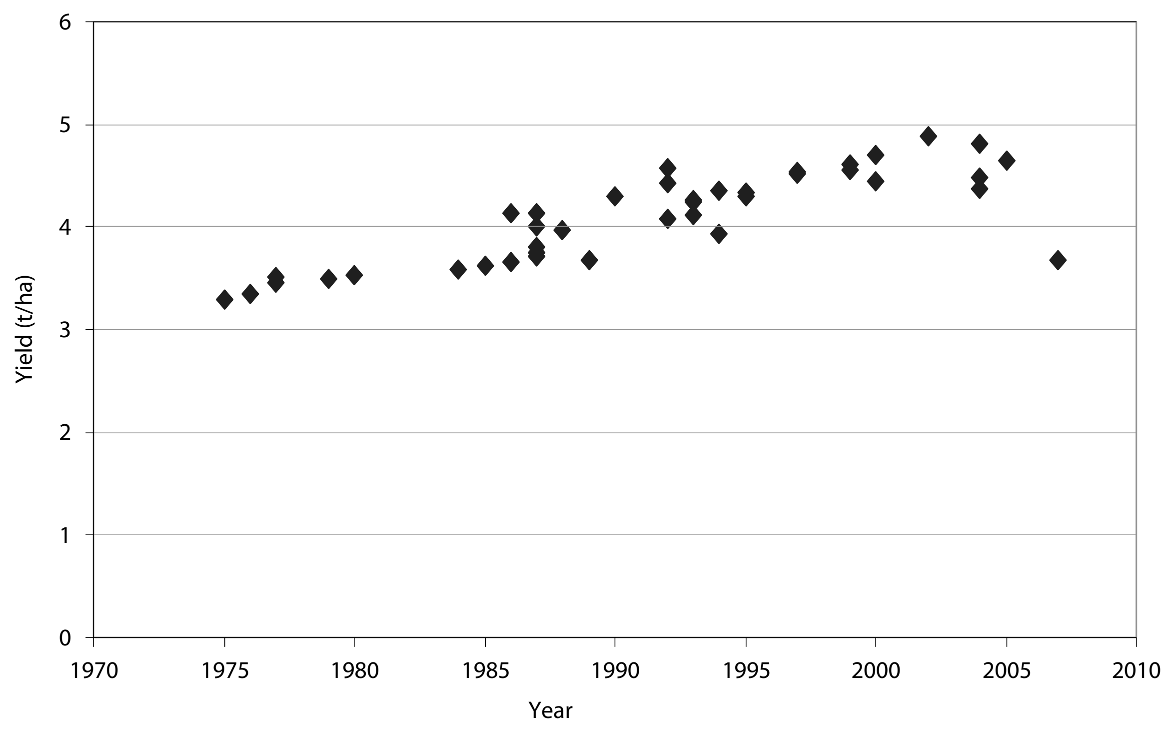

Figure 16.4 Rice varietal yields in southern Vietnam, by year of release

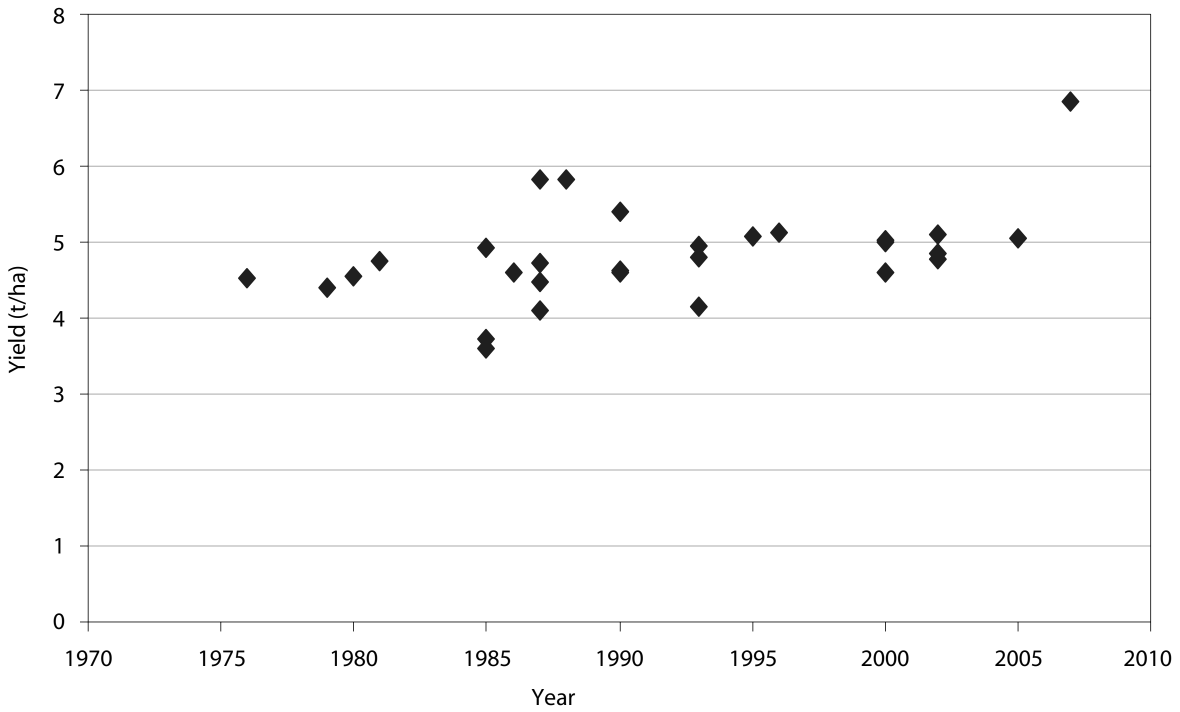

Figure 16.5 Yields of IRRI-related rice varieties in northern Vietnam, by year of release

17 Analysis of impact of IRRI in Vietnam

17.1 IRRI impacts in southern Vietnam

Data on percentage shares of varieties planted were collected at the provincial level in Vietnam, then aggregated to the regional level. The analysis of the impact of varietal change was undertaken at the regional level. For each region, the data on the areas sown to each variety were combined with varietal yields to give the IVI for each year, as outlined in Section 2.4. The index provides an annual measure of the yield improvement attributable to varietal change between 1985 and 2009.

The analysis using the IVI shows that rice varietal yields in southern Vietnam increased 28% between 1985 and 2009 (Table 17.1). Most of those yield gains were achieved by 2003, when the increase had reached 24%, with a slower rate of improvement in recent years (Figure 17.1). This reflects the fact that the varieties released from the late 1990s to around 2007 showed a lower rate of yield increase than those released in the preceding decade. It may also reflect the varietal mix being grown in southern Vietnam—farmers may have been trading off higher yields for varietal diversity and therefore security of yield.

When the percentage IRRI contribution to each variety is combined with the varietal share data, it gives a weighted measure of the contribution of IRRI to each year's improvement (Table 17.1, Figure 17.2). The change in IRRI's share of the yield gains in southern Vietnam is evident. From 1985 to 1994, the relative contribution of IRRI was around 60%, but then jumped to over 70% in 1995. The IRRI contribution has declined steadily since then to below 40% in more recent years. This reflects changing role of IRRI, with breeders such as CLRRI now more likely to use IRRI lines as parents or other ancestors rather than releasing them directly as new varieties. This change in the importance of IRRI lines in the pedigrees can be seen as a sign of the maturing of the Vietnamese R&D organisations, as they make increasing contributions to the varieties grown by farmers, while using IRRI and other agencies as sources of the materials to incorporate in those varieties.

The above two measures, when combined, give a measure of the varietal yield improvement that is attributable to IRRI (Table 17.1). For southern Vietnam, gains attributable to IRRI were 9.8% by 2009. These gains had reached a peak of 13.4% in 2004, but have declined slowly since then as a result of a slowing in the overall rate of varietal yield improvement combined with a sharp decline in the IRRI contribution to those gains.

The value of the yield gains attributable to IRRI can be estimated by converting the yield gains to additional production, then valuing the production increases. Using the export price detailed in Section 2.6, the total value of the varietal yield increases in southern Vietnam in 2009 was US$3,471 million, or an annual average of US$1,078 million (in constant 2009 dollars) over the whole period since 1985 (Table 17.2). The IRRI contribution to those gains in 2009 was valued at US$1,223 million, or an annual average of $558 million (in constant 2009 dollars) over the whole period.

The figures show that there was rapid growth in the value of the varietal yield increases from 1985 to 1998, with IRRI contributing approximately half of those gains (Figure 17.3). Over the following few years, there was a slump in the value of increases. Since 2002, the benefits have increased significantly, although IRRI's declining share has meant that its benefits have increased more slowly. Again, as in the Philippines and Indonesia, the exceptionally high prices of 2008 and 2009 have led to marked increases in the value of the yield improvements in the most recent 2 years.

To put these estimated benefits from IRRI into a broader perspective, the IRRI contribution to the yield gains in southern Vietnam have been expressed on a per hectare basis (Table 17.2). The average annual value of the gains from IRRI is equivalent to US$127/ha in 2009 values across the average rice area in southern Vietnam of over 4.2 million ha/year since 1985. This is significantly higher than the average value per hectare for the Philippines (US$52/ha) and Indonesia (US$76/ha) (see Sections 7.3 and 12.3, respectively).

Table 17.1 Rice yield increases attributable to varietal change, selected regions, southern Vietnam, 1985–2009

Year	Increase in varietal yields (%)				IRRI contribution (%)	Gains attributable to IRRI
	Mekong Delta	South East	South Central Coast	Southern Vietnam		
1985	0.0	na	na	0.0	59	0.0
1986	0.4	na	na	0.3	61	0.2
1987	1.0	na	na	0.7	59	0.4
1988	2.1	na	na	1.6	59	1.0
1989	3.7	na	na	2.9	59	1.7
1990	5.5	na	na	4.3	59	2.5
1991	7.2	na	na	5.7	59	3.4
1992	8.3	na	na	6.6	59	3.9
1993	10.0	na	na	8.0	59	4.7
1994	12.1	na	na	9.7	57	5.5
1995	14.5	na	na	11.7	73	8.5
1996	16.8	1.0	0.2	13.8	72	9.9
1997	18.5	1.9	0.6	15.3	71	10.8
1998	20.2	3.1	2.0	17.1	67	11.4
1999	21.4	4.1	3.0	18.3	64	11.8
2000	22.9	5.4	4.5	19.8	62	12.2
2001	24.5	6.7	6.8	21.3	59	12.7
2002	25.9	8.9	8.7	22.9	57	13.1
2003	27.1	11.0	11.0	24.2	55	13.3
2004	27.7	13.6	12.0	25.1	53	13.4
2005	28.0	16.3	14.0	25.9	51	13.2
2006	28.0	19.2	14.8	26.2	47	12.3
2007	28.4	21.6	15.6	26.7	43	11.4
2008	28.8	22.7	15.7	27.2	39	10.5
2009	29.2	24.8	16.0	27.7	35	9.8

Note: na = Not available

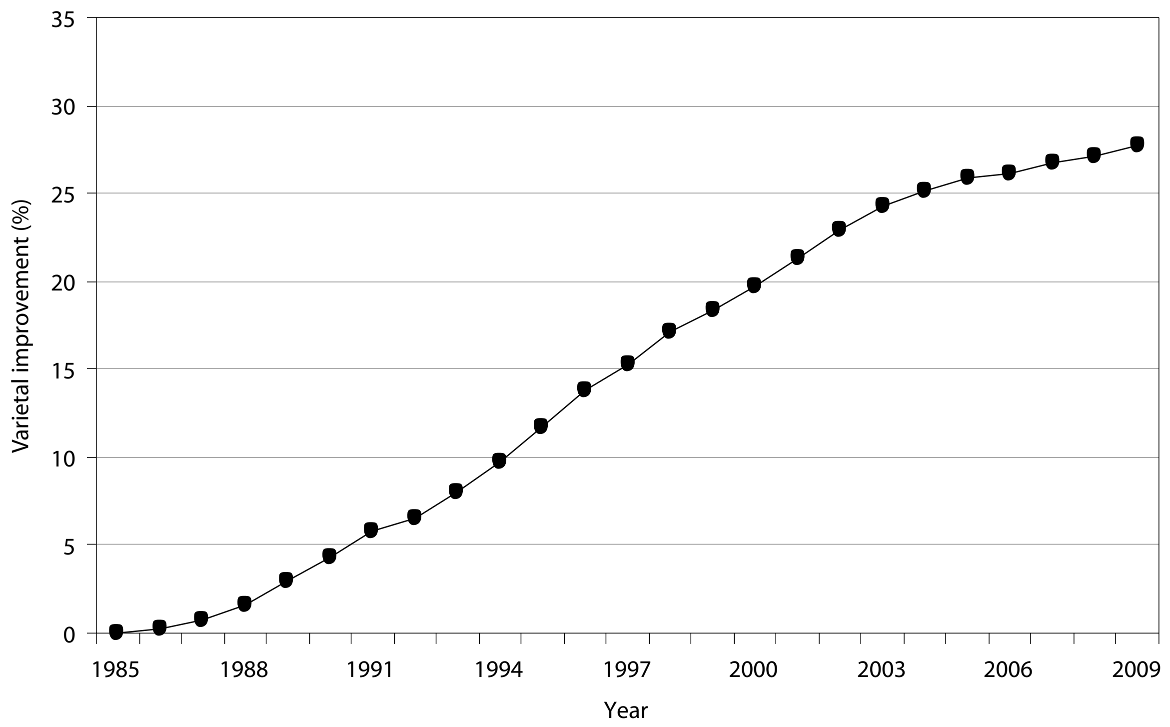

Figure 17.1 Varietal yield increase from 1985, southern Vietnam

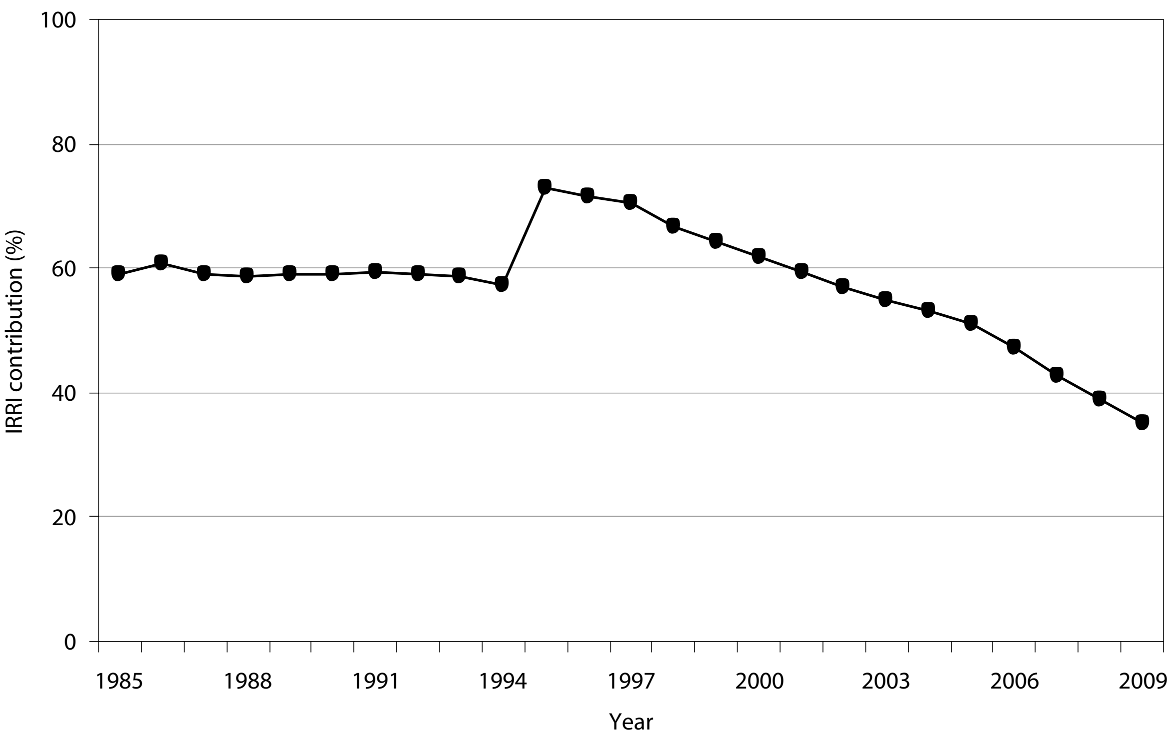

Figure 17.2 IRRI contribution to varieties grown in southern Vietnam, weighted by area harvested

17.2 IRRI impacts in northern Vietnam

The analysis of northern Vietnam was carried out for three regions (Red River Delta, North Central Coast, North West) where data were available on varietal share and yield, and rice area, for a set of selected provinces within each region. These represent over 51%, 19% and 25%, respectively, of production in northern Vietnam. The data were collected at the provincial level for the three regions in northern Vietnam, then aggregated to the regional level. As described in Section 15.4, where data were available for only some of the provinces within a region, those provinces were assumed to represent the other provinces in that region.

Table 17.2 Value of rice varietal yield increases in southern Vietnam (US$ million, 2009 values)

Year	Value of rice varietal yield increases (US$ million)	Value of IRRI contribution (US$ million)	Value of IRRI contribution (US$/ha)
1985	0	0	0
1986	12	7	2
1987	29	17	6
1988	92	54	18
1989	183	108	34
1990	237	140	43
1991	358	212	60
1992	381	224	61
1993	432	254	68
1994	567	325	85
1995	835	609	154
1996	1,073	768	181
1997	1,058	746	174
1998	1,293	863	189
1999	1,194	767	159
2000	1,039	643	134
2001	911	542	117
2002	1,137	649	140
2003	1,208	661	144
2004	1,526	811	176
2005	1,879	960	211
2006	1,896	895	197
2007	2,040	872	197
2008	4,107	1,593	351
2009	3,471	1,223	270
Average per year	1,078	558	127

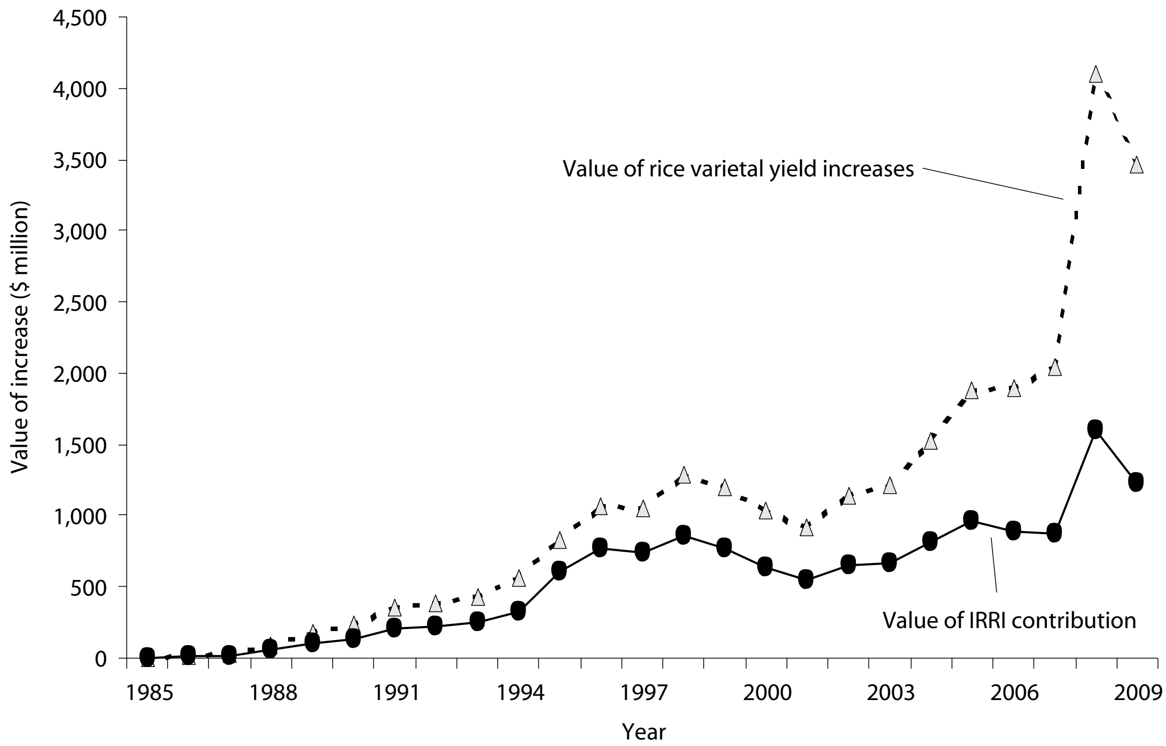

Figure 17.3 Value of rice varietal yield increases in southern Vietnam, 1985–2009

The analysis of the impact of IRRI in northern Vietnam is different from that for the Philippines, Indonesia and southern Vietnam, because the data were not available to use the same approach as that used for the other areas. The only data available in northern Vietnam were for the varieties that are related to IRRI, so the calculations could be undertaken for IRRI-related varieties only. Nevertheless, the data enabled estimates of the varietal improvement through IRRI-related varieties in the regions from 1985 to 2009.

For each region, the data on varietal area share of IRRI-related varieties were combined with varietal yields to give a partial IVI for each year, as outlined in Section 2.4. The index provides an annual measure of the yield improvement attributable to varietal change through IRRI-related varieties between 1985 and 2009. It provides a different measure from those for the Philippines, Indonesia and southern Vietnam because it relates to only the area that was planted to IRRI-related varieties. For example, if in a given year the IVI indicated that IRRI-related varieties had contributed a 12% varietal yield increase, but that IRRI-related varieties were only grown on 40% of the area, then the estimated increase in the IVI from the IRRI-related varieties is 4.8% (= 12% × 40%).

The analysis using the IVI shows that rice varietal yields of IRRI-related varieties in northern Vietnam increased 5.3% between 1985 and 2009 (Table 17.3), ranging from 3.2% to 5.9% in the regions. For northern Vietnam as a whole there were no, or even negative, gains in varietal yield[3] through IRRI-related varieties between 1985 and 1991 (Figure 17.4), followed by a rapid increase to 1996. The annual benefits then showed a slow decline until 2007, followed by a sharp increase in the most recent years. This reflects the fact that the IRRI-related varieties such as CR203, released in the mid 1980s, provided little yield improvement, while those released at the end of the decade (DT10 and IR17494) provided some yield increases in northern Vietnam. Subsequently, there was a yield decline in the decade to 2007. Only since 2007 (with the high-yielding variety BC15) was there a further yield increase in these regions from IRRI-related varieties.

3 See Section 18.1 for further discussion of the interpretation of negative yield gains found in some situations in this study.

Table 17.3 Rice yield increases attributable to varietal change through IRRI-related varieties, selected regions, northern Vietnam, 1985–2009

Year	Increase in varietal yields (%)				IRRI contribution to varieties (%)	Gains attributable to IRRI
	Red River Delta	North Central Coast	North West	Northern Vietnam		
1985	0.0	0.0	0.0	0.0	77	0.0
1986	0.3	0.1	−3.0	0.2	79	0.1
1987	−0.1	−0.6	0.2	−0.2	77	−0.2
1988	−0.2	−0.4	4.9	−0.1	76	0.0
1989	−0.7	−0.1	8.4	−0.2	76	−0.1
1990	−0.8	−0.1	9.3	−0.1	75	−0.1
1991	−0.6	0.3	10.3	0.2	74	0.2
1992	0.0	2.5	11.1	1.6	74	1.2
1993	1.6	3.8	12.3	3.0	74	2.2
1994	2.3	5.0	11.3	3.9	72	2.8
1995	2.1	4.4	12.5	3.5	72	2.6
1996	3.2	6.5	12.2	5.1	71	3.7
1997	2.5	6.3	10.1	4.4	70	3.1
1998	1.9	5.7	9.1	3.5	66	2.3
1999	2.8	3.8	7.9	3.5	64	2.2
2000	2.7	3.9	6.4	3.3	61	2.0
2001	3.0	5.0	4.5	3.8	59	2.2
2002	2.8	3.3	2.7	3.0	57	1.7
2003	2.5	2.3	3.2	2.6	55	1.4
2004	2.3	3.5	4.5	2.9	53	1.5
2005	2.1	4.5	3.7	3.0	51	1.5
2006	1.8	3.2	3.8	2.5	47	1.2
2007	1.9	3.4	3.7	2.6	42	1.1
2008	2.9	3.7	2.8	3.3	38	1.3
2009	5.9	4.6	3.2	5.3	34	1.8

The pattern varied for the different regions. For example, in the Red River Delta and North Central Coast until 1992, IRRI-related varieties provided no increases in varietal yield over those in 1985 (Table 17.3). In contrast, there was a very different pattern in the North West region, where there were very strong yield increases in IRRI-related varieties between 1986 and 1995, although there have been declines in the yield increases since that time. In contrast, in the North Central Coast there were steady yield increases until 1996, but no increases in IRRI-related varieties since that time. The reasons for these regional differences are not explored in this study.

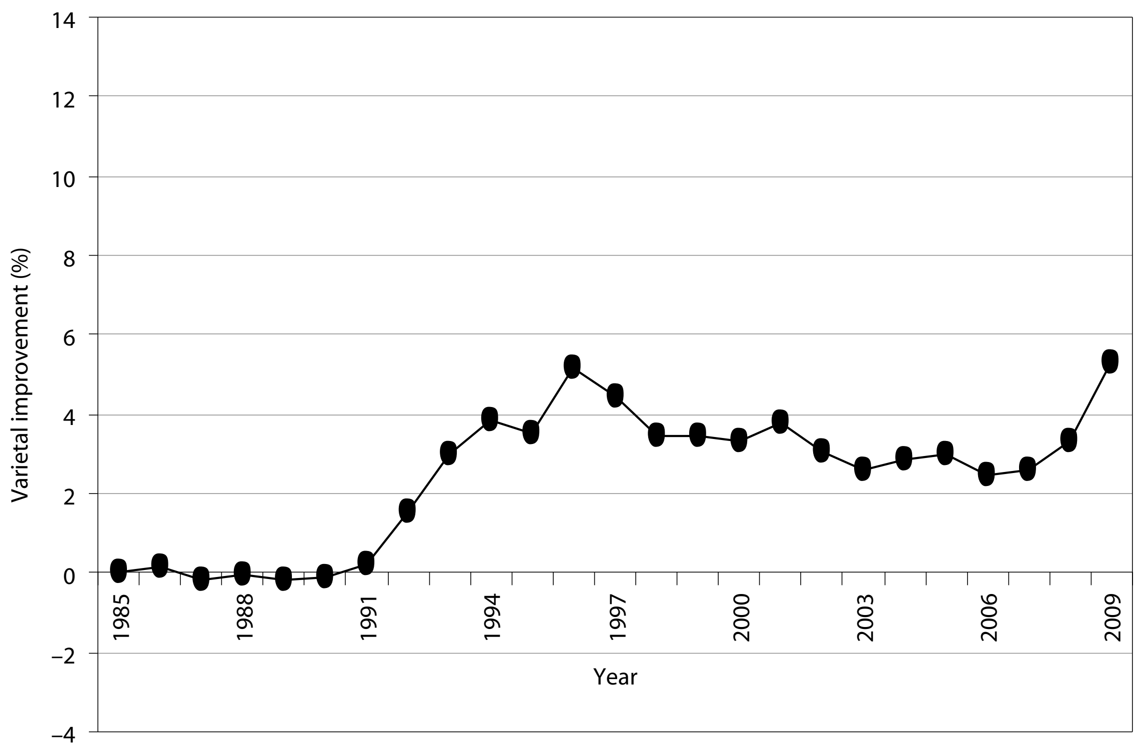

Figure 17.4 Varietal yield increase in northern Vietnam through IRRI-related varieties, 1985–2009

The percentage IRRI contribution to each of the IRRI-related varieties can be calculated, with the contribution being based on the classification of varieties according to their parentage and release institution (see Section 16.2). When the contribution of IRRI to each of these varieties is weighted by the variety's share of the area planted, the decline in IRRI's share of the yield gains from IRRI-related varieties since 1997 is evident (Table 17.3, Figure 17.5). From the mid 1980s to 2000, the relative contribution of IRRI to the pedigree of IRRI-related varieties was over 60%, but has declined steadily since then, to 34% in 2009. This change in IRRI's role in this period reflects the movement by Vietnam's breeders to be more likely to use IRRI lines as parents or other ancestors rather than releasing them directly as new varieties, as well as the increasing influence of genetic material from China.

There appear to be two elements in the increase in relative importance of materials from China in northern Vietnam (Nguyen Nga, pers. comm.). Inbred rice varieties from China have been well adapted to the range of soils and climatic conditions in northern Vietnam, and have been found to provide stable yields for farmers. In addition, hybrid rice varieties based on material sourced from China (introduced in 1992, but boosted since 1996) have been developed over a wide area in the north. Because farmers in the north faced food-security problems and needed grain for livestock, hybrid rice production was subsidised, and now accounts for about 20% of the rice area in the Red River Delta.

This measure of IRRI contributions to IRRI-related varieties is combined with the varietal improvement data to give a weighted measure of the contribution of IRRI to each year's improvement through the IRRI-related varieties. This analysis shows that the IRRI contribution to overall rice yield improvement in northern Vietnam was negligible until 1991, before increasing to 3.7% in 1996. It has declined since that time, and has been around 1–2% since the late 1990s (Table 17.3). In 2009, for example, the IRRI-related varieties had increased yields by 5.3%, and IRRI contributed 34% to the IRRI-related varieties, so that IRRI contributed a gain of 1.8% in that year, as compared with 9.8% in southern Vietnam (Section 17.1), 6.7% for the Philippines (Section 7.2) and 13.0%

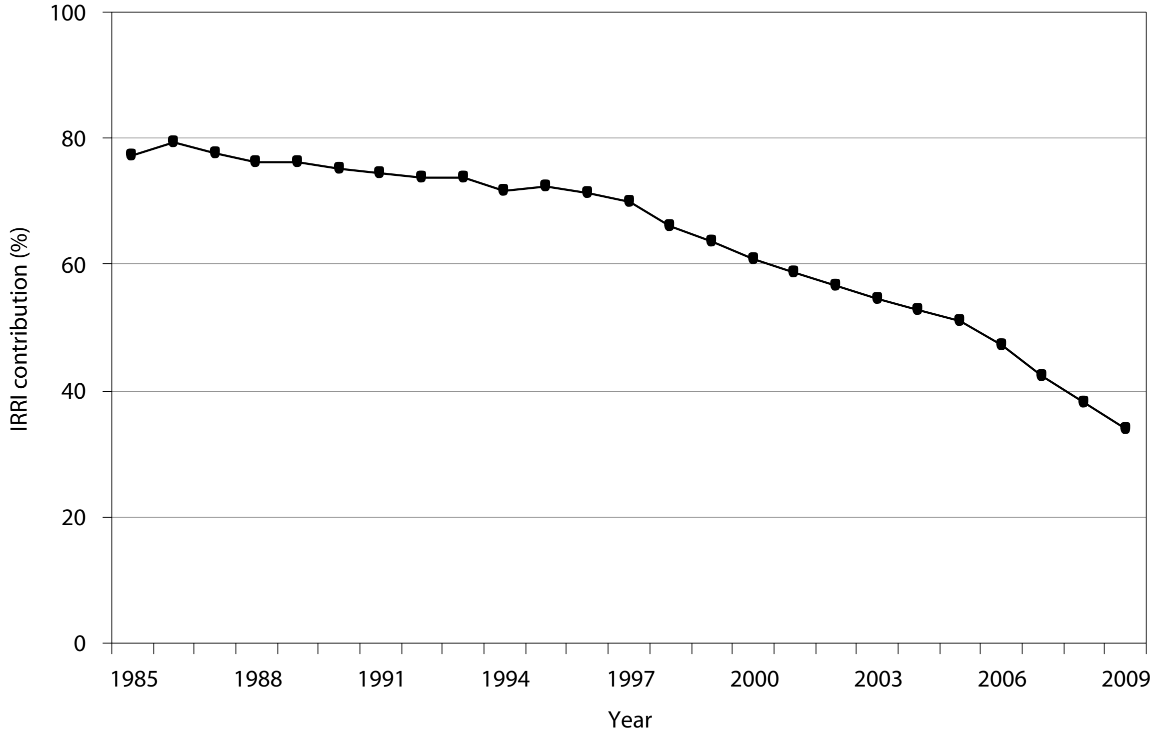

Figure 17.5 IRRI contribution to IRRI-related varieties grown in northern Vietnam, weighted by area harvested

for Indonesia (Section 12.2). As discussed above, the recent change in gains attributable to IRRI is a result of the declining yield gains and the reduction in IRRI's contribution to the IRRI-related varieties.

As for the other countries, the value of the yield gains attributable to IRRI has been estimated by converting the yield gains to additional production, then valuing the production increases. Using the export price detailed in Section 2.6, the total value of the varietal yield increases in northern Vietnam in 2009 was US$302 million, or an annual average of US$86 million (in constant 2009 dollars) over the whole period since 1985 (Table 17.4). The IRRI contribution to those gains in 2009 was valued at US$156 million, or an annual average of $53 million (in constant 2009 dollars) over the whole period.

There was steady growth in the value of the varietal yield increases from 1985 to 1996, with IRRI contributing most of those gains (Figure 17.6). Over the following few years, there was a decline in the value of increases. As in the other countries, the exceptionally high prices of 2008 and 2009 have led to marked increases in the value of the yield improvements in the last 2 years of the study.

The IRRI contribution to the yield gains in northern Vietnam on a per hectare basis is shown in Table 17.4. The average annual value of the gains from IRRI is equivalent to US$26/ha in 2009 values across the average rice area in northern Vietnam of 2.5 million ha/year since 1985. This is approximately half the benefit per hectare for the Philippines, one-third of that for Indonesia (see Sections 7.3 and 12.3, respectively) and only 21% of the benefit (US$127/ha) found for southern Vietnam (Section 17.1).

17.3 Aggregate impacts of IRRI in Vietnam

Aggregating the benefits found from IRRI for both southern and northern Vietnam gives average annual benefits of $610 million, with the overwhelming proportion (91%) of those being achieved in southern Vietnam (Table 17.5). While those benefits dwarf those of northern Vietnam, the overall benefits of over $100 million/year in northern Vietnam in recent years have still been substantial.

Table 17.4 Value of rice varietal yield increases through IRRI-related varieties in northern Vietnam (US$ million, 2009 values)

Year	Value of rice variety yield increases (US$ million)	Value of IRRI contribution (US$ million)	Value of IRRI contribution (US$/ha)
1985	0	0	0
1986	4	3	2
1987	−5	−4	−2
1988	−2	−2	−1
1989	−5	−4	−2
1990	−3	−3	−1
1991	5	5	2
1992	46	40	20
1993	94	81	41
1994	106	83	42
1995	125	95	47
1996	187	138	69
1997	156	109	54
1998	126	83	41
1999	110	62	31
2000	87	49	24
2001	82	38	19
2002	75	36	18
2003	63	30	15
2004	84	46	23
2005	95	50	25
2006	88	49	25
2007	90	50	26
2008	227	126	65
2009	302	156	80
Average per year	86	53	26

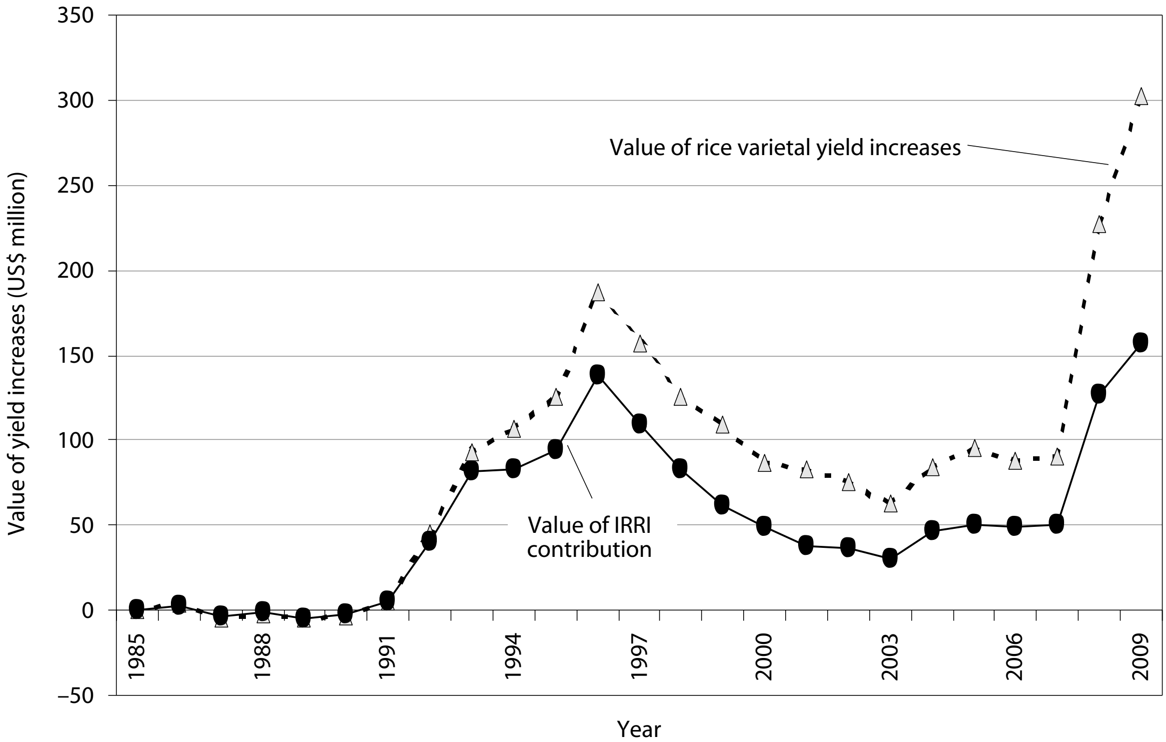

Figure 17.6 Value of IRRI-related rice varietal yield increases in northern Vietnam, 1985–2009

Table 17.5 Value of IRRI contribution to rice varietal improvement in Vietnam (US$ million, 2009 values)

Year	Southern Vietnam	Northern Vietnam	Vietnam
1985	0	0	0
1986	7	3	11
1987	17	–4	14
1988	54	–2	52
1989	108	–4	104
1990	140	–3	137
1991	212	5	217
1992	224	40	264
1993	254	81	335
1994	325	83	408
1995	609	95	703
1996	768	138	906
1997	746	109	855
1998	863	83	945
1999	767	62	829
2000	643	49	692
2001	542	38	580
2002	649	36	686
2003	661	30	691
2004	811	46	857
2005	960	50	1,010
2006	895	49	944
2007	872	50	922
2008	1,593	126	1,719
2009	1,223	156	1,380
Average per year	558	53	610

PART V
Synthesis and economic analysis

18 Summary of findings

18.1 Yield gains from IRRI

The analysis undertaken in this study shows that there have been large and sustained yield gains flowing to countries in South-East Asia from IRRI's work on varietal improvement. In each of the three countries examined, the flow of new rice varieties has led in considerable progress in developing higher yielding varieties.

The yield gains from IRRI's contribution to varietal improvement from 1985 to 2009 have ranged from 1.8% in northern Vietnam to 9.8% in southern Vietnam, 6.7% in the Philippines and 13.0% in Indonesia and, in 2009, averaged 11.2% across the three countries studied (Table 18.1). Through the whole period since 1985, the average yield increase attributable to IRRI was 5.0%.

The average yield gain of 11.2% by 2009 is equivalent to an annual growth rate of 0.44% in varietal yields since 1985. At average yields of 4.04 t/ha, the yield gain is equivalent to an increase of 454 kg/ha in varietal yield over that period.

The yield gains vary between countries, in terms of both the size of the gains and in the changes in those gains over time. For example, in southern Vietnam the gains were substantial in the 1990s, while in Indonesia the gains were lower in that period but more substantial in the period since 2000.

It is difficult to assess relative progress from the varieties released in Phases MV3 and MV4 defined by Estudillo and Otsuka (2006) and discussed in Section 2.1. However, the proportional share of varieties being grown in each of the countries reveals that MV3 varieties were rapidly adopted in each country, and MV4 varieties have also been replacing those in more recent years (Figure 18.1).

In Indonesia, planting of older varieties continued through the period. In the other countries and regions, by around 2000, almost all varieties released before 1985 had been replaced by more recent releases. MV4 varieties were taken up most rapidly in the Philippines, and have had the least impact in northern Vietnam.

It is apparent that yield progress has varied in its timing in the different countries, and even in the regions within countries. This is demonstrated in Table 18.2, where the changes in IRRI contribution to yield improvements are shown in 5-year intervals. In the early 1990s, when the Philippines and Indonesia were experiencing low or negative varietal yield growth from IRRI varieties, the northern and southern areas of Vietnam were both experiencing their highest growth. Similarly, since 2000, Indonesia has experienced good varietal yield growth from IRRI's contribution, while Vietnam has experienced low or negative varietal yield growth from the IRRI contribution.

Negative varietal yield growth in these figures indicates that the IRRI-related varieties being grown in the particular period do not produce the same yields as those grown previously. That does not mean that farmers are receiving lower benefits from those varieties since, in this study, we are measuring only yields. The negative yield gains in a given period may be the result of farmers being prepared to grow lower yielding varieties to obtain other benefits such as higher quality or resistance or tolerance to significant biotic or abiotic constraints. It can also occur where varieties released for rainfed conditions (and which have been tested and evaluated in those conditions) are subsequently grown in irrigated environments. In those cases, the yields used in this analysis may not adequately reflect the varietal yield under irrigated conditions, and may result in apparent negative yield gains because the varietal yield used in the analysis has been measured under different (lower yielding) conditions.

Table 18.1 Yield gains (%) from IRRI's contribution to varietal improvement, 1985–2009

Year	Philippines	Indonesia	Southern Vietnam	Northern Vietnam	Aggregate
1985	0.0	0.0	0.0	0.0	0.0
1986	3.2	0.0	0.2	0.1	0.8
1987	3.3	–0.4	0.4	–0.2	0.6
1988	4.1	0.4	1.0	0.0	1.4
1989	2.5	0.6	1.7	–0.1	1.2
1990	2.3	1.2	2.5	–0.1	1.7
1991	2.0	1.0	3.4	0.2	1.7
1992	2.0	1.0	3.9	1.2	1.8
1993	2.0	0.9	4.7	2.2	2.0
1994	3.0	1.3	5.5	2.8	2.8
1995	2.9	1.5	8.5	2.6	3.3
1996	3.7	1.4	9.9	3.7	4.8
1997	3.9	1.3	10.8	3.1	4.8
1998	4.3	1.3	11.4	2.3	4.9
1999	4.8	1.4	11.8	2.2	5.0
2000	5.5	1.5	12.2	2.0	5.7
2001	6.0	2.2	12.7	2.2	6.7
2002	6.6	3.2	13.1	1.7	6.6
2003	6.3	5.7	13.3	1.4	8.0
2004	7.0	7.1	13.4	1.5	8.7
2005	7.3	10.8	13.2	1.5	10.7
2006	6.1	11.1	12.3	1.2	10.2
2007	5.1	13.7	11.4	1.1	11.1
2008	5.2	14.8	10.5	1.3	11.6
2009	6.7	13.0	9.8	1.8	11.2
Average	4.2	3.8	7.9	1.4	5.0

18.2 Value of benefits from IRRI yield gains

When the economic value of varietal yield gains is calculated using constant prices, the economic benefits are shown to be extremely high (Table 18.3). The total benefits averaged US$1.46 billion (in constant 2009 dollars) per year across the three countries. Over 44% of those benefits occurred in Indonesia, while a further 38% occurred in southern Vietnam, 14% in the Philippines and 4% in northern Vietnam.

By 2007, the annual benefits of the varietal yield increases since 1985 were US$3.1 billion. In all cases, the increase in rice prices in 2008 and 2009 lifted the

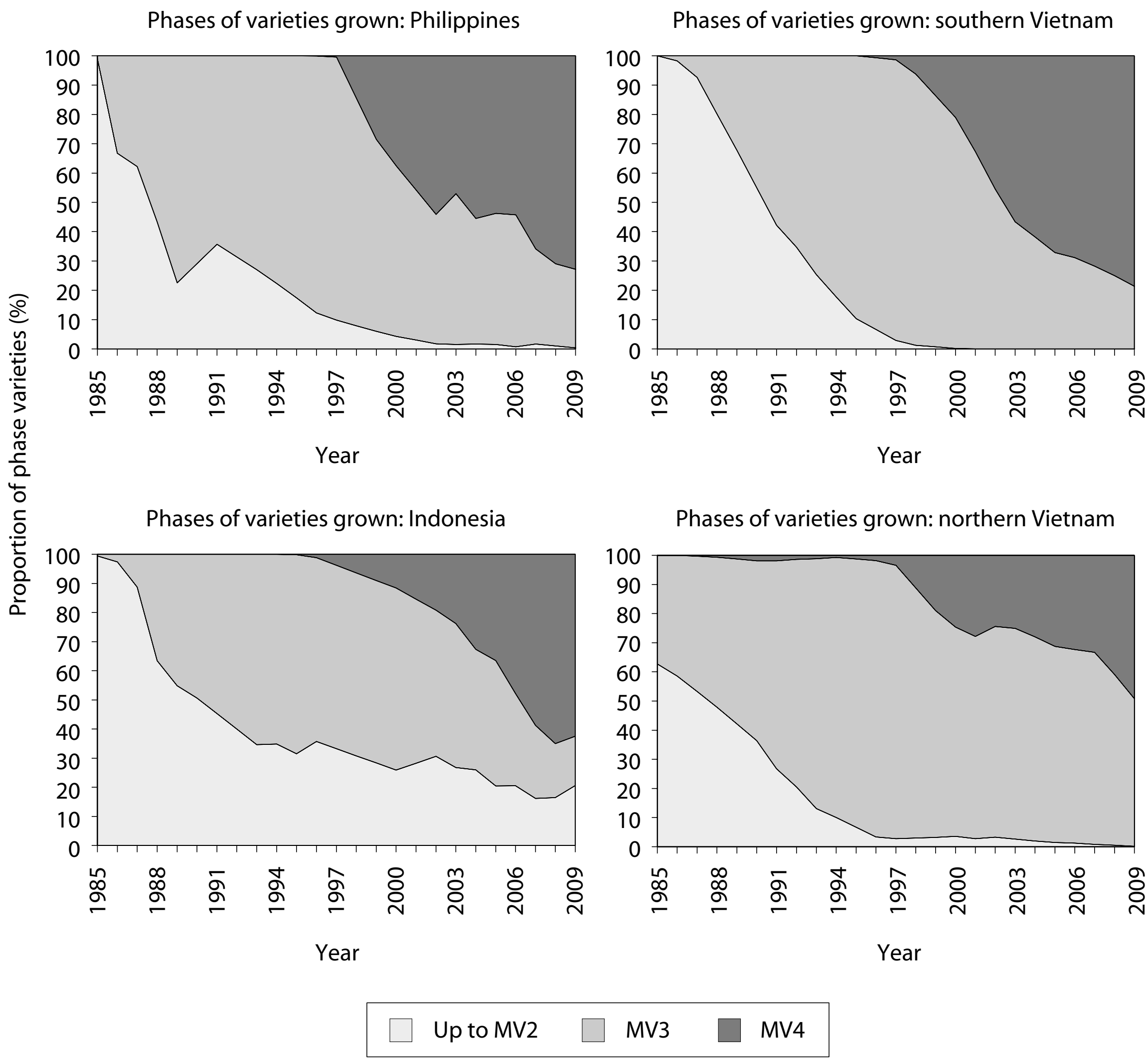

Figure 18.1 Adoption of rice varieties from Phases MV3 and MV4 of the release of modern varieties, 1985–2009

Table 18.2 IRRI contribution (%) to varietal yield increases, in 5-year intervals

Period	**Philippines**	**Indonesia**	**Southern Vietnam**	**Northern Vietnam**	**Aggregate**
1985–90	2.3	1.2	2.5	−0.1	1.7
1990–95	0.7	0.3	6.0	2.7	1.7
1995–00	2.5	0.1	3.7	−0.5	2.3
2000–05	1.8	9.3	1.0	−0.5	5.0
2005–09	−0.6	2.1	−3.5	0.3	0.6

benefits significantly in those 2 years, so benefits in 2009 were US$6.0 billion. As rice prices fall back from those peak levels, then the value of future varietal yield increases may decline from levels shown in the most recent 2 years.

When the benefits identified are expressed as benefits per hectare per year (Table 18.4), those for the Philippines (US$52) and Indonesia (US$76) are less than those for southern Vietnam ($127). Benefits for northern Vietnam (US$26/ha) are lower, reflecting the lower comparative advantage of IRRI-related varieties in that environment compared with the others in this study. For Vietnam as a whole, the average benefit was US$87/ha. Across the three countries, the benefits have averaged US$88/ha for the period since 1985 and, in recent years, have reached over US$200/ha.

For comparison, Hossain et al. (2003, table 5.8) found that the net gains from the initial adoption of MVs was equivalent in 2009 dollars to US$227/ha in the Philippines, US$208/ha in Indonesia and US$160/ha

Table 18.3 Aggregate benefits (US$ million, 2009 values) from IRRI's contribution to varietal improvement, 1985–2009

Year	Philippines	Indonesia	Southern Vietnam	Northern Vietnam	Aggregate
1985	0	0	0	0	0
1986	138	−20	7	3	129
1987	134	−68	17	−4	80
1988	212	57	54	−2	322
1989	135	92	108	−4	331
1990	103	161	140	−3	401
1991	98	176	212	5	491
1992	89	195	224	40	548
1993	87	219	254	81	641
1994	124	264	325	83	797
1995	140	292	609	95	1,135
1996	191	234	768	138	1,330
1997	186	119	746	109	1,160
1998	153	154	863	83	1,253
1999	190	153	767	62	1,173
2000	179	162	643	49	1,032
2001	175	155	542	38	910
2002	209	175	649	36	1,070
2003	203	442	661	30	1,336
2004	277	653	811	46	1,787
2005	311	1,091	960	50	2,411
2006	297	1,331	895	49	2,571
2007	281	1,859	872	50	3,062
2008	575	4,198	1,593	126	6,493
2009	601	4,017	1,223	156	5,997
Average	**204**	**644**	**558**	**53**	**1,458**

for Vietnam. Thus, the value of improvements since 1985 has been less than that from the initial gains from the green revolution. The gains per hectare since 1985 represent 23%, 36% and 53% of the gains from the initial adoption of MVs in the Philippines, Indonesia and Vietnam, respectively.

Table 18.4 Per hectare benefits (US$/ha, 2009 values) from IRRI's contribution to varietal improvement, 1985–2009

Year	Philippines	Indonesia	Southern Vietnam	Northern Vietnam	Aggregate
1985	0	0	0	0	0
1986	40	−2	2	2	9
1987	41	−8	6	−2	6
1988	63	7	18	−1	23
1989	39	11	34	−2	23
1990	31	19	43	−1	28
1991	29	18	60	2	31
1992	28	18	61	20	32
1993	27	18	68	41	35
1994	34	27	85	42	48
1995	37	27	154	47	64
1996	48	39	181	69	100
1997	48	18	174	54	82
1998	48	20	189	41	87
1999	48	18	159	31	72
2000	44	23	134	24	69
2001	43	28	117	19	68
2002	52	21	140	18	66
2003	51	63	144	15	90
2004	67	77	176	23	109
2005	76	165	211	25	166
2006	71	151	197	25	154
2007	66	217	197	26	185
2008	129	433	351	65	363
2009	133	306	270	80	280
Average	52	76	127	26	88

19 Significance of findings

19.1 Discussion

It is apparent that rice breeders in South-East Asia have continued to produce higher yielding varieties in the period since 1985. The benefits to farmers of those increased varietal yields have been large and sustained. However, IRRI's role in the development of those varieties has changed since the early years when IRRI developed and released the early MVs directly for use by farmers in these countries.

The principal level on which IRRI's contribution has changed, and the one that has been measured in this study, has been in the direct genetic contribution to the varieties that are being released to farmers. While lines developed by IRRI feature prominently in the genetic composition of the varieties, they have increasingly become used as parents or other ancestors to the recent varieties, rather than being direct releases of IRRI crosses. This is consistent with a move towards more specific adaptation to meet local production constraints rather than the more general adaptation that was evident in the earlier varieties produced and released by IRRI. As NARES have looked to increase local adaptation to deal with their particular soils, pests, diseases and climatic conditions, they have tended to use IRRI lines as parents to enable the high productivity of the IRRI lines to be combined with locally desirable traits, characteristics and tolerances, to develop productive and stable varieties with suitable quality.

Since IRRI ceased directly releasing varieties for farmers in 1975, it has also had less input into these varieties in terms of the testing, evaluation and release activities that have been transferred to NARES. This reflects a maturing of the respective roles of IRRI and NARES, and is a sign that NARES in these countries have developed into productive and effective organisations. Indeed, Fischer and Cordova (1998) emphasise that the impact of IRRI is really the impact of the accomplishments of IRRI's partnerships with NARES.

The change from a dominant IRRI contribution towards a more significant NARES contribution may also be associated with a decline in IRRI core funding that started in the early 1990s and which affected mainly those activities that did not attract restricted grants, particularly the mainstream irrigated-rice breeding programs. That decline has been reversed since 2006 (Dr A. Dobermann, IRRI, pers. comm., March 2011), and there is an expectation that the downward trend in IRRI's contribution may already be showing some reversal. Factors in this reversal since 2006 include: (a) increased resources for IRRI breeding programs; (b) increased role of hybrids based on IRRI germplasm; (c) increased access of partner breeders to early generation IRRI materials; and (d) increased cooperation with varietal testing and seed production operations.

Of course, there are many other contributions that IRRI has made, and continues to make, apart from the genetic input into the yields of new varieties. These include capacity building such as training, and non-yield impacts of IRRI germplasm such as improved eating quality, increased resistance and tolerance to pests and diseases, and contributions to overcoming other production constraints. The fact that these have not been included in the calculated benefits in this study does not imply that that are in any way less significant benefits, merely more difficult to measure in a study such as this.

The impact of these varietal yield changes on the wellbeing of the poor is difficult to assess from the analysis in this study. Hossain and Pingali (1998) found that the evidence is that, as a whole, landowners with smallholdings, landless rural people, and rural and urban poor have all gained from the increased productivity, improved farm and postharvest operations, and lower real rice prices for consumers emanating from the green revolution. However, they reported that those impacts began to erode in the late 1980s as the rate of yield increases slowed. They noted the reversal of the real rice price decline in the Philippines and Indonesia from around 1980 to 1996. Given the sharp price rises in recent years, and the slowing of the rate of yield improvement found in some periods, the impact of these more recent changes in varietal yield improvement is unclear.

It should also be noted that the higher rice prices in recent years have certainly led to higher returns to the investment in IRRI and in rice research in general. If those higher prices prevail, the returns on investment in IRRI in the future, whether through ACIAR or otherwise, are likely to be higher than those found in this study.

19.2 Limitations of the study

As in all studies such as this, the results are only as good as the data that have been used in the analysis. The data used have been the best available, but need, of course, to be assessed carefully in interpreting the final results.

There are several limitations in this study that signal caution in using and interpreting the results of the analysis:

1. The varietal yield data are a key parameter in assessing the progress through time of yields of new varieties. The varietal yield data used in this analysis are drawn from a combination of on-station and on-farm trials. Because trial management may have changed over time, any such changes in management will have affected the yields of more recent varieties in relation to those tested in earlier years (and under possibly changed management). If that is the case, the results may overstate the rate of varietal yield improvement, on the basis that management changes are likely to have increased rather than reduced expected variety trial outcomes. However, in discussions with breeders at IRRI, it appeared that trial management procedures had changed little over the past 20 years or so.
2. A related issue for varietal yields has been that, in some cases, they have been tested in one environment—in rainfed (lower yielding) environments, for example—then grown in other conditions such as irrigated (high-yielding) environments. In that case, the varietal yield improvement measured in this study would not correctly represent the rate of varietal yield improvement on farms in those areas. It is unclear how prevalent this has been in the data examined in this study, although there were some instances that came to notice. It is also unclear whether this issue would have led to an over- or understatement of the rate of varietal yield improvement, since varieties tested in rainfed environments could have been grown in irrigated environments and vice versa.
3. The analysis in this study is based on the implicit assumption that the percentage rate of varietal yield improvement on farms is the same as that found in varietal trials. It is always possible that trends in yield under trial conditions may not correlate with those observed under farmer management, although no evidence of that possibility was found among these data. To the extent that relative farm performances of varieties were different from relative trial performances, the results of this study would not adequately reflect the yield changes on farms.
4. The yield improvement in this study is the yield that is achieved in trials. As such, it does not include underlying changes in host plant resistance, abiotic stress tolerances and maintenance of yield potential, except insofar as those traits are expressed under trial conditions. Thus, for example, where there has been pest pressure on a trial, any improved resistance would result in higher yields in that trial for the varieties with that resistance. Similarly, any trials grown in environments where there were abiotic stresses would have any such tolerances to those stresses expressed in the higher yields of those varieties with those tolerances. Therefore, some of these varietal improvements are included in this study. However, to the extent that those improved resistances and tolerances are not expressed in the trials, they would not be accounted for in this study. A more detailed, trait-level analysis would be needed to assess all of those other yield-related traits that have not been well identified or measured in this study.

5. As described in Section 2.5, the attribution method used in this study is necessarily a simplified one. The data were not available to enable pedigree-level or genetic analysis to be carried out for the three countries. When a Mendelgram analysis was tested for the Philippines, it showed the same trends in IRRI contribution as did the simpler rule-of-thumb method used in this study. However, it is clear that a more detailed, genetic-level assessment of the role of IRRI germplasm may have resulted in some different estimates of the impact of IRRI lines on the varietal yield improvements measured in this study. A larger study involving breeders and geneticists would be required for that analysis to be possible. The key issue for this study is whether its finding that IRRI's role has changed and that its contribution in the countries studied has declined is valid or is an artefact of the method used. That can only be determined accurately when a thorough genetic study has been undertaken. That study would also have to assess the level of non-genetic input (testing, evaluation, characterisation etc.) into each variety, as well as the genetic contribution. Since the analysis in this study is based on only the contribution of IRRI lines to the pedigree, with no attribution for the institution that released the variety, the declines identified here reflect the introduction of non-IRRI materials as parents.

These limitations and caveats need to be borne in mind when using and interpreting the results of this study. Had more substantial data and a more detailed approach been possible, the results may well have been different. Only when more detailed studies have been carried out can the accuracy of the results of this study be fully assessed.

20 Assessment of ACIAR's investment in IRRI

It is clear from the foregoing analysis that IRRI has continued to produce strong economic benefits for the countries of South-East Asia of particular interest to ACIAR. Given that the benefits in recent years have been in the order of US$2–6 billion/year, as against IRRI's total budget of some US$40 million/year, it is apparent that investment in IRRI is likely, on average, to be a very productive investment of public funds.

There are, of course, many other costs incurred by the various NARES in getting these benefits to farmers, but it is apparent that continuing investment in IRRI is likely to provide a high economic return.

Moreover, IRRI also produces benefits for other countries not examined in this study, so the total benefits from IRRI are likely to be well above those measured here. Further, the outcomes of the other activities of IRRI besides the genetic improvement of rice varieties are not measured here, and undoubtedly lead to further benefits in the countries studied here and in other countries.

In assessing values from past and future in relation to present, it is necessary to discount future values and compound past values to have comparable current values. For example, 20 years ago $1 was worth more in present terms than $1 now, and we need to calculate the present value of the benefits of each year to provide a consistent measure of the benefits over time. The real discount rate we have used for the analysis is 5% per year, the standard rate to be used in ACIAR impact assessments (Davis et al. 2008). A higher real discount rate of, say, 10%, would reduce the current value of future costs and benefits and increase the current value of past costs and benefits.

In analysing the benefits and costs of the impacts of research, one key parameter to consider is the lag between incurring the costs and the realisation of benefits. For plant breeding, the lag is generally 5–8 years from the peak of breeding expenditures to the realisation of benefits on farms. For the analysis in this report, a lag of 7 years is used. Given those lags, if benefits are being measured from 1985, the costs from 1978 to 1984 should be included. There are always difficulties in the economic analysis of an ongoing research program such as breeding in attributing benefits to investments in particular time periods. The approach adopted here assumes that the benefits from 1985 are solely due to breeding activities since 1978, even although some of those benefits could be attributed to earlier work. Similarly, the approach implies that none of the expenditure between 1978 and 1984 had any impact before 1985.

While a detailed economic analysis of IRRI's contribution to the rice industry in South-East Asia is beyond the scope of this study, the figures derived here can be used for a brief indicative assessment of the benefits and costs identified here. The following assumptions were made:

- a discount rate of 5% per year
- a lag of 7 years between IRRI expenditure and benefits
- benefits projected in the future at an average of real 2005–07 benefits

- IRRI costs measured from 1978 to 2009 in constant 2009 dollars (based on the US consumer price index) and projected into the future as US$40 million per year.[4]

Thus, the analysis involves a large component of ex-post analysis (relating to the period 1985 to 2009), but also involves some ex-ante analysis for the benefits flowing from those activities in perpetuity (Davis et al. 2008).

On that basis, the results of the analysis reveal an internal rate of return of 28% on IRRI's total investment in rice improvement, a benefit:cost ratio of 21.7 (Table 20.1) and a net present value of US$97 billion. If we were to ignore future benefits and identify merely those that have already accrued, the net present value would be US$47 billion.

Clearly, given that IRRI's total budget is included and that the benefits include only varietal yield improvement in three selected countries, the level of return would have been higher if the benefits of all of IRRI's activities were included, including non-yield varietal improvements and non-varietal benefits. This analysis therefore provides a lower bound for the likely returns from investment in IRRI.

In assessing the role of ACIAR in partly funding IRRI, it must be remembered that the Centre provides only a small component of the Institute's budget, and can claim only a correspondingly small component of the benefits measured here. In recent years, the ACIAR contribution to IRRI has been approximately US$1.0–1.5 million/year, with IRRI's total budget being some US$40 million. If ACIAR were to claim an equivalent share of the benefits as it does of the costs of IRRI, the rate of return on ACIAR's investment would be the same as that for all IRRI investments (see Table 20.1).

Of course, these benefits are average benefits, and do not reflect the marginal benefits that might be received from the marginal increase in funds that ACIAR provides to IRRI. For example, if ACIAR were to withdraw its funding from IRRI entirely, IRRI would continue to operate and produce benefits. The implicit assumption in attributing the same proportion of IRRI's benefits to ACIAR as the proportion of IRRI's funds from ACIAR is that the marginal returns from that additional funding are the same as average returns. There is no information available to provide any other basis for comparison.

The results of this study lead to a general conclusion that broad benefits from IRRI reflect strong benefits from continuing investment in IRRI, and that that investment is likely to produce benefits that are appropriate to ACIAR and its mandate. Hossain et al. (2003, p. 98) concluded that 'the case for international rice research is outstanding'. The continuing progress through IRRI-related varieties indicates that the same is likely to apply to ACIAR's investment in IRRI.

Table 20.1 Cost–benefit analysis of IRRI's contribution

Present value of gains (US$ million, 2009 values)	101,228
Present value of costs (US$ million, 2009 values)	4,670
Net present value (US$ million, 2009 values)	96,558
Internal rate of return	28%
Benefit:cost ratio	21.7

4 Because of genetic drift and changes in the biological system after a new variety is established (such as the breakdown of pest resistance etc.), it is appropriate to continue the costs into the future as they represent the cost of maintaining the projected yield.

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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	AS1/1983/034, AS1/1987/017 and AS1/1993/222
2	George P.S. 1998.	Increased efficiency of straw utilisation by cattle and buffalo	AS1/1982/003, AS2/1986/001 and AS2/1988/017
3	Centre for International Economics 1998.	Establishment of a protected area in Vanuatu	ANRE/1990/020
4	Watson A.S. 1998.	Raw wool production and marketing in China	ADP/1988/011
5	Collins D.J. and Collins B.A. 1998.	Fruit fly in Malaysia and Thailand 1985–1993	CS2/1983/043 and CS2/1989/019
6	Ryan J.G. 1998.	Pigeonpea improvement	CS1/1982/001 and CS1/1985/067
7	Centre for International Economics 1998.	Reducing fish losses due to epizootic ulcerative syndrome—an ex ante evaluation	FIS/1991/030
8	McKenney D.W. 1998.	Australian tree species selection in China	FST/1984/057 and FST/1988/048
9	ACIL Consulting 1998.	Sulfur test KCL–40 and growth of the Australian canola industry	PN/1983/028 and PN/1988/004
10	AACM International 1998.	Conservation tillage and controlled traffic	LWR2/1992/009
11	Chudleigh P. 1998.	Postharvest R&D concerning tropical fruits	PHT/1983/056 and PHT/1988/044
12	Waterhouse D., Dillon B. and Vincent D. 1999.	Biological control of the banana skipper in Papua New Guinea	CS2/1988/002-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

IMPACT ASSESSMENT SERIES <CONTINUED>

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25	Brennan J.P. and Quade K.J. 2004.	Genetics of and breeding for rust resistance in wheat in India and Pakistan	CS1/1983/037 and CS1/1988/014
26	Mullen J.D. 2004.	Impact assessment of ACIAR-funded projects on grain-market reform in China	ADP/1997/021 and ANRE1/1992/028
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/1984/057, FST/1987/036, FST/1988/048, FST/1990/044, FST/1994/025, 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 and 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	AS2/1990/028, AS2/1994/017, AS2/1994/018, AS2/1999/060, CS1/1990/012, CS1/1994/968, FST/1993/016 and PHT/1990/051
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

No.	Author(s) and year of publication	Title	ACIAR project numbers
47	Fisher H. and Gordon J. 2007.	Improved Australian tree species for Vietnam	FST/1993/118 and FST/1998/096
48	Longmore C., Gordon J. and Bantilan M.C. 2007.	Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia	CS1/1994/968
49	Fisher H. and Gordon J. 2007.	Minimising impacts of fungal disease of eucalypts in South-East Asia	FST/1994/041
50	Monck M. and Pearce D. 2007.	Improved trade in mangoes from the Philippines, Thailand and Australia	CS1/1990/012 and PHT/1990/051
51	Corbishley J. and Pearce D. 2007.	Growing trees on salt-affected land	FST/1993/016
52	Fisher H. and Gordon J. 2008.	Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts	AS2/1994/023
53	Monck M. and Pearce D. 2008.	The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology	AH/1997/115
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	CP/1997/079, CP/2001/027, CP/2002/086, CP/2007/002, CP/2007/187, 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, PHT/1990/051, PHT/1993/87 and PHT/1994/133
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	
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74