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Integrated management of *Fusarium* wilt of bananas in the Philippines and Australia

105

ACIAR IMPACT ASSESSMENT SERIES

Impact assessment of integrated management of *Fusarium* wilt of bananas in the Philippines and Australia

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The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. ACIAR operates as part of Australia's international development assistance program, with a mission to achieve more productive and sustainable agricultural systems, for the benefit of developing countries and Australia. It commissions collaborative research between Australian and developing-country researchers in areas where Australia has special research competence. It also administers Australia's contribution to the International Agricultural Research Centres.

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Photo: Conor Ashleigh

Foreword

The Australian Centre for International Agricultural Research (ACIAR) has been supporting research into the management and mitigation of the destructive *Fusarium* fungus in banana growing areas in Indonesia since the early 2000s, in the Philippines since 2014, in Laos in 2020 and in Mozambique, South Africa and Tanzania since 2022. This impact assessment of the 'Integrated management of *Fusarium* wilt of bananas in the Philippines and Australia' (HORT/2012/097) project clearly demonstrates the value of this ongoing research program in managing Fusarium wilt internationally and in Australia.

The international partnerships that underpin research supported by ACIAR aim to improve the productivity and sustainability of agricultural, forestry and fisheries systems in partner countries. Through this research, Australia contributes to improving food security, food system resilience and the livelihoods of smallholder farmers in the Indo-Pacific region. Importantly, as exemplified in this report, such partnerships also benefit the Australian agricultural innovation system, with flow-on benefits to rural industries and regional communities.

This impact assessment highlights the important scientific knowledge that was developed by research to improve management of *Fusarium* wilt in the Philippines and Australia led by the Queensland Department of Agriculture, Fisheries and Forestry. It found that this knowledge has already been positively applied in both countries, informing the quick detection and containment of a Fusarium outbreak in Queensland, which had the potential to devastate the Australian banana industry.

The full impact of research-for-development work in agriculture, forestry and fisheries is realised over decades and cannot be properly evaluated when the research first takes place. For more than 30 years, ACIAR has systematically undertaken independent impact assessment studies of its portfolio of research activities, that have consistently found high returns on investment. In this case, the impact of the project in the Philippines and Australia was so substantial that the benefit:cost ratio was estimated conservatively to be 71:1. In other words, each dollar invested in the research generated at least 71 dollars of measured benefits. This reflects the quality of both the research undertaken, and the ACIAR partnership model, which ensures a high level of engagement with in-country partners, and a high level of adoption of research results.

The impact assessment found that this project contributed to significant scientific capacity building in the Philippines, providing a strong foundation for on-going local research and management which will continue to help local banana growers well into the future.

Andrew Campbell
Chief Executive Officer, ACIAR

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Abbreviations

ABGC	Australian Banana Growers’ Council
ABS	Australian Bureau of Statistics
ACIAR	Australian Centre for International Agricultural Research
AUD	Australian dollar
DFAT	Department of Foreign Affairs and Trade
FAO	Food and Agriculture Organization of the United Nations
ha	hectare
PCAARRD	Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development
PHP	Philippine peso
PSA	Philippine Statistics Authority
RD&E	research, development and extension
t	tonne
tpa	tonne per annum
TR4	*Fusarium* wilt tropical race 4 (variant)
UNESCO	United Nations Educational, Scientific and Cultural Organization
USeP	University of Southeastern Philippines
WEF	World Economic Forum

Summary

The purpose of this impact assessment is to identify the impact of a project titled 'Integrated management of *Fusarium* wilt of bananas in the Philippines and Australia' (HORT/2012/097). The project was funded by the Australian Centre for International Agricultural Research (ACIAR) and undertaken between 2014 and 2019. A summary of the project's impacts is shown in the tables in the following pages.

The project had a very strong capacity and scientific impact in the Philippines and Australia. The project's scientific impact was balanced between advancement of science and development of knowledge unique for application in context. Collaborators excelled in their respective fields of specialisation during the project. The project provided strong scientific knowledge on the epidemiology, containment and management of *Fusarium* wilt, specifically tropical race 4 (TR4). This knowledge was used to help contain the disease in Australia, especially in light of the moratorium on the use of contaminated soil and plant material in Australia. Scientific findings from the project were used to develop disease-suppression systems that have gained widespread international credibility. The project also had a high environment impact in Australia, achieving practice change that is reducing soil erosion and run-off, preventing contaminants reaching the ocean preventing water pollutants from contaminating the Great Barrier Reef.

In the Philippines, the project had a small impact on reducing the area contaminated by TR4 and encouraging adoption of partially resistant varieties. This led to a high economic impact, indicatively valued at about AUD27 million (PHP600 million) to 2028, the year to which benefits are expected to be generated. The project had a strong economic impact in Australia, indicatively valued at AUD93 million to 2030, playing an important role in preventing the disease from wiping out the banana industry in Queensland. The ratio of total project benefits to costs is estimated to be about 71, meaning that for every dollar invested by ACIAR, the project is expected to generate about 71 dollars (PHP2,600) in return. This represents a very good return on investment compared with other agricultural research projects.

Reasons for the project's success included:

- the collaborative and multidisciplinary nature of the project team, where project partners specialised in complementary fields well-suited to the study of *Fusarium* wilt and soil health and condition
- the project's focus on one commodity (banana) and one issue (*Fusarium* wilt), and centring collaboration in the Philippines on one institution (University of Southeastern Philippines)
- the use of a project platform for sharing information on human resources, websites, resources, security, logistics, communication channels and events, which created significant social capital
- the adaptive capacity of the project team, a thirst for research capacity in the Philippines and a mutual understanding of the importance of containing the disease in Australia
- the strong adaptive capacity of banana producers in Australia, especially in light of the potential decimation of the banana industry in Queensland if TR4 was not contained
- an established extension network in Australia that was known by project participants so that extension and implementation initiatives were successful when TR4 was first detected in Queensland
- the ability of the project team to 'influence the influencers', engaging with prominent farmers who were determined to understand disease containment and suppression systems and who facilitated farmer-to-farmer practice change
- the vertical integration of supply chains in Australia, so the project's contribution to protecting the banana industry had flow-on benefits of protecting the industry's supply chain.

Weaknesses of the project included poor engagement with Philippine smallholders from the start of the project due to security concerns and a lack of understanding of the structure of the Philippine banana industry. At the start of the project, it was not fully understood that decision-making resided with multinational corporations and prominent local families rather than small-scale landholders. These weaknesses could be addressed in future projects by:

- conducting a feasibility study at the outset of large projects to ensure strong understanding of the relevant industries and associated impact pathways
- including influential farmers and representatives of local government units in the project from the beginning, making sure they are aware of the research process to facilitate feedback loops and smallholder engagement, and to encourage farmer-to-farmer practice change and adoption beyond the life of the project
- stronger local coordination, with support from the ACIAR Country Manager, to help navigate the difficulties around security, financial management and conflicts of interest
- using local coordinators to assist in grass-roots processes, monitor the progress of the project and provide security and logistics guidance.

<table>
<tr><th>Impact type</th><th>Project impact in the Philippines</th><th>Project impact in Australia</th></tr>
<tr><td rowspan="3">Economic</td><td>High</td><td>Very high</td></tr>
<tr><td>Reduction in area contaminated by TR4 by about 700 ha by 2021 due to:
improved on-farm biosecurity measures, such as marked walkways and vehicle tracks; using effective sanitiser on vehicles, clothes, etc.; early detection; and quick destruction of diseased plants
awareness of the importance of maintaining groundcover to prevent and suppress spread of the disease
increase in adoption of partially resistant varieties on land affected by TR4, about 700 ha by 2021.
The indicative economic benefit from the project in the Philippines is estimated to be AUD27 million (PHP1,000 million) to 2028.</td><td>Reduction in area contaminated by TR4 by about 6,500 ha by 2021 due to provision of scientific information and containment advice on:
use of groundcovers
biosecurity measures
fertiliser practices
farm design.
The indicative economic benefit from the project in Australia is estimated to be AUD93 million to 2030.</td></tr>
<tr><td colspan="2">The project cost was AUD822,050 in 2014, which, after adjusting for inflation and accounting for the time value of money, is equivalent to a present value of AUD1.7 million. The total benefit of the project is estimated to be AUD120 million. The indicative net benefit of the project (the difference between the present value of the benefits and costs) is estimated to be AUD118 million (PHP4,400 million). The ratio of total benefits to costs is 71, meaning that for every dollar invested by ACIAR, the project will generate about 71 dollars (PHP2,600) in return. The benefit:cost ratio is 71:1, which represents a very good return on investment compared with other agricultural research projects.</td></tr>
<tr><td rowspan="2">Inclusivity of value chains</td><td colspan="2">Low</td></tr>
<tr><td>The project did not have a specific value chain focus, and as such did not have a strong impact on inclusivity of value chains. The project faced difficulties engaging with supply chain participants due to security concerns on behalf of non-project stakeholders. There is an opportunity for women to play a larger role across the supply chain and in distribution channels.</td><td>Not applicable in the Australia context.</td></tr>
<tr><td rowspan="2">Environmental</td><td>Low</td><td>High</td></tr>
<tr><td>Improved awareness of:
using groundcovers to increase microbial activity in the soil and reduce the incidence and severity of Fusarium wilt
reducing the use of environmentally damaging and ineffective agrichemicals, including herbicides and insecticides
using urea to generate ammonium gas to kill the Fusarium wilt inoculum.
While the project has led to a small environmental impact so far, this and the subsequent ACIAR project are expected to lead to significant environmental impact as awareness and adoption of environmental practices grow.</td><td>The project is having a large and sustained environmental impact in Australia due to the proximity of banana production to the Great Barrier Reef. Project recommendations having significant environmental impacts include:
the use of groundcovers to increase microbial activity in the soil and reduce the incidence and severity of Fusarium wilt
increased biodiversity management
the encouragement of smart input production systems and nutrient management plans.</td></tr>
</table>

<table>
<tr><th>Impact type</th><th>Project impact in the Philippines</th><th>Project impact in Australia</th></tr>
<tr><td rowspan="2">Capacity</td><td colspan="2">High</td></tr>
<tr><td>The project's largest impact in the Philippines was in capacity building. Before the project commenced, understanding of soil biology was low, as was knowledge of Fusarium wilt, its potential impact on the banana industry, and containment and management practices. The project worked closely with staff and students from the University of Southeastern Philippines. These partners excelled in their respective fields of specialisation.
Some of the individual skills and competencies developed by staff and students include:
• a deeper understanding of soil biology beyond ecology and disease suppression
• skill development in laboratory techniques and methods for soil microscopy
• collaborative research skills development and the capacity to continue Fusarium wilt and microbiome research beyond the life of the project.</td><td>The project had strong capacity impacts in Australia across stakeholders, including research staff and students, industry and banana producers. Capacity development included:
• in-depth understanding of microbial ecological relationships and how they impact the incidence and suppression of Fusarium wilt
• understanding of how land and soil management affect soil organisms and therefore the expression of the disease
• skills in testing, diagnosis and measurement of Fusarium wilt.
The project worked closely with the Queensland Department of Agriculture and Fisheries and the Australian Banana Growers' Council, providing synergistic capacity benefits to additional investment in banana disease research.</td></tr>
<tr><td rowspan="2">Scientific</td><td colspan="2">High</td></tr>
<tr><td colspan="2">The project provided strong scientific knowledge about the epidemiology, containment and management of TR4. Initial scoping studies on microbiomes of banana cultures helped to develop disease suppression systems that have gained widespread credibility as a field of science. The project leadership generated a strong culture of publishing scientific findings, attending conferences and meeting peers to generate scientific impact. In the Philippines, the project challenged management responses that were unscientific and without evidence base, debunking myths and bringing fact-based scientific analysis to research and extension staff. The project's scientific findings in the Philippines were used to help contain the disease in Australia, especially in light of the moratorium on the use of contaminated soil and plant material in Australia. The project's scientific impact went beyond the Philippines and Australia to other parts of the world within the broad network of Fusarium wilt specialists. The project generated a strong scientific impact due to the collaborative and multidisciplinary nature of the project team, where project partners specialised in complementary fields well suited to the study of Fusarium wilt and soil health and condition.</td></tr>
<tr><td rowspan="2">Policy</td><td>Low</td><td>Moderate</td></tr>
<tr><td>• There is a need for a biosecurity directive, policy or adoption pathway that can facilitate biosecurity practice change by small and medium landholders that are supported by directives from multinational corporation.
• Plantation areas have inadequate zoning policy to protect spread of the disease.
• The project had little policy impact in the Philippines, although policy change is expected over time based on the project's capacity-building initiatives.</td><td>• The project influenced the Queensland Government's biosecurity policies and responses.
• The project team provided swift policy advice to government and landholders to prevent significant outbreak of the disease.
• The project diffused antagonism between the Philippine and Australian banana industries.
• The project helped establish a program of Fusarium wilt research that works simultaneously on current prevention of the disease as well as future management of the disease.</td></tr>
<tr><td rowspan="2">Gender and youth</td><td colspan="2">Low</td></tr>
<tr><td colspan="2">The project did not have a specific gender or youth focus and disaggregation of gender- and youth-related variables to assess structural inequities was not a specific strategy. The project did analyse the proportion of women and men who were involved in the project, and their location and kind of work. The project encouraged gender equality and practiced gender inclusion in all its activities.</td></tr>
</table>

1 Introduction

Fusarium wilt is considered to be the most destructive of all banana diseases. In the early 2000s, ACIAR began supporting a program of work to reduce the impact of *Fusarium* wilt on banana production. This program of work has so far involved 6 projects. The completed projects are:

- 'Diagnosis and management of wilt diseases of banana in Indonesia' (CP/2004/034)
- 'Mitigating the threat of banana *Fusarium* wilt: understanding the agroecological distribution of pathogenic forms and developing disease management strategies' (HORT/2005/136)
- 'Integrated crop production of bananas in Indonesia and Australia' (HORT/2008/040)
- 'Integrated management of *Fusarium* wilt of bananas in the Philippines and Australia' (HORT/2012/097).

The current projects are:

- 'An integrated management response to the spread of *Fusarium* wilt of banana in South-East Asia' (HORT/2018/192) [Indonesia, Laos, Philippines], which is expected to run from January 2020 to December 2024
- 'Developing a biosecurity system for small banana growers resilient to *Fusarium* wilt TR4 in southern and eastern Africa' (HORT/2020/128) [Mozambique, South Africa, Tanzania], which is expected to run from July 2021 to June 2026.

The purpose of this impact assessment is to identify the impact of the fourth completed project – 'Integrated management of *Fusarium* wilt of bananas in the Philippines and Australia' (HORT/2012/097) – on intended next and final users of project outputs and outcomes. The project was undertaken between 2014 and 2019. The goal was to improve the livelihoods of smallholders and communities who depend on export Cavendish production by reducing losses due to TR4 and improving the productivity and viability of production. The commissioned organisation was the Queensland Department of Agriculture, Fisheries and Forestry (now Queensland Department of Agriculture and Fisheries), with collaborating organisations including the Australian Banana Growers' Council (ABGC), Bioversity International, the University of Southeastern Philippines (USeP) and the Philippines Provincial Agricultural Office in Davao del Norte (PCAARRD).

The specific aims of the project were:

- develop options to limit losses of smallholder Cavendish production in Davao del Norte and Ladyfinger production in Australia due to *Fusarium* wilt
- evaluate the effectiveness of best-bet integrated crop management approaches in enabling commercial banana production in the presence of *Fusarium* wilt
- determine the barriers to adoption of systems to suppress *Fusarium* wilt in banana production in the Philippines and Australia.

The primary outputs were expected to be:

- an integrated crop management system for banana production in areas affected by *Fusarium* wilt, based on partially resistant cultivars, reduced movement of infected soil, management of inoculum in infected plant material and pathogen suppression in the soil using vegetative groundcovers
- documented techniques for management of *Fusarium* wilt published in peer-reviewed journals about the integrated crop management system and its components, vegetative groundcover effects, restricting soil movement in banana plantations and treatment of infected plant material
- documented information on *Fusarium* wilt to help banana growers make informed decisions
- reports on change in *Fusarium* wilt, banana management practices and their costs, and grower attitudes due to the project activities.

This impact assessment highlights the range of impacts of 'Integrated management of *Fusarium* wilt of bananas in the Philippines and Australia' (HORT/2012/097) qualitatively and, where possible, quantitatively, in terms of economic, value chain, environmental, capacity, scientific, policy, gender and youth impacts.

Hanging bananas after harvesting in Queensland to prevent bruising and to delay ripening
Photo: ACIAR

2 Methodology

The impact assessment team included one team member in Australia, Dr Elizabeth Petersen of Advanced Choice Economics Pty Ltd and the University of Western Australia, and one team member in the Philippines, Ms Joyce Luis, who is a freelance consultant and affiliated with University of Philippines Los Baños.

Four tasks were conducted to complete the impact assessment:

1. **Desktop literature review** of project documentation and related publications to research available data and information on the project and its impact.
2. **Consultation of project partners.** Semi-structured interviews of 9 people were conducted, including project leaders and participants who are currently in the Philippines, Australia and Fiji. The aim of this consultation was to:
   a. understand the types and magnitude of project outputs, outcomes and impacts
   b. determine next and final users of project outputs, outcomes and impacts
   c. understand the nature of value-chain, economic, environmental, capacity, scientific, policy, and gender and youth impacts
   d. determine further data collection requirements.
3. **Discounted cashflow analysis of quantifiable economic impacts of the projects.** This analysis is presented in Section 5.2 Economic impact. It involves the following processes for both the Philippines and Australia:
   a. estimating current and expected future prevalence of *Fusarium* wilt
   b. estimating the counterfactual – expected prevalence of *Fusarium* wilt in the absence of the project
   c. estimating the reduction in affected area attributable to project
   d. estimating the economic benefit of the reduction in area affected by *Fusarium* wilt over time
   e. applying standard discounted cashflow analysis methodology to estimate the present value of the economic impact of the project.
4. **Summarising findings in this impact assessment report.** This impact assessment report provides a summary of data and information generated from desktop literature review, consultation with project partners, and discounted cashflow analysis. Background information is provided in Section 3, a list of next and final users is provided in Section 4, and the value-chain, economic, environmental, capacity, scientific, policy, and gender and youth impacts are presented in Section 5. An overview of the impacts is provided with a summary of reasons for project impacts in Section 6.

Inspecting a banana plantation with *Fusarium* wilt infection
Photo: Conor Ashleigh

3 Background

This section provides background information on the incidence and severity of *Fusarium* wilt, the banana industries in the Philippines and Australia, and the impact of *Fusarium* wilt in both countries.

3.1 *Fusarium* wilt

Fusarium wilt (*Fusarium oxysporum* f. sp. *cubense*, also known as Panama disease) is a disease of banana and is considered among the most destructive of all plant diseases (Altendorf 2019). It was first detected in banana plantations in Australia in 1876 and the first large-scale outbreak was reported in 1890 in Panama. The first strain of *Fusarium* wilt (race 1) devastated the global banana industry in the mid-1950s and caused the export industry to permanently switch its entire production from the Gros Michel variety to the resistant Cavendish variety (Altendorf 2019).

The current most virulent strain of the disease is termed 'race 4', which is usually split into subtropical (STR4) and tropical (TR4) races. STR4 produces symptoms in Cavendish bananas after a period of cold or other abiotic stress, whereas TR4 can be triggered in Cavendish bananas grown under a broad range of conditions. TR4 is considered to be the most virulent form of the pathogen. TR4 was first discovered in 1970 in Cavendish banana plantations in Taiwan. Its earliest detection in Australia was in the Northern Territory in 1997 (Bentley et al. 2001; Conde and Pitkethley 2001). It is believed to have first affected bananas in the Philippines in the early 2000s. In 2019, TR4 was confirmed in 17 countries, predominantly in South and Southeast Asia (Altendorf 2019). There are currently no effective long-term control measures to manage TR4. Unlike the previous race 1 epidemic, when the global banana industry could shift from a non-resistant variety (Gros Michel) to a resistant variety (Cavendish), there is presently no resistant, widely accepted replacement for Cavendish bananas (Salacinas et al. 2022).

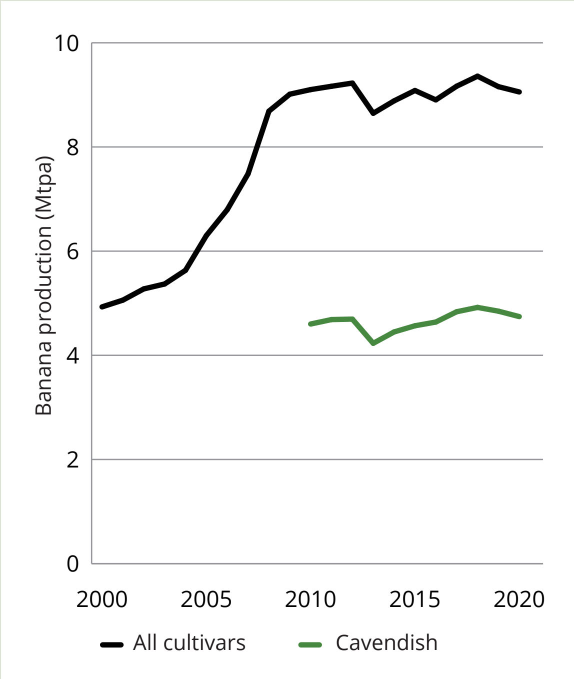
Fusarium wilt is a soil-borne fungus. The mycelium and spores of *Fusarium* wilt can spread through infected plant material and soil particles attached to shoes, vehicles and tools, and through water, including irrigation drainage and floods. TR4 quickly causes total yield loss in infected plants and affects a much broader range of cultivars than previous strains (Ploetz 2015). There is currently no effective fungicide or other eradiation method that can eliminate it. Once a farm is contaminated, managing the disease is extremely challenging and costly and poses a significant threat to banana production. Disease prevention, rapid containment and quarantine are extremely important.

3.2 The banana industry in the Philippines

Bananas are an important export commodity for the Philippines. In 2020, the Philippines were the fifth-largest exporter of bananas in the world in terms of quantity, and second-largest in terms of value (FAO 2022). They are by far the Philippines largest export crop. Banana exports totalled 1.9 million tonnes in 2020, valued at AUD2.3 billion (PHP80 billion) (FAO 2022). Bananas are the Philippines' fifth-largest crop in terms of production, at approximately 9.1 million tonnes per year (PSA 2021).

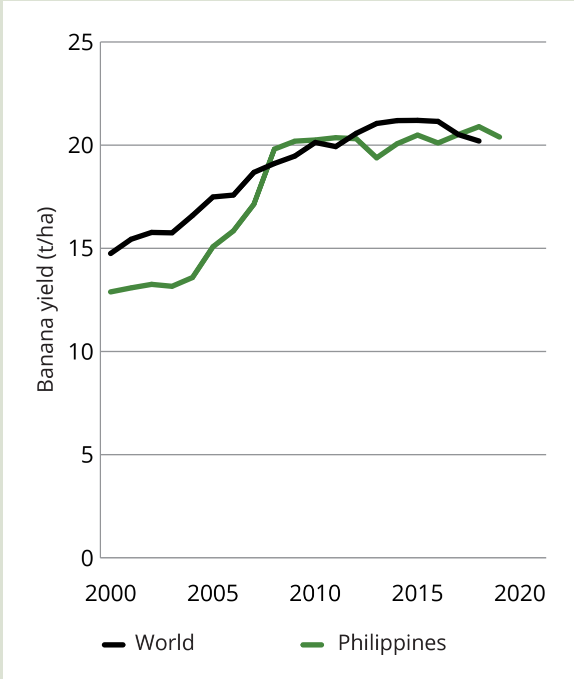
The growth in the country's banana production increased rapidly between 2004 and 2008 but has stagnated since then (Figure 3.1). The major banana cultivar grown in the Philippines is Cavendish (52% of production in 2020). While Cavendish is the main variety exported, as many as 90 cultivars are grown for domestic consumption, with the main ones being Saba and Lakatan (Vezina and Van den Burgh 2020).

The stagnation in banana production in the Philippines since 2008 is largely attributable to the stagnation in yields. Figure 3.2 shows that yields increased quickly between 2004 and 2008 but have since plateaued. This stagnation in yields has occurred globally.



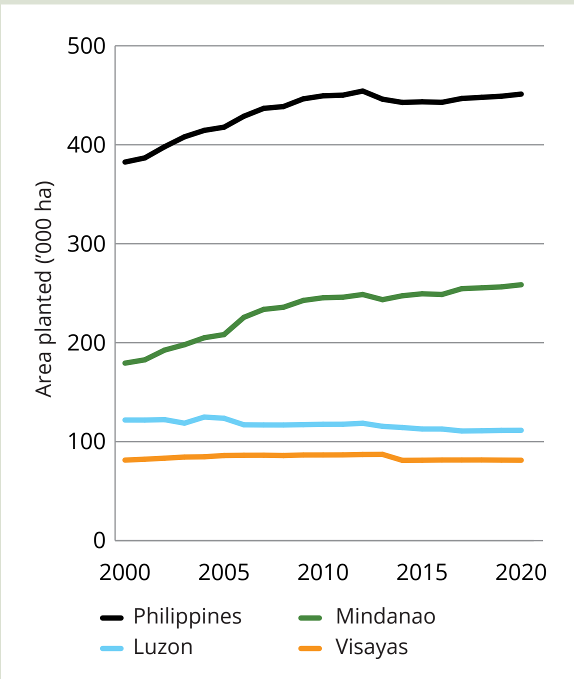
Note: Data for Cavendish before 2010 is unavailable.
Sources: PSA 2015, 2018, 2021

Figure 3.1 Production of bananas in the Philippines, 2000–2020



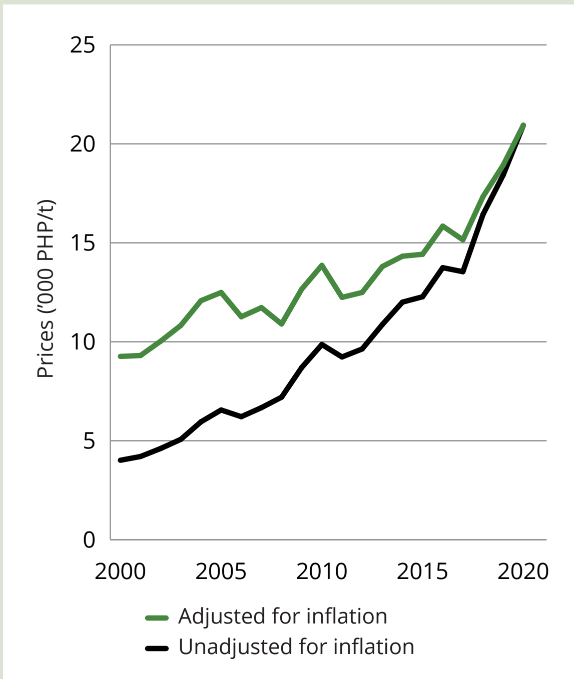
Sources: PSA 2003, 2009, 2010, 2015, 2018, 2021; ourworldindata.org

Figure 3.2 Average annual banana yields, 2000–2019



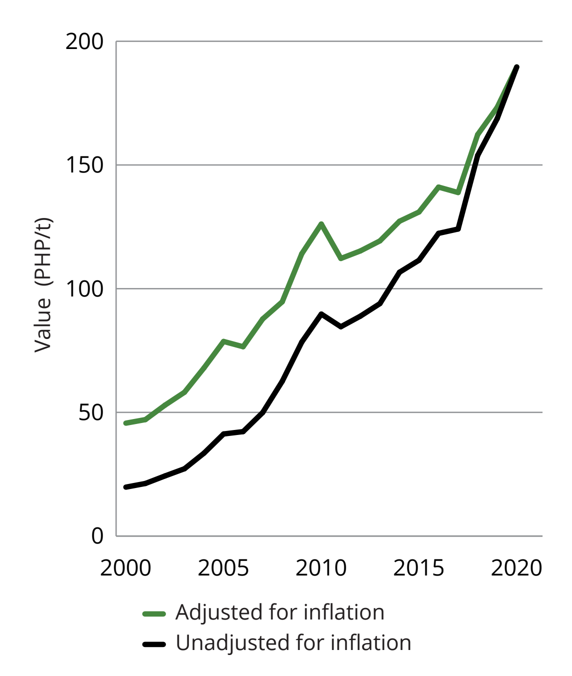
Source: PSA 2021

Figure 3.3 Total area planted to bananas in the Philippines, and on Mindanao, Luzon and Visayas, 2000–2020



Source: FAO 2022

Figure 3.4 Banana producer prices in the Philippines, adjusted and unadjusted for inflation using the food CPI, 2000–2020



Source: Authors' estimates based on data used in Figures 3.3 and 3.4

Figure 3.5 Value of banana production in the Philippines, adjusted and unadjusted for inflation, 2000–2020

In 2020, 57% of the area planted to bananas was in Mindanao, followed by Luzon (25%) and Visayas (18%) (Figure 3.3). The area planted to bananas in the Philippines increased by 1% annually between 2000 and 2012. Since then, the area has declined, partly due to increased incidence of TR4. Of the 259,000 ha planted to bananas in Mindanao, 33% (86,000 ha) was Cavendish. Cavendish is almost exclusively grown in Mindanao, with only very small areas of Cavendish grown in Visayas (423 ha) and Luzon (141 ha).

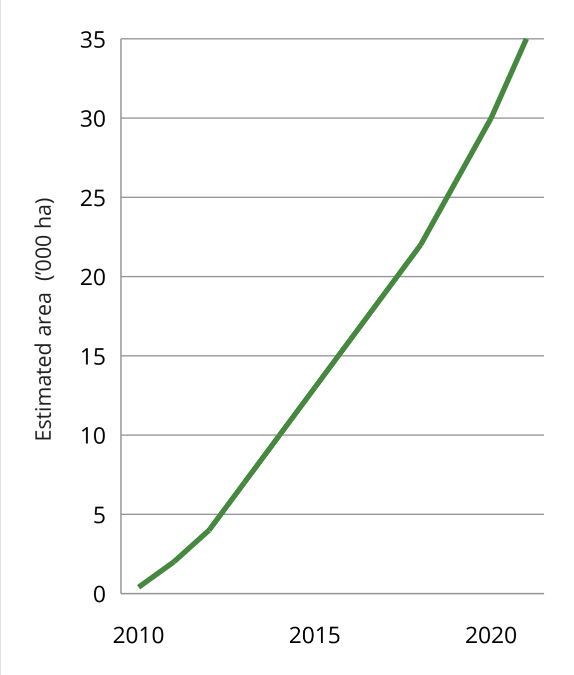
Producer prices of bananas have increased over time, especially in recent years (Figure 3.4). Despite the stagnation in banana production in recent years, the value of banana production has increased steadily (Figure 3.5). The value of banana production in 2020 was estimated to be PHP190,000 billion (AUD5.6 billion), which is about 1.1% of total gross domestic product and 10% of agricultural gross domestic product.

Banana production in the Philippines is dominated by multinational corporations that were established in the first half of the 20th century when the Philippines welcomed investment to create plantations. The development of these plantations led, in part, to the development of its export-oriented industry. Local residents and people migrating from elsewhere in the Philippines are the workforce of these plantations. During the 1960s, the workforce organised into unions which, through civil action, allowed workforce associations to apply for land ownership through cooperatives. Further land reform of the 1980s and civil action in the 1990s has allowed Indigenous plantation workers to gain further control of land (Bacon 2020). Today, export banana production is jointly controlled by multinational corporations and prominent local families, each managing more than 100 ha, who hire workers or contract small to medium landholders to plant and process the crop. In 2016, there were approximately 190 multinationals, corporations and cooperatives employing about 48,000 people (PSA 2019).

3.3 *Fusarium* wilt in the Philippines

TR4 was first reported in the Philippines in 2002 (Molina et al. 2008), but serious concerns were not raised until 2011 when flash flooding caused the significant spread of the disease and nearly 700 ha was affected in the Davao Region (Herradura et al. 2018). More than 5,000 ha of banana farms were abandoned due to the disease in 2013 (Generalao et al. 2018). The area of land affected by TR4 was estimated to be at least 15,500 ha in 2015 (Montiflor et al. 2019), 15,700 ha in 2016 (Altendorf 2019) and 35,000 ha currently (consultation processes). From this information, we have estimated the area of land affected by TR4 over time (Figure 3.6). TR4 is widely distributed in Mindanao, especially in Davao Region (Table 3.1), but has not been detected in Luzon or Visayas (Herradura et al. 2018).

A recent survey of 48 banana growers from the Davao del Norte province – conducted as part of a current ACIAR project, 'An integrated management response to the spread of *Fusarium* wilt of banana in South-East Asia' (HORT/2018/192) – highlighted the vulnerability of smallholder growers to TR4. The survey showed that 71% of growers owned less than 1 ha, from which 90% of respondents derived most of their household income, and 93% of respondents had land affected by TR4.



Source: Authors' estimates

Figure 3.6 Estimated area of banana-producing land affected by TR4 in the Philippines, 2010–2021

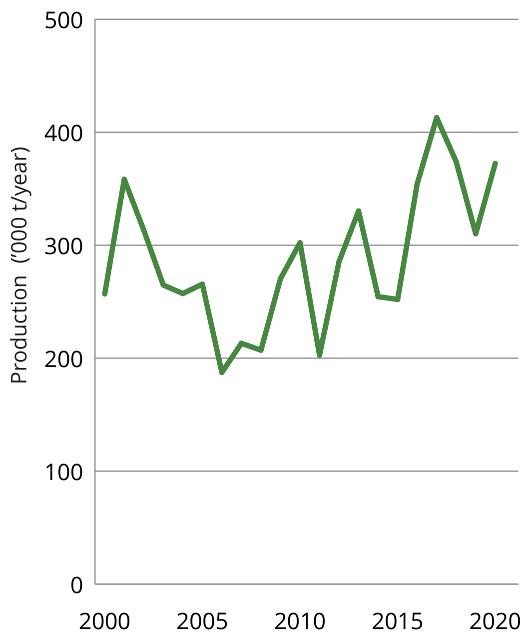
Table 3.1 Estimated area of banana-producing land affected by TR4 in Davao Region and the Philippines, 2015

	Banana (all varieties) (ha)	Cavendish (ha)	Area affected with TR4 (ha)	Cavendish area affected by TR4 (%)
Davao del Norte	36,368	28,972	13,743	47
Davao del Sur	15,413	3,642	436	12
Davao Oriental	10,539	156	36	23
Compostela Valley	19,131	11,934	1,083	9
Davao City	6,834	3,346	210	6
Total Davao Region	**88,365**	**48,050**	**15,508**	**32**
Total Philippines	**443,370**	**85,809**	**Not available**	**Not available**

Source: Montiflor et al. 2019

3.4 The banana industry in Australia

The banana industry in Australia is much smaller than that in the Philippines. There are approximately 260–270 banana growers in Australia (Campbell 2019). In 2019–20, just over 12,000 ha of bananas were harvested, with an average yield of 30 tonnes per ha, leading to 372,000 tonnes of production (Table 3.2). Approximately 96% of harvested bananas are produced in Queensland, with small amounts of production in Western Australia, New South Wales and the Northern Territory. The value of banana production in Australia in 2019 was AUD490 million. Production has been increasing since 2006 (Figure 3.7), largely because yields have increased by 80% (Figure 3.8), but also due to the 10% increase in area harvested (Figure 3.9). Imports and exports are very small compared with production, with exporting years associated with high production years, and vice versa. In 2018, 90% of Australia's banana production was consumed domestically as food, with 8% processed and 2%
post-harvest losses (FAO 2022). In 2016–17, the Australian banana industry employed 5,325 people, 90% of whom are in Far North Queensland, and a further 13,418 people along the supply chain (Hall 2018).



Source: FAO 2022

Figure 3.7 Banana production in Australia, 2000–2020

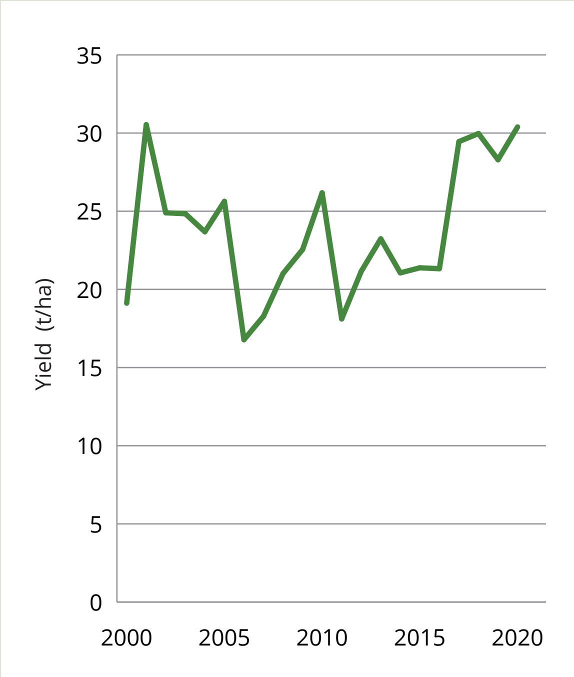
Table 3.2 Banana production and yield in Australia, by state and territory, 2019–20

	Total area of bearing age (ha)	Proportion by state (%)	Banana production (tpa)	Yield (t/ha)
Queensland	11,507	94	359,010	31.2
Western Australia	352	3	9,437	26.8
New South Wales	341	3	2,902	8.5
Northern Territory	53	0	1,084	20.3
Australia	**12,254**	**100**	**372,433**	**30.4**

Source: ABS 2021–22

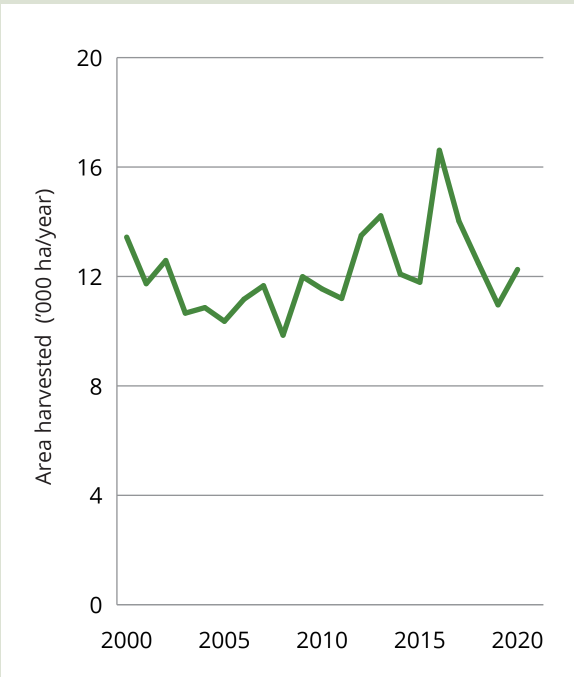
3.5 *Fusarium* wilt in Australia

The first detection of TR4 in Australia was in the Northern Territory in 1997 (Pegg et al. 2019). Despite the implementation of quarantine measures to contain the disease, the spread could not be controlled and it all but wiped out the Northern Territory banana industry (Pegg et al. 2019). In 2015, TR4 was detected in north Queensland, which was of particular concern because this region produces over 95% of Australia's banana production in a small geographic area (O'Neill et al. 2016). The disease has largely been contained in Queensland, with the number of infected properties increasing from one in 2015 (14 known infected plants) to 5 in 2022 (168 known infected plants) (Figure 3.10). The disease has been successfully controlled and contained in Queensland with significant investment in surveillance, testing and biosecurity.



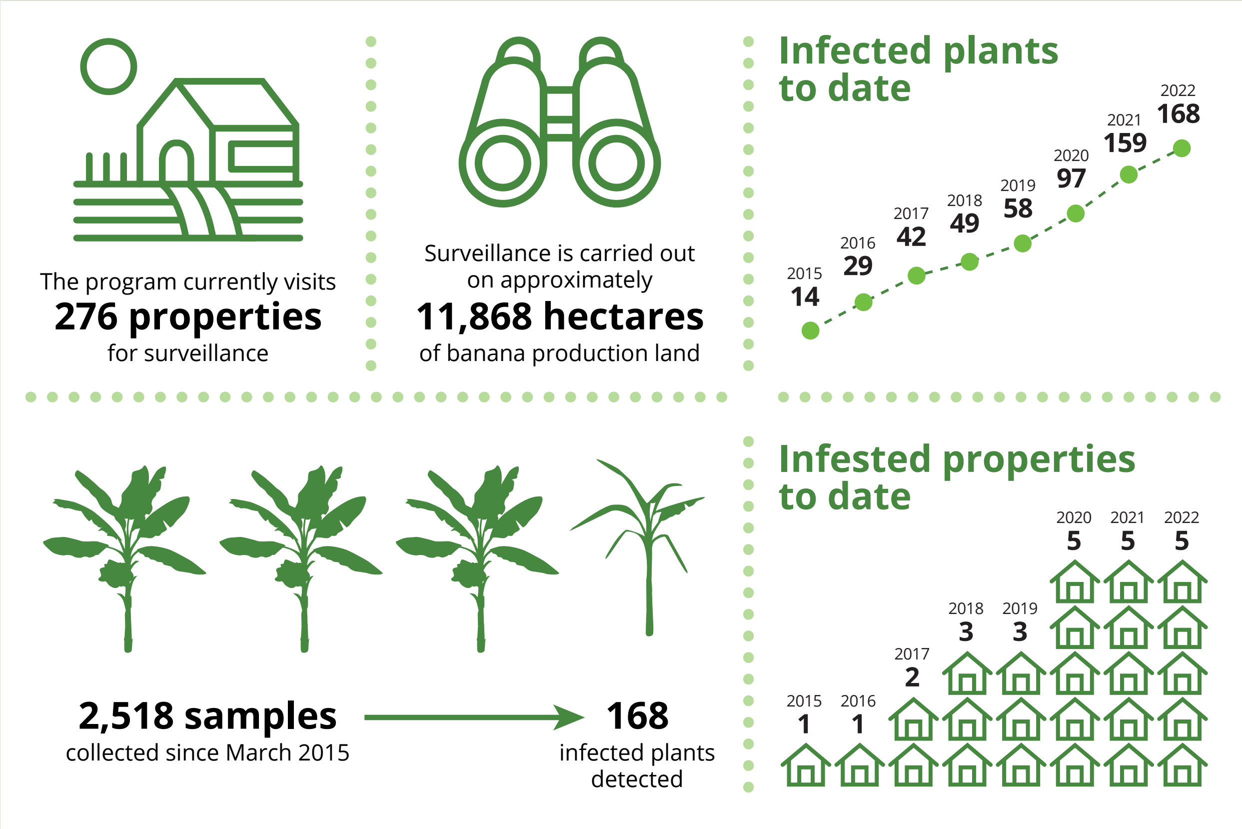
Source: FAO 2022

Figure 3.8 Banana yields in Australia, 2000–2020



Source: FAO 2022

Figure 3.9 Area of bananas harvested in Australia, 2000–2020



Source: Panama TR4 Protect n.d.

Figure 3.10 Spread of TR4 in Queensland

Collecting samples from infected banana in the Philippines for laboratory testing
Photo: Conor Ashleigh

4 Next and final users of the project

A list of next users for the projects is provided below. As more than 2 years has passed since the completion of the project, knowledge has been dispersed throughout the Philippines and internationally. This list is not considered to be complete or definitive.

Industry

- Philippines Banana Industry Development Council
- Mindanao Banana Farmers and Exporters Association
- Pilipino Banana Growers and Exporters Association
- Australian Banana Growers' Council

Research

- University of Southeastern Philippines
- Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (DOST-PCAARRD) Crops Research Division in Los Baños, Laguna
- Southern Mindanao Agriculture and Resources Research & Development Consortium (SMARRDEC), one of the Consortia of PCAARRD
- Horticulture Innovation

Government

- Provincial Agricultural Offices, especially in Davao del Norte but also in Mindanao, Luzon and Visayas
- Queensland Department of Agriculture and Fisheries (including Biosecurity Queensland)

Final users are current and potential banana farmers in the Philippines and Australia. This includes multinational corporations and prominent farming families in the Philippines who manage banana plantations.

Using a disinfectant footbath before entering a field to minimise the spread of *Fusarium* wilt
Photo: Conor Ashleigh

5 Impact assessment

5.1 Impact pathways

The project had well-defined impact pathways that were well implemented, although initially lacking in direct engagement with farmers and local governments in the Philippines. The project was successful in facilitating behaviour change in Australia, as the project team was familiar with the structure of the Australian banana industry, worked directly with producers who understood the consequences of not managing the outbreak, and was able to 'influence the influencers'. The project was less successful in facilitating behaviour change in the Philippines due to poor engagement with Philippine smallholders from the start of the project due to security concerns, and an initial lack of understanding of the structure of the banana industry in the Philippines, where behaviour is determined by multinationals and prominent families rather than small-scale farmers. These findings are explained in more detail below.

The Philippines

The project had well-defined extension and communication activities. The initial project leader is an extension specialist who facilitated a strong impact pathway for the project, including:

1. **Placed-based experimentation and learning.** The provincial agricultural departments conducted trials in Davao Del Norte in collaboration with USeP's Tagum campus.
2. **Cooperation.** Cooperation between researchers and local government staff throughout the project.
3. **Development of information, extension and communication materials.** These materials were prepared in the form of leaflets and posters containing information on basic biology and epidemiology of the disease, as well as quarantine and proper management protocols.
4. **Distribution of information, extension and communication materials.** Materials were distributed to banana growers during training activities, consultations and the Mindanao-wide symposium. Davao del Norte extension officers held many small-group meetings. The symposium was attended by over 150 people across 11 provinces, including banana growers, provincial agriculturalists and representatives of industry bodies. It was designed to bring together agriculturalists across provinces in Mindanao and update them on *Fusarium* wilt biosecurity and farm management practices. The Philippine and Australian research team, as well as banana growers from Australia, attended and contributed to the symposium.
5. **Facilitation of further municipal agriculture extension materials.** These were based on project materials that were distributed to banana growers.

There were some weaknesses in this impact pathway. Smallholders were not engaged with the project at the start, as they were deemed to be in areas of high security risk and far from Davao City, making monitoring difficult. A consultant who was engaged specifically to assist with smallholder engagement was included as a project partner. However, as the project progressed, a large part of their engagement was with large corporate groups, and the consultation, inclusiveness and engagement with local government units was poor.

There has been little evidence of *Fusarium* wilt biosecurity and management change arising from the project. The project was successful in achieving its objectives and outcomes, but this has not translated to significant landholder behaviour change in the Philippines. The project conducted surveys of almost 400 Philippine banana growers at the start (2015) and towards the conclusion (2017) of the project. The surveys showed there had been an increase in the incidence of the disease over the project and a sharp drop in number of growers with no *Fusarium* wilt. By the end of the project, there were small increases in awareness and knowledge of the disease and how to manage it. The project changed attitudes to microbes and soil health but created little change in the eradication methods used by banana growers or in attitudes towards disease control measures.

Two of the project's recommended management practices were of primary importance:

1. the use of vegetated groundcovers, which are essential for increasing microbial activity in the soil, thereby reducing the incidence and severity of the disease
2. the use of resistant banana varieties.

By the end of the project, there was a 4% increase in awareness of the importance of vegetated groundcovers and a 28% increase in the number of respondents using a resistant variety (Pattison 2019). However, banana growers still lacked sufficient knowledge about the disease to implement the proper management approaches, many growers lacked sufficient capital to implement these approaches, there was still a popular misconception that there was no effective method to manage the disease, and the adoption of the resistant variety was still low (Pattison 2019). The final survey found that the reasons for this lack of behaviour change included financial constraints, limited access to planting material of the resistant variety, and conflicting practices recommended by the government, the grower's cooperative and/or fruit buyers. The latter issue was a major impediment. Information was conflicting and there was no recognised single, reliable source of information the farmers trusted that was presented in a language and format they could understand and implement.

Recent consultation with project partners has indicated that, since the conclusion of the project, grower response to the disease is still slow. The project has improved the evidence base for identification, diagnostics and response, but biosecurity to prevent and manage the disease is still poor and the disease continues to spread.

The dominant reason for the lack of behaviour change due to the project is that key practices for managing *Fusarium* wilt conflicted with those recommended by multinationals. When developing the project proposal, it was largely assumed that the structure of the banana industry in the Philippines was similar to that in Australia. In reality, the industry structures are quite different. In Australia, farm-level decision-making resides with individual banana producers. In the Philippines, it is jointly controlled by multinational corporations and prominent local families. Small-scale landholders are contracted by multinational companies and must follow the standard procedures outlined by the company or they are unable to sell their produce.

Often multinationals required farming practices that encouraged the spread of *Fusarium* wilt, rather than its suppression. For example, during the project, multinational organisations required no groundcovers on banana plantations, whereas the project highlighted that groundcovers are essential for suppression of the disease. If smallholder farmers went against the multinational requirements, buyers such as Dole had the right to forego sale and the farmers had no other options for selling their bananas. The goal of the project was to improve the livelihood of smallholders and communities, and the impact pathway was developed to work with smallholder banana growers. As smallholders were unable to change practices without endorsement from the multinationals, there was little behaviour change.

As the project progressed, the understanding of the structure of the industry also progressed, and project team members realised the importance of engaging the multinationals. While ACIAR was flexible and in favour of changing communication activities to focus on multinationals, project partners found it difficult to gain access to representatives of these companies. The heads of the research and development units of these organisations were difficult to engage. When the project team could engage with multinationals, they encountered difficulties in conducting research activities. For example, trial sites that were preferred by multinationals were not considered by the local research team to be the most appropriate sites for scientific purposes. Towards the end of the project, team members had a good relationship with multinational companies, but by then it was too late to gain significant behaviour change through the project. The opportunity to work with Department of Agriculture officers in the Mindanao Region, who work closely with the multinationals for mutual benefit, was underutilised.

A more holistic and nuanced understanding of the structure of the banana industry in the Philippines would have allowed impact pathways to focus on gaining awareness, understanding and behaviour change within multinationals and prominent farming families. A feasibility study at the outset of the project may have provided this understanding, as well as including farmers and industry in the project team. Working closely with local government units to support their extension efforts, and working with influential farmers from the outset of a project, to make sure they are aware of the research process, facilitates important feedback loops and can generate stronger farmer-to-farmer practice change.

Lessons learned from issues in the project's impact pathway in the Philippines have allowed for different approaches to future work in this area. Significant groundwork has focused on understanding banana industries in Laos and Indonesia (HORT/2018/192) and Mozambique, South Africa and Tanzania (HORT/2020/128) for the current *Fusarium* wilt projects. These projects aim to address the disease in countries with significant banana production and consumption, so the initial focus of understanding industry structure in these countries is likely to have a significant impact on smallholder livelihoods.

Australia

The project's impact pathways worked very well to facilitate practice change in Australia. The impact pathway included:

- farmer-driven and place-based experimentation and learning
- cooperation between researchers, industry and farmers throughout the project
- use of field days and roadshows for farmer extension activities
- extension material produced and disseminated by the banana industry
- adaptive learning in response to emerging issues.

Extension activities were primarily performed by the banana industry. The project team brought content, knowledge and advice to the Australian Banana Growers' Council (ABGC), Australia's peak banana industry body, who engaged with the project team and other state government researchers (Queensland Biosecurity) to provide extension services to growers. *Fusarium* wilt had not yet reached Queensland when the project first commenced. When it was first identified in Queensland, the industry reacted quickly and decisively. No visitors were allowed on the affected property, and the ABGC purchased the property and ceased its banana production. The industry was then vigilant with surveillance and biosecurity. Grower meetings were held frequently (almost weekly) in many locations. The project team and growers who had visited the Philippines as part of the project were a major information resource at this time and contributed significantly to these activities.

The project was able to 'influence the influencers'. One grower held field trials on his farm aiming to find ways to manage *Fusarium* wilt. He took the research further than the team expected and his work was a key success of the project.

Of particular benefit to growers in learning to prevent the spread of *Fusarium* wilt in Australia was a biosecurity planning and knowledge workshop delivered by the ABGC. The project team contributed significantly to the workshop. Growers who participated in the workshop brought aerial photos of their farm and were able to draft a biosecurity plan for protecting their farm from the disease. The post-workshop evaluation indicated an improved attitude to disease prevention and a strong increase in planning and knowledge.

Project partners gave significant content and knowledge to a number of forums that were held to increase awareness and knowledge of *Fusarium* wilt management, including:

- Panama disease field day (12 May 2017), held in South Johnstone with 100 banana growers and agribusiness representatives
- Australian Banana Industry Congress (22 June 2017), held in Sydney with 200 banana growers and agribusiness representatives
- 6 Australian Banana Industry roadshows (24 July to 30 August 2018), with 120 banana industry representatives.

A number of videos and multimedia were produced, with significant input from the project. This included *Landline* programs and YouTube videos on the history and science of *Fusarium* wilt, and the benefits of disease prevention.

These activities helped growers understand the major barriers and drivers to implementing biosecurity measures. They were able to understand what they needed to do to prevent *Fusarium* wilt entering their property, and how to do it. The reasons for the success of the project's impact pathway in Australia were that the project team was more familiar with the structure of the Australian banana industry, the banana farming systems in Australia were well understood, extension networks were already well established, the size of the banana industry is small (relative to the Philippines), the consequences of not managing the outbreak were understood, and the project team and its collaborators were able to 'influence the influencers'.

5.2 Economic impact

The project was timely in both the Philippines and Australia. While it had limited impact on practice change in the Philippine banana industry as a whole, due to the size and value of the industry even this limited impact on practice change has created a valuable economic impact. The scientific base generated in the Philippines was of very high value in helping contain the outbreak of TR4 in Australia a year after the project started.

Quantifying the economic impacts of the project is difficult and fraught with uncertainty. The following estimates should be considered as indicative only.

The Philippines

Source of economic impact

In the Philippines, the project:

- improved on-farm biosecurity measures, such as the use of marked walkways and vehicle tracks; the use of effective sanitiser on vehicles, clothes and other; and early detection and quick destruction of diseased plants
- developed awareness of the importance of maintaining groundcover to prevent and suppress spread of the disease
- encouraged adoption of cultivars that are partially resistant to TR4.

When land is affected by TR4, small landholders usually plant short-duration vegetables and maize instead. Multinational companies generally leave infected banana crops for some time then replace them with resistant varieties of banana.

The project showed farmers that if TR4 was detected in their banana plantation, they did not have to switch to other crops or abandon the land, but could continue to produce bananas by using partially resistant varieties within an integrated crop management system. This includes monitoring for early detection, appropriately destroying affected plant material (using urea rather than burning), employing biosecurity measures such as establishing entry and exit points, using footbaths, using cover crops and reducing the use of agrochemicals.

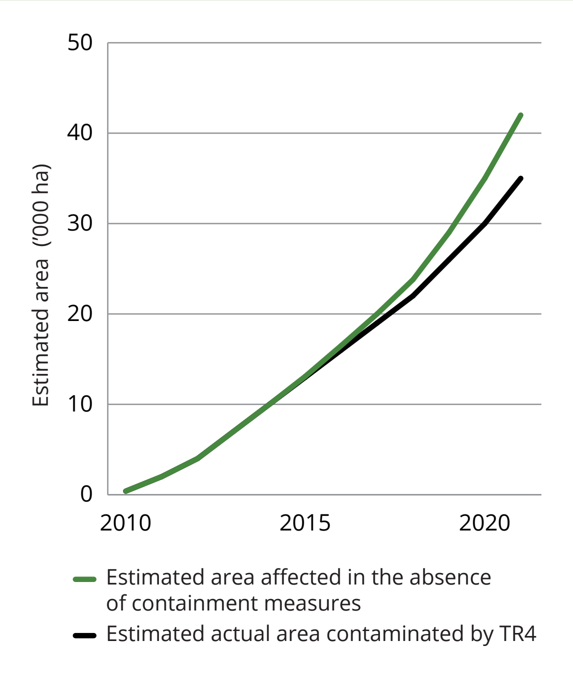
Based on the consultation process undertaken to inform this impact assessment, it is assumed that the project had 2 major economic impacts:

- reducing the spread of *Fusarium* wilt
- encouraging the adoption of partially resistant varieties on affected land.

Reducing the spread of *Fusarium* wilt

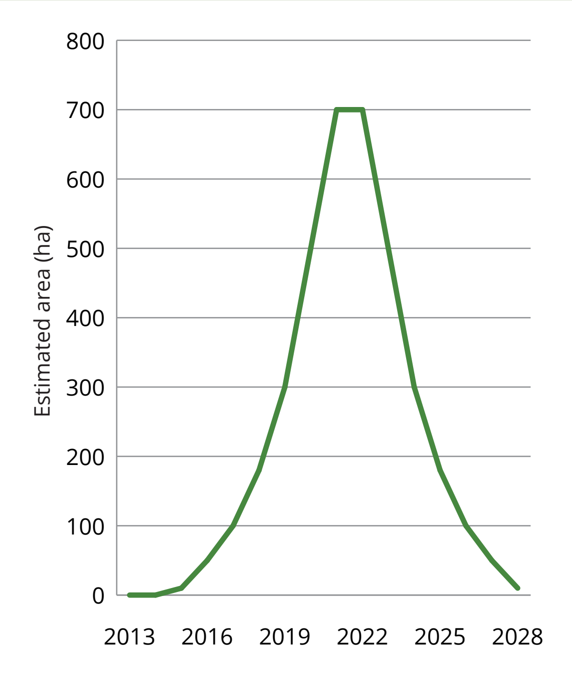
Figure 5.1 shows the estimated area of land currently affected by TR4 (black line), and the estimated area that would have been affected in the absence of control measures (green line). The green line is an estimate based on information provided by project participants during the consultation process about the extent of the impact of the project in containing the disease. It represents spread of the disease without research, development and extension (RD&E) activities. The difference between the green and black lines provides an indication of the adoption benefits of *Fusarium* wilt RD&E in the Philippines.

Based on our consultation process, we estimate that that 10% of this adoption benefit is attributable to the project. The estimated adoption impact of the project to 2030 is shown in Figure 5.2. The benefits attributable to the project are expected to have begun to diminish from 2022 as they become superseded by the scientific and extension efforts of the current project.



Source: Authors' estimates based on consultation

Figure 5.1 Estimated area of banana-producing area in the Philippines affected by TR4 and affected in the absence of containment measures, 2010–2020



Source: Authors' estimates

Figure 5.2 Estimated banana-producing area in the Philippines unaffected by TR4 due to the project, 2013–2028

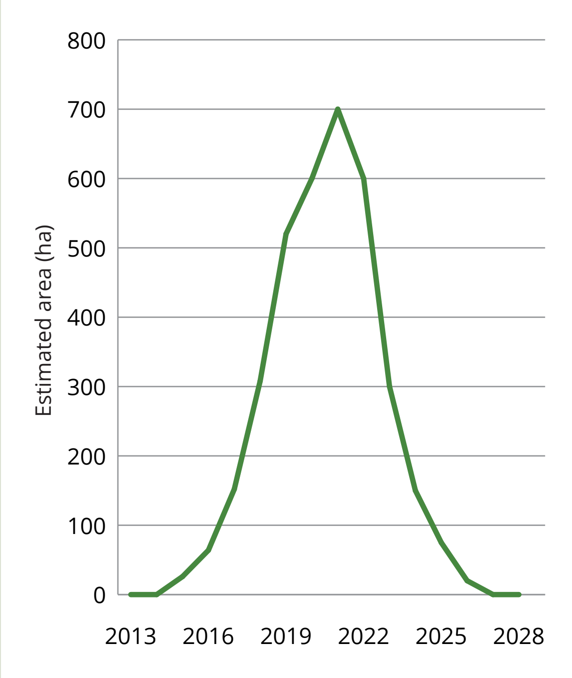
Encouraging adoption of partially resistant varieties on affected land

Based on consultation processes, we estimate that by the completion of the project approximately 20% of land affected by *Fusarium* wilt in the Philippines had been sown to partially resistant varieties, and that 10% of this adoption can be attributed to the project. Figure 5.3 shows the project's adoption impact for encouraging use of partially resistant varieties, extrapolated to 2028.

Estimating the economic benefits of the project's adoption impacts

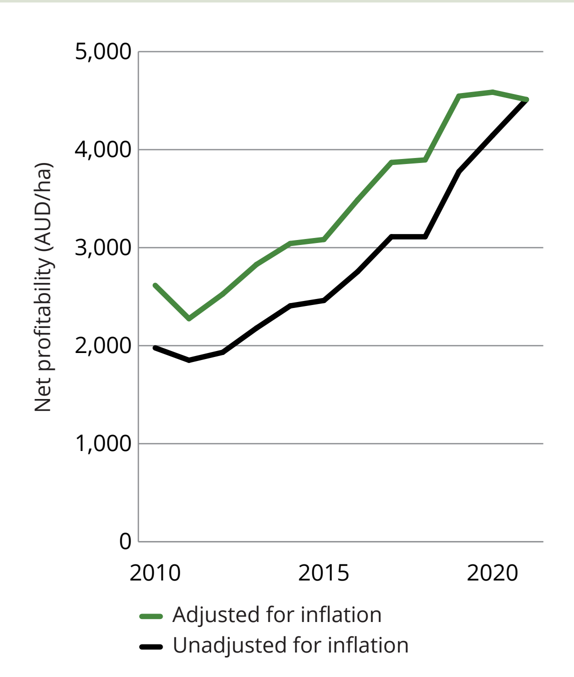
The value of the project's adoption impact is estimated to be profitability of banana production minus the profitability of maize production (considered to be the next best alternative) in the Philippines. The estimated profitability of banana and maize production over time is shown in Figures 5.4 and 5.5.

The value of the project's impact in terms of reducing the area affected by TR4 can be calculated by multiplying the difference between the net profitability of banana and maize production by the area of land unaffected by TR4 due to the project (Table 5.1).



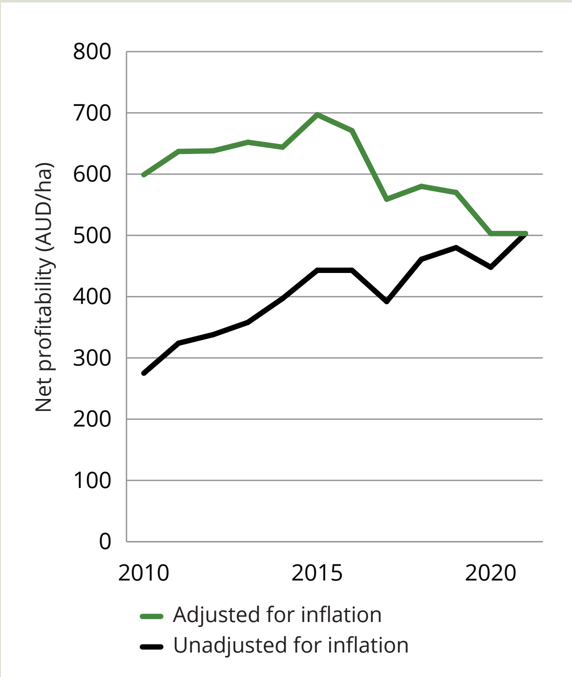
Source: Authors' estimates

Figure 5.3 Estimated area of land contaminated with TR4 planted to partially resistant banana varieties due to the project, 2013–2018



Source: Authors' estimates using FAO 2022 and Loquias et al. 2022

Figure 5.4 Estimated profitability of banana production in the Philippines, adjusted and unadjusted for inflation, 2010–2021



Source: Authors' estimates using FAO 2022

Figure 5.5 Estimated profitability of maize production in the Philippines, adjusted and unadjusted for inflation, 2010–2021

Table 5.1 Calculation of the value of the project's impact on reducing the area affected by TR4

Year	Reduction in FW area due to project (ha)	Net profit of banana production (AUD/ha)	Net profit of maize production (AUD/ha)	Value of reduction in FW area due to project (AUD/ha)	(AUD)
	A	B	C	B – C	A x (B-C)
2015	10	3,083	697	2,386	23,864
2016	50	3,488	671	2,817	140,842
2017	100	3,869	559	3,309	330,926
2018	180	3,895	580	3,315	596,646
2019	300	4,546	570	3,976	1,192,781
2020	500	4,586	503	4,083	2,041,724
2021	700	4,511	503	4,008	2,805,536
2022	700	4,511	503	4,008	2,805,536
2023	500	4,511	503	4,008	2,003,954
2024	300	4,511	503	4,008	1,202,372
2025	180	4,511	503	4,008	721,423
2026	100	4,511	503	4,008	400,791
2027	50	4,511	503	4,008	200,395
2028	10	4,511	503	4,008	40,079

Note: FW – Fusarium wilt; AUD – real AUD

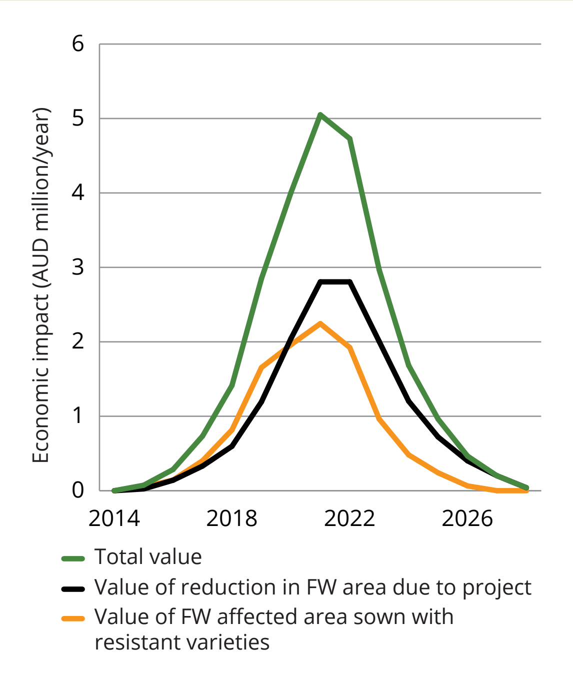


Figure 5.6 Indicative economic impact of the project in the Philippines, 2014–2028

Similarly, the value of the project's impact in encouraging adoption of partially resistant varieties on areas affected by TR4 can be calculated by multiplying the net profitability of banana production by the area of land affected by TR4 sown to partially resistant varieties (Figure 5.6). Partially resistant varieties are estimated to yield 80% of the profitability of non-resistant varieties in the absence of *Fusarium* wilt. Adding the value of the project's impact of reducing the area affected by TR4 (black line in Figure 5.6) and value of the project's impact in encouraging adoption of partially resistant varieties on areas affected by TR4 (orange line) leads to the total economic impact of the project over time (green line).

Australia

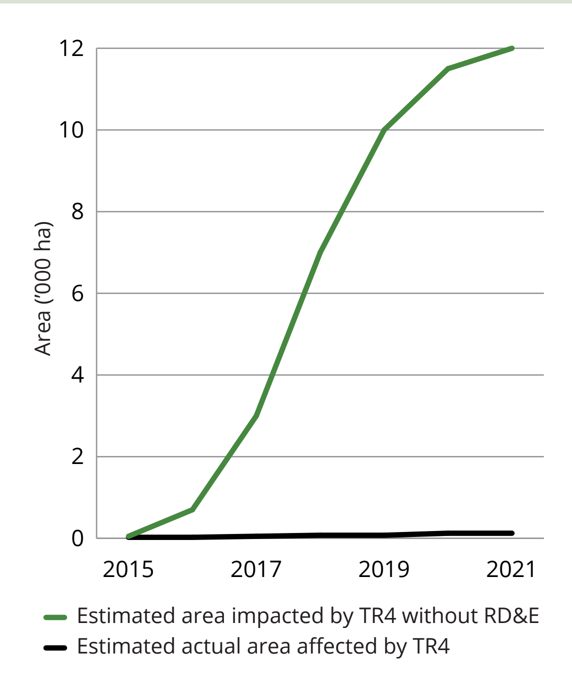
Source of economic impact

TR4 was first detected in Queensland about a year into the project. By then the project team had developed strong experience in disease suppression systems and was able to provide scientific knowledge about how to contain the disease by using groundcovers and appropriate biosecurity measures, fertiliser practices and farm design. The Queensland Department of Agriculture and Fisheries biosecurity extension team held workshops with farmers and industry to extend this knowledge. The project's work in the Philippines made a major contribution to the successful containment of TR4 in Queensland, especially as Australia imposed a moratorium on the use and movement of contaminated plant material. While the overwhelming contribution to the successful containment of TR4 in northern Queensland was the state biosecurity legislation and investment by state and federal government, the project made an important contribution to the increased knowledge about TR4 and enhanced Australia's capability to effectively manage the disease. It was a key information source at a time when the Australian banana industry was very vulnerable.

Australia's banana industry is solely focused on Cavendish, which is suspectable to TR4. Some varieties have high tolerance to TR4, but they have approximately 25% less yield potential. No productive varieties are likely to be available in the short to medium term. Moving the Queensland banana industry is also not an option as the only suitable land in Far North Queensland is a small coastal strip. There are few alternative enterprises in the high-rainfall region that have similar profitability. For example, the domestic market for pawpaw and other tropical fruits is so small that changing land use to these fruits would flood the market, leading to low prices and reduced profitability. It is unlikely that Australia will have comparative or competitive advantage in tropical fruit in the export market. We assume that the next best alternative use of the land is sugarcane, which is significantly less profitable.

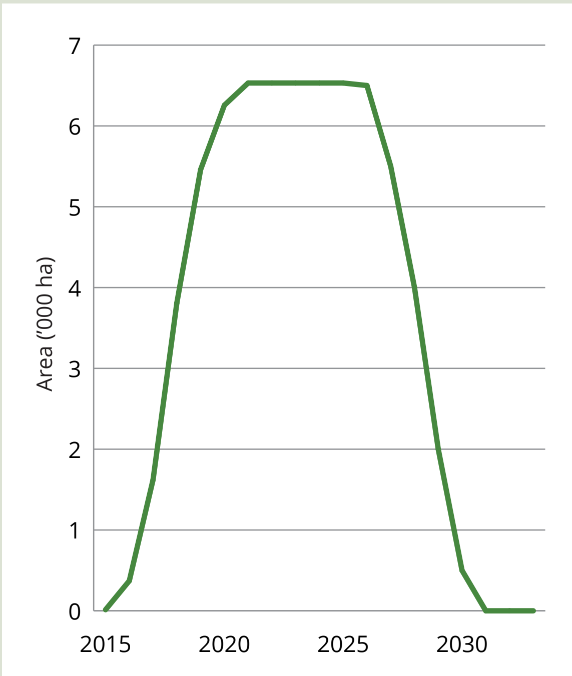
Estimating the impact of the project in reducing the spread of *Fusarium* wilt

Figure 5.7 shows the estimated area of land currently affected by TR4 in Australia (black line), and the estimated area that would have become contaminated without RD&E activities (green line). These estimates are based on information provided during our consultation. The difference between the black and green lines provides an indication of the adoption benefits of *Fusarium* wilt RD&E in Australia.



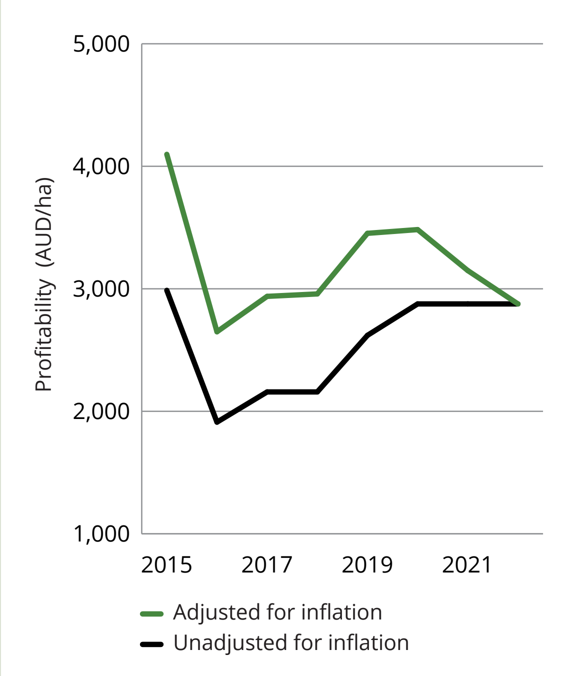
Source: Authors' estimates based on consultation

Figure 5.7 Estimated area of TR4 in Australia with and without *Fusarium* wilt RD&E activities, 2015–2021



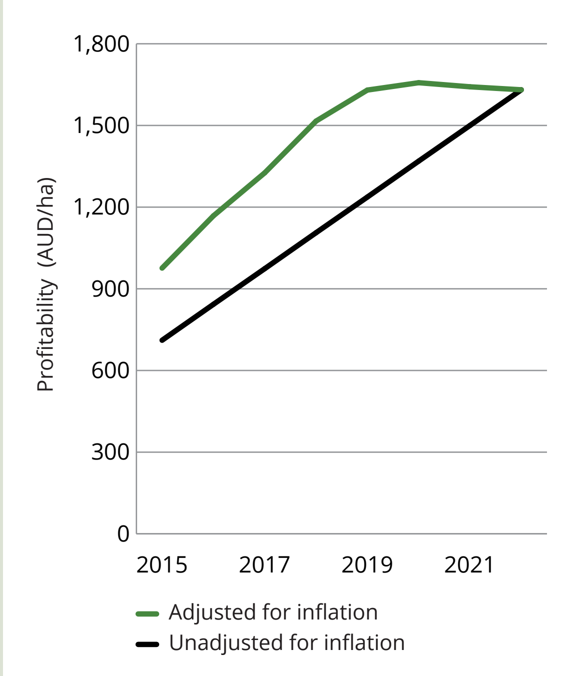
Source: Authors' estimates

Figure 5.8 Estimated banana-producing area in Australia prevented from being affected by TR4 due to the project, 2015–2035



Source: Authors' estimates using FAO 2022 and Hall 2018

Figure 5.9 Estimated profitability of banana production in Australia, adjusted and unadjusted for inflation, 2015–2022



Source: Authors' estimates using FAO 2022 and Hall 2018

Figure 5.10 Estimated profitability of sugarcane production in Australia, adjusted and unadjusted for inflation, 2015–2022

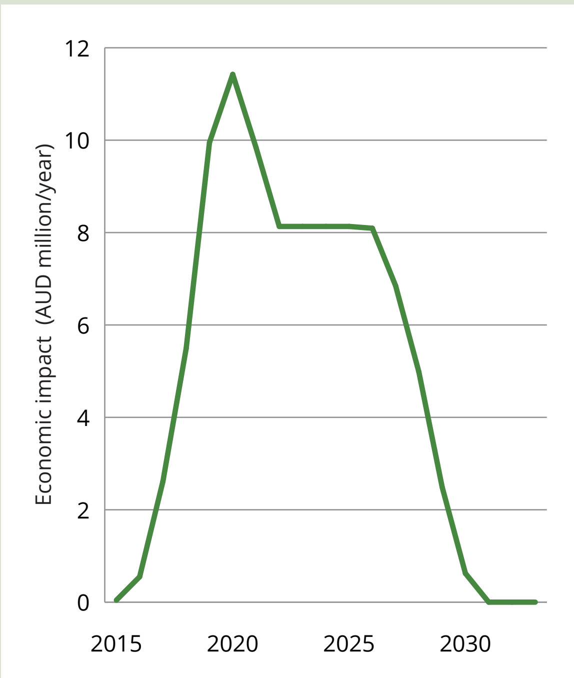


Figure 5.11 Indicative economic impact of the project in Australia, 2015–2031

During the consultation phase, we asked project participants what proportion of this adoption benefit they thought was attributable to the project. The average of all responses was 55%. The estimated adoption impact of the project is shown in Figure 5.8 (page 21), extrapolated to 2035. The benefits of the project are expected to diminish in time as RD&E initiatives from other projects supersede that of this project.

Estimating the economic benefits of the project's adoption impacts

The value of the project's adoption impact is determined by the difference between the profitability of banana production and sugarcane production in Australia (Figures 5.9 and 5.10).

The value of the project's impact of helping to contain TR4 in Australia (Figure 5.11) can be calculated by multiplying the area prevented from being affected by TR4 due to the project (Figure 5.8) by the difference in profitability of banana and sugarcane production (Figures 5.9 and 5.10).

Discounted cashflow analysis of the project's economic impact

Standard discounting cashflow analysis is used to estimate the project's economic impact. All values are converted from nominal (current) monetary values to real (2022) values. The time value of money is accounted for using a discount rate. A 5% standard discount rate is used. Results of the discounted cashflow analysis are presented in Table 5.2 for the indicative benefits generated by the project. Summing the compounded benefits over time comes to AUD27 million (PHP1,000 million) for the project's work in the Philippines, and AUD93 million for its work in Australia, for a total of AUD120 million (PHP4,400 million).

Table 5.2 Discounted cashflow analysis of the indicative economic impact of the project (present values)

	AUD (million)	PHP (million)
Indicative benefits – The Philippines	26.6	985
Indicative benefits – Australia	93.5	3,460
Total indicative benefits	120.1	4,440
Total costs	1.68	62.2
Net indicative benefit	118	4,380
Benefit:cost ratio	71.5	

The project cost was AUD822,050 in 2014, which, after adjusting for inflation and accounting for the time value of money, is equivalent to a present value of AUD1.7 million. The indicative net benefit of the project (the difference between the present value of the benefits and costs) is estimated to be AUD118 million. The benefit:cost ratio is 71, meaning that for every dollar invested by ACIAR, the project is expected to generate about 71 dollars (PHP2,600) in return. This represents a very good return on investment compared with other agricultural research projects. For example, Alston et al. (2020) found that over the past 5 decades, CGIAR's investment in agricultural research has returned a benefit:cost ratio of 10:1.

A sensitivity analysis was conducted on key assumptions of the discounted cashflow analysis, and the resulting benefit:cost ratios are presented in Table 5.3. Four key assumptions are considered:

1. the discount rate – a low discount rate of 3%, a standard rate of 5% and a high discount rate of 7%
2. the benefits of *Fusarium* wilt control in the Philippines attributable to the project – a low level of 5%, a standard level of 10% and a high level of 25% (values provided through the consultation process)
3. the benefits of *Fusarium* wilt control in Australia attributable to the project – a low level of 25%, a standard level of 55% and a high level of 75% (values provided through the consultation process)
4. the banana gross margin – where the standard gross margins are reduced and increased by 20%.

Based on this sensitivity analysis, it is estimated that the project's benefit:cost ratio may range between 44 and 99. The ratio is most sensitive to our estimates of banana gross margin.

5.3 Inclusivity of the value chain impact

The project did not have a specific value chain focus, and as such did not have a significant impact on the inclusivity of the value chain, although its production-based research had flow-on value chain impacts. This was especially true in Australia where supply chains are more vertically integrated than those in the Philippines.

The Philippines

The project recommended the use of resistant and partially resistant cultivars within a disease suppression system. Demand for these cultivars outstripped supply from established nurseries, meaning that smallholder growers were unable to access the cultivar to replant fields (Pattison 2019). The project recognised the limited access that smallholders had to resistant cultivars and, in response, established tissue culture laboratories at USeP Tagum and the Provincial Agricultural Office in Davao del Norte.

Table 5.3 Benefit:cost ratio with low, standard and high values for key assumptions of the discounted cashflow analysis, 2015 to 2030

	Level of each key assumption		
Key assumptions	**Low**	**Standard**	**High**
Discount rate (3%, 5%, 7%)	83	71	62
Project attribution in the Philippines (5%, 10%, 25%)	67	71	86
Project attribution in Australia (25%, 55%, 75%)	47	71	88
Banana production gross margin (0.8, 1.0, 1.2)	44	71	99

This has improved confidence for landholders to continue production of bananas in the presence of the disease, providing hope for ongoing employment and investment.

While the project did not have a specific value chain focus, team members did try to engage with the supply chain participants but faced difficulties. For example, multinational companies prevented the project team from visiting packing houses for bananas due to security concerns.

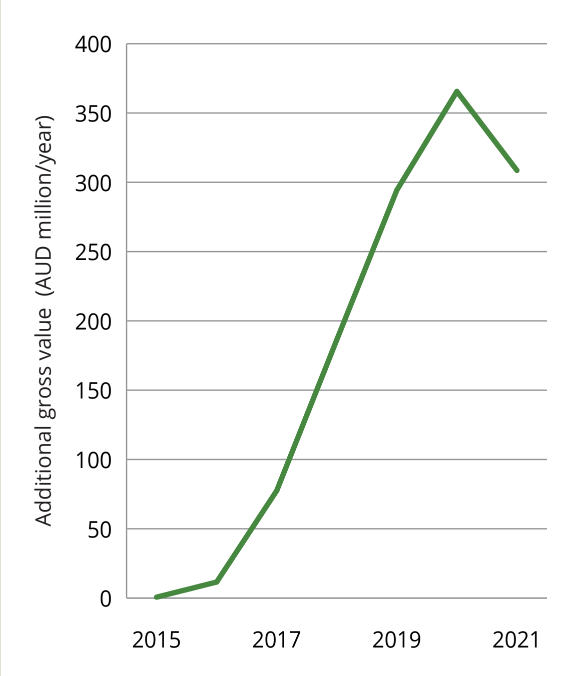
The producers whom the project engaged with were mostly men. The project managers observed that more men work on farms and more women work in packaging plants. Most of the senior staff in the offices of the cooperatives are women. There is an opportunity for women to play a larger role across the supply chain and in distribution channels.

Australia

Supply chains are vertically integrated in Australia, so the project's contribution to protecting the banana industry had flow-on benefits in protecting the industry's supply chain. Hall and Gleeson (2013) estimate an output multiplier of 1.88 for Far North Queensland's banana industry, meaning that a 1 unit increase in final demand in the industry is estimated to lead a 1.88 unit increase in the total value of sales across all industry sectors. The output multiplier includes:

- direct impacts (expenditure by banana growers)
- indirect impacts (additional purchases made in the region by businesses that deal with the banana industry as a result of the income they derive from the banana industry)
- induced impacts (expenditure on local goods and services made by households who earn wages or income from the banana industry).

The estimated gross value of the Australian banana industry due to the project's success in facilitating containment of *Fusarium* wilt over time is shown in Figure 5.12. This is calculated by multiplying the additional area of banana production in Australia prevented from being affected by TR4 due to the project (Figure 5.7) by the yield and price of bananas each year. Multiplying these values by the output indicator (1.88), compounding them to present values and summing them across time provides an estimate of the impact on the value of the project across the whole industry. The final value is about AUD12 billion between 2015 and 2021.



Source: Authors' estimates

Figure 5.12 Estimated additional gross value of the Australian banana industry attributable to the project, 2015–2021

It is predicted that, in the absence of RD&E activities, the banana industry in Far North Queensland would have been destroyed by TR4, leading to the loss of about 4,800 full-time jobs. Assuming that 55% of this impact can be attributed to the project, that equates to the saving of about 2,600 full-time jobs. Multiplying this by the employment multiplier of 2.52 (Hall 2018) suggests that the project has saved about 6,700 full-time jobs along Australia's banana supply chain by helping to contain *Fusarium* wilt.

5.4 Environmental impact

The project improved awareness of environmental management practices in the Philippines that have the potential to generate significant environmental impact over time. In Australia, the project was instrumental in generating environmental practice change that is likely to reduce agrochemical run-off into the Great Barrier Reef.

The Philippines

The project improved awareness of the use of environmentally sustainable management practices that suppress *Fusarium* wilt in banana production. Environmental practices that were recommended by the project include:

- **Use of groundcover.** Groundcovers increase microbial activity in the soil and reduce the incidence and severity of *Fusarium* wilt. Groundcovers that are local to the area, such as legumes, grow quickly and stabilise the soil, reducing soil loss and erosion as well as increasing soil organic carbon and nitrogen. By the end of the project, there was significant awareness and interest among small to medium landholders and multinational companies about the use of groundcovers. This is especially important in the Mindanao area, where typhoons are common and are expected to increase in frequency and severity. Over the last 10 years, flooding has occurred on average twice each year on 40% of land planted to Cavendish in Davao del Norte, making the spread of *Fusarium* wilt extremely difficult to contain. Use of groundcovers will reduce the spread of the disease during flood events.
- **Reduction in the use of agrichemicals.** The project increased awareness of appropriate chemical biosecurity measures and recommended that banana growers stop using hazardous chemicals, such as formalin, which are known to be corrosive, toxic and ineffective at reducing *Fusarium* wilt. It also recommended reduced use of herbicides and insecticides to increase microbial activity in the soil and reduce the incidence and severity of *Fusarium* wilt.
- **Use of urea.** Urea generates ammonium gas, which kills the *Fusarium* wilt inoculum. The banana industry had been burning rice hull to kill the inoculum in the soil, but this practice contributes to the release of greenhouse gases into the atmosphere, especially carbon dioxide. Rice hull burning had been prohibited by local government ordinance but the ban was largely unenforced and rarely heeded by growers. The recent development of a market for rice hull has helped reduce burning, but the project's cost-effective recommendation to use urea to kill the inoculum has also contributed to reduced burning of rice hulls and associated environmental impacts.

The project raised awareness of these environmental practices in the Philippines, and this has developed into strong interest from small- to large-scale growers and multinational corporations. While the project has led to little environmental impact so far, this and the subsequent ACIAR projects ('An integrated management response to the spread of *Fusarium* wilt of banana in South-East Asia' (HORT/2018/192) and 'Developing a biosecurity system for small banana growers resilient to *Fusarium* wilt TR4 in southern and eastern Africa' (HORT/2020/128)) are expected to lead to significant environmental impact as ways to prevent and mitigate the diseases develop and associated awareness and adoption of environmental practices grows.

Australia

The project had a large environmental impact in Australia, and this is expected to be sustained in the long term. One of the reasons for this impact is the proximity of banana production to the Great Barrier Reef – a United Nations Educational, Scientific and Cultural Organization (UNESCO) world heritage site and the world's largest collection of coral reefs (UNESCO 2022). Behaviour change attributable to the project is expected to reduce the environmental impact of soil erosion and water run-off the water quality of the Great Barrier Reef.

Project recommendations having significant environmental impacts include:

1. **Use of groundcover.** Groundcovers increase microbial activity in the soil and reduce the incidence and severity of *Fusarium* wilt. This practice had been established in the banana industry to manage soil erosion and soil quality, but its adoption increased quickly once the project advocated for its disease control benefits.
2. **Increased biodiversity management.** The project encouraged farmers to allow the natural growth of plants as groundcover on the orchard floor, instead of maintaining a bare orchard floor or sowing or encouraging groundcover monocultures. A diversity of groundcover increases soil microbes, reducing the incidence and severity of *Fusarium* wilt and preventing soil erosion.
3. **Use of smart input production systems and nutrient management plans.** These systems include reduced use of agrochemical inputs, including nitrogenous fertiliser, increased use of environmentally sustainable non-toxic sanitiser, and safe use and disposal of chemicals. This reduces the potential for eutrophication of the Great Barrier Reef and the release of nitrous oxide emissions from the soil. The suppression of TR4 through reduced nitrogen inputs will also help the banana industry in north Queensland meet the nutrient application targets that are intended to improve run-off water quality and protect the Great Barrier Reef (Pattison 2019).

Adaptive capacity of banana producers is strong in Australia, fuelled at least in part by the potential decimation of the banana industry in Queensland if *Fusarium* wilt is not contained. This has led to strong behaviour change and sustained environmental impact.

5.5 Capacity impact

The project had a strong capacity impact among project staff and students in the Philippines, and broadly among project participants, industry and producers in Australia.

The Philippines

The project's largest impact in the Philippines was in capacity. Before the project commenced, understanding of soil biology was low, as was knowledge of *Fusarium* wilt, its potential impact on the banana industry, and containment and management practices. The project worked closely with staff and students of research institutions, particularly USeP. The Philippine project partners were from USeP's main Obrero campus, but the project extended capacity support to the Tagum-Mabini campus. Many of these staff and students had family members involved in banana production who helped disseminate the project findings.

Some of the capacity developed by staff and students at USeP due to the project include:

- a deeper understanding of soil biology beyond ecology and disease suppression, including soil biological diversity, degradation of pollutants, soil structure, nutrient cycling and retention
- skills in laboratory techniques and methods for soil microscopy
- collaborative research skills development and the capacity to continue *Fusarium* wilt and microbiome research beyond the life of the project.

Philippine project partners were involved as project managers and led a team of researchers to conduct specific research activities and experiments. These partners excelled in their respective fields of specialisation. The project teams developed science-based capacity that had flow-on scientific benefits for the country, such as improved understanding of how to measure enzymatic activity and infection in the soil, which is an indicator of soil microbial activity and function.

The project built scientific capacity through the establishment of a molecular laboratory at USeP's Tagum campus, which improved access for students and researchers to equipment. While the project financed the purchase of the equipment, the Australian partners gave hands-on training on the operation of the equipment and taught scientific explanations of results and findings. Students learned how to use equipment through hands-on tuition. Throughout the project life, the Australian project leaders and team monitored Philippine partners and imparted newer techniques and skills each time they visited.

The project also helped change the mindset of project partners from a top-down approach where members were uncomfortable voicing their opinions to their superiors to a more collaborative and supportive approach. This created a paradigm shift leading to an adaptive management method of RD&E.

The project team conducted significant training of local government officials in key management practices that suppress the spread of *Fusarium* wilt, such as the use of groundcovers and the adoption of resistant banana varieties. The project provided training on extension techniques, which are expected to lead to long-term economic benefits to Philippine banana growers.

The project held a workshop in Davao City with team members, Australian banana growers and provincial agriculturalists to create an understanding of biosecurity requirements for containing *Fusarium* wilt. However, this strengthened capacity did not lead to significant on-farm practice change due to lack of adaptive capacity of smallholders, as decision-making was directed through multinational corporations.

ACIAR held annual meetings in the Philippines for all its horticulture projects to allow partners to interact and engage across projects. International researchers came from other ACIAR projects (e.g. Indonesia and Pakistan). This created capacity benefits beyond the project in Mindanao to all banana-producing areas in the Philippines and beyond.

The project employed 4 research assistants who completed their Master of Science at USeP. Thirty students participated in field research activities and 7 students (2 male and 5 female) presented outcomes at scientific forums. The project facilitated 2 scholarship opportunities for postgraduate studies: one John Allwright Fellowship and one Australian Award Scholarship.

The project undertook 5 specific activities in the Philippines to increase capacity in *Fusarium* wilt containment and suppression by banana growers and their service providers:

1. 556 banana growers participated in 11 focus group activities in 2015 in Davao del Norte
2. 385 banana growers participated in Good Agricultural Practice training in 2016 in Davao del Norte
3. 368 banana growers participated in focus group activities in 2017 in Davao del Norte
4. 500 professional agriculturalists attended the Philippine Agriculturists' Summit held in Davao City in November 2016
5. 150 banana growers and service providers attended the Mindanao Wide Symposium in February 2018 (Pattison 2019).

These activities generated significant capacity in Philippines among RD&E staff and students as well as growers. Two case studies are provided to illustrate this capacity impact. However, this capacity impact led to little behaviour change by banana growers, who were the intended beneficiaries of the project. A second project has been initiated, in part to address this limitation.

Case study: capacity building – Dr Cesar Limbaga

Dr Cesar Limbaga completed a Bachelor of Agricultural Science in 1998 at the Visayas State University, majoring in horticulture; a master degree in 2001 at USeP; and a PhD in Horticulture in 2011 at the Visayas State University. He has been employed at USeP since 2013.

Dr Limbaga joined the project when it commenced in 2014 and remained a project partner until the project's termination. His main research participation was evaluating and validating integrated crop management approaches to enable banana production in the presence of *Fusarium* wilt. He led a diverse team that conducted activities in Davao del Norte, setting up field experiments at 2 sites with varying experimental designs and conducting statistical analyses.

He developed significant understanding of *Fusarium* wilt disease and its management, which has allowed him to capitalise on opportunities since the project's completion. In 2018, he took part in an ACIAR John Dillon Fellowship where he had an opportunity to enhance his leadership skills in agricultural research management, agricultural policy and extension technologies.

Through participation in the research, Dr Limbaga learned that technology development must be science-based and dynamic, and that developing a suitable technology for a certain community must consider the system as a whole, be locally adapted and be tested through on-farm and off-farm trials. He also recognised the importance of the commitment of growers to adopt new technology, as they are the end users of the improved systems. He developed the confidence to share information on technologies and practices to suppress *Fusarium* wilt with students, academic staff, banana agriculture technicians and growers.

The capacity he developed from the project has helped him succeed in his career. He was Dean of the College of Agriculture and Related Sciences at USeP and is now Chancellor of USeP's Tagum-Mabini campus. He teaches major undergraduate and postgraduate subjects in horticulture and is engaged in research studies in the fields of *Fusarium* wilt on bananas, sucker management in Cavendish bananas and fertiliser management of bananas. Dr Limbaga is paying forward the support he received from the project by working to develop agricultural capacity in the university's staff and students. He continues to work towards managing *Fusarium* wilt in the Philippines.

Case study: capacity building – Ms Tamsi Jasmin Gervacio

Ms Tamsi Jasmin Gervacio is currently pursuing her PhD in the field of Agriculture, Land, and Farm Management at the University of New England, Australia. She has a bachelor degree in biology from St Paul College in Quezon City, the Philippines, and 2 master degrees: a Master of Agriculture in Environmental Dynamics and Management from Hiroshima University, Japan (2004) and a Master of Agricultural Studies from the University of Queensland, Australia (2009).

She joined the HORT/2012/097 research team at the start of the project in 2014 on the recommendation of the Director for the Southern Mindanao Agriculture and Resources Research & Development Consortium. She led project activities with a team of university staff and students and local government partners aimed at developing options for limiting production losses of Cavendish banana affected by *Fusarium* wilt. These activities included analysis of vegetative groundcover compared to bare soil to suppress *Fusarium* wilt, methods to reduce soil movement around the banana plants within and between plantations, and TR4 suppression in crop residue decomposition and plant eradication. The team conducted laboratory experiments and trials, validating their findings with on-farm experiments.

Ms Gervacio's team was trained and guided closely by the Australian partners in conducting the experiments using the latest techniques and equipment. The project funded the purchase of the new machinery by the university. Before the project, she did not have any knowledge of laboratory techniques for soil enzyme analyses or community level physiological profiling using Microresp, or capacity to operate a spectrophotometer.

She received hands-on training and improved her skills in conducting enzymatic tests, from soil collection and preparation to soil microbial profiling. Ms Gervacio has shared her technical learnings with students, farmers and other researchers, and has introduced her undergraduate students to these experiments.

As a faculty member, she had been teaching foundation and advanced subjects to undergraduate and postgraduate students, and was a thesis adviser to bachelor and master degree students majoring in biology. During the project, she supervised 16 female and 8 male bachelor students, and 1 male and 1 female master students. Overall, she had 30 students who participated in field research activities, 7 of whom received postgraduate qualifications. The significant capacity she developed while working on the project led her to a John Allwright Fellowship and the opportunity to study at University of New England.

Ms Gervacio recognised that, given farmers are the end users of project findings, they should be involved at the initial stage of the project planning. She believes that technology adoption and implementation can only prosper if farmers are consulted on the appropriateness of the technology and if it caters to their needs. She says, 'If farmers who are directly affected by *Fusarium* wilt are not made partners in a research project, appreciation and adoption of new knowledge and innovation will not prosper as it is perceived by project proponents.' This view has led to her shift into the multidisciplinary field of agriculture, land and farm management for her PhD studies. She believes that combined biological and social sciences research will lead to enhanced practice change and innovation by farmers.

Australia

The project had strong capacity impacts in Australia across stakeholders, including research staff and students, industry, and banana producers. Capacity development included:

- an in-depth understanding of microbial ecological relationships and how they impact the incidence and suppression of *Fusarium* wilt
- an understanding of how land and soil management affect soil organisms and therefore the expression of the disease
- testing, diagnosis and measurement of *Fusarium* wilt.

The project provided financial support for staff and graduate students to attend conferences related to *Fusarium* wilt. The project worked closely with the Queensland Department of Agriculture and Fisheries and the ABGC, providing synergistic benefits to additional investment in banana disease research.

In Australia, the project contributed to the development of significant capacity among banana growers in their knowledge of *Fusarium* TR4 and the management practices that prevent its spread. This information was presented at 4 banana industry forums:

1. 50 banana growers attended the Cassowary Coast Banana Growers' Association meeting in Silkwood in 2015
2. 100 banana growers attended the Panama disease field day in South Johnstone in May 2017
3. 30 agribusiness and policy makers were present at the Horticulture and Forestry Science Stakeholder engagement day in April 2017
4. 200 banana growers and service personnel participated in the Australian Banana Industry Congress in Sydney in June 2017 (Pattison 2019).

5.6 Scientific impact

ACIAR assesses scientific impact as either the **advancement of science** through the production of highly credible quality science research or the **development of knowledge unique for application in context**. This project's scientific impact was balanced between these two measures.

The project provided strong scientific knowledge of the epidemiology, management and social impact of TR4 (Pattison 2019). Initial scoping studies on microbiomes of banana cultures helped to develop disease suppression systems that have gained widespread credibility as a field of science. The project leadership generated a strong culture of publishing scientific fundings, attending conferences and meeting peers to generate scientific impact. The project's scientific findings in the Philippines were used to help contain the disease in Australia, especially in light of the moratorium on the use of contaminated soil and plant material in Australia.

The project's scientific impact went beyond the Philippines and Australia to other parts of the world within the broad network of *Fusarium* wilt specialists. The methodology used to determine soil microbial functions (such as assessment of soil enzymes and community level physiological profiling) is now being used in other crops, like sugarcane and avocado, for soil health assessments in Australia. The project finding of increasing soil biodiversity using vegetated groundcovers to suppress *Fusarium* wilt is being adapted for other banana-growing regions, such as Africa, Latin America and Asia. There is growing scientific interest in the project's recommended farm soil management practices to slow the spread of soil-borne disease as well as the integration of disease suppressive soil management practices with other management strategies.

The project produced 4 scientific papers:

1. Pattison AB, Molina AB, Chao CP, Viljoen A and Lindsay SJ (2018) 'Integrated management practices to support banana production in the presence of *Fusarium* wilt', *Acta Horticulturae*, 1196:129–136
2. McBeath AV, East DJ, Wright CL and Pattison AB (2018) 'Monitoring microbial functional and structural diversity for management of disease-suppressive soils', *Acta Horticulturae*, 1196:121–128
3. Pattison AB, East D, Ferro K and Dickinson G (2018) 'Agronomic consequences of vegetative groundcovers and reduced nitrogen applications for banana production systems', *Acta Horticulturae*, 1196:155–162
4. Rames EK, Pattison AB, Czislowski E and Smith MK (2018) 'Soil microbial community changes associated with ground cover management in cultivation of Ducasse banana (Musa sp. ABB, Pisang Awak subgroup) and suppression of *Fusarium* oxysporum', *Australasian Plant Pathology*, 47: 449–462

Altmetrics as at 1 May 2022:

- 4 citation indexes
- 1 link-out
- 2 export-saves
- 25 readers
- 2 social media tweets.

The Philippines

The project challenged management responses that were unscientific and without an evidence base, debunking myths and bringing fact-based scientific analysis to research and extension staff. A scientific impact of the project was the generation of resistant varieties that became part of the recommended suite of good agricultural practices. The project's scientific work on using cover crops for soil conditioning and limiting the use of herbicides led to these measures becoming an important part of current integrated crop and pest management practices.

Specific science-based findings that pertain to the use of biological control, planting resistant varieties and determination of the soil microorganism level include:

- the assessment of the use of biological control in areas with high incidence of the inoculum and the planting of resistant varieties 218 and 219
- the determination of the most effective conditions for resistant varieties 218 and 219 to survive in the presence of *Fusarium* wilt in the soil
- an understanding of the relationship between microorganisms in soil and the nutritional condition of the soil (e.g. soil organic carbon levels).

The scientific impact of the findings was stifled due to issues associated with land use rights. The trial sites were selected with the encouragement of multinational or prominent farming families and were not considered by many project participants to be the best sites for scientific purposes. One rented trial site of 50 ha was converted to housing after one generation was measured, preventing the project from reaching full scientific conclusions. In another experiment, the area was operated by a cooperative but was given back to multinational administration before the trials were completed.

Australia

The project was able to quickly apply the scientific knowledge and capacity developed in the Philippines to the Australian context during the initial outbreak of TR4 in Queensland. The project swiftly held meetings with Queensland Government staff, the ABGC and banana growers, highlighting the importance of a quick response. The team brought evidence-based findings to Australia, encouraging the use of groundcover, biosecurity measures, fertiliser practices and farm design. With a moratorium on the use of contaminated soil and plant material in Australia, researchers were able to use the scientific findings generated in the Philippines and apply them to an Australian context.

The project had a scientific impact on biosecurity work that has been developed and published by other groups. Information on *Fusarium* wilt has been disseminated to other parts of the world, forming a broader network of *Fusarium* wilt researchers. Countries with *Fusarium* wilt research largely developed in response to this project include China, Indonesia, Laos and some in Africa (consultation processes).

The project generated a strong scientific impact due to the collaborative and multidisciplinary nature of the project team, where project partners specialised in complementary fields well-suited to the study of *Fusarium* wilt and soil health and condition (e.g. nematology and microbial ecology).

5.7 Policy impact

In summary, the project had little policy impact in the Philippines, although policy change is expected in the future as a result of the project's capacity-building initiatives. It had a strong influence on Australia's biosecurity policies and responses, and diffused antagonism between the Philippines and Australian banana industries. These findings are explained further below.

The Philippines

The project had little policy impact in the Philippines. Initially, the project focused on practice change with small-scale banana growers. However, these growers had little ability to make decisions regarding the adoption of new technologies, as they were required to follow the protocols and procedures of the multinationals. There is a need for a biosecurity directive, policy or adoption pathway that can facilitate small, medium and large landholders to freely access new technologies, especially farm practices that suppress devastating diseases such as *Fusarium* wilt. This need was identified during the project and is a focus of the current subsequent project.

Plantation areas have inadequate zoning policy. Plantation areas that are abandoned due to *Fusarium* wilt are often converted into housing programs or used for other agricultural purposes. These activities can often exacerbate spread of the disease, and do not preclude the land being converted back to banana plantations at a later stage without assessing contamination risk. Premature cessation of on-farm trials on *Fusarium* wilt stifled the evidence base for policy reform.

The project team was aware that policy issues muted the scientific impacts of the project. The project partnered with the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) in Los Baños, Laguna. They discussed project findings on biosecurity policies with them, and PCAARRD agreed to advocate for policy change. The project team encouraged the local Provincial Agricultural Office to promote biosecurity measures and use banana varieties resistant to *Fusarium* wilt. The project team trained provincial officers in ways of explaining key management practices that suppress spread of the disease. This capacity building may likely lead to policy change in the future.

Australia

The project's policy impacts are more definite in Australia. It influenced the Queensland Government's biosecurity policies and responses. The project was timely, as TR4 was first detected in Queensland in 2015, about a year after commencement of the project. Project participants had developed significant experience in biosecurity measures needed to contain the disease. The project team was able to provide swift policy advice to government and landholders to prevent significant outbreak of the disease. For example, the project provided advice for measures such as:

- how to prevent the disease from reaching your farm
- how to contain the disease
- how to manage widespread infection.

In addition, the project proponents talked with funders to encourage a long-term program of work for management of *Fusarium* wilt.

The project facilitated engagement between government, researchers, industry, producers and other stakeholders. The banana industry in Australia is small. The project was instrumental in engaging external stakeholders to observe caution when entering banana farms (e.g. local councils, electricity suppliers, friends and other people working or entering banana farms). An understated result of the project was the social response to the disease among producers. The project facilitated the change of venues for meetings and social gatherings so they occur in pubs and other off-farm venues rather than on farms. This social response was necessary to protect the banana industry and contributed to the successful containment of the disease in Queensland.

This was an enormously challenging project. At the time, the relationship between the Philippine and Australian banana industries was antagonistic. The Philippines wanted to export bananas to Australia and Australia wanted to stop Philippine imports. The project was initiated at a time when the Australian industry had spent a lot of money on research to support its industry, preventing imports.

Including ABGC members in the project team was a sign of Australia's goodwill to the Philippine banana industry. As the project progressed and TR4 was first detected in Australia, the scientific findings of the project in the Philippines were enormously beneficial to the Australian banana industry in allowing it to contain the disease. The relationship between Australian regulators and the Australian banana industry improved as industry developed a better understanding of the production systems, giving them a strong scientific platform to support their response to risk assessment and appropriateness of import protocols. This allowed the Australian banana industry to demonstrate goodwill towards the Philippines banana industry. This mutual support diffused the antagonism between the Australian and Philippine banana industries.

The project has also had a significant impact on *Fusarium* wilt research in Australia. It convinced government of the need to fund a long-term RD&E program to work simultaneously on current prevention of the disease as well as future management of the disease.

An Australian white paper on international aid development (DFAT 2017) featured Stewart Lindsay in a case study showing foreign policy in action.

5.8 Gender and youth impact

The project did not have a specific gender or youth focus and disaggregation of gender-related and youth-related variables to assess structural inequities was not a specific strategy of the project. However, the project actively encouraged a new generation of agricultural scientists. As a result, innovative research, new ideas and skills have entered the banana industry to better contain *Fusarium* wilt.

The project did analyse the proportion of women and men who were involved, and their location and kind of work. The project encouraged gender equality and practiced gender inclusion. In the Philippines, over 50% of the project partners, project participants and young researchers were women. In project activities, there was significant engagement by female participants (43%) and recent graduates (70%). A large proportion of the project staff engaged in the decision-making process were female, with greater prospects arising from project opportunities to develop female leadership within the agriculture sectors of Australia and the Philippines. The Global Gender Gap Report 2021 suggests that the Philippines has 1.5 females to 1 male in high-level positions (WEF 2021), and the project benefited from many strong proactive women in the industry. Within the project, there was a shift to greater inclusion of females in decision-making positions, but there was no obvious change in the roles of men and women in banana farming (Pattison 2019).

Women and men participating in field experiments in the Philippines to control *Fusarium* wilt in bananas
Photo: Conor Ashleigh

6 Conclusion and reasons for project impacts

An overall impact assessment of the project is provided in Table 6.1. The project had a strong impact on capacity among staff and students in the Philippines, and broadly among project participants, industry and producers in Australia. It also had high scientific impact in the Philippines, Australia and internationally. Scientific findings from the project were used to develop disease-suppression systems that have gained widespread international credibility as a field of science.

The project also had high economic and environmental impacts in Australia, playing a significant role in containing the *Fusarium* wilt outbreak in Queensland and saving the industry from being decimated. The *Fusarium* wilt suppression systems include management practices that reduce the use of agrochemical inputs. This change is expected to have a long-term environmental impact, helping the banana industry in north Queensland meet its nutrient application targets of improved run-off water quality and consequently avoiding effects on the Great Barrier Reef.

The project was very successful at achieving its goals and outcomes in the Philippines, but behaviour change was limited due to the initial lack of understanding of the complex structure of the banana industry in the Philippines. Adaptive capacity of banana producers in the Philippines is weak because landholders must adhere to directives of multinational operations.

The project was able to achieve a small reduction in area affected by *Fusarium* wilt and encouraged adoption of partially resistant banana varieties. The value of banana production in the Philippines is very high, so these modest changes lead to a moderate economic impact in the Philippines.

The project also achieved a moderate policy impact in Australia, having a strong influence on the Queensland Government's biosecurity policies and responses, stimulating social change (encouraging meetings and social gatherings to occur in town rather than on farms), diffusing antagonism between the Australian and Philippine banana industries, and helping to establish a long-term *Fusarium* wilt RD&E program in Australia.

Reasons for the project's success included:

- the collaborative and multidisciplinary nature of the project team, where project partners specialised in complementary fields well suited to the study of *Fusarium* wilt and soil health and condition
- the project's focus on one commodity (banana) and one issue (*Fusarium* wilt), and centring collaboration in the Philippines on one institution (USeP)
- the use of a project platform for sharing information on human resources, websites, resources, security, logistics, communication channels and events, which created significant social capital

Table 6.1 Summary impact assessment of the project in the Philippines and Australia

Impact	The Philippines	Australia
Economic	High	Very high
Inclusivity of the value chain	Low	Low
Environmental	Low	High
Capacity	High	High
Scientific	High	High
Policy	Low	Moderate
Gender and youth	Low	Low

- the adaptive capacity of the project team, a thirst for research capacity in the Philippines, and a shared understanding of the importance of containing the disease in Australia
- the strong adaptive capacity of banana producers in Australia, especially in light of the potential decimation of the banana industry in Queensland if TR4 was not contained
- an established extension network in Australia that was known by project participants so that extension and implementation initiatives were successful when TR4 was first detected in Queensland
- the ability of the project team to 'influence the influencers', engaging with prominent farmers who were determined to understand disease containment and suppression systems and who facilitated farmer-to-farmer practice change
- the vertical integration of supply chains in Australia, so the project's contribution to protecting the banana industry had flow-on benefits of protecting the industry's supply chain.

Weaknesses of the project included poor engagement with smallholders from the start due to security concerns and a lack of understanding of the structure of the banana industry in the Philippines. The project relied on network and extension advice from a person outside the region to navigate the banana industry structure and politics. At the start of the project, it was not fully understood that decision-making does not reside with small-scale landholders, but is jointly controlled by multinational corporations and prominent local families. This weakness could be addressed in future projects by:

- conducting a feasibility study at the outset of large projects to ensure strong understanding of the relevant industries and associated impact pathways
- including influential farmers and representatives of local government units in the project from the beginning and making sure they are aware of the research process to facilitate feedback loops and smallholder engagement, and encourage farmer-to-farmer practice change and adoption beyond the life of the project
- stronger local coordination, with support from the ACIAR Country Manager, to help navigate the difficulties around security, financial management and conflicts of interest
- using local coordinators to assist in grass-roots processes, monitor the progress of the project and provide security and logistics guidance.

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Appendix 1: Discounted cashflow analysis calculations

Philippines

$$\text{Total indicative benefits} = \sum_{t=-1}^{-7} \frac{\text{Total impact}_t}{(1+i)^t} \tag{1}$$

$$\text{Total impact}_t = \text{Spread prevention impact}_t + \text{Adoption of new variety impact}_t \tag{2}$$

$$\text{Spread prevention impact}_t = \text{Value of spread prevention}_t * \text{Area of spread prevention}_t \tag{3}$$

$$\text{Value of spread prevention}_t = \text{Banana gross margin}_t - \text{Maize gross margin}_t \tag{4}$$

$$\text{Adoption of new variety impact}_t = \text{Value of adoption of new variety}_t * \text{Area of adoption}_t \tag{5}$$

$$\text{Value of adoption of new variety}_t = \text{Banana gross margin}_t * a \tag{6}$$

where: t = –1 for 2021 to –7 for 2015

i = discount rate (%, assumed to be 5%)

Banana gross margin = gross margin of banana production in year, t (AUD or PHP/ha)

Maize gross margin = gross margin of maize production in year, t (AUD or PHP/ha)

a = gross margin of new variety as a proportion of Cavendish (assumed to be 0.8)

Australia

$$\text{Total impact}_t = \text{Spread prevention impact}_t \tag{7}$$

$$\text{Spread prevention impact}_t = \text{Value of spread prevention}_t * \text{Area of spread prevention}_t \tag{8}$$

$$\text{Value of spread prevention}_t = \text{Banana gross margin}_t - \text{Sugarcane gross margin}_t \tag{9}$$

where: *Sugarcane gross margin* = gross margin of sugarcane production in year, t (AUD/ha)

Philippines and Australia

$$\text{Total costs} = \sum_{t=-22}^{-27} \frac{\text{Project costs}_t}{(1+i)^t} \tag{10}$$

where: Project costs_t = funding provided by ACIAR to conduct the project in year, t

$$\text{Net indicative benefit} = \text{Total indicative benefits} - \text{Total costs} \tag{11}$$

$$\text{Indicative benefit:cost ratio} = \frac{\text{Total indicative benefits}}{\text{Total costs}} \tag{12}$$

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