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Strengthening the Fiji papaya industry through applied research and information dissemination

104

ACIAR IMPACT ASSESSMENT SERIES

Strengthening the Fiji papaya industry through applied research and information dissemination

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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 cooperation 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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Credit: ACIAR

Foreword

The international partnerships that underpin research supported by the Australian Centre for International Agricultural Research (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, this research also helps improve the Australian agricultural innovation system, with flow-on benefits to rural industries and regional communities.

The ACIAR Horticulture Program takes a complete supply-chain approach to crop production, which considers consumer needs for safe, high-quality food, and works with the whole chain to deliver sustainable competitive advantages to the smallholders. This impact assessment reviews the outcomes and impacts of a project focused on strengthening the Fijian papaya industry, within the broader development goal of improving the livelihoods of rural people in Viti Levu.

At the time of the project commencement, Fiji was facing the demise of its sugar industry due to the phasing out of preferential access to the European Union sugar market. Urgent diversification of export and livelihood opportunities was required. The existing, but fragile, papaya production and export industry offered one of the most promising diversification avenues for small farmers. The ACIAR-funded papaya project worked to strengthen the local industry and improve livelihoods by customising papaya production techniques for the Fijian context.

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. These evaluations have consistently found high returns on investment, reflecting the quality of Australian agricultural science and our partnership model, which ensures a high level of engagement with in-country partners, and a high level of adoption of research results.

The results of this impact assessment confirm the positive impact of the ACIAR papaya industry project in Fiji, with benefits extending across the entire supply chain. This analysis suggests that more than 10 years after the project was initiated, the overall impact of the investment in Fiji is positive, with a benefit:cost ratio on ACIAR investment of around 2.1:1.

The study also showed flow-on benefits for the Australian papaya industry through the adoption of project recommendations. This demonstrates how ACIAR's long-term model of brokering and funding research for development partnerships can lead to benefits for all partners.

Andrew Campbell
Chief Executive Officer, ACIAR

Contents

List of tables

List of figures

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
AusAID	Australian Government Aid Program
BAF	Biosecurity Authority of Fiji
CTA	Technical Centre for Agricultural and Rural Cooperation
DAF	Department of Agriculture and Fisheries (Queensland)
ha	hectare
HACCP	Hazard Analysis Critical Control Points
HTFA	high-temperature, forced-air (quarantine treatment for fruit export)
MOA	Ministry of Agriculture, Fiji
MORDI	Mainstreaming of Rural Development Innovation (Tonga)
NWC	Nature's Way Cooperative (Fiji) Ltd
PARDI	Pacific Research for Development Initiative (ACIAR)
PPP	public–private partnership
RD&E	research, development and extension
SPC	Pacific Community (formerly Secretariat of the Pacific Community)
t	tonne
USA	United States of America

Summary

This document is an impact assessment study of a single ACIAR-funded project, 'Strengthening the Fiji papaya industry through applied research and information dissemination' (HORT/2008/033), known as the Fiji papaya project. The project ran from January 2009 to June 2015.

The Fiji papaya project objectives were to:

- strengthen the capacity of the Fijian papaya industry to plan, conduct and adopt the products of problem-solving research
- expand and increase the resilience of the Fijian papaya industry
- enhance the profitability and competitiveness of the Australian papaya industry by improving the supply chain
- promote the adoption of project outputs in the Fijian papaya industry and elsewhere.

Prior to the project, the Fijian papaya industry had established itself as a profitable exporter that provided opportunities for smallholder participation. However, the industry lacked information on growing papaya and post-harvest care under Fijian conditions. The industry was also fragile, being susceptible to natural disasters, shortages of airfreight capacity and post-harvest losses during the wet season.

Outputs delivered by ACIAR-funded research

Project outputs targeted the Fijian papaya industry located in the western Viti Levu provinces of Nadroga-Navosa and Ba and the Australian industry located in Far North Queensland.

Research outputs in Fiji were:

- Local adaptations of the Sunrise Solo variety were identified and selected to establish a varietal standard for Fiji Red papaya that is suitable for supply to export markets. Exporters report Fiji Red now has higher brix and more consistent shape and weight.
- Best-practice seed production and a certification system were established. The seed-production standard established during the project included techniques to avoid cross-pollination. The seed certification scheme is operated profitably by the private sector and audited by the Ministry of Agriculture (MOA) Fiji.
- Papaya seedling production best practice, including seedling production trials and a demonstration seedling nursery in Nadi. The project has contributed to a national network of small-scale commercial seedling nurseries.
- New production knowledge was communicated to growers through training and fact sheets on the use of drip irrigation, crop thinning to improve papaya quality, cultivar selection, pre-harvest fungicides and cyclone management. Cyclone management and recovery techniques are now used by most papaya growers in Fiji.
- Organic production systems were successfully trialled and found to be technically and economically viable. Commercial take-up of organic papaya production was hampered by adverse weather events and failure to secure access to the United States of America (USA) market.
- Quality monitoring, traceability and a feedback system were developed for the export supply chain. Feedback on the performance of papaya from individual growers was provided to the growers during and after the project, but has now been suspended due to funding constraints.
- Pre-export papaya treatment technology was refined following extensive trials using modified atmosphere packaging, surface treatments, chemical fungicides and hot water dips. Hot water dips were found to be cost-effective and used to minimise rejection rates during the wet season.
- Export supply chain refinement followed the identification of critical sources of post-harvest damage. Refinements included lining field bins with newspaper to protect papaya from transport damage, Hazard Analysis Critical Control Points (HACCP) certification at export treatment facility Nature's Way Cooperative (NWC) and the addition of newspaper packing to export cartons.
- Trial sea freight shipments to New Zealand and simulated sea freight trials to Australia incorporated a redesigned export carton and pallet. While the sea freight trials were successful, exporters have not been able to secure sufficient papaya volume to establish a commercial trade.
- Export market research was undertaken to confirm the existence of profitable opportunities for Fiji Red. Opportunities were identified in Australia, New Zealand, Hong Kong and Japan, and potentially the USA if market access can be secured.

Research outputs in Australia were:

- Technology for the remote assessment of nitrogen levels in papaya crops was refined. While the technology has potential to deliver improvements in plantation management, it has not been commercialised for Australian growers.
- Sources of papaya damage in the Australian supply chain were identified as pre-harvest disease, tree age, fruit maturity at harvest, fruit sourced during the wet season, a coastal growing location, harvest injury, post-harvest disease control and ripening-room temperature.
- Pre-harvest disease control through both sound orchard hygiene and the removal of older trees, which can harbour disease, was found to eliminate a significant source of fruit breakdown in the Australian supply chain.
- Post-harvest treatments to reduce fruit breakdown caused by fruit rot were investigated, including coatings, chemicals and hot water sterilisation. A subtle reduction in ripening room temperature was found to reduce fruit breakdown and has subsequently been adopted by 2 major Australian growers.

Capacity building in Fiji

The project trained and built capacity in farmers, technical staff and the export supply chain using an innovative public–private partnership (PPP) that included NWC, a private for-profit company. Focusing the development of capacity through NWC ensured that the training supplied, and the capacity developed, was commercially relevant and had a better chance of being sustained after project completion.

Project team, MOA and NWC research and extension staff were trained in disease detection, variety evaluation, seed certification, seedling production, fruit post-harvest handling, hot water dipping, value-chain analysis and sea freight of fresh horticultural commodities. The establishment of an industry operated and focused research and extension service that was managed, and subsequently funded, by NWC was a major achievement of the project.

MOA extension services personnel engaged with the project through observation and participation in activities at project trial sites. MOA personnel participated in 'train the trainer' workshops. Staff from the Fiji College of Agriculture visited project trial sites and engaged with the project throughout its duration. Koronivia Research Station hosted a number of project trials and its staff benefited from participation in trials. Twelve farmer workshops and field days were successfully completed by the project, with 300 farming households (approximately 900 people) trained.

Eleven exporter enterprises (approximately 100 people) were trained in selecting and managing papaya for export. Capacity-building materials produced by the project and used by industry included a television documentary, a project website, posters and fact sheets. Industry consultation completed as part of the impact assessment revealed that growers continue to make use of extension materials and the certified papaya seed program.

Adoption and Fijian industry resilience

Adoption of research and development outputs was assured through the central position afforded to NWC in the project. NWC extension staff encouraged grower uptake of project-generated production technologies. Exporters were trained to request and observe post-harvest project recommendations prior to papaya purchase. NWC purchased capital equipment and adopted papaya hot water dipping to reduce export supply chain loss during the wet season.

As a consequence of the project, the Fijian papaya industry is more resilient. The industry has more capacity to recover from natural disaster. Growers, extension officers, researchers and value-chain workers have all been trained. Pre-cyclone and post-cyclone mitigation measures have been adopted and additional production knowledge ensures rapid and high-quality post-disaster crops. The industry is following project recommendations and slowly relocating to less disaster-prone areas (sheltered and sloped land to avoid floods and cyclone damage).

Project impacts in Fiji and Australia

In the absence of this project, and linked investment measures, it is likely that the Fijian papaya industry would have ceased to export. Instead, a more capable and resilient industry has maintained its presence in export markets.

The project has resulted in sustained, profitable papaya production for commercial growers and smallholders. Production and post-harvest technologies developed and adopted have supported the ongoing supply of papaya into export markets and improvement in the quality and value of papaya sold on the domestic market. An improvement in the quality and consistency of papaya on the domestic market has been a major project benefit.

Women and youth have benefited from a more resilient papaya sector. While smallholder papaya is grown by family units, around 30% of these enterprises are headed by females and 5% are headed by growers under 30 years of age. Skills required for modern commercial horticulture are substantially greater than for the sugar industry and the quality of employment available for rural women and young people has been enhanced by the project.

Both women and young people are attracted to papaya by the crop's favourable financial returns and year-round cash flow. Smallholder enterprises adopting project recommendations are estimated to have realised a 20.5% increase in annual income. In total, a present value benefit of A$0.822 million has been estimated for rural women in Fiji as a result of the project.

The project has contributed to Fijian Government policy goals including resilient smallholder enterprises, diversification from sugar production, poverty alleviation, food security, consumption of a healthy diet, and the sustainable management of natural resources. The seed production and value-chain approach pioneered by the project are now considered to be examples of policy best practice by the Fiji Government.

The project has had no negative impacts on the Fiji environment. Papaya is grown and exported mostly without the use of chemicals. Biodegradable packaging (newspaper) has been substituted for manufactured foam. Provided the slow transition of production to irrigated, flood-free slopes is managed judiciously, no negative environmental impacts are anticipated from the project.

Project impacts on the Australian supply chain

The Fiji papaya project recommended the use of lower temperatures in the fruit ripening room. This recommendation has been adopted by the 2 largest Australian papaya growers, and has resulted in improved papaya shelf life and eating quality, and a reduction in fruit loss.

Economic impacts in Fiji and Australia

The Fiji papaya project has delivered economic benefits to smallholder papaya growers, the papaya industry and the Fijian economy. It has also enhanced the profitability and competitiveness of the Australian papaya industry.

The total investment of A$2.82 million (present value terms) from ACIAR and its research partners in the Fiji papaya project has been estimated to produce gross benefits of A$5.98 million (present value terms), providing a net present value of A$3.16 million and benefit:cost ratio of 2.1:1 (over 30 years using a 5% discount rate). The ACIAR investment has been successful.

Conclusions

The Fiji papaya project has delivered benefits to both the Fijian and Australian papaya industries. Factors contributing to project success include a strong commercial focus, a PPP with NWC and a market orientation that included trial export shipments of Fiji Red papaya supplied by smallholders. Feedback from these trial shipments was provided to the growers, and the results also informed ongoing research.

1 Introduction

This document is an impact assessment study of a single Australian Centre for International Agricultural Research (ACIAR) project that focused on improving the exportability of papaya in Fiji and the efficiency of the papaya supply chain in Australia.

1.1 Background

An established focus for ACIAR has been understanding the impact of research on smallholders and communities in its partner countries and Australia resulting from the adoption by next users and final users of research outputs.

Assessing these impacts has provided evidence in accounting for ACIAR investments to stakeholders and demonstrating the net benefits from ACIAR projects. Further, the impact assessment activities applied to projects and the subsequent findings and lessons learned contribute to ACIAR priority setting and the design and management of new ACIAR programs and projects.

By undertaking these ex-post assessments, ACIAR engages with research partners and project participants, further developing their skills and understanding of research-for-development investments beyond the formal life of the research projects themselves.

Accordingly, an impact assessment was required of the ACIAR project 'Strengthening the Fiji papaya industry through applied research and information dissemination' (HORT/2008/033), known as the Fiji papaya project. This project operated from 1 January 2009 to 30 June 2015, with the Secretariat of the Pacific Community (SPC) as the project's commissioning organisation.

The project recognised the potential of Fiji's papaya industry to increase exports to high-value markets, with beneficial implications for Fijian smallholder papaya producers, the Fijian papaya industry and the Fijian economy. Specifically, this project sought to increase the contribution of papaya exports to the livelihoods of rural people in western Viti Levu, through increased exports, decreased quality-related losses, increased participation of farmers in export production and improved competitiveness in export markets.

1.2 Terms of reference

The terms of reference for the impact assessment were to identify the impacts of the Fiji papaya project on smallholder papaya producers, the papaya industry and the Fijian economy (key focus for the impact assessment), and to detail the project's intended impact pathways and quantify impacts through the value chain, at household/farm level and in industry, and, where possible, disaggregate these results for women and youth. The assessment was also to address the impacts on the environment and capacity, and examine the influence of the scientific knowledge arising from the project investments made by ACIAR and its partners. Where applicable consideration of impacts on policy was to be described and assessed at least qualitatively. The impact pathway(s) resulting from the project was to address the next and final users of project outputs, outcomes and impacts.

Analysis of the impact pathway(s) was to be consistent with *Guidelines for assessing the impacts of ACIAR's research activities* (Davis et al. 2008), including presentation of a counterfactual to value impacts and investment returns. Relevant counterfactuals could include other relevant research investments undertaken by other investors that contributed to or affected the ACIAR projects and their impacts, along with other external factors, including scientific, market or policy factors in Australia or partner countries.

1.3 Impact assessment methods and activities

The impact assessment was completed using *Guidelines for assessing the impacts of ACIAR's research activities* (Davis et al. 2008) and ACIAR's Impact Assessment Framework (Figure 1.1).

An understanding of the Impact Assessment Framework was developed via best-practice examples (for example, *Impact pathway analysis of ACIAR's investment in rodent control in Vietnam, Lao and Cambodia* (Palis et al. 2013), journal articles such as Douthwaite et al. 2007, and the authors' experience on the ACIAR impact assessment studies IAS88, IAS96 and IAS98).

Interviews were completed with the project's commissioning authority and partner research scientists in Fiji and Australia. Fieldwork for this impact assessment, with a focus on smallholder papaya producers, the papaya industry and the Fijian economy, was completed in November and December 2020. Fieldwork was completed by Lennard Powell, Technical Advisor, Kalang Consultancy Services. Michael Clarke completed all other components of the impact assessment.

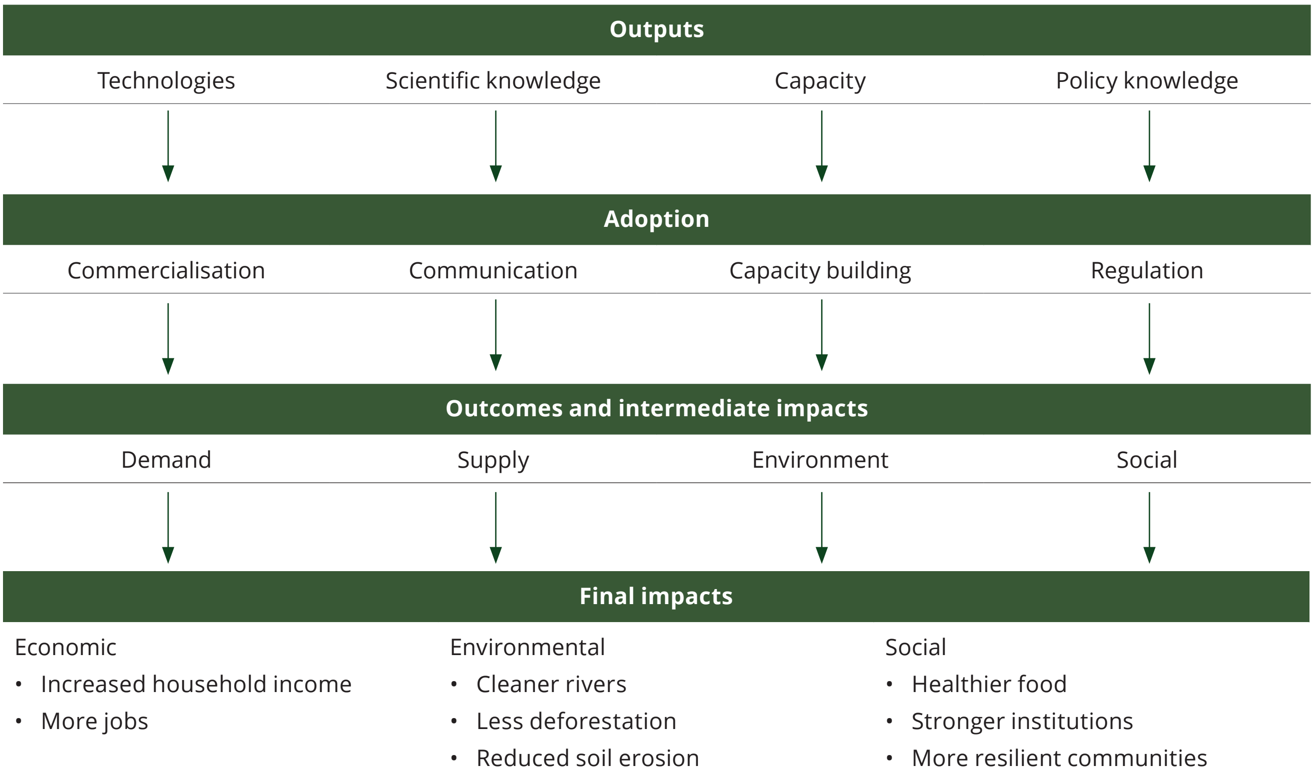

Figure 1.1 Impact assessment framework

2 Project location and description

2.1 Project context

The Fiji papaya project focused on the western Viti Levu provinces of Nadroga-Navosa (Sigatoka Valley) and Ba (Nadi area) (Figure 2.1).

Prior to project commencement, Fijian farmers in both provinces had recognised the potential of papaya as a source for household income and many new farmers were embracing papaya production. Papaya was seen as a profitable alternative to sugarcane following loss of preferential access to sugar markets in the European Union.

While existing and new papaya growers in Viti Levu were able to access international information on papaya production, limited information was available on papaya growing and post-harvest care under Fijian conditions. There was no formal research into the issues facing the Fijian papaya industry, and an unacceptably high percentage of fruit received from farms was being rejected prior to it entering the export supply chain.

Consequently, the project was designed to meet the immediate needs of the Fijian papaya industry and develop a framework to advance the industry over the longer term. The project was developed in cooperation with the Fijian papaya industry through NWC Project design, and execution was aided by collaboration with both the Hawaiian and Australian papaya industries.

The Fiji papaya project targeted a substantial increase in the contribution of papaya to the livelihoods of rural people in western Viti Levu: a threefold increase in papaya exports, a twofold increase in people employed in the papaya industry and a 50% reduction in the rejection rate of fresh fruit received from smallholder farms. Research completed prior to the project indicated that additional demand existed in export markets for fresh Fijian papaya, as long as quality and supply were consistent. Targets set at project commencement by the project team are reproduced in Table 2.1.

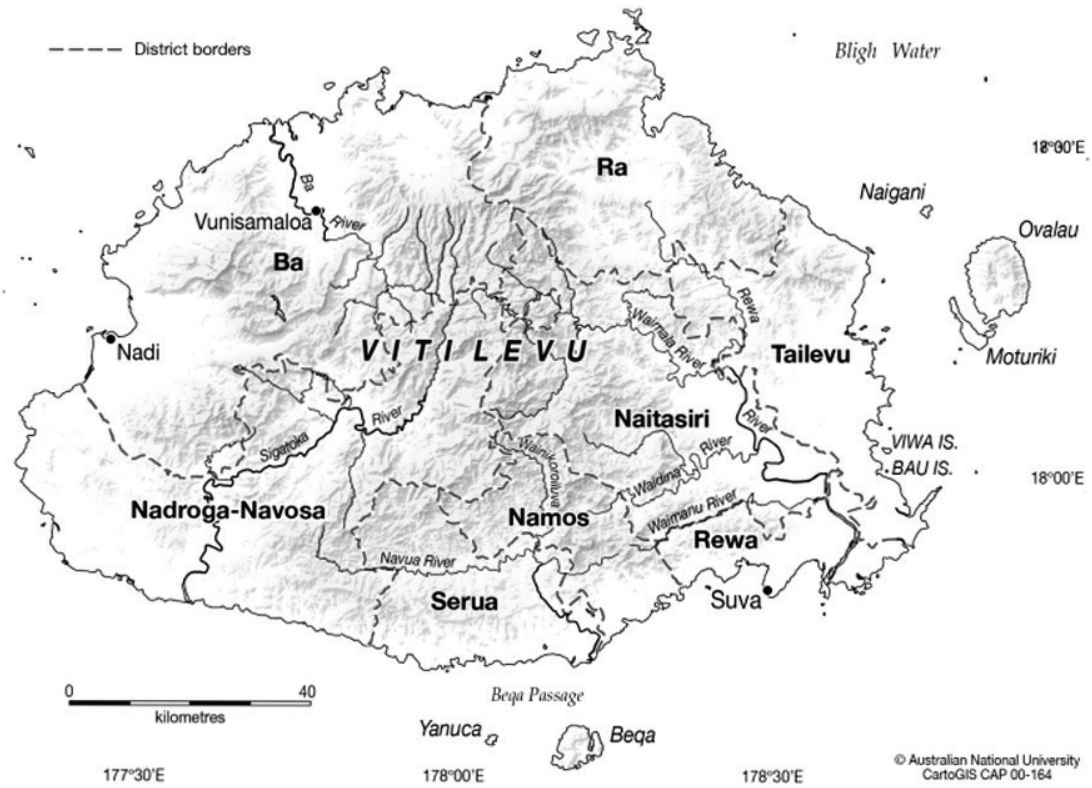

Figure 2.1 Project location – Nadroga-Navosa and Ba provinces, Viti Levu, Fiji

Source: ANU n.d.

Table 2.1 Export targets and target markets for Fijian papaya, 2011 and 2014

Market	Forecast papaya markets (t)	
	2011	2014
New Zealand	600	1,000
Australia	300	500
Japan	120	200
United States	0	100
Fiji – tourism	800	1,500
Fiji – non-tourism	800	1,200
Total	**2,620**	**4,500**

Source: McGregor and Stice (unpublished a)

The project targeted FJ$7 million in fresh papaya export earnings, with FJ$3.5 million captured by smallholder growers. A successful project would also deliver 600 jobs in field operations, value-adding opportunities linked to tourism and flow-on benefits for the value chain.

In Australia, the papaya industry was constrained by high losses in the supermarket system and inconsistent flavour and fruit ripening. Research addressing the value chain was required to reduce costs and deliver product that better meets consumer needs (especially elite lines). The Fiji papaya project would monitor Australian papaya quality, handling practices and conditions through the value chain and identify areas for improvement. The project targeted a 10% decrease in current market losses.

Consequently, the project's objectives were to:

1. strengthen the capacity of the Fijian papaya industry to plan, conduct and adopt the products of problem-solving research
2. expand and increase the resilience of the Fijian papaya industry
3. enhance the profitability and competitiveness of the Australian papaya industry by improving the supply chain
4. promote the adoption of project outputs in the Fijian papaya industry and elsewhere.

2.2 Other relevant research, development and extension projects

Other research, development and extension (RD&E) and aid projects with the potential to contribute to the Fiji papaya project objectives were identified through a literature review and project consultation. These projects are summarised in Table 2.2.

As can be seen from the table, many projects were working in partnership to lift the supply of Fijian papaya and improve its exportability.

Table 2.2 Other research, development and extension projects contributing to the improved exportability of Fijian papaya

Project name	Funding source	Project linkage to the Fiji papaya project
Commercial Ag Development Project	USAID	High-temperature, forced-air treatment commenced at Nature's Way Cooperative (NWC) in 1996.
Alternative Livelihoods Project	Asian Development Bank	This 2006 preliminary needs analysis for horticulture development in Fiji identified priorities that included papaya export treatment capacity and improved market access.
NWC Market Access Initiative	NWC with donor funding from AusAID	In early 2008, NWC acquired the services of a recently retired United States Department of Agriculture specialist to initiate the market access process for papaya export to the USA.
Papaya Market Study for Fiji and the Pacific islands	SPC with funding support from the European Union 'Facilitating Agricultural Commodity Trade' project	This 2009 study confirmed the availability of profitable papaya export markets in Pacific Rim countries (New Zealand, Australia, Japan and the USA) that were able to absorb increased Fiji production, as long as quality and consistent quality and supply volumes were maintained.
Pacific Horticulture and Market Access Project	AusAID with funding support from NZAid	This 2009 investment project aimed to secure new and additional export market access for fresh produce from Pacific island countries.
Farmer–Market Linkage Activity	United Nations Food & Agriculture Organisation in partnership with NWC	This 2009 project aimed to upgrade the capacity within NWC to support the industry in its efforts to increase the supply of papaya sourced from small farmers, reduce the current demand–supply gap and improve farmer–market linkages.

Table 2.2 Other research, development and extension projects contributing to the improved exportability of Fijian papaya (continued)

Project name	Funding source	Project linkage to the Fiji papaya project
NWC Extension Program	NWC with support from AusAID	A full-time extension officer was provided for a 3-year period and they were able to work with multiple projects targeting smallholder involvement in the Fijian papaya industry. Around 6,000 people were expected to benefit from this and other NWC initiatives.
NWC Expansion Program	NWC with support from the Fiji Ministry of Trade and Commerce and the AusAID Enterprise Challenge Fund	The expansion of the quarantine treatment facility to 3,000 t per annum supported increased papaya production capacity.
Taiwanese Technical Mission Smallholder Papaya Project	Government of Taiwan	Based in the Sigatoka Valley of western Viti Levu, this project supported linkages between small papaya growers, the Fiji papaya project and the NWC extension officer. The project supported a 3-year planting program. Planting commenced in 2008 with 8.6 ha and 40 farmers. A total of 400 people (family members, casual labour, supply chain partners, etc.) were targeted to benefit. A second phase of the project involved 60 farmers with an additional 700 people targeted to benefit from papaya production.
NWC Extension Program	NZAid with AusAID support	This 2013 industry recovery assistance ran for 3 years after the 2012 floods and cyclone.
Green Valley Export/ MG Marketing New Zealand papaya joint venture	NZAid	Focused on sea freight exports to New Zealand, the target of this project was a single 10 t reefer per week, increasing to 60 t per week over 4 years. The NWC extension officer worked with this project to increase papaya supply from smallholders.
NWC Dubalevu Papaya Planting Program	NWC with its own resources	This papaya production project in Dubalevu involved 175 farming families over a 3-year period.
Pacific Research for Development (PARDI) Papaya Consumer Preference Research	ACIAR PARDI partnership with NWC, growers, Queensland Department of Agriculture and Fisheries, Trade and Investment Queensland and Hort Innovation	This project ran from September 2013 to December 2014 and addressed consumer preferences for papaya, including size, shape, flavour, packaging, certification and branding in current and potential export markets (Australia, New Zealand, Hong Kong, Japan and the USA).

Source: McGregor and Stice (unpublished a) and stakeholder consultation

2.3 Post-project research

After the Fiji papaya project, a subsequent ACIAR project, 'Enhanced fruit production and postharvest handling systems for Fiji, Samoa, and Tonga' (HORT/2014/077), also addressed Fiji Red papaya but only in a limited way. The enhanced fruit production project made Fiji Red papaya seed available to Tonga and Samoa to rectify concern that the Fiji papaya project did not address regional scale-out of ACIAR project benefits (Associate Professor Steven Underhill, HORT/2014/077 project leader, University of the Sunshine Coast, written communication, October 2020).

The Tongan rural development agency, Mainstreaming of Rural Development Innovation (MORDI), successfully established seed trees from the imported material and in 2020 was planning to distribute seeds and seedlings to communities as part of their wider tree fruit planting program. In late 2019, NWC staff travelled to Tonga to train MORDI nursery staff in seedling establishment and seed harvest. A similar program of work has been completed in Samoa with Scientific Research Organisation Samoa as part of the 'Enhanced fruit production and postharvest handling systems for Fiji, Samoa, and Tonga' (HORT/2014/077) project (Associate Professor Steven Underhill, HORT/2014/077 project leader, University of the Sunshine Coast, written communication, October 2020).

3 Papaya industry context

3.1 Fijian papaya industry

Overview

Papaya is grown throughout Fiji with most farms located in the western areas of Viti Levu surrounding Nadi and the Sigatoka Valley.

Papaya grown in Fiji is dominated by the Sunrise Solo variety, marketed as Fiji Red. Fiji Red is a relatively small fruit (a 5 kg carton contains 12 pieces) that has a reputation in the export market for its outstanding sweetness (brix 10–12%) and the strong red colour of its flesh, and is prized by consumers.

Fiji farmers have also grown the Waimanalo yellow-flesh variety, which performs better in more humid and wet conditions. Waimanalo is resistant to the papaya ring spot virus, which while highly destructive to papaya industries in other countries, is not present in Fiji.

At project commencement, the industry consisted of 9 exporters (4 handling most of the papaya); 11 large, registered papaya farmers (producing more than 1 t of papaya per week); 100 small, registered farmers; 8 seed and seedling producers; and one industry-owned and operated quarantine treatment facility (NWC, Nadi).

Stice et al. 2009 identified 165 papaya farmers in the Sigatoka Valley, 22 farmers along the Sigatoka coast, 12 in the Nadi-Lautoka corridor and 20 in Dawasamu, Tailevu. The NWC and MOA require farmers to register to participate in the papaya export supply chain. Small growers who prefer to supply only local markets do not participate in the MOA registration process.

McGregor (2019) notes that there were 18 exporters in 2018 but that only 9 shipped papaya. Mahen and Manasa export to New Zealand on a consistent basis from the lower Sigatoka Valley. Since 2013, Sunrise Produce has been the largest papaya grower in Fiji and only exports to Australia. UNO Ltd and PSL are closed. Fiji Waters large investment in papaya was destroyed by Tropical Cyclone Winston in 2016.

The quarantine treatment facility that prepares papaya for export uses high-temperature, forced-air (HTFA) technology, requires no chemicals or irradiation and is able to qualify for organic market status. HTFA treatment is acceptable to the Australia and New Zealand quarantine authorities as a control method for Pacific fruit fly. The HTFA treatment facility has an annual fruit treatment capacity of 3,000 t (McGregor 2019).

Changes in the Fijian papaya industry since project inception are summarised in Table 3.1.

Papaya production

Papaya production and export data sourced from the United Nations Food and Agriculture Organization and updated with data from McGregor (2019) and project consultation, is shown in Table 3.2. Key events affecting papaya supply are also noted in the table.

Table 3.1 Changes in Fijian papaya industry since Fiji papaya project inception

Industry sector	2008	2015	2020
Smallholder papaya producers (registered and participating in export supply chains)	100	110	110
Female smallholder papaya producers	30%	30%	30%
Large papaya growers (>1 t/week)	11	15	15
Seed and seedling producers	8	12	7
Persons employed in papaya	300	300	300
Papaya exporters	9 (4 major)	11 (8 active)	9 (5 active)
Export treatment facilities	1	1	1

Source: McGregor and Stice (unpublished b) and project consultation

Table 3.2 Fijian papaya production and export 2000–2020

Year and critical event	Area (ha)	Production (t)	Productivity (t/ha)*	Export (t)	Export share production
2000	65	752	11.6	70	9%
2001	194	2,267	11.7	190	8%
2002	91	1,179	13.0	200	17%
2003	221	2,403	10.9	208	9%
2004 (Aus open using HTFA)	244	2,757	11.3	303	11%
2005	160	1,871	11.7	291	16%
2006 (Aus production shortage)	240	2,768	11.5	662	24%
2007	750	9,091	12.1	470	5%
2008	600	7,265	12.1	398	5%
2009 (Fiji cyclone and flood)	250	2,446	9.8	178	7%
2010	233	2,129	9.1	436	20%
2011 (Aus production shortage)	283	3,097	10.9	786	25%
2012 (Fiji cyclone and floods)	224	2,667	11.9	182	7%
2013	205	2,777	13.5	252	9%
2014 (glut in Fiji supply despite rain)	399	5,777	14.5	458	8%
2015	294	4,201	14.3	409	10%
2016 (Fiji cyclone and floods)	290	3,174	10.9	133	4%
2017	244	3,434	14.1	281	8%
2018 (Fiji flooding esp. Sigatoka)	228	3,285	14.4	107	3%
2019	292	4,088	N/a	254	6%
2020 (Fiji cyclones – Mar and Dec)	N/a	N/a	N/a	150	N/a

*Note: * Productivity may be underestimated with the inclusion of fallow land.*
Source: United Nations Food and Agriculture Organization FAOSTAT database (FAO n.d.); data published in McGregor (2019)

Papaya export

Fijian papaya export markets include the HTFA treatment markets of New Zealand and Australia as well as the small, non-treatment markets of Canada, Hong Kong, Japan and Nauru.

At project commencement in 2009, papaya was Fiji's most important fruit export and had the potential to be a major commodity for the country. Key markets for Fijian papaya were New Zealand, Australia and potentially the USA. New Zealand is Fiji's largest and most consistent export market.

In 2009, the main factors limiting Fiji's papaya exports to New Zealand were:

- price – Fijian papaya was 25% more expensive than Philippines papaya
- reliability of supply – Fiji Red was only sporadically available in the marketplace
- quality – the product had a short shelf life
- marketing – there was low awareness of the product among New Zealand consumers (Stice et al. 2009).

In the 1980s, Fiji was a significant exporter of papaya to Australia, peaking at 132 t in 1987. Prohibition of the treatment agent ethylene dibromide in the 1990s meant that the trade with Australia ceased until 2004, when the Australian Government formally accepted HTFA as an export treatment option.

In 2009, Fiji Red papaya had a good reputation in the Australian market, although there were issues with its small size and inconsistent quality. Post-harvest fruit rots following periods of rain in production areas were also a problem (Chapman and Hazelman unpublished).

Research to support an application for USA market access for Fijian papaya was undertaken in 2008 and a submission was lodged with the USA Government in 2009. In 2020, approval to export Fijian papaya to the USA market had still not been secured (Andrew McGregor, Koko Siga, personal communication, November 2020).

Papaya export supply chain

The papaya export value chain consists of input suppliers (seed/seedlings, fertiliser, fungicide, etc.); small, medium and large registered growers; medium and large growers who are exporters; specialist exporters; NWC, who provide quarantine treatment for export; airlines who provide airfreight; and importer wholesalers in end markets (Stice et al. 2009).

Central to the export supply chain is NWC. NWC supplies production inputs (for example, certified seed, fruit fly traps and field crates), invests in improving export market access, and delivers research and extension services for papaya growers and planting programs to increase the supply of export fruit. Annually, NWC treats between 1,000 t and 1,500 t of papaya, mango, eggplant and breadfruit for export (Kaitu Erasito, research and extension officer, NWC, personal communication, November 2020).

3.2 Australian papaya industry

Overview

Australian papaya production is concentrated in Far North Queensland, with 90% of output sourced from Innisfail and Mareeba. Queensland production spans an area between Bundaberg and Lakeland. New production areas in Kununurra (WA) and Darwin (NT) target gaps in the Queensland supply window (HIA 2017).

Product is either yellow-fleshed, referred to as pawpaw, or red-fleshed, known as papaya. There are also commercial hybrids of yellow and red types. Red-fleshed Hybrid RB1, Sunrise Solo, Linda Solo and Sunset Solo are the most popular papaya varieties grown in Queensland (HIA 2017). In 2020, RB1 is the dominant Australian variety (Yan Diczbalis, coordinating scientist, HORT/2008/033, personal communication, November 2020).

Papaya production and trade

Australian papaya production averaged 16,149 t in the 5 years ending 30 June 2019 and had a corresponding production value of A$28.8 million (Table 3.3).

Australia is a net importer of papaya, sourcing between 40 t and 420 t per annum from Fiji, with a small volume also imported from Thailand. Australian papaya exports are mostly destined for New Zealand (HIA 2020).

One hundred and thirty Australian growers produce papaya, but production is dominated by a small number of large producers. Depending on the year, between 30% and 60% of the Australian crop will be sourced from the 2 largest Far North Queensland growers – Mackay Estates and Lecker Farms (HIA 2017).

Table 3.3 Australian papaya production and trade 2000–2019

Year	Production (t)	Production (A$M)	Import (t)	Import (A$M)	Export (t)	Export (A$M)	Fresh supply (t)	Wholesale value (A$M)
2013	12,704	20.0	0	0	3	<0.1	12,510	23.5
2014	15,138	24.9	244	0.7	18	<0.1	15,137	29.7
2015	13,949	25.2	162	0.5	2	<0.1	13,900	29.9
2016	16,949	28.4	106	0.3	89	0.2	16,516	33.4
2017	18,729	31.6	61	0.2	57	0.2	18,130	37.1
2018	16,196	31.4	131	0.4	16	<0.1	16,087	37.2
2019	14,921	27.5	40	0.2	45	0.2	14,710	32.3

Source: HIA, Horticulture Statistics Handbook, various years

Papaya supply chain

Papaya grown in Queensland can be transported to all other Australian jurisdictions except Western Australia. Papaya consigned to Tasmania, Victoria, South Australia and certain areas of New South Wales must be produced and treated under specific interstate certification assurance schemes.

Transport is through refrigerated road transport to wholesale markets. Wholesale transportation to retail is predominantly through unrefrigerated road transport. The supply of premium quality fruit to distant interstate markets has been an ongoing challenge for the industry (HIA 2017).

Other research, development and extension projects relevant to the Australian papaya supply chain

After the Fiji papaya project, a subsequent Horticulture Innovation Australia project (PP13000) addressed papaya pre-harvest fungicide and post-harvest hot water applications (Vawdrey 2016). PP13000 built on the findings from the Fiji papaya project and also contributed to a reduction in papaya spoilage in the Australian supply chain.

4 Research investment

Investment by ACIAR and its partners in the Fiji papaya project between January 2009 and 30 June 2015 is shown in Table 4.1.

ACIAR was the major contributor to the Fiji papaya project (approximately A$1.15 million over 7 years), with significant contributions received from SPC, Koko Siga, the Queensland Department of Agriculture and Fisheries (DAF) and NWC. Koko Siga had primary responsibility for delivering the Fiji papaya project in Fiji. DAF had primary responsibility for delivering the project in Australia. Investment funds were allocated 81% to Fiji and 19% to Australia (anonymous correspondent, 2008).

Table 4.1 ACIAR and partner investment in the Fiji papaya project (year ending 30 June)

	2009	2010	2011	2012	2013	2014	2015	Total
ACIAR	159,313	237,119	214,618	169,386	88,923	215,016	69,940	1,154,313
Partners								
SPC	6,780	13,060	16,560	28,560	5,280	19,560	0	89,800
Koko Siga	15,000	30,000	30,000	30,000	15,000	30,000	0	150,000
DAF	11,962	25,001	26,124	27,298	14,194	28,388	0	132,967
NWC	11,675	20,650	19,150	19,150	8,975	17,950	0	97,550
Partners total	**45,417**	**88,711**	**91,834**	**105,008**	**43,449**	**95,898**	**0**	**470,317**
Total	**204,730**	**325,830**	**306,452**	**274,394**	**132,372**	**310,914**	**69,940**	**1,624,630**

Notes:
DAF – Department of Agriculture and Fisheries (Queensland); NWC – Nature's Way Cooperative (Fiji) Ltd; SPC – Pacific Community
Source: Stice et al. (unpublished)

5 Impact pathway and impact map

An impact pathway for the Fijian and Australian papaya industries and for other Pacific island countries was developed using project literature and subsequent consultation. The impact pathway is shown in Figure 5.1.

ACIAR impact mapping teases out the important distinctions between project outputs, adoption, outcomes and intermediate impacts and final impacts. An impact map, covering both Fiji and Australia is presented in Figure 5.2.

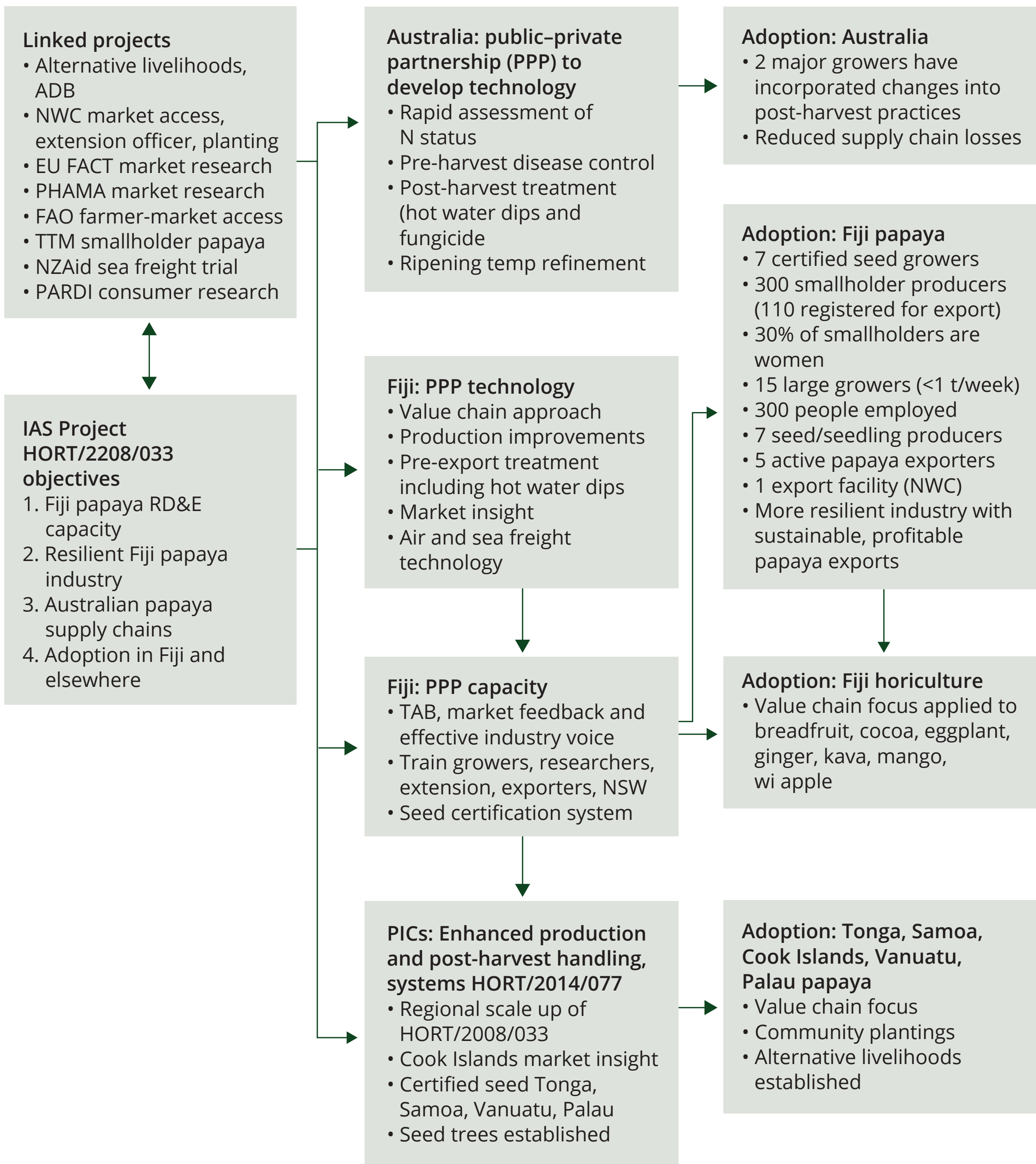

Figure 5.1 Impact pathway for Fiji, Australia and other Pacific island countries

Outputs

Technologies

- Sunrise Solo cultivars selected, define Fiji Red
- Best-practice seed and seedling production
- Organic production trialled successfully
- Papaya quality monitoring, traceability and feedback system developed
- Pre-export treatment technology – hot water dips, Sportak, HTFA
- Fiji export supply chain improvement – HACCP, newspaper packing
- Carton and pallet redesign for sea freight – vents, fly-proof sock, reinforcing
- Australian production, supply chain – rapid N, tree age, fungicides, ripening

Scientific knowledge

- Fiji production – organics, irrigation, thinning cultivars, pre-harvest fungicides
- Cyclone management – ratooning, defoliation and sunburn prevention
- Tree age affects incidence of post-harvest disease in Australia
- Market insight – additional analysis in Australia, New Zealand, Hong Kong, Japan and the USA
- Turnout study results, Fijian papaya in Melbourne
- Post-harvest sources of Fiji damage and disease identified in airfreight
- Successful sea freight trial to New Zealand, simulation trial for Australia
- Sources of damage to Australian papaya identified for domestic supply chain

Capacity

- Knowledge processed into fact sheets
- Technical Advisory Board, an effective PPP, identifies grower problems and conducts research
- More than 300 Fiji farming households (900 people) trained
- 11 Fiji exporters (100 people) trained
- Seed certification system developed and seed growers trained
- Project and MOA staff trained by DAF in Queensland
- Master of Science in non-chemical control of *Phytophthora* in papaya (thesis uncompleted)

Policy goals

- Fiji: further development of export horticulture suitable for smallholders with rapid recovery from natural disaster
- Fiji: some further diversification from sugar
- Fiji: MOA Research Division engaged and providing seed and nursery certification
- Successful private-sector seed production with MOA audit now the guiding principle for Fiji's seed policy formulation process
- Consumption of papaya in Fiji has been encouraged in line with Ministry of Health healthy diet initiative
- Australia: profitable and sustainable horticultural production

Adoption

Commercialisation

- A more consistent Fiji Red grown for export
- Organic papaya production explored at commercial scale
- Grower feedback system by NWC post project
- Pre-export hot water dips used to reduce rejection rates, Fiji
- Ripening temp adjusted, Australia
- Sea freight exports of Fijian papaya to New Zealand trialled
- Two of the largest Australian growers changed packing lines, ripening facilities to reduce losses

Communication

- Scientific papers – sea freight, organics, disaster mitigation and post-harvest fungicides, value chains
- Internal reports – field fungicides, ripening temp, post-harvest fungicides
- Refinement of New Zealand quarantine protocols
- Airfreight findings adopted (e.g., HACCP) with improved fruit turnout in export markets
- Improved disaster recovery for Fijian papaya – certified seeds and orchard management techniques

Capacity building

- Fact sheets used by growers
- Technical Advisory Board institutionalised by NWC and provided a continuous research and extension partnership for some years after project completion
- Certified seed production operated successfully by 7 small growers
- Certified seed is used by all growers supplying export markets
- Industry with additional disaster recovery capacity

Policy

- Legislation enacted banning import of papaya seeds (to prevent incursion of papaya ring spot virus and maintain GM-free access to Japanese market)
- Fiji Government will continue to support crops with export potential suitable for smallholders

Figure 5.2 Impact map for the Fiji papaya project

Outcomes and intermediate impacts

Demand	Supply	Environment	Social
• Increased industry resilience and ability to meet demand for Fiji Red in export markets (Fiji) • Reduced supply chain losses, allowing retailers to grow papaya demand (Australia)	• Increased ability to supply export markets (Fiji) and domestic markets (Fiji, Australia), consistently (e.g. quicker recovery following natural disaster setbacks, less supply chain loss)	• Papaya grown and exported from Fiji does not require chemicals • Organic production in Fiji • Biodegradable packaging • Risk of erosion as production shifts to slopes to avoid flood	• Increase in sustainability of 'papaya-based' livelihoods – smallholders and the supply chain (Fiji) • New confidence that industry can recover from cyclone (Fiji, Australia)

Final impacts

Economic	Environmental	Social
• Fiji – improved livelihoods via reduced fruit loss, saved supply chain costs, improved prices • Australia – reduced production cost by reducing post-harvest losses	• No negative impacts if Fiji industry relocation to flood-free slopes judiciously managed	• A 20.5% increase in smallholder income with project adoption • Some poverty alleviation potential • Australia – jobs and industry confidence with rapid cyclone recovery

Notes: HACCP – Hazard Analysis Critical Control Points; HTFA – high-temperature, forced-air; MOA – Ministry of Agriculture (Fiji); NWC – Nature's Way Cooperative; PPP – public–private partnership;

Figure 5.2 Impact map for the Fiji papaya project (continued)

6 Project outputs

6.1 Technologies

New technologies developed as a result of ACIAR and partner investment in the Fiji papaya project are described for Fiji and Australia.

Technologies developed in Fiji

The project was ambitious and somewhat unusual, with trial papaya shipments taking smallholder produce into a global setting. The Fiji papaya project focused its trial activities on existing papaya farms in the Sigatoka and Nadi areas rather than government-operated research stations. Papaya growers and exporters viewed the project as practical and action oriented. The project produced a range of technologies to facilitate production and expansion of the commercial trade, including a better defined papaya cultivar, best practice for seed and seedling production, organic papaya, a grower feedback system, improved pre-export treatments, supply chain refinements and a redesigned carton and pallet.

Local Sunrise Solo cultivars selected to define Fiji Red

Planned importation of Sunrise Solo seed from Hawaii was aborted due to concerns about the threat of papaya ring spot virus, bacterial crown rot and the risk to export markets if seed that had been genetically modified to resist papaya ring spot virus was used. Instead, selections of locally adapted Sunrise Solo were identified and graded to establish a varietal standard for Fiji Red papaya suitable for supply to export markets.

NWC notes that selection to define Fiji Red has resulted in fruit with higher brix and more consistent shape and weight (Kaitu Erasito, NWC, personal communication, November 2020).

Best-practice seed production and a seed certification system established

The project completed seed-production trials in the Sigatoka and Nadi areas to ensure a consistent and ‘true to type’ Fiji Red, Sunrise Solo. The trials were used to compare seed from bagged flowers to non-bagged flowers and concluded that bagging was necessary to avoid genetic contamination from cross-pollination. Effective bagging techniques were identified. A package for best-practice seed selection was documented from these trials and a national seed-production standard was developed by the project and the MOA Research Division. The certification scheme is operated profitably by the private sector, and is audited and certified by MOA.

All seed used for export papaya and most seed used for domestic production is supplied through the certification scheme. Certified seed has also been supplied to growers in Viti Levu (Fiji), Taveuni Island (Fiji), Tonga, Samoa, Vanuatu, and Palau (Andrew McGregor and Livai Tora, Koko Siga, personal communication, November 2020).

Papaya seedling production practices evaluated

The project collaborated with the AusAID-funded Small and Micro Nursery Enterprise Development project for Sustainable Seedling Supply to develop and evaluate a model for cost-effective production of quality papaya seedlings. Seedling production trials and a demonstration nursery were established in Nadi. The trial and nursery were successful, and a best-practice seedling production package was prepared and promoted to small papaya nurseries across Fiji (Stice et al. 2016). In 2019, there was a national network of small commercial seedling nurseries that were the direct result of the Fiji papaya project (McGregor 2019).

Organic production system trialled successfully

Production trials were completed in the Sigatoka and Nadi area with Hawaii's Kumu Farms, comparing conventional and organic production. The aim of the trials was to determine the economics of organic papaya production under Fijian conditions. A profitable organic production system was documented, and subsequent market research completed by the project showed that profitable export markets exist for organic Fiji Red papaya, especially in the USA.

Research results were used by Fiji's then-largest grower/exporter, PSL (Produce Specialities Limited), and the newly formed Sabeto Organic Producers' Association to investigate commercial organic ventures in partnership with Kumu Farms. Additional work required prior to a successful commercial venture included verification of the economics of organic papaya production and third-party organic certification. The project investigated certification with the Pacific Organic and Ethical Trade Community.

The later stages of the project supported a Kumu Farms commercial organic production planting in the Nadi area. The Kumu Farms planting was adversely impacted by floods in March 2012 and destroyed by Tropical Cyclone Winston in February 2016. The long-term success of organic papaya production will be dependent on access to the USA market, which had not been secured in 2020 (Andrew McGregor, Koko Siga, personal communication, November 2020).

Quality monitoring, traceability and feedback system developed

Prior to project commencement, the bilateral quarantine agreement with New Zealand required the coding of all field crates packed by registered growers before they entered the NWC treatment plant. This procedure required strengthening and the project developed and implemented an export-quality monitoring, traceability and feedback system. The system provided growers with information on the performance of their papaya. Feedback was communicated to growers on a quarterly basis during the project via the project's Technical Advisory Board, newsletters and the project website. Feedback was made available through the NWC-managed Research and Extension Partnership Committee for a number of years after the project. Reactivation of this committee has been identified as an industry priority (Andrew McGregor, Koko Siga, personal communication, November 2020).

Pre-export papaya treatment technology defined

Post-harvest trials were completed by the project using partially permeable plastic packaging to modify the CO_2/O_2 environment of the fruit. This form of modified atmosphere packaging was found to be helpful in controlling ripening and reducing papaya water loss. Hot water dips and various surface treatments were also trialled and found to reduce the development of papaya rots during a simulated transport period.

Various post-harvest treatments were trialled in conjunction with the HTFA treatment to control fungal disease. A post-harvest, pre-export treatment regime based on hot water dips and the use of the fungicide Sportak (prochloraz) was recommended.

The Fiji papaya project's final report notes that adoption of post-harvest, pre-export treatment recommendations will overcome a major source of post-harvest loss currently experienced by the industry. The recommendation was the result of a collaboration between the Fiji papaya project, DAF and SPC (Stice et al. 2016).

In 2020, NWC found that hot water dipping treatment has helped minimise papaya rejection rates in export markets during the wetter months of the year. Chemical fungicides are not used (Kaitu Erasito, NWC, personal communication, November 2020).

Export supply chain refinement

A series of harvest and post-harvest assessments were carried out by Queensland's DAF in 2010. These assessments tracked the supply chains of 2 local papaya exporters to investigate where the greatest level of physical damage was occurring. The investigation showed that most damage was occurring during transportation from Sigatoka to Nadi, and additional packing material was recommended (Stice et al. 2016).

Analysis of the export supply chain and Fijian papaya turnout at the Melbourne Wholesale Fruit Markets identified opportunities to improve fruit quality and reduce supply chain loss. Recommendations included NWC adoption of HACCP certification and the development of simple low-cost handling and packing materials to avoid fruit damage. HACCP certification was advanced as a result of the European Union-funded SPC 'Facilitating Agricultural Commodity Trade' project. Simple solutions to avoid damage to export papaya included the use of newspaper to line harvest bins and additional packing material in export cartons. Newspaper was subsequently approved by both New Zealand and Australia as a carton packing material for export papaya. The switch to newspaper from purchased foam was also more cost-effective (Stice et al. 2016).

NWC has subsequently secured HACCP certification (Kaitu Erasito, NWC, personal communication, November 2020).

Carton and pallet redesign for sea freight

As a result of a successful trial of sea freighting papaya from Fiji to New Zealand, cartons and pallets were redesigned to align with larger sea freight containers. Vents were added to the papaya export cartons to enhance temperature control, an internal collar was added for stacking strength and the pallet was covered in a 'sock' to prevent fruit fly access. The project showed that it was technically possible to sea freight papaya from Fiji to New Zealand.

However, for sea freight of papaya to be economically viable, a 40-foot refrigerated container (known as a reefer) must be filled. A reefer requires 10 times more fresh produce by volume than an airfreight container. The supply of available papaya has not yet been sufficient to allow commercial sea freight (Andrew McGregor, Koko Siga, personal communication, November 2020). To date, in 2020, no exporters have attempted sea freight export of papaya (Kaitu Erasito, NWC, personal communication, November 2020).

Technologies developed in Australia

The Australian component of the Fiji papaya project mapped 5 domestic supply chains and worked with 4 major commercial partners (Mackay Estates, Lecker Farms, Tropical Coast Papaya and Skybury Farm) to identify issues affecting papaya quality. Technologies developed for the Australian situation included rapid assessment of the nitrogen status of papaya plantations, pre-harvest disease control, post-harvest treatment and pre-ripening temperature adjustment.

Rapid assessment of nitrogen status of plantations

Rapid assessment of nitrogen status has been made possible using satellite images or drone footage calibrated to known nitrogen status blocks. The technology was fine-tuned during the project using papaya petiole leaf nitrogen data collected as part of another experiment. The technique has the potential to deliver improvements in plantation management and hence economic return. To date, the technology has not been adopted by Australian papaya producers (Yan Diczbalis, coordinating scientist HORT/2008/033, personal communication, November 2020).

Pre-harvest disease control

The project identified the role older trees play in hosting fungal diseases and the importance of orchard hygiene for pre-harvest disease control. Acting on both these measures addressed a significant source of fruit breakdown in the Australian supply chain.

Post-harvest treatment

The project investigated post-harvest treatment of papaya using hot water dips, applying the post-harvest fungicide Sportak and enveloping individual papaya in modified atmosphere packaging. Post-harvest fungicide research included assessment of Sportak application methods, the effect of solution pH and potential alternative fungicides. The project identified subtle changes in pre-dispatch, especially the importance of lowering fruit ripening temperature, that, when implemented, improved fruit quality. Ripening room temperature recommendations have been adopted by industry (Gerard Kath, Lecker Farms and president of Papaya Australia, personal communication, November 2020).

6.2 Scientific knowledge

The research completed as part of the project has made contributions to the science of papaya production and post-harvest management as well as the resolution of supply chain issues that facilitate Fijian papaya exports and the long distance, interstate movement of Australian papaya. Across the Australian and Fiji project teams, a total of 35 papers and reports were produced.

Scientific knowledge created in Fiji

Areas of knowledge developed by the Fiji papaya project (HORT/2008/033) in Fiji include papaya production, disaster recovery, the impact of tree age on fruit fungus, market insight, sources of damage in the airfreight supply chain and the viability of sea freighting Fijian papaya.

Production knowledge

The project delivered results from field trials that addressed organic production, the use of drip irrigation, crop thinning to improve papaya quality, and the testing of papaya varieties and cultivars. While trials were interrupted by both a flood and a cyclone, useful insights were generated and communicated by the project to papaya producers. A scientific paper, *The economics of organic papaya production in Fiji*, was prepared and presented at the Third International Symposium on Papaya in Chiang Mai, Thailand, in 2011, and was subsequently published in the conference proceedings (Stice et al. 2014).

Production research also included working with the SPC Plant Pathology team to identify disorders and formulate solutions. The ability to respond quickly when a disorder was identified meant that supply to the Australian market could continue uninterrupted (McGregor 2019). The project investigated a range of pre-harvest fungicides on post-harvest papaya quality and completed a preliminary evaluation of the harvest maturity effects on post-harvest fruit quality for new hybrid papaya lines (McGregor et al. 2012; Stice et al. 2016).

Disaster recovery

When Tropical Cyclone Evan devastated the Fijian papaya industry in 2012, the project turned adversity into opportunity and completed preliminary cyclone preparation and recovery research. Research included ratooning and defoliation pre-cyclone, and control of fruit sunburn post-cyclone.

The research was relevant to the Fijian and Australian industries, which are both susceptible to cyclone damage. Disaster recovery techniques developed during the project, including sunburn management, are now practised by the majority of papaya growers (Manoa Iranacolaivalu, MOA, personal communication, November 2020). Growers now have a better understanding of how to prepare their farms prior to, and post, adverse weather conditions (Kaitu Erasito, NWC, personal communication, November 2020).

Tree age and the incidence of post-harvest disease

The importance of tree age and the role of older trees in hosting fungi was also researched in Fiji. The pronounced link between older papaya trees and fruit contamination that is apparent in Australia was not apparent in Fiji. The research concluded that the Fijian cropping environment has a lower fungal load than that found in Australia.

Market insight and Pacific value chains

Market and value-chain knowledge were created by the project in partnership with the European Union 'Facilitating Agricultural Commodity Trade' project. Markets for Fiji Red papaya identified as profitable included Australia, New Zealand, Hong Kong and Japan, and potentially the USA, if access can be secured. NWC has invested to secure access to the USA market, with a particular focus on the supply of organic papaya. A paper based on these studies titled *An appraisal of value-chain development in the Pacific* (McGregor et al. 6–9 November 2012) was presented at a Technical Centre for Agricultural and Rural Cooperation (CTA) International Value Chain Conference in 2012 and subsequently published by CTA.

A Cook Islands industry representative participated in papaya-related meetings in Fiji, including an industry presentation of the market study findings (Stice et al. 2016).

Fruit quality assessment at Melbourne Markets

Fruit quality assessments for 2 Fijian exporters were completed at the Melbourne Wholesale Fruit Markets in 2012, and for one in 2014. These assessments identified key quality issues, documented and communicated research findings through the project's Technical Advisory Board, and proposed further research and strategies to solve shortfalls in product quality.

Successful sea freight trials to New Zealand and Australia simulation

The project built on previous investigations completed during other research projects to trial shipping Fijian papaya to New Zealand. The trial was successful, and research was completed to further enhance fruit turnout on arrival in Auckland, for example, by ripening at destination. The cost of sea freight was nearly 50% lower than the cost of airfreight.

A simulated sea freight trial with a transit time of between 15 and 21 days was also successfully completed. A transit time of this duration would be short enough to both deliver Fijian papaya to east coast Australian markets and provide fruit with a commercially viable shelf life.

Table 6.1 Fijian reports and publications prepared as part of the Fiji papaya project

Year	Report/publication title and authors
2010	*Report on a visit to the Fiji papaya industry* (Lindsay and Vawdrey)
2011	*Fiji papaya supply chain – report outline*, Oct 2010, ACIAR PC 2008-03 (Diczbalis, Campbell, Stice and Tora)
2011	*Optimising sea freight Fiji papaya, R&D trials – preliminary report* (Campbell, Diczbalis, Stice and Tora)
2011	*Papaya fruit assessment – Nadi, Fiji to Melbourne, Australia*, Exporter Pacific Harvest (Diczbalis)
2011	*Papaya fruit assessment – Nadi, Fiji to Melbourne, Australia*, Exporter PSL (Diczbalis)
2012	*An appraisal of value-chain development in the Pacific* (McGregor, Stice, Tora and Erasito)
2012	*An evaluation of post-harvest treatments for the control of post-harvest rots in export papaya from Fiji* (Diczbalis, Stice and Tora)
2012	*Natural disaster mitigation strategies for the Fiji papaya industry* (Stice and McGregor)
2013	*Effect of hot water and fungicide treatments on papaya postharvest quality* (Henriod, Diczbalis, Sole and Stice)
2014	*Developing a commercial hot water treatment to control post-harvest rots on Fiji Red papaya* (Stice, Tora, Henriod, Diczbalis and Sole)
2014	*Modified atmosphere packaging effects on the postharvest quality of papaya fruit* (Sole, Diczbalis, Stice and Tora)
2014	*The economics of growing organic papaya in Fiji* (Stice, Tora and McGregor)

Source: Various, including Chapman and Hazelman unpublished and ACIAR project records

Fijian reports and publications

Fijian reports and publications prepared as part of the Fiji papaya project are summarised in Table 6.1.

Scientific knowledge created in Australia

Areas of knowledge developed by the Fiji papaya project in Australia include sources of papaya damage in the Australian supply chain, use of post-harvest fungicide to improve papaya quality and reduction in ripening temperature to avoid fruit loss. A comprehensive set of internal papers and scientific publications was generated from the Fiji papaya project research in Australia.

Sources of papaya damage in the Australian supply chain

Sources of papaya damage in the long interstate Australian supply chain were identified by the project. Sources of damage included pre-harvest disease, tree age, fruit maturity at harvest, fruit sourced during the wet season, a coastal growing location, harvest injury, post-harvest disease control and ripening room temperature.

Use of post-harvest fungicide to improve papaya quality

Fungal species most commonly identified on Australian grown papaya were anthracnose (*Colletotrichum gloeosporioides*), stem-end rots (caused by *Mycosphaerella* and/or *Phomopsis*), black rot (*Phoma* sp.), rhizopus rot (*Rhizopus* sp.) and *Phytophthora* fruit rot (*Phytophthora palmivora*). During the wet season, and prior to this project, fruit spoilage at interstate wholesale markets was as high as 30% (Stice et al. 2016).

The project investigated the use of the post-harvest fungicide Sportak to improve the quality of papaya in the Australian value chain. Sportak was found to be effective and recommendations were prepared outlining optimal concentration rates, the importance of maintaining solution pH and the need to manage the depletion of the active ingredients during the recycling of solutions. The research resulted in the preparation and publishing of a scientific paper titled *Evaluation of the use of prochloraz for control of post-harvest diseases of papaya in Australia* (Diczbalis et al. 2014) that was presented to the Third International Symposium on Papaya, in Chiang Mai, Thailand, in 2011.

The project also investigated alternative chemicals, coatings and hot water treatments. Hot water treatments were found to be the most effective. Research effort was applied to refining temperature by exposure times to ensure disease control without causing scald damage or ripening delays due to high temperature breakdown of ripening enzymes (Stice et al. 2016).

Reduction in ripening temperature to avoid papaya loss

Project research showed that lowering papaya ripening temperature from 26–30 °C to 18–22 °C reduced fruit loss and improved shelf life and eating quality. As a result of this work, the 2 largest papaya growers, who produce between 30% and 60% of the Australian crop, have reduced their pre-ripening room temperatures to 20–24 °C (Stice et al. 2016; Yan Diczbalis, coordinating scientist HORT/2008/033, personal communication, November 2020).

Australian reports and publications

Australian reports and publications prepared as part of the Fiji papaya project are summarised in Table 6.2.

Table 6.2 Australian reports and publications prepared as part of the Fiji papaya project

Year	Report/publication title and authors
2009	*Papaya monitoring report – tableland papaya to Brisbane* (Campbell, Lindsay, Henriod and Sole)
2009	*Papaya monitoring report – tropical coast papaya to G Stanton & Sons, Brisbane* (Campbell, Lindsay, Henriod and Sole)
2010	*Effects of field applied fungicide sprays on post-harvest diseases in papaya fruit* (Henriod, Campbell, Lindsay and Sole)
2010	*Red papaya handling chain monitoring report – RB1 red papaya to Sydney markets* (Campbell and Lindsay)
2010	*Ripening temperature effects on papaya fruit quality during the dry season* (Henriod, Campbell, Lindsay and Sole)
2010	*Ripening temperature effects on papaya fruit quality during the wet season* (Henriod, Campbell, Lindsay and Sole)
2011	*A preliminary investigation into the use of high resolution imagery for the determination of nitrogen status, plant health and crop production areas in papaya (*Carica papaya*) crops in far north Queensland* (Ibell and Diczbalis)
2011	*A preliminary investigation into the use of SPAD chlorophyll meter for the determination of nitrogen status in papaya (*Carica papaya*) variety 1B in far north Queensland* (Ibell and Diczbalis)
2011	*Effect of ripening temperature and growing location on the saleable life of 1B papaya fruit* (Henriod, Diczbalis, Campbell and Sole)
2011	*Evaluation of the effect of pH on the efficacy of Sportak as a postharvest fungicide* (Diczbalis, Henriod and Sole)
2011	*Evaluation of the use of prochloraz in the control of post-harvest diseases of papaya in Australia* (Diczbalis, Henriod, Sole and Campbell)
2011	*Lecker papaya – Mareeba to Melbourne and Mareeba to Brisbane* (Diczbalis and Campbell)
2011	*Papaya post-harvest supply chain work – Australian activities* (Diczbalis, Henriod, Campbell and Sole)
2011	*Papaya saleability trial – summary May 2011* (Henriod)
2012	*Effect of hot water and chitosan on post-harvest disease control in papaya* (Henriod, Diczbalis and Sole)
2012	*Effect of pH on the efficacy of Sportak (prochloraz) for post-harvest disease control in papaya* (Henriod, Diczbalis and Sole)
2013	*Effects of post-harvest Ethrel and Sportak treatments on papaya quality* (Henriod, Diczbalis, Sole, Tora and Iranacola)
2013	*Effects of post-harvest fruit coatings and fungicide treatments on papaya fruit quality* (Henriod, Diczbalis, Sole, Tora and Iranacola)
2013	*Investigation into the efficacy of several commercial fungicides on papaya postharvest quality* (Henriod, Diczbalis, Sole and Stice)
2014	*Hot water treatment effects on fruit quality of several commercial papaya varieties* (Henriod, Diczbalis and Sole)
2014	*Investigation into various fungicides and alternative solutions for controlling postharvest diseases in papaya fruit* (Henriod, Diczbalis, Sole, Stice and Tora)

Source: Various, including Chapman and Hazelman unpublished and ACIAR project records

6.3 Capacity development

Capacity development can be thought of in terms of people, networks and infrastructure and their ongoing application to in-country research questions and extension issues. Capacity development as a result of ACIAR investment in the Fiji papaya project is described for Fiji and Australia.

Capacity development in Fiji

People

Technical staff

The project trained and built capacity in technical staff, farmers and workers in the export supply chain using an innovative PPP that included NWC. Focusing the development of capacity through NWC ensured that the training supplied, and the capacity developed, was commercially relevant and had a better chance of being sustained after project completion.

Individual technical staff trained during the project, the training provided and the individual's current role in papaya and horticulture are summarised in Table 6.3.

Project team, MOA and NWC research and extension staff were trained in variety evaluation, seed production, post-harvest handling, hot water dipping, value-chain analysis and sea freight of fresh horticultural commodities. The establishment of an industry-operated and -focused research and extension service, managed by NWC, was a major achievement of the Fiji papaya project (Andrew McGregor, Koko Siga, personal communication, November 2020).

Project technical staff were trained through a series of applied engagement activities. Project leader Kyle Stice and coordinator Sant Kumar travelled to North Queensland in August 2009 on a technical exchange visit to meet Australian project partners.

A study tour to Hawaii was completed by Kyle Stice and project team member Livai Tora in November 2011. Tim Casey, chair of the project's Technical Advisory Board, visited North Queensland in 2012 to review the Australian papaya industry and relevant research and extension systems.

In March 2012, post-harvest treatment trials were completed by project, Queensland DAF and MOA staff. MOA pathologist Mereia Lomavatu developed additional skills in the identification of pathogens (Stice et al. 2016).

At the invitation of Queensland DAF, 4 Fijian researchers (Livai Tora, Kaitu Erasito, Manoa Iranacola and Timote Waqainabete) were invited to collaborate on a series of Australian papaya post-harvest trials. Over a period of 4 weeks in 2013, these project staff worked with their DAF counterparts at the post-harvest laboratory in Cairns. Training included value-chain analysis, fruit quality evaluation, temperature monitoring and modified atmosphere packaging gas measurement (Stice et al. unpublished).

In 2014, the plant pathology component of the project was completed with SPC. No important diseases of papaya were identified on Viti Levu. Officers from MOA, the Biosecurity Authority of Fiji (BAF) and NWC were trained to detect the primary symptoms of the major exotic diseases of papaya.

Technical staff prepared and presented papers at international horticulture and papaya conferences. Project leader Kyle Stice was invited to present a paper and chair a session at the Second International Symposium on Papaya held in Madurai, India, in 2010. Papers were also presented at the Third International Symposium on Papaya in Chiang Mai, Thailand, and the International Horticulture Congress in Lisbon, Portugal.

The project supported an incomplete Master of Science thesis by Vika Raiwalui (Livai Tora, Koko Siga, personal communication, November 2020). The thesis addressed the management of *Phytophthora* root rot in papaya using *Brassica* species.

A major output of the project has been an improved understanding of the horticultural value chain. Value-chain analysis has subsequently been applied to the development of Fijian commodities including breadfruit, cocoa, eggplant, ginger, kava, mango, pineapple, taro, vanilla and wi apple. Two publications have been prepared:

- McGregor A and Stice K (2014) *Agricultural value chain guide for the Pacific islands: making value-chain analysis a useful tool in the hands of farmers, traders and policy makers*, CTA
- PIFON (Pacific Island Farmers Organisation Network) (2019) *Agricultural value chain guide for the Pacific*, PIFON.

Both these documents employed the Fijian papaya export value-chain model. The project team also provided value-chain training using the Fiji papaya project experience in Tonga, Samoa and Vanuatu (Andrew McGregor and Livai Tora, Koko Siga, personal communication, November 2020).

Table 6.3 Fijian technical staff trained as part of the Fiji papaya project

Name	Project role	Training provided	Current role in industry
Kyle Stice	Project leader	• Study tour to Australia to review the Australian papaya industry • Study tour to Hawaii to review the Hawaiian industry and organic papaya production • Hands on practical training received which laid the foundations for his Fiji horticultural career and role as an industry leader	• Managed ACIAR project 'Enhanced fruit production and postharvest handling systems for Fiji, Samoa, and Tonga' (HORT/2014/077) from 2016 to 2020 • Served as the acting manager of NWC and is currently the manager of the Pacific Island Farmers Organisation Network • Recently authored a chapter in the book *Vulnerability of Pacific island agriculture and forestry to climate change* (Taylor 2016)
Kaitu Erasito	Project coordinator	• Participant in Australian post-harvest papaya trials in Cairns • Worked directly with farmers and nursery owners	• Ongoing role with NWC research and extension team with particular responsibility for the Fiji Red papaya certified seed program • Leading trainer of farmers in understanding the value chain and improving the capacity of nursery owners
Sant Kumar	Project coordinator	• Study tour to Australia to review the Australian papaya industry • Lead coordinator of nursery component of the project • Worked with/coordinated the Taiwanese Technical Mission	• Principal of BulaAgro Enterprises, the largest and most successful Fiji certified papaya seedling producer • Chief executive officer of NWC • Works across the value chain with freight agents and agricultural input suppliers servicing papaya
Livai Tora	Project coordinator	• Study tour to Hawaii to review industry, organic papaya production • Participant in Australian post-harvest papaya trials in Cairns • Worked directly with farmers and nursery owners • Established the Sabeto Organic Papaya Association • Trained in organic production with Grant Schule, Molakai, Hawaii	• Chair of the NWC • Actively involved in 'train the trainer' value-chain understanding initiatives in Fiji and other Pacific island countries (value-chain training has been provided to growers of a wide variety of tropical crops including breadfruit, cocoa, eggplant, ginger, kava, mango, pineapple and wi apple)
Timote Waqainabete	Project coordinator	• Participant in Australian post-harvest papaya trials in Cairns	• Private-sector agribusiness consultant
Mereia Lomavatu	Researcher	• Trained using project resources and developed additional skills in the identification of pathogens and assisted with analysis of residue levels following fungicide treatment	• MOA pathologist
Vika Raiwalui	Researcher	• Scholarship funding provided by ACIAR to support completion of a MSc	• MSc commenced
Manoa Iranacola	MOA staff	• Participant in Australian post-harvest papaya trials in Cairns	• Principal research officer for horticulture within MOA

Source: Industry consultation

Extension officers and potential papaya growers

MOA extension services personnel engaged with the project through observation and participation in activities at Fiji papaya project trial sites. MOA personnel participated in 'train the trainer' workshops. Staff from the Fiji College of Agriculture visited project trial sites and were engaged with the project throughout its duration. The Fiji papaya project was delivered in partnership with the Koronivia Research Station, which hosted a number of project trials and whose staff benefited from trial participation.

Twelve farmer workshops and field days were successfully completed by the project with 300 farming households (approximately 900 people) trained (Stice et al. 2016). In May 2011, a major Sigatoka Valley field day was organised by the project, MOA and the Taiwanese Technical Mission Smallholder Papaya Project. A total of 450 farmers and agriculture students visited project trial sites between December 2009 and June 2012 (Chapman and Hazelman unpublished).

Export supply chain employees

Eleven exporter enterprises (approximately 100 people) were trained in selecting and managing papaya for export (Stice et al. 2016). Papaya exporters and the export supply chain were engaged in the Fiji papaya project through the presentation of research findings to meetings of the Fiji Fresh Produce Exporters Association and the preparation and distribution of best-practice Fiji Red papaya grading and packing guides.

Extension materials

Capacity-building materials produced by the Fiji papaya project and used by farmers and the supply chain included a project documentary, website, posters and fact sheets. Project activities were highlighted in a documentary that aired on a regional Viti Levu TV program called *Pacific Way*. The project website hosted information on research trials, workshop and field day participation opportunities, and papaya fact sheets. The project website was used by Viti Levu growers, as well as regional and international stakeholders, including stakeholders in other Pacific island countries. The project website has now been transferred to the NWC Research and Extension Network website (**nwcfiji.com/fiji-red-papaya/**).

Project posters were prepared and distributed to growers and exporters. Posters detailed specific guidelines on harvesting, fruit colour, grading and packing. Posters also addressed National Disaster Mitigation Strategies for the Fiji papaya industry.

Fact sheets produced and distributed by the project via email and newsletter included:

- Fiji Red
- Papaya farming as a business
- Fiji papaya – the BQA (Bilateral Quarantine Arrangement Fiji–NZ) pathway
- The business of exporting papaya
- High-quality seedlings for success
- Sex and papaya
- Harvest maturity
- Grading and packing
- Hidden damage of papaya fruit.

It was intended that these fact sheets would be consolidated into a Fiji Red papaya production manual. This did not occur, and training material now needs to be updated and made more 'farmer friendly'. A significant number of copies of finalised material will need to be printed and also made available online (Andrew McGregor, Koko Siga, personal communication, November 2020).

Technical Advisory Board

The Technical Advisory Board was established by the project in 2009 to identify papaya production and post-harvest problems and conduct on-farm and supply chain research. The TAB was made up of exporters, growers, government officials (MOA, BAF) and technical advisor representatives (SPC, HORT/2008/033). The Technical Advisory Board held 20 well-attended quarterly meetings over the life of the project and one of its major achievements was leveraging of technical inputs from other stakeholders, including MOA Research, SPC and the Taiwanese Technical Mission.

After the project was completed, the Technical Advisory Board evolved into an effective papaya industry representative body. The Technical Advisory Board was maintained by NWC as a Research and Extension Partnership Committee. The first committee meeting was held in February 2014. Unfortunately, the committee has been discontinued due to lack of funding. The HTFA Commodities Plan 2019 (McGregor 2019) proposes that the Research and Extension Partnership Committee be reinstated.

Network monitoring

The export-quality monitoring, traceability and feedback system established by the Fiji papaya project provided feedback to growers on the quality of their fruit during the project. The feedback system was established in conjunction with NWC Field Services and provided information to growers via the Technical Advisory Board, the Research and Extension Partnership Committee, and the NWC website.

Seed certification scheme

Project researchers and the MOA worked together to identify 8 private-sector seed producing enterprises. Training was provided to the enterprises, which were also supported with project-produced production guidelines and quality standards. The seed certification scheme has persisted and is run on a commercial basis by NWC, with oversight and auditing by the MOA. At the project's end, Viti Levu had 12 certified papaya seed producers (Stice et al. 2016).

Certified seed production and stockpiling has enabled the industry to recover after natural disasters and is a major Fiji papaya project achievement (McGregor 2019).

Public–private partnership implementation model

The PPP model developed to implement the Fiji papaya project in Fiji was novel. Central to the model was NWC, a private, for-profit entity. The PPP model linked through from ACIAR to SPC to NWC, MOA and the industry. NWC was incentivised to make the project work through the need to generate a profit. This ensured that project outputs were commercially focused (for example, papaya of consistent quality and at lower cost and more effective supply chains). NWC communicated the project findings to growers and adopted outputs to maximise its profit. The PPP model should be considered by ACIAR for other supply chain projects in Pacific island countries (Chapman and Hazelman unpublished).

Capacity development in Australia

People

Technical staff

As part of the project, Queensland DAF team members developed and refined core competencies in applied horticultural RD&E. No Queensland DAF staff received training as part of the project.

Papaya growers

The project attracted 35 current and potential growers to a Papaya Variety Field Day and a further 32 participants to a Supply Chain Research Workshop. The project team attended monthly Papaya Australia meetings in Innisfail to aid with the transfer of project findings to industry (Stice et al. unpublished). Papaya Australia is the peak body for the industry in Australia.

Extension materials

Extension materials produced and distributed by the project included posters and fact sheets addressing disease treatments and revised ripening temperatures. Extension materials were aimed at improving post-harvest handling and the consistency of Australian papaya through the interstate supply chain.

6.4 Policy and development goals

Fijian policy and development goals

The development of horticultural exports, including papaya, has been a policy priority in Fiji since the loss of preferential European Union sugar market access at the turn of the century. The Fiji papaya project has directly addressed this longstanding and important priority.

Specific Fijian Government agricultural policy and development goals addressed by the Fiji papaya project are summarised in Table 6.4.

Table 6.4 Fijian agricultural policy priorities

Policy goal	Red papaya project contribution
Food security through the provision of extension and research services both livestock and crops	• Approximately 2,000 t of papaya is consumed annually by smallholder growers and through local markets. The balance of production is consumed through hotels and export. • The project provided demonstration sites and extension material for use by smallholders. • Papaya production has been encouraged in other parts of Fiji, including Taveuni Island.
Quick economic recovery through the implementation of the Demand Driven Approach Program and other commodity projects	• The project developed agronomic systems to minimise cyclone damage and maintain papaya quality in the cyclone recovery phase. • The project provided recommendations pertaining to the relocation of the industry to land on a slope to avoid flood damage.
Poverty alleviation by building capacity of farmers to increase production	• More than 300 smallholder farmers (900 people) were trained via workshops, field days and fact sheets.
Sustainable management of natural resources through sustainable land management practices	• No negative implications for sustainable land management if industry relocation to flood-free slopes is judiciously managed and soil erosion is avoided.

Source: MOA website (agriculture.gov.fj/divisions)

The project has made a meaningful contribution to all 4 policy priorities.

The success of the project's certified seed program resulted in a Fijian Government policy (regulations) prohibiting the import of Hawaiian Sunrise Solo papaya seed. The policy change was made to ensure that Fiji was not exposed to the risk of importing highly destructive papaya ringspot virus (Andrew McGregor, Koko Siga, personal communication, November 2020).

The project's success with papaya seed production based on private-sector profitability, MOA audit and certification has become the guiding principle for Fiji's seed policy formulation process (Stice et al. 2016). The improved supply of Fiji Red papaya, at the expense of the less palatable Waimanalo type, has brought with it substantial food security and nutritional benefits (Andrew McGregor, Koko Siga, personal communication, November 2020).

Following the project, the MOA has adopted a policy of value-chain analysis for investment in industry RD&E. A value-chain approach was successfully pioneered through the Fiji papaya project with a focus on end markets and solving fruit losses in the post-harvest supply chain.

The project encouraged consumption of papaya in Fiji in line with the Ministry of Health's healthy diet initiative. The initiative was aimed at promoting a healthy diet by consuming more fruits and vegetables (Stice et al. 2016).

It has been suggested that Fijian Government policy be developed around the national carrier (Fiji Airways) taking a more responsive approach to scheduling to meet the needs of fresh produce exporters when determining flight schedules and future aircraft acquisition. The national carrier needs a broader focus than just catering to tourism development (McGregor 2019).

Australian policy and development goals

Australian Government policy is to support sustainable and profitable horticultural industry through matching funding for RD&E. The Australian papaya industry has 3 RD&E development goals (Table 6.5).

The project has made a meaningful contribution to all 3 Australian papaya industry development goals.

Table 6.5 Australian papaya industry priorities

Industry priority	Red papaya project contribution
Increased quality to ensure consistency of supply to the consumer	• Identification and reduction of sources of papaya supply chain loss
Access to new varieties and improved pest and disease management to improve grower productivity and profitability	• Identification of fungal disease, especially in older trees as a significant source of post-harvest papaya loss • Fungal disease solutions communicated to Australian growers
Improved market access and increased consumer demand to increase returns to growers	• A more consistent papaya that is less prone to breaking down in the supply chain and has a longer post-purchase shelf life, to encourage increased consumption in Australia

Source: HIA 2017

7 Uptake of research and development outputs

Adoption of R&D outputs includes uptake of new technologies, new scientific knowledge and new knowledge models. It considers R&D uptake by both initial users (for example, researchers) and final users (for example, papaya growers).

7.1 Research and development outputs adopted in Fiji

An uptake timeline for R&D outputs in Fiji is shown in Table 7.1.

Table 7.1 Uptake of new technology and science, Fiji

Date	Research output and its uptake
2009	• Technical Advisory Board established and feedback supplied to growers on the quality of papaya sent and received in exports
2010	• High-quality certified papaya seed produced and used by growers supplying export markets • NWC achieves HACCP certification as a result of project and European Union 'Facilitating Agricultural Commodity Trade' project support • Growers and exporters aware of best-practice harvest and post-harvest practices to minimise papaya damage • Low-cost solutions adopted, e.g. newspaper lining of field bins
2011	• The profitability of organic papaya production established • A farmer group trials organic papaya production (Stice et al. 2016) • Successful New Zealand sea freight trial led to a number of trial consignments • NWC investment in improved sea freight facilities at the HTFA complex • Major Papaya Industry Stakeholder Workshop held in the Sigatoka Valley, 24 May 2011
2012	• MOA Flood Damage Assessment Report identifies 33 ha of papaya destroyed • The Fiji papaya project and AusAID provide 80,000 seedlings to plant 65 ha of papaya • Cyclone recovery strategy to avoid sunburn damage adopted by growers • Small, registered papaya grower numbers increase from 100 to 110 and papaya exporter numbers increase from 9 to 11 (Chapman and Hazelman unpublished)
2013	• MOA extension officers trained in project findings ('train the trainer') • Fiji College of Agriculture staff introduced to the project and its implications • 300 farming households and 11 exporter enterprises trained in the use of improved agricultural and post-harvest technologies • Presentations made to Fiji Produce Exporters Association to ensure post-harvest recommendations are requested and observed prior to purchase • NWC adopts project recommendations in relation to post-harvest treatment – hot water dipping used on wet season fruit; NWC make capital investment in hot water treatment facility (Stice et al. 2016)
2014	• NWC commences supply of project-generated certified Fiji Red papaya seed and sales are brisk, meaning the industry is no longer at risk from imported seed (Stice et al. 2016) • Commercial investment in organic papaya production stalls due to failure to secure access to the USA market

Table 7.1 Uptake of new technology and science, Fiji (continued)

Date	Research output and its uptake
2015	• Technical Advisory Board 'institutionalised' by NWC and continues to identify research priorities and supply feedback on papaya quality to growers (Technical Advisory Board/ Research and Extension Partnership was suspended in 2020) • Trained MOA, BAF and NWC staff engage in papaya disease surveillance work • A cohesive industry created from a previously fragmented growers network • The industry is well positioned to respond to the needs of its members (Stice et al. 2016)
2016 to 2020	• Growers have made use of project outputs, especially certified papaya seed – all export derives from certified Fiji Red papaya seed (major project achievement) • Growers have additional papaya production capacity, including cyclone recovery • Post-harvest damage has been reduced through harvest and transport care • Fiji Red now has higher brix and more consistent shape and weight • Anecdotally, rejection rates for Fiji Red are now lower in export markets • Industry success limited by adverse climatic events and supply of airfreight

Source: Project literature and consultation

7.2 R&D outputs adopted in Australia

An uptake timeline for R&D outputs in Australia is shown in Table 7.2.

Table 7.2 Uptake of new technology and science, Australia

Date	Research output and its uptake
2010	• Australian supply chains mapped and external issues affecting papaya quality identified (Stice et al. unpublished) • Information on sources of damage and practice change required communicated to 32 growers at a September 2010 Supply Chain Research Workshop and via an Innisfail Papaya Growers Association meeting • Innisfail meetings routinely attended by 8 to 18 papaya growers, including the large growers that dominate industry production (Stice et al. unpublished)
2011	• Growers considered the costs and logistics of installing post-harvest hot water dips to further reduce supply chain damage
2012	• Papaya variety field day held at Lecker Farm in May 2012 and used to discuss supply chain solutions with the 35 Australian papaya growers in attendance (Stice et al. unpublished)
2014	• Use of hot water dips for disease control required further demonstration (Stice et al. 2016) and demonstration was pursued through Horticulture Innovation Australia project PP13000 (note: as of 2020 there has been no investment in hot water dipping technology by the Australian industry (Gerard Kath, Papaya Australia, personal communication, November 2020))
2015	• Project research showed that lowering papaya ripening temperature from 26–30 °C to 18–22 °C reduced fruit loss, and improved shelf life and eating quality • Two large growers who account for between 30% and 60% of Australian papaya production reduced their pre-ripening room temperatures to 20–24 °C (Gerard Kath, Papaya Australia, personal communication, November 2020)
2016 to 2020	• Improvements to inconsistent product flavour and fruit ripening behaviour, and reduced post-harvest losses, have been catalysed by the project among the wider Australian papaya industry (Stice et al. 2016) • Lowering of ripening room temperature, in line with the Fiji papaya project recommendations, is the major change in the industry afforded by the project (Gerard Kath, Papaya Australia, personal communication, November 2020)

Source: Project literature and consultation

7.3 Other Pacific island countries and Fijian fruit industries

The Fiji papaya project also had a brief to identify nascent papaya industries in other Pacific island countries and other fruit industries in Fiji that would benefit from the project approach. A Cook Islands industry representative participated in several papaya project meetings in Fiji, including the industry presentation of export market study findings. In the past, the Cook Islands had a successful papaya export industry, and the country was looking to re-establish the trade. In addition, the project assisted the Samoa Farmers Association in addressing papaya production problems experienced by their members.

Requests were made to Fiji papaya project staff for certified Fiji Red papaya seed by regional countries, including Tonga, Vanuatu, Samoa and Palau. Certified seed was supplied, and the resource was used to establish seed trees in regional countries. A follow-up ACIAR project, 'Enhanced fruit production and postharvest handling systems for Fiji, Samoa, and Tonga' (HORT/2014/077), made use of the value-chain approach used in the Fiji papaya project and turned certified seed and seed trees into community plantings, thus laying the foundations for alternative, smallholder livelihoods.

In Fiji, staff from the Fiji papaya project assisted the Tutu Rural Training Centre on Taveuni to establish a commercial papaya planting program, which now supplies local markets on the island, including tourist hotels. The Tutu Rural Training Centre was also developed as a diversified seed source to supply Viti Levu growers following a cyclone (Stice et al. unpublished). In Fiji, the value-chain approach used by the Fiji papaya project has subsequently been applied to breadfruit, cocoa, eggplant, ginger, kava, mango and wi apple development.

A papaya plantation in Fiji
Photo: ACIAR

8 Assessment of outcomes and impacts

8.1 Economic outcomes and impacts

ACIAR investment in the Fiji papaya project has created positive economic impacts in Fiji and Australia. An assessment of key research outcomes and impacts is provided for both countries.

Fijian economic outcomes and impacts

This assessment of project outcomes and impacts incorporates the timetable of key Fijian papaya industry events, a description of the 'without project' counterfactual, the outlook for the Fijian papaya industry (including the plan to address remaining constraints), forecast papaya markets, quantification of benefits for growers supplying export markets, quantification of benefits for growers supplying domestic markets, quantification of value-chain impacts and overarching assumptions used in the economic evaluation.

Key Fijian papaya industry events

The following timetable of events is significant to assessment of Fiji papaya project outcomes and impacts in Fiji (Table 8.1).

Every second or third year since project commencement in January 2009, cyclone and/or flood has destroyed or damaged a substantial area of Fiji's papaya production. Papaya production is particularly vulnerable to cyclone and flood damage in the traditional growing area of the Sigatoka Valley, where most farmers are located (McGregor 2019).

'Without project' counterfactual

In the absence of the Fiji papaya project, and linked papaya development projects, it is assumed:

1. Consistent, high-quality, Fiji Red papaya seed and seedlings would not have become available to growers. Consequence: export markets tire of inconsistent fruit and the market contracts or is completely lost.
2. Papaya growers would not have been trained in improved farming systems, especially recovery from extreme weather events. Consequence: growers become overwhelmed by cyclone and flood and switch to alternative crops.
3. There would not have been an effective response to the unknown fungal disease identified on Fijian papaya in Australia. Consequence: Australian biosecurity would have lost confidence in HTFA treatment and market access would have been withdrawn.
4. Post-harvest management systems on-farm, during transport and through the value chain would not have been refined and high post-harvest losses would have persisted. Consequence: growers would operate at low profit levels and export markets reject inconsistent fruit. Export markets would contract or be completely lost.
5. Cost-effective export-packing systems that involve the substitution of purchased foam for newspaper would not have been identified and adopted. Consequence: Fiji Red papaya would be less cost-effective in export markets.
6. A regular supply of high-quality papaya would not have been secured for domestic consumption by locals and the tourism sector. Consequence: grower income earned from local papaya sales would have been considerably less, further undermining the viability of the papaya industry.

Under the 'without project' counterfactual, the Fijian papaya industry would have been less resilient and profitable, and Fiji Red papaya exports would have ceased.

Outlook for Fiji Red papaya exports

In 2019, a commodities plan was prepared for NWC to increase utilisation of its HTFA export treatment facility (McGregor 2019). NWC treats most of the papaya exported from Fiji.[1] Consequently, its plan for export of the commodity is relevant to the outlook for Fiji Red papaya exports and the ongoing impacts of the Fiji papaya project.

1 Small volumes of papaya that do not require quarantine treatment are sent on an ad hoc basis to export markets such as Canada, Hong Kong and Nauru.

Table 8.1 Fijian papaya industry events affecting project outcomes and impacts

Year	Event
1996	• NWC, HTFA treatment facility for export papaya, and a protocol for papaya export to New Zealand using HTFA, are established
2000s	• The development of horticultural exports, including papaya, becomes a policy priority with the loss of preferential access to the European Union sugar market
2004	• Fiji is granted Australian market access for papaya using HTFA
2006	• Australian papaya production shortage and Fiji exports a total of 662 t, more than twice the long-term average, with most fruit sent to Australia and New Zealand
2009	• Fiji papaya project commences, January 2009 • 'One-in-50-year' floods and Tropical Cyclone Mick destroy 60% of Fiji's papaya production in December 2009
2011	• Australian papaya production shortage and Fiji exports peak at a total of 786 t
2012	• Devastating floods in western Viti Levu in March 2012, followed by Tropical Cyclone Evan in December 2012, impact papaya export volumes • Exports further impacted by an unknown fungal disease which threatens to close the trade with Australia • Exports total 182 t
2014	• Rain submerges a large area of young papaya trees in the Sigatoka Valley, which subsequently die of *Phytophthora*
2015	• Red papaya project concludes in June 2015
2016	• Tropical Cyclone Winston in February 2016 is the 'most destructive cyclone ever' and impacts Ba Province, followed by severe flooding from Tropical Cyclone Zena in Sigatoka Valley and Nadi area
2018	• Floods severely impact production in the Sigatoka Valley, Fiji's main papaya growing area
2020	• Tropical Cyclone Harold impacts papaya in the Sigatoka Valley and Nadi area, April 2020 • *Fiji Times*, 4 June 2020, reports 'uptick in papaya exports post tropical cyclone Harold' • Tropical Cyclone Yasa, December 2020, does not impact Sigatoka Valley papaya growing • Extreme shortage of airfreight due to Covid-19 lockdowns • New growers start to expand papaya production into Ba and Ra provinces, which are less exposed to natural disasters

Source: Literature review and industry consultation

Papaya export market research was updated as part of the commodities plan and ongoing export opportunities were confirmed in New Zealand, Australia and Japan, with the possibility of USA market exports by 2024 (McGregor 2019).

Constraints to achieving export market opportunities and the plan to address them were identified as:

- a concentration of growers in the traditional Sigatoka Valley growing areas
- lack of entry of substantial new exporters
- market access to the USA not yet secured
- airfreight capacity.

Concentration of growers in the traditional Sigatoka Valley growing areas

Agronomically suitable alternative growing areas have been identified in the Ba and Ra provinces (see Figure 2.1 for province locations). However, uptake by smallholders has been constrained by:

- ongoing subsidies paid to sugarcane growers to keep them in production[2]
- the unwillingness of exporters to service alternative production areas.

2 Even with sugarcane subsidies, papaya growing is more profitable if grown using Fiji papaya project recommendations (McGregor 2019).

Solutions proposed in the commodities plan include:

- NWC funding assistance for new Ba and Ra papaya growers, including irrigation and papaya seedling cost-sharing
- extension support for exporters prepared to establish demonstration farms in Ba and Ra
- extension support for new growers supplying the nucleus exporter in the new area. Sunrise Produce, the largest Fijian papaya exporter, has expressed interest in being involved in industry establishment in Ra and the Sabeto Valley of Ba.

Lack of entry of substantial new exporters

Many of the large commercially focused exporters handling papaya at project commencement have suffered setbacks. National Exports, PSL and Rams Valley Fresh experienced loss of critical staff members. UNO, Turners & Growers and Sanko Agriculture Ltd have undergone a change in business focus. Kumu Farms and Fiji Water ceased production when USA market access failed to eventuate.

To address this lack of exporter capacity, it is proposed that NWC will provide technical support and funding assistance to the remaining papaya exporters and emerging operations where this is required.

Market access to the USA not yet secured

NWC remain optimistic that USA market access for Fijian papaya, including organic papaya, will be secured. HTFA technology was developed to allow exports of Hawaiian papaya to the USA mainland, has been consistently effective since establishment in Fiji in 1996, and has been supported by 2 USA firms (Kumu Farms and Fiji Water). NWC, in partnership with BAF and the MOA, will continue to press Fiji's case for access to the USA market.

Airfreight capacity

Despite successful sea freight trials completed as part of the Fiji papaya project, airfreight remains the only commercial channel for fresh fruit export. Capacity is limited and the national carrier has had a focus on passenger travel.

MOA and NWC are working with Fiji Airways to encourage the leasing of wide-bodied aircraft with additional container capacity. The proposal has received favourable consideration from the national carrier. Furthermore, Sunrise Produce has expressed interest in adoption of sea freight following the successful research completed as part of the Fiji papaya project. Project research showed sea freight is both technically and financially viable but requires a much greater volume of papaya for export than is currently available.

Forecast papaya markets

Further external investment is required to deliver the 2019 NWC commodities plan. In the absence of investment certainty, this impact assessment assumes that Fijian papaya exports recover to their long-term average of 300 t per annum relatively quickly and remain at this level for the foreseeable future.[3] Sales of high-quality Fiji Red continue to dominate domestic and tourist hotel consumption, which each require 1,000 t per annum. The balance of production is absorbed by the informal sector which includes home consumption by smallholder growers (Table 8.2).

Table 8.2 Forecast Fijian papaya markets

Market	Forecast papaya consumption (t/year)
Exports	300
Domestic consumption (local market, non-tourism)	1,000
Tourist hotels in Fiji	1,000
Informal including consumption by grower's family	1,000
Total	**3,300**

Source: AgEconPlus analysis

A total market of 3,300 t per annum of papaya is consistent with long-term Fijian production including 'dips' in production experienced after cyclone and flood events.

3 Assumption tested using sensitivity analysis.

Impacts on growers supplying export markets

Registered smallholder and commercial growers are required to supply Fijian papaya exports. The Fiji papaya project and linked papaya development projects contributed to the retention of export markets, the price premiums that export markets deliver for growers, and reduced production and post-harvest losses. To estimate these impacts on growers supplying papaya to export markets, a 'without project' and a 'with project', annualised enterprise budget has been prepared (Table 8.3).

An increase in grower profit for papaya supplied to export of FJ$15,773/ha (FJ$38,825/ha 'with project' less FJ$23,052/ha 'without project') has been estimated. For smallholder growers with an average production area of 0.4 ha who earn half their income from papaya, the increase in earnings for fruit sent to export is significant. The share of a smallholder's crop sent to export will depend on the quality profile of the fruit, and overall quality has been improved through the project and linked research.

Table 8.3 Fiji farm export papaya 'without project' and 'with project' investment

	Unit	Annualised returns 'without project' (export market closes)	Annualised returns 'with project' (exports sustained)
Income			
Yield – 3 year average	t/ha	33	33
Marketable papaya	%	90	92
Marketable production	t/ha	30	31
Papaya price for export	FJ$/t	1,000	1,500
Total income	FJ$/ha	**29,970**	**45,854**
Costs			
Fertiliser	FJ$/ha	499	499
Crop protection	FJ$/ha	120	120
Seedlings	FJ$/ha	556	556
Machinery	FJ$/ha	193	193
Labour	FJ$/ha	1,733	1,768
Transport	FJ$/ha	3,817	3,893
Total cost	FJ$/ha	**6,918**	**7,029**
Operating profit			
Operating profit	FJ$/ha	**23,052**	**38,825**
Profit per tonne marketed	FJ$/t	769	1,270
Increase in profit with R&D	FJ$/t		500.90
Increase in profit with R&D	A$/t		320.58

Source: Fiji farm management budget manual 2014 (MOA 2014), updated during project consultation. Returns annualised to reflect differences in revenues and expenditure over the 3-year crop cycle

Impacts on growers supplying domestic markets

An improvement in the quality and consistency of papaya on the domestic market has been a major benefit from the project. The Fiji papaya project, and linked papaya development projects, have increased the quality and consistency of domestically available Fiji Red. Fijian consumers and buyers for tourist hotels demand this type of papaya and there is no longer a market for inferior Sunrise Solo grown without accessing certified seed or the local yellow Waimanalo pawpaw (Andrew McGregor, Koko Siga, personal communication, January 2021).

Local market development has lifted prices and the implementation of the Fiji papaya project recommendations has reduced production and post-harvest loss. To estimate this impact on mostly unregistered smallholder growers, a domestic market 'without project' and 'with project', annualised enterprise budget has been prepared (Table 8.4).

An increase in grower profit for papaya supplied to the domestic Fiji market of FJ$2,017/ha (FJ$25,069/ha 'with project' less FJ$23,052/ha 'without project') has been estimated. This increase in earnings is important for smallholder growers who do not need to be registered and who send most of their papaya to the domestic market. Papaya provides year-round income for smallholder growers.

Table 8.4 Fiji farm domestic papaya 'without project' and 'with project' investment

	Unit	Annualised returns 'without project'	Annualised returns 'with project'
Income			
Yield – 3-year average	t/ha	33	33
Marketable papaya	%	90	92
Marketable production	t/ha	30	31
Papaya price, domestic market	FJ$/t	1,000	1,050
Total income	FJ$/ha	**29,970**	**32,098**
Costs			
Fertiliser	FJ$/ha	499	499
Crop protection	FJ$/ha	120	120
Seedlings	FJ$/ha	556	556
Machinery	FJ$/ha	193	193
Labour	FJ$/ha	1,733	1,768
Transport	FJ$/ha	3,817	3,893
Total cost	FJ$/ha	**6,918**	**7,029**
Operating profit			
Operating profit	FJ$/ha	**23,052**	**25,069**
Profit per tonne marketed	FJ$/t	769	820
Increase in profit with R&D	FJ$/t		50.90
Increase in profit with R&D	A$/t		32.58

Source: Fiji farm management budget manual 2014 (MOA 2014), updated during project consultation. Returns annualised to reflect differences in revenues and expenditure over the 3-year crop cycle

Impacts on the value chain

The Fiji papaya project developed, and NWC subsequently implemented, a pre-export papaya treatment technology using hot water dips. The hot water dip process reduced export supply chain losses due to rot from around 10% to 1% (Stice et al. 2016).

In addition, the project recommended the substitution of manufactured foam papaya packaging for locally sourced newspaper. The switch to newspaper from purchased foam decreased packing cost from FJ$200/t to FJ$4.68/t of papaya shipped (Stice et al. 2016).

Profit earned from the addition of hot water dipping and packaging recommendations to NWC's papaya export operations is shown in Table 8.5.

The incorporation of hot water dipping and packaging recommendations are estimated to deliver net benefits of FJ$433.72/t of papaya exported.

Table 8.5 Fiji value chain 'with project' investment – additional profit

	Unit	Annualised returns 'with project'
Papaya export	t	300
Reduction in value-chain rot	%	9%
Papaya value free-on-board	FJ$/t	2,660
Gross value of recovered papaya	FJ$	71,820
Less: hot water dipping – capital & operating costs	FJ$/t	1
Cost of hot water dipping	FJ$	300
Additional profit – avoided papaya rot	FJ$	**71,520**
Packaging cost saving from switch to newspaper	FJ$/t	195.32
Additional profit – saved packaging cost	FJ$	**58,596**
Total – rot and packaging saving	FJ$	**130,116**
Additional profit of exports	FJ$/t	**433.72**
Additional profit of exports	A$/t	**277.58**

Source: Stice et al. 2016 and project consultation

Attribution of Fijian impacts to the Fiji papaya project

At the same time as the Fiji papaya project was being completed, a number of other RD&E and aid projects were under way to secure Fijian papaya exports and improve returns for smallholder growers. These projects included:

- United Nations Food and Agriculture Organization Farmer–Market Linkage Activity – to build NWC capacity and smallholder ability to supply export papaya
- NWC Extension Program – to increase smallholder involvement in the Fijian papaya industry
- Taiwanese Technical Mission Smallholder Papaya Project – smallholder planting program designed to increase the supply of papaya for export.

Consequently, it is estimated that 40% of the Fijian economic outcomes and impacts described are attributable to other projects and 60% are attributable to the Fiji papaya project. This attribution factor has been applied to quantification of project impacts.

Summary of assumptions used to value impacts, Fiji

Additional assumptions used to value Fiji papaya project impacts on the Fijian papaya industry are summarised in Table 8.6.

Table 8.6 Assumptions used to value the impact of Fiji papaya project on the Fijian papaya industry

Variable	Assumption	Source and comment
Year of first impact	2012–13	Growers marketing papaya grown with project recommendations and certified seed
Year of maximum impact	2021–22	Analyst assumption after considering export data and allowing time for exports to recover to a steady state of 300 t/year
Final year of project impacts	Impact is maintained for 20 years, in a 30-year analysis period, before project approaches are replaced with new technology	Analyst assumption after considering 'low tech' nature of solutions provided and scope for ongoing innovation
Probability of valuable outputs	100%	Analyst assumption – outputs have already been delivered to the Fijian papaya industry by the Fiji papaya project
Probability of valuable outcomes	90%	Analyst assumption – the technology has proven to be effective, but some under-adoption and disadoption may occur
Probability of impact	85%	Analyst assumption – impacts can be 'derailed' by factors such as natural disasters, airfreight loss and market closure
Attribution	60%	Linked projects make an important contribution to identified impacts
Counterfactual	100%	In the absence of the Fiji papaya project and linked projects, it has been assumed that it is 100% likely that the papaya export sector would have failed (see above explanation)

Source: AgEconPlus analysis

Australian economic outcomes and impacts

The assessment of project outcomes and impacts includes a description of impacts realised in Australia, quantification of impacts, articulation of the counterfactual, attribution of benefits to the Fiji papaya project and overarching assumptions used in the economic evaluation.

Impacts realised in Australia

As a result of the project, Australian papaya growers are aware of the sources of papaya damage in the Australian supply chain and have taken low-cost measures to reduce fruit damage (for example, improved orchard hygiene). Growers have also responded to research findings that showed better quality papaya are supplied at lower ripening room temperatures. Consequently, ripening room temperatures have been reduced from an average of 28 °C to 20 °C. Lowering of ripening room temperature has also been achieved by growers at low or no additional cost.

Prior to the project, fruit spoilage at interstate wholesale markets due to disease, injury and a too-hot ripening room was as high as 30% during the wet season (Stice et al. 2016). Annualised, and accounting for lower rot levels in the dry season, year-round losses were estimated at 10%. Application of project outcomes is thought to have reduced annual loss to 5% (Yan Diczbalis, coordinating scientist, HORT/2008/033, personal communication, November 2020).

As a result of these on-farm changes, growers have been able to increase their saleable yield and profit per tonne of papaya supplied (Table 8.7).

Improved orchard and on-farm ripening room practices are estimated to deliver net benefits of A$36.07/t of Australian papaya marketed to growers who have adopted project recommendations.

Table 8.7 Australian farm financial performance 'without project'/'with project' Fiji papaya project outcomes

	Unit	Annualised returns 'without project'	Annualised returns 'with project'
Income			
Yield (2-year average)	t/ha	55	55
Marketable papaya	%	90	95
Marketable production	t/ha	50	52
Fruit price	A$/t	1,800	1,800
Total income	A$	**89,100**	**93,555**
Costs			
Land preparation	A$	126	126
Planting	A$	700	700
Fertiliser	A$	2,510	2,510
Insect and disease control	A$	765	765
Weed control	A$	327	327
Irrigation	A$	249	249
Harvesting and marketing	A$	65,571	67,210
Crop removal	A$	66	68
Total cost	A$	**70,314**	**71,955**
Operating profit			
Operating profit	A$	**18,786**	**21,600**
Profit per tonne marketed	A$/t	380	416
Increase in profit with R&D	A$/t		36.07

Source: Johnston 1997 updated with data supplied by Yan Diczbalis, coordinating scientist, HORT/2008/033, personal communication, November 2020

'Without project' counterfactual

In the absence of the Fiji papaya project, it is 70% likely that an alternative research project would have investigated improvement in the efficiency of the papaya supply chain in Australia. The Australian papaya industry has a research levy in place and its current strategic investment plan identifies supply chain efficiency as a priority for the industry (HIA 2017).

Attribution of impacts to the Fiji papaya project

After project completion, a second Queensland DAF project examined control and management options for growers to reduce post-harvest papaya decay. The project was called 'PP13000: Effect of curative and protective pre-harvest fungicide and post-harvest hot water applications on decay of papaya' (Vawdrey 2016). PP13000 further investigated pre-harvest disease as a source of post-harvest loss and recommended against pre-harvest fungicide use. Removal of dead papaya leaves, which act as a reservoir for fungus, and post-harvest hot water dips were recommended to growers. PP13000 generated new information on reducing post-harvest losses and, while working with Queensland papaya growers in Innisfail and Mareeba, helped to reinforce project findings. Consequently, it has been assumed that impacts described for the Fiji papaya project are 20% attributable to another project.

Summary of assumptions used to value impacts, Australia

Assumptions used to value Fiji papaya project impacts on the Australian papaya industry are summarised in Table 8.8.

Table 8.8 Assumptions used to value the impact of the Fiji papaya project on the Australian papaya industry

Variable	Assumption	Source
Australian papaya production	16,149 t per annum total	Five-year average to June 2019 sourced from the Australian Horticulture Industry Statistic Handbook, various issues
Maximum share of Australian papaya production adopting Fiji papaya project recommendations	60%	Only the larger growers ripen their papaya on-farm and have capacity to adjust ripening room temperature (Gerard Kath, Lecker Farms, president of Papaya Australia, personal communication, November 2020)
Year of first impact	2014–15	Changes made to ripening room temperature in 2015
Year of maximum impact	2019–20	Large grower adoption complete
Final year of post-harvest losses	Impact is maintained throughout the 30-year analysis period	Analyst assumption
Probability of valuable outputs	100%	Analyst assumption – outputs have already been delivered by the Fiji papaya project
Probability of valuable outcomes	100%	Analyst assumption – the technology has proven to be effective
Probability of impact	90%	Analyst assumption – growers have confidence in the technology
Attribution	80%	Analyst assumption – Horticulture Innovation Australia project PP13000 contributes to and reinforced Fiji papaya project findings for growers
Counterfactual	70%	Analyst assumption – in the absence of the Fiji papaya project it is likely, but not certain), that a domestic Horticulture Innovation Australia project would have addressed the same supply chain issues

Quantification of impacts in Fiji and Australia

Investment return was determined over a 30-year period starting in the first year after project completion (2015–16). All benefits and costs were expressed in Australian dollar terms using an exchange rate of FJ$1 to A$0.64. All benefits and costs were discounted to 2019–20 values using a discount rate of 5%.

The total investment of A$2.82 million (present value terms) from ACIAR and its research partners in the Fiji papaya project has been estimated to produce gross benefits of A$5.98 million (present value terms), providing a net present value of A$3.16 million and a benefit:cost ratio of 2.12:1 (over 30 years using a 5% discount rate). Table 8.9 shows return on both total and ACIAR share of Fiji papaya project investment.

Table 8.9 Summary of Fiji papaya project investment returns

Criterion	Total investment	ACIAR investment
Present value of benefits (A$ million)	5.98	4.26
Present value of costs (A$ million)	2.82	2.01
Net present value (A$ million)	3.16	2.25
Benefit: cost ratio	2.12:1	2.12:1

Note: A discount rate of 5% has been used.

The ACIAR investment has been successful. The economic benefits created from the total investment are estimated to flow to papaya growers, including smallholders (33.3%) and the Fijian papaya industry (14%). The remaining benefits accrue to the Australian papaya industry (Table 8.10).

Table 8.10 Benefits of Fiji papaya project investment by stakeholder group

Stakeholder beneficiary	Present value of benefits (A$ million)	Share of project benefits (%)
Fijian papaya growers supplying export markets (including smallholders)	0.97	16.2
Fijian papaya growers supplying domestic markets (mostly smallholders)	1.02	17.1
Fijian papaya supply chain	0.84	14.0
Australian papaya industry	3.15	52.7
Total	**5.98**	**100.00**

Sensitivity analysis

Sensitivity analysis was carried out on 4 sets of variables and results are reported in Tables 8.11 to 8.14. All sensitivity analyses were performed for the total investment and with benefits taken over the life of the investment plus 30 years from the year of last investment. All other parameters were held at their base values.

Table 8.11 presents the sensitivity of the results to the discount rate. The results are moderately sensitive to the discount rate used and continue to show a positive return on investment at the higher discount rate of 10%.

Table 8.11 Sensitivity to discount rate (total investment, 30 years)

	Discount rate		
Criterion	0%	5% (base)	10%
Present value of benefits (A$ million)	8.96	5.98	4.78
Present value of costs (A$ million)	1.86	2.82	4.23
Net present value (A$ million)	7.10	3.16	0.55
Benefit:cost ratio	4.81:1	2.12:1	1.13:1

Table 8.12 shows the sensitivity of the investment criteria to the 'without project' counterfactual. The analysis has been completed assuming that in the absence of the Fiji papaya project and linked investment, papaya exports would have ceased. If this assumption is reduced to 50% likely, the project continues to deliver a positive return on investment. In fact, even if it is assumed that cessation of exports is only 5% likely, the project still does better than break-even.

Table 8.12 Sensitivity to counterfactual (total investment, 30 years)

	Likelihood of Fijian papaya export collapse without the Fiji papaya project		
Criterion	5%	50%	100% (base)
Present value of benefits (A$ million)	3.29	4.57	5.98
Present value of costs (A$ million)	2.82	2.82	2.82
Net present value (A$ million)	0.47	1.74	3.16
Benefit: cost ratio	1.17:1	1.62:1	2.12:1

Table 8.13 presents the sensitivity of the results to the assumed volume of Fijian papaya exports. At an assumed future long-term average export level of 185 t/year – the average for the years 2016 to 2020 – the project continues to deliver an acceptable return on investment.

Table 8.13 Sensitivity to Fijian papaya export volume (total investment, 30 years)

Criterion	Fijian papaya exports		
	185 t/year	300 t/year (base)	500 t/year
Present value of benefits (A$ million)	5.58	5.98	6.74
Present value of costs (A$ million)	2.82	2.82	2.82
Net present value (A$ million)	2.76	3.16	3.91
Benefit:cost ratio	1.98:1	2.12:1	2.38:1

A final sensitivity analysis tests impact assessment results to changes in the level of Fijian papaya grower profit 'with project' and 'without project'. In this sensitivity test, prices received by growers supplying both export and domestic markets, yields achieved, and production costs incurred were all adjusted so that the sensitivity of results to a 20% increase and decrease in profit over assumptions used in the base analysis could be assessed (Table 8.14).

Confidence ratings

The results produced are highly dependent on the assumptions made, some of which are uncertain. There are 2 important factors that warrant recognition. The first is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these 2 factors has been given to the results of the investment analysis (Table 8.15). The rating categories used are high, medium and low, where:

- high denotes a good coverage of benefits or reasonable confidence in the assumptions made
- medium denotes only a reasonable coverage of benefits or some uncertainties in assumptions made
- low denotes a poor coverage of benefits or many uncertainties in assumptions made.

Table 8.15 Confidence in analysis of project

Coverage of benefits	Confidence in assumptions
High	Medium

Coverage of benefits was assessed as high – the most important potential benefits to Fijian growers, including smallholders, and the value chain have been quantified. Benefits have also been quantified for the Australian papaya industry. Confidence in assumptions was rated as medium – some assumptions required analyst estimation.

Lindner et al. 2013 reviewed 27 impact assessment reports covering 103 ACIAR research projects and classified each analysis on the basis of its transparency and economic rigour as being either 'conceivable', 'plausible' or 'convincing'. Using their approach, this analysis is self-assessed as 'conceivable'

Table 8.14 Sensitivity to changes in Fiji farm profit (total investment, 30 years)

Criterion	Change in Fijian farm profit		
	Export: A$256.5/t Domestic: A$26.0/t	Export: A$320.6/t Domestic: A$32.6/t (base)	Export: A$384.7/t Domestic: A$39.1/t
Present value of benefits (A$ million)	5.61	5.98	6.38
Present value of costs (A$ million)	2.82	2.82	2.82
Net present value (A$ million)	2.79	3.16	3.56
Benefit:cost ratio	1.99:1	2.12:1	2.26:1

8.2 Social outcomes and impacts

Social impacts of the project focus on Fiji and include more resilient and healthier village communities. This section also analyses the benefits by gender.

Papaya production in smallholder villages

In Fiji, papaya is grown on either large commercial farms, producing more than 1 t of fruit per week, or smallholdings in a village setting. Villages typically consist of 50 families of which 10 to 12 families grow papaya. Family units are mostly headed by a male in his early to mid-forties. Around 30% of family enterprises are headed by females and 5% are headed by growers under 30 years of age. A family enterprise is 0.4 ha with between 300 and 400 trees. Papaya makes up approximately 50% of the family's income, provides favourable financial returns and year-round cash flow.

Smallholder growers interviewed as part of this impact assessment indicated that their enterprises were better able to cope with setbacks such as cyclone and flood following the project. Production and post-harvest management techniques have been improved and growers now practise 'phase planting' so that only a small proportion of the crop is vulnerable to cyclone at any one time. Cyclone recovery has been aided by the adoption of project-generated techniques to avoid fruit sunburn on defoliated trees and by the ready availability of certified seed.

Smallholders indicated favourable prices for their papaya whether it is sold on the export or domestic market. Prices received are not set at a level that precludes home consumption or exchange within the village. Home consumption and exchange provides an important outlet for Class 2 fruit. Papaya forms part of a healthy diet in the village and has made a small, positive contribution to food security.

Benefits realised by women in Fiji

Women contribute to all facets of papaya growing and work in both the commercial and smallholder papaya value chain. Activities completed by women include planting, crop management, harvesting, grading and packing. Skills required for modern commercial horticulture are substantially greater than the sugar industry and the quality of employment available for rural women has been enhanced by the project. However, there is a gender imbalance among papaya exporters. Papaya exporting is a male-dominated activity requiring access to investment capital and this may not be available to Fijian women. Male dominance of the value chain is an issue across all Fijian horticultural industries (Kyle Stice, project leader, HORT/2008/033, personal communication, November 2020).

Research has shown that Fijian women are more likely to be underemployed or paid below the poverty line than their male counterparts (for example, Narsey 2007). The project addressed this issue by carrying out papaya production and post-harvest training that included women. Enterprises led by women will enjoy the same level of income increase as male smallholders adopting project recommendations. Smallholder income increase following project adoption has been estimated at 20.5% (Table 8.16).

In total, a present value benefit of A$0.597 million has been estimated for rural women in Fiji as a result of the project. That is 30% of total on-farm benefits, estimated at a present value of A$1.99 million, being made up of an export market benefit for growers of A$0.97 million plus a domestic market benefit for growers of A$1.02 million (see Table 8.10 above).

Social impacts – Australia

Social impacts in Australia included an increase in employment and industry confidence resulting from more profitable supply chains and more rapid cyclone recovery following adoption of project benefits.

Table 8.16 Benefits realised by smallholders 'without project' and 'with project' investment

	Unit	Annual income 'without project'	Annual income 'with project'
Papaya income from smallholder orchard (0.4 ha)	FJ$/household	9,221	15,531
	FJ$/ha	23,052	38,825
Income from other sources (e.g. cassava)	FJ$/household	9,221	9,221
Total income	FJ$/household	18,442	24,751
Increase in income due to research	FJ$/household		6,309
Annual net benefit of the Fiji papaya project using a 60% attribution factor	FJ$/household		3,785
Increase in smallholder income	%		20.5

8.3 Environmental outcomes and impacts

Fiji – environmental impacts

There are no negative environmental impacts associated with the adoption of the Fiji papaya project findings. Papaya is mostly grown without chemicals in Fiji. Fungicide may be used during the rainy season to control fungal rots. On-farm fungicide use has not changed as a result of the project and may actually decline in the future if organic production is adopted.

Pre-export, NWC relies on HTFA treatment and hot water dipping. The project investigated chemical and non-chemical fungus controls but found that hot water dipping was both effective and cost-effective.

Biodegradable packaging (newspaper) has been substituted for manufactured foam as a result of the project. Newspaper is locally sourced and adds to the sustainability of the Fijian papaya industry.

The project has recommended industry relocation to Ba and Ra provinces, which are less flood-prone. Relocation will require the adoption of drip irrigation for papaya production and this will need to be managed so that pressure is not placed on groundwater or natural stream flows. Judicious management of industry relocation to sloped land will also be required to ensure papaya production does not lead to soil erosion. Techniques developed for growing sugarcane on sloped land in Fiji can be applied to papaya relocation. Future impacts of the project can be accommodated without environmental impact.

Australia – environmental impacts

In Australia, no environmental impacts were associated with project recommendations addressing improved orchard hygiene or removal of old papaya trees that are more likely to harbour disease. Project recommendations addressing a lower ripening room temperature may result in fuel cost savings and a small positive environmental impact.

8.4 Lessons learned from this impact assessment

Economic, social and environmental impacts have created positive net benefits from investment in the Fiji papaya project. Adoption by final users has occurred. However, targets set prior to project commencement have not been realised (Table 8.17).

Lessons learned from the impact assessment include:

- Targets set prior to project commencement were too ambitious. Papaya is a difficult crop to grow and export. The industry is subject to perpetual boom and bust cycles.
- It is likely that in the absence of the project, and linked investment measures, the Fijian papaya industry would have ceased to export. Export has been sustained; consequently, the project must be viewed as a success.
- An improvement in the quality and consistency of papaya on the domestic market in Fiji has been a major, sometimes overlooked, project benefit.
- Success was a function of a commercially focused project. A PPP with NWC ensured that relevant research issues were addressed and findings were adopted and mostly sustained following project completion.
- Where possible, the PPP approach used for the Fiji papaya project should be considered and adopted by ACIAR for applied research projects in other regions and for other commodities.
- The project had a strong market focus – trial commercial shipments and taking smallholders to the global market – and this is not something that ACIAR normally attempts in one of its research projects. The approach has merit and is worth consideration by ACIAR in other settings.
- Field trials were carried out on existing growers' fields and were viewed by smallholders as relevant and practical.
- Key Fijian papaya knowledge gaps have now been addressed, for example, technologies for relocating to less flood-prone areas, growing and selecting fruit for export, minimising post-harvest losses and cost-effective sea freight.
- The industry will remain static unless further commercial impetus is supplied. Such impetus would be provided by access to the USA organic papaya market. USA market access is more likely to be a political decision than a research issue that ACIAR might address.

Table 8.17 Realisation of project targets

Project target	Achievement
Substantial increase in contribution of fruit/vegetable exports to rural people's livelihoods in western Viti Levu	A 20.5% increase in annual smallholder income was estimated as a result of the project. However, the project achieved only a modest increase in the number of registered smallholder papaya growers, from 100 to 110.
Threefold increase in the volume of papaya exported from Fiji	The 10-year average for papaya exports from Fiji prior to the project was 297 t. The 11-year average 2010 to 2020 was 313 t. Export has been static.
Annual Fijian papaya exports valued at FJ$7 million per year, with half this total captured by smallholder growers	The 5-year average value of papaya exports since project completion in June 2015 has been FJ$1 million per year.
Double the number of people employed in the Fijian papaya industry (600 jobs)	The number of people employed in the Fijian papaya industry has remained static at 300.
50% reduction in culled fruit from the farm	Base data on cull rate is not available from NWC, MOA or the project team. However, project consultation points to a 2% improvement in saleable yield as a result of the Fiji papaya project and linked project research.
Increase in the competitiveness of Fijian papaya on the export market through the use of sea freight	Sea freight confirmed as being technically viable and 50% more cost-effective than airfreight. However, there is an insufficient volume of papaya available to fill large sea freight containers.

Source: McGregor and Stice (unpublished a)

- ACIAR should not invest in another single-country, single-commodity research project targeting Fijian papaya. Papaya could be part of a further multicountry, multicommodity research project that builds on 'Enhanced fruit production and postharvest handling systems for Fiji, Samoa, and Tonga' (HORT/2014/077).
- Fijian papaya production research questions that could be addressed in a diversified follow-on project include plant nutrition, soil management to control *Phytophthora*, soil organic matter and pH management.
- Effort is also required to consolidate and publish a Fiji Red papaya production manual, which was originally envisaged as part of the Fiji papaya project.
- Post-harvest issues to investigate could include research to support Fiji Red papaya market access applications of the type already prepared for the USA. Other priority destinations could include markets in Asia, the Middle East and Europe.
- Policy research could address the role of the national carrier (Fiji Airways) and creating a service that is more responsive to the export of horticultural commodities.

Papaya harvest from an ACIAR research partner farm in Queensland
Photo: ACIAR

9 Conclusions

This impact assessment has reviewed ACIAR project 'Strengthening the Fiji papaya industry through applied research and information dissemination' (HORT/2008/033), known as the Fiji papaya project. The impact assessment has quantified economic impacts in Fiji and Australia as well as providing a qualitative analysis of project social and environmental benefits.

The total investment of A$2.82 million (present value terms) from ACIAR and its research partners in the Fiji papaya project has been estimated to produce gross benefits of A$5.98 million (present value terms), providing a net present value of A$3.16 million and benefit:cost ratio of 2.1:1 (over 30 years using a 5% discount rate). The ACIAR investment has been successful.

Factors contributing to project success include a strong commercial focus, a PPP with NWC, and a market orientation that included trial export shipments of Fiji Red papaya. Trial shipments were made with papaya supplied by smallholders, and feedback was provided to the growers and guided ongoing research.

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