Improving Citrus Value Chains in Australian and Nepalese Examples

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By

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Improving Citrus Value Chains in Australian and Nepalese Examples

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PREVIOUS SUBMISSION STATEMENT

This paper has not been submitted for an award by another research degree candidate (Co-Author), either at CQUniversity or elsewhere.

List of Abbreviation

AKC- Agriculture Knowledge Centre

AMO- Agricultural Mineral Oil

AusAid- Australian Agency for International Development

Cal- Calibration

CQ- Central Queensland

CQU- Central Queensland University

CV- Cross Validation

DAF- Department of Agriculture and Forestry

DOA- Department of Agriculture

IGA- Independent Grocers' Association

LiDAR- Light Detection and Ranging

MEDEP- Micro Enterprise Development Program

MoALD- Ministry of Agriculture and Livestock Development

NASAA- National Association for Sustainable Agriculture Australia

NIR- Near-infrared

NIRS- Near-infrared Spectroscopy

PLSR- Partial least Square Regression

PMAMP- Prime Minister Agriculture Modernization Project

POP- Population

PPD- Plant Protection Directorate

PPP- Public Private Partnership

PQPMC- Plant Quarantine and Pesticide Management Centre

Pred- Prediction

PSLP- Public Sector Linkage Project

QFF- Queensland Farmers' Federation

QLD- Queensland

R^2- Coefficient of Determination

RGB- Red, Green and Blue

RMSECV- Root Mean Square Error of Cross Validation

RMSEP- Root Mean Square Error or Prediction

RTP- Research Training Program

SD- Standard Deviation

SDGs- Sustainable Development Goals

SDR- Standard Deviation Ratio

SSC- Soluble Sugar Content

TA- Titratable Acid

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Abstract

An integrated method literature review was undertaken on characterisation and mapping of value chains in general and citrus production value chains, specifically. The operation of three small-scale citrus value chains in Central Queensland, Australia, two export-oriented citrus value chains around Wallaville, Queensland, Australia and a citrus value chain in western region, Nepal was described through descriptive case studies based on semi-structured interviews with owners, managers, packhouse managers, a labour supply coordinator, government officials and other stakeholders. Various innovations by, and limitations of, the small-scale Queensland citrus farms were documented. Common issues included achieving a market niche, with development of early-season production in other regions leading to a loss of a premium market. Other issues included intergenerational transfer, restrictions on water supply in dry years and cyclone damage. The Queensland export-oriented producers were based on access to water and reasonably priced land and were characterized by diversification in production across different fruits and varieties and activity through the value chain. Key constraints identified included labour shortage, disease and pest infestation, harvest timing and yield estimation, and market price volatility. Citrus production in Nepal was limited by small land holdings, improper planting materials, irrigation, diseases and pests, inadequate post-harvest handling, and lack of a premium market. A critical issue for each citrus value chain was explored further: (i) The insurance needs of small-scale citrus producers in Central Queensland was described, with cyclone, drought, hail, and fire being the major risks. The applicability of two insurance products, crop insurance and event insurance, was considered. Crop insurance requires valuation of the crop, which is difficult to document, although new technologies in fruit load estimation could aid such estimations. Insurance premiums typically range from 6-11 % of crop value although few insurance providers cover fruit crops like citrus. (ii) A technology for non-invasive and rapid assessment of fruit Brix was assessed in context of aiding the export orientated farms in estimation of optimum harvest time. (iii) The prospect for the development of a premium market through export of citrus from Nepal to Tibet, China was explored, drawing on experiences of the Australian value chains. Policy recommendations including disease-pest management, post-harvest management and export policies were made to allow small-holder farmers to participate in such a value chain.

Keywords: Semi-structured interviews, constraints, export, Brix, insurance, labour

1.0 Introduction

Any product involves a chain of actors between producer and end-user that should each add value. A successful value chain for any product must be resilient, able to adapt to a changing environment (Pokhrel, 2011). The resilience requirement is particularly valid for value chains of perishable commodities such as fruit.

Descriptions of value chain characteristics can assist identification of constraints and innovations, informing changes to the chain. This can assist a particular value chain to become more efficient, bypass one actor or a technology phase compared to other chains. For example, mobile phone technology came into widespread use before landline technology in rural Nepal and its availability can be used to disseminate market information to growers (Onlinekhabar, 2018).

Fruit production contributes a significant share of value chain operations and income generation in many national economies (Plant Health Australia, 2019). Citrus crops come within the top ten (orange-fifth and tangerines-eighth) fruit commodities by value within the global fruit industry (Shahbandeh, 2019). Due to a revolution in information technology and transport utilities, the world has become smaller in the general movement of goods, including fresh produce like citrus fruit. This evolution of the global value chain presents both opportunities and challenges to producers and marketers (Gereffi & Fernandez-Stark, 2011).

Australia has developed rapidly into one of the world’s largest exporters of citrus fruits (USDA, 2019). Australian citrus value chains have strategies to maintain and increase their citrus export operation, including into China. This trade provides a useful benchmark for a potential trade in citrus from Nepal to Tibet. Other Australian citrus value chains are small-scale, operating at a size and scale comparable to larger citrus producers in Nepal. However, these chains differ in technologies employed, e.g., level of mechanisation, and marketing processes.

The intent of the proposed research is to characterise several citrus value chains: (i) two Australian large-scale, export-oriented value chains, (ii) three Australian small-scale value chains, and (iii) a typical Nepalese value chain. Characterisation involves the identification of the main actors and their roles in the value chains and the operational features of the trade. Key constraints in each value chain will be identified and a solution recommended.

The thesis research represents an extension of the Australian Aid-funded Public Sector Linkage Project (PSLP); Structures to improve entrepreneurial activity: a case study around citrus producers of Nepal (AUSAID/PSLP, 2016). The candidate was involved in that project as an interviewer. It is intended that the characterisation of the Australian value chains will inform suggested improvements in the Nepalese citrus value chain.

1.1 Research aim

a. To characterise and suggest improvements for three citrus value chains by identifying key constraints.

1.2 Research objectives

a. To undertake descriptive case studies of three different citrus value chains (Australian large-scale conventional value chain, Australian small-scale value chain; and typical Nepalese value chain), with identification of critical constraints and advantages in each chain
b. To evaluate suggested solutions to a limiting factor of each chain

1.3 Research questions

a. What are key constraints to these citrus value chains and what solutions can be proposed for these constraints?
b. What aspects of Australian citrus value chains are adaptable to Nepalese citrus value chains?

1.4 General Methods

Research methodology

The research design of this thesis involved a review of literature and available secondary data, documents, news and media releases, descriptive case studies in which key constraints of each value chain were identified, and a solution proposed and evaluated (Fig. 1).

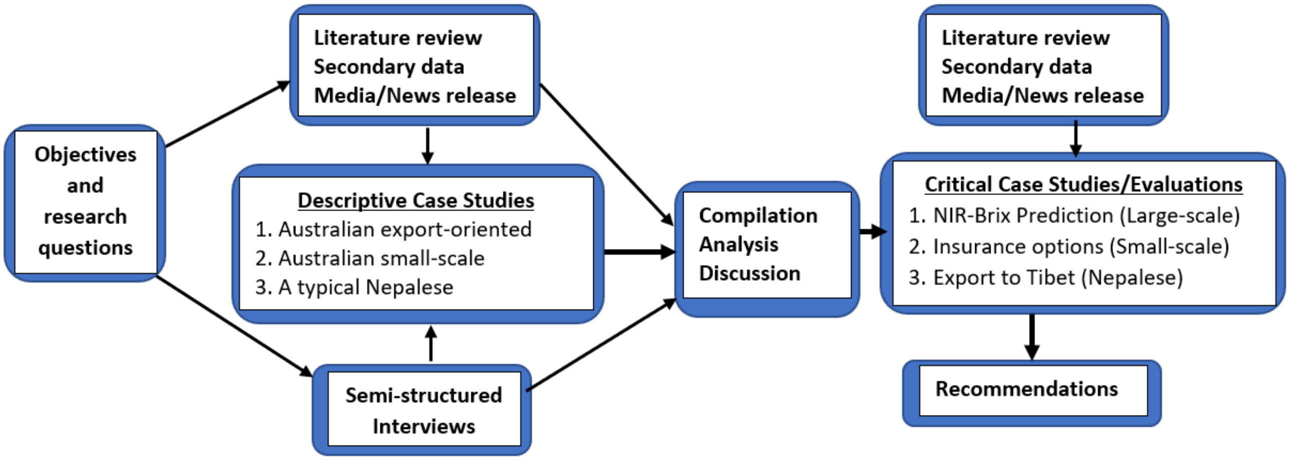

Figure 1: Research design framework (source: own sketch)

A descriptive case study methodology was used for development of descriptions of value chains as: (a) the focus was to answer 'how, what, and why' questions (Crowe et al., 2011), (b) there was no behaviour manipulation of target groups, and (c) there were no clear boundaries regarding the context and the phenomenon (Yin, 2003). The descriptive case studies used mixed methods, involving reviews of documents, semi-structured interviews conducted both face-to-face and by zoom or telephone, a value chain walk concept, and other references to gain insights into the operation of the selected citrus value chains.

Selection of sample value chains

The Nepalese citrus value chains were those involved in the Australian Aid-funded Public Sector Linkage Project (PSLP); Structures to improve entrepreneurial activity: a case study around citrus producers of Nepal (AUSAID/PSLP, 2016). This included larger scale, by Nepalese standards, producers in the Syangja area, and smaller scale producers in the Parbat area. This region is the largest mandarin production region in Nepal. The original involvement of growers in the two areas was based on an open invitation to participate distributed by the Ministry of Agriculture Development (MOAD), Department of Agriculture (DoA), and the Micro Enterprise Development Programme (MEDEP). The follow up interviews in 2020 were based on recontact of the original interviewees or, where not available, recommendations of alternates from local government officials and respective District Agriculture Development Offices (DADO). Actors in other parts of the value chain, such as transport providers and the large format retailer, were targeted for interviews.

Two types of Australian citrus value chains were targeted - small scale producers that were similar in production scale to the larger Nepalese producers, and large-scale producers with export focus. The small-scale producers were selected on the basis of locality, being in the Rockhampton vicinity. The three producers interviewed were the only remaining citrus producers in the area, although even these producers were not full time. The two large scale producers were located in the Wallaville area, being part of an area that expanded in citrus production as Rockhampton region production decreased. These producers were the closest large-scale producers to Rockhampton. Other value chain actors were selected on the basis of relevance to these producers. The Wallaville citrus production area was chosen as being the most accessible larger scale production to Rockhampton, being a 3.5 h drive south on the national highway. Both large scale citrus producers in the Wallaville area were interviewed. Both producers had previous involvement with Central Queensland University IFFS-Sensors group in other projects.

Information collection

Data and information were collected by mixed methods, including case studies supported by semi-structured interviews (Kuter & Yilmaz, 2001). Interviews were conducted both face-to-face and by electronic means (video conference or telephone). This research operated under CQU Ethics approval 0000022287. An information sheet (Appendix A) with project details was provided for participants before the interviews. Consent for interview recording and information was agreed to in a verbal statement (Appendix B) by participants before the primary interview. The developed case studies were provided to the main interviewees for comment and release approval.

Secondary information was collected from previous projects and studies, available literature, government body reports, other organisational reports and published papers or media releases. For the Nepalese value chain case study, staff of government bodies and research organisations were surveyed using a web-based survey tool (Qualtrics) to gather data on technology support by government offices/departments, subsidies, and relevant policies in stakeholder organisations.

Semi-structured interviews were undertaken with selected respondents (value chain actors) of each citrus value chain (see Appendix C). A draft list of topics and interviews were subject to informal pre-testing among several citrus value chain actors, with editing as required before executing the final interviews. Each interview was audio recorded and was transcribed later by the researcher listening to the recording. The researcher provided translation for Nepalese interviews in the Nepalese language while NVivo transcription was used for English language recordings. Due to the COVID-19 pandemic, some interviews were virtual (telephone and teleconference) rather than face to face.

The interviewees included growers, wholesalers, transport provider, packaging supplier, labour supply agency, export facilitator and other service providers (Appendix H). At least one value chain actor at each level of each mapped chain was interviewed or dialogued.

In the case of the Nepalese citrus value chain, ten small-holder growers from two regions were interviewed in three different years. These interviews occurred at the start and at the end of the AUSAID/PSLP project, i.e., 2013 and 2015, and a virtual interview in 2020. NVivo was used to categorise the specific information under certain topics (i.e., value chain features) which were used as codes within the NVivo software. Thematic analysis (Guest et al., 2011) was undertaken using resource-based approaches (Barrett et al., 2010).

Addressing value chain constraints

Based on descriptive case studies, areas of constraint were identified in each of the citrus value chains. A key constraint was selected, and a solution was proposed and evaluated.

2.0 Literature Review

An integrative method was adopted in this literature review, providing an introduction of value chain terminology and description of typical citrus value chains in terms of the roles of different value chain actors, constraints identification, and examples of recommendations for improvement. Priority was given to available literature on citrus value chains, but the studies on closely related agricultural commodities were also utilised.

2.1 Global Citrus Production and Trade

Citrus fruit is one of the significant fresh fruit crops across the globe. Global orange production for 2018/19 was estimated by the United States Department of Agriculture (USDA) at 54.3 million tons, with annual production increasing continuously over the last eight years. Mandarin/tangerine production estimate is at 32 million tons, with China contributing 22 million tons, USA 805,000 tons, the European Union 3.4 million tons, Morocco 1.4 million tons and Turkey 1.7 million tons (USDA, 2019).

Australia produced 715,000 tons of citrus fruit (five-year average) from 28,000 ha of planting and 1,900 growers, with a farmgate value of $627 million and export valued at $332 million export (Plant Health Australia, 2019). In Nepal, annual citrus fruit production for the year 2019 was recorded as 259,191 tons with mandarin (174,868 tons), sweet orange (50,518 tons) and lemon (7,121 tons) contributing the maximum volume of production (MoALD, 2020).

China boasts two-thirds of global mandarin/tangerine production and one-fifth of global exports, and yet almost one-third of domestic citrus fruit consumption is imported (USDA, 2019). This situation opens an opportunity for exporters to serve the Chinese market. Australia has already utilised that opportunity to some extent, with their value chains evolving to meet market requirements of phytosanitary and food quality standards (Landline, 2013).

2.2 Evolution of ‘supply’ to ‘value’ chain concept

A supply chain includes the actors and steps involved from producing an article to purchase by consumer, while a value chain is focussed on the creation of value by each step and actor (Nabi &

Luthria, 2002) - e.g., https://keydifferences.com/difference-between-supply-chain-and-value-chain.html. Supply chain thinking comes from operational management and can be characterised as documenting the steps involved in meeting a product request, with focus on value creation. In contrast, value chain thinking comes from business management and can be characterised as documenting the steps between a customer request. Both concepts cover all stages of product production and handling processes and the relationships between those stages which make product available for consumption (Stern & Anderson, 2001). A sustainable chain will have an interactive relationship between stages with information flow both ‘up’ and ‘down’ the chain. A useful review and practical manual for domestic and international value chain development was published by Collins et al. (2016).

The term ‘value chain’ was defined by Porter (1985). Porter’s value chain analysis described a transformation of ‘inputs’ to ‘outputs’ and differentiated between activities from production to marketing and after sale services. It was recognised that an operation does not need to be accomplished by a single actor but can be provided by a number of actors, which nowadays is described as a ‘system’. Subsequently, greater emphasis has been placed on description of the value creating activities (Girvan, 1987). In working with unstable value chains, Gereffi and Korzeniewicz (1994) developed thinking around the need for coordination among the independent actors, with description of the positions of power determining the value chain dynamics. This was a significant contribution to the development of Porter’s concept and is recognised as the ‘parent’ of modern-day global value chain analysis (Gereffi et al., 2005).

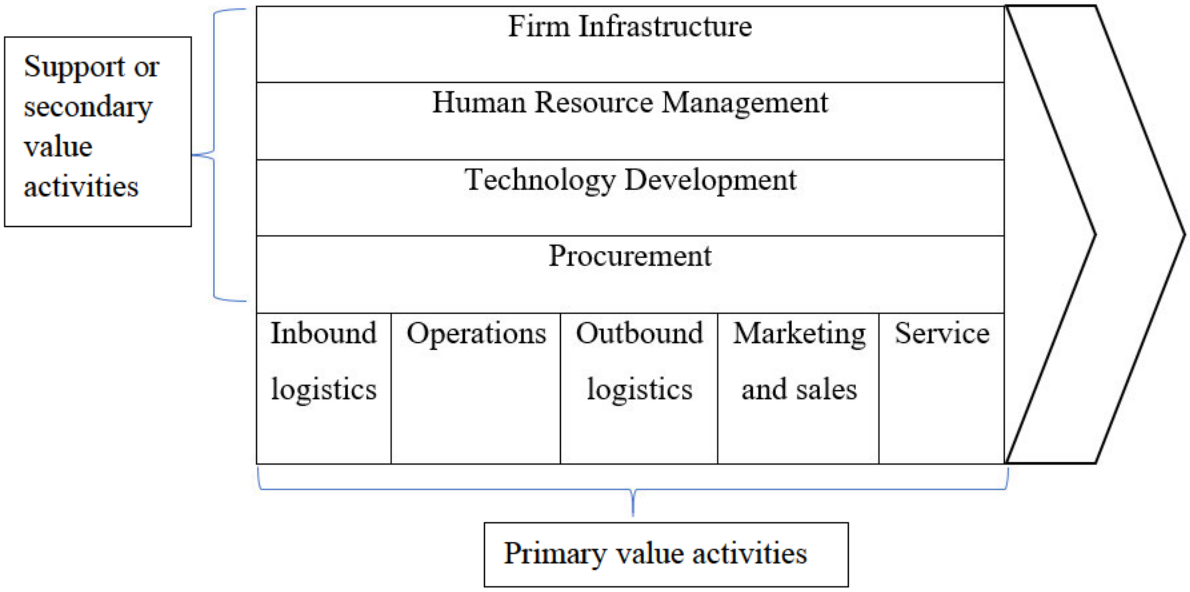

Figure 2: Porter's Value Chain Model (1985)

With increasing globalisation of value chains in the last few decades has come clarification of terminology, focus on the role of labour in global value chains and consideration of social and environmental sustainability of value chains (Parrilli et al., 2013). The increased complexity of global value chains has led to the uptake of 'value stream mapping', a process adopted from lean manufacturing that involves documentation of the value chain (Womack & Jones, 1996). Other developments have included analysis of other features of value chain operation, including rental distribution along the value chains of primary commodities, contracting, and subcontracting within a value chain (Morris & Staritz, 2014), ownership and transfer pricing (Vaitsos, 1974). The ownership of a value chain may be fragmented, or, in a vertically integrated chain, be large under ownership of one entity. Ownership boundaries impact the behaviour of value chain actors in terms of coordination and linkages. Popular forms of coordination between actors in fresh food chains includes grower-contractor agreements for market price and grower-contractor agreements for input supplies.

2.3 Evolution of value chains from local to global

Global value chains have existed for thousands of years, with trade in luxury items such as spices, e.g., across the 'Silk Road' and the 'Spice Route' (Walsh, 2022). However, most production was local to the area of consumption, limited by political restrictions, the cost of transport and the perishability of goods. For example, Nepal maintained closed borders until late 1940s, and the first road to Kathmandu was opened in 1956 (https://www.redcarpetjourney.com/highways-of-nepal/). Australia, with its small population, was export focussed for non-perishable commodities until the development of refrigerated transport in the late 20th century. The 20th century also saw a transition of western countries from a largely agrarian to an urban population, a process accelerating after World War II, and this process has continued into developing world countries (Tannerfeldt & Ljung, 2012). A form of agrarian socialism prevailed in Australia until the late 20th century, with single desk marketing for a range of agricultural products, including wool, wheat and fruit and vegetables. This was an era of many small producers, and the single desk gave scale for marketing and for inputs. These organisations were strengthened during World War II, acting to mobilise and distribute required resources and prioritise use of outputs. In Queensland, these roles were delivered for fresh fruit and vegetables by the 'Committee of Direction' (COD).

Disadvantages of national single desk marketing included lack of marketing flexibility at a producer level and increasingly bureaucratic procedures, with issues related to contracts, delayed payments, non-payments, and non-deliveries, e.g., the 1990s saw the growth of European value chains suspended due to late payments (Gorton et al., 2000). Many analyses point to inefficiencies in these value chains, especially in the USSR value chains (Swinnen & Rozelle, 2006) and examples of low credit repayment rates in Africa (Warning & Key, 2002). Liberalisation and privatisation were the highlights of value chain development in the 1980s and 1990s. The development of world trade under the framework of World Trade Organisation (WTO) membership involved the dismantling of national single desk marketing unless growers voted overwhelming to participate in such a desk. None now exist in Australia, but kiwifruit growers in NZ agreed to maintain single desk marketing (through Zespri P/L). State controlled value chains have continued in some communist country settings, as a central control and command system with production, processing, marketing, credit, and other aspects related to the value chain is authorised by the state. Variations of this form of value chain exist in Russia, China and Vietnam.

Advocates of the liberal trading regime point to the benefits of increased competition among agriculture value chains with increased innovation required to win market share. Competition in supply chains improves quality and efficiency in an explicit manner, ideally to the benefit of both producers and consumers, as documented in a cotton value chain (Swinnen et al., 2007). With competition, values chains also tend to diversify into systems, with increased out-sourcing of specific functions for improved overall efficiency, e.g., service for farmers in ploughing fields, timely supply of fertiliser, pesticides, and up to date payment after harvest of crop (Goulding et al., 1998).

However, there be disadvantages if the value chain becomes too specialised and dominant. Like an apex predator in a given environment that does not service change in environment and ecosystem, the coordination among the links may break down and impact the whole value chain system resulting in failure in a changed environment. Continual monitoring, coordination and information sharing channels is required to maintain a sustainable value chain.

In the fresh fruit industry, fruit was traditionally marketed into urban centres through a central market system. As reviewed by Walsh (2022), a significant change of the last decades has been the rise of direct marketing between large growers and large retailers, with product shipped directly from farm to the retailer distribution centre (Walsh, 2022). A parallel development has been the removal of state enforced eating quality standards, generally imposed by inspections at central markets, with private label specifications. In Australia, the development of these specifications is generally guided by work of the industry associations.

Developing countries are following a similar path in value chain development, and thus can learn from experiences in developed countries. For example, the first large retailer format store named Bhatbhateni (https://www.bbsm.com.np/) opened in Nepal in 1984 and has progressed to some limited direct purchase of (organic vegetables) from Nepalese producers, while otherwise importing fresh produce from abroad.

Agriculture value chains have thus experienced significant change over recent decades. There has been a shift from local to global value chains and from state-controlled chains to privately governed chains operating under liberalised marketing conditions. Possible disadvantages include a decreased robustness of such chains under a changed environment. For example, the current scenario of restrictions on payment system used by Russia, if not sale of produce itself into Russia, will have ripple effects through global fresh fruit value chains. This could be an important aspect for future research.

2.4 Typical Citrus Value Chain

A typical citrus value chain involves input providers, growers, traders, wholesalers, retailers, and consumers as the core chain actors in the central part of the value addition channel (Siddique & Garnevska, 2018). The core chain actors are connected to numerous other actors connected by various functions, improving the citrus product's value. Some actors supply production input (chemicals, fertiliser, planting materials, pesticides, equipment, packing materials, transport vehicles) and credit (banks, financial institutions, and cooperatives). In contrast, others provide Policies (Government), Research and Development (Universities, Government & Non-Government institutions, Research Stations/Centres) and export promotion (Government, exporters).

Any value chain, at any scale, is constantly facing a changing environment and so varying constraints. Horticulture value chains deal with additional constraints relevant to perishable biological products such as variable quality, shelf life and phytosanitary trade barriers. The demand-supply balance results in a variable cost of production (Fig. 3). Thus, value chain characterisation and recommendations for improvement are an ongoing need.

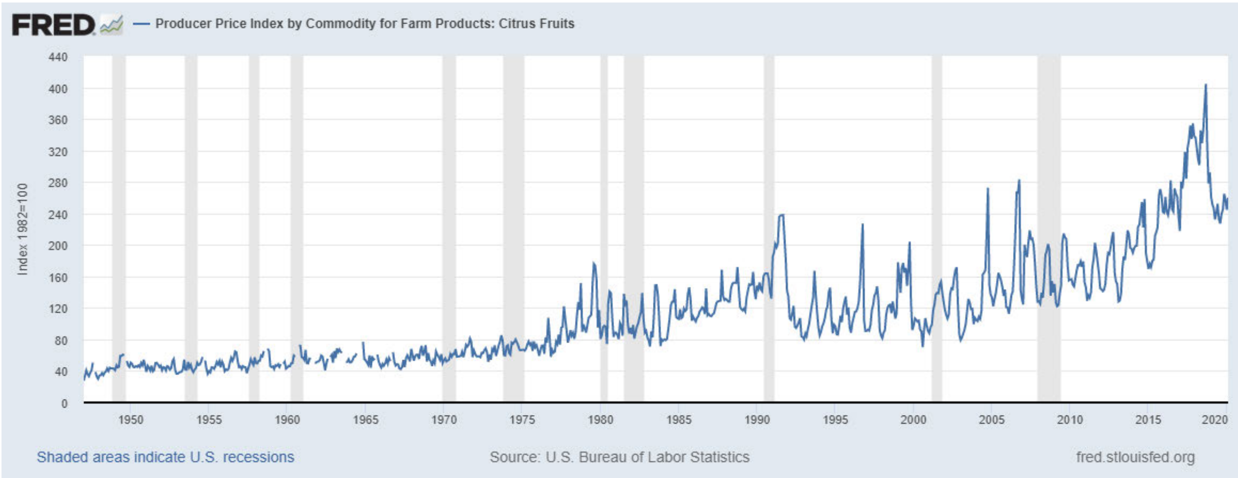

Figure 3: Citrus Producer Price Index 1950-2020 (Source: US Bureau of Labour Statistics via FRED https://fred.stlouisfed.org/)

This need is illustrated by the turmoil within the global citrus trade within weeks of the Russian invasion of Ukraine (Knowles, 2022). With imports to Russia either embargoed by exporting countries or prevented by military operations, large shifts in global trade have occurred rapidly. South African citrus previously marketed into Russia is now diverted into other markets, causing displacement of other producers (http://www.fruitnet.com/eurofruit/article/187806/russian-imports-must-reroute-after-old-lines-are-cut, DOA 19/03/2022). Fuel, fertiliser, and agricultural chemical prices have already dramatically increased, by over 100% on many items, with flow on effects on commodity pricing to follow. Value chains that do not evolve in the face of these factors will fail.

2.5 Characterisation of Value Chains

The characterisation of a value chain involves identifying the main actors and their roles in these value chains, identifying the key constraints, and potential future solutions to improve these value chains (Eltholth et al., 2015). Value chains will have specific features that impact their operation, e.g., proximity to the market (Pokhrel, 2011), issues related to losses of fruits (Bhattarai et al., 2013), tariff and phytosanitary barriers and market niches, e.g., in organic food demand (Joshi & Gurung, 2009).

Various methods can be used in characterisation of value chains. For example, survey and group discussion were used by Acharya et al. (2011), while a case study method was used by Pokhrel

(2011). A value chain walk concept was implemented by Adhikari et al. (2012) following the produce from the farm to the market whereas, a mixed method of surveys and interviews was used by Ali et al. (2018).

2.6 Mapping Value Chains

Mapping value chains involves placement of actors at their respective positions based on their roles and the production process or the information flow (Fig. 4). Sometimes, small factors can play a prominent role in determining the efficiency and success of a value chain model. For example, a system of informal credits encouraged farmers to invest back into their citrus crops (Shrestha, 2015), while an auction system in which buyers bid for the displayed citrus product was used in the central markets in Bhutan to improve market efficiency (Joshi and Gurung (2009).

A resilient value chain is characterised by a diversified set of actors at each level. For example, Olife et al. (2015b) provide an example of diversification in the citrus value chain in Nigeria when the traditional constrained chain of grower-trader-wholesaler-small retailer-consumer was broken with an entry of supermarkets and food processors.

The mapping process should include indirect value chain actors, called facilitators, who contribute towards the efficient operation of the value chains. Facilitators in the value chains include support providers (Emana & Nigussie, 2011) for smooth operation. For example, Waqar et al. (2018) map actors providing Information and Communication Technology (ICT) support along the citrus value chain. Literacy, both written and financial, support providers are essential in less developed scenarios (Waqar et al., 2018).

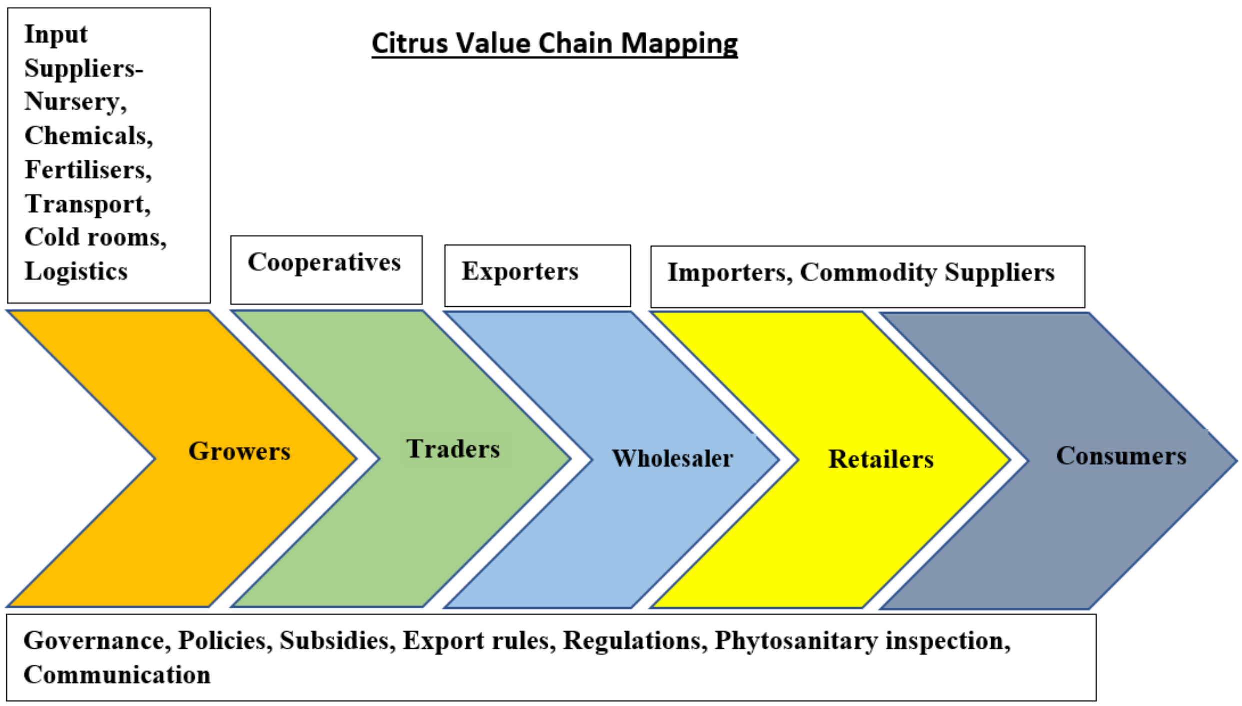

Figure 4: A typical citrus value chain based on product and information flow in Pakistan. Source: own sketch, based on Ahmad et al. (2018)

2.7 Critical value chain analysis

The role of each actor in a specific value chain is different and unique. Sometimes, the role of a specific actor in a value chain is played by a completely different actor in another value chain (Tu, 2008), and the role can change with change in the scenario. The actors' roles should be clarified in the value chain operations (Lazzarini et al., 2001).

Critical value chain studies propose changes in the role of actors. Role integration is a common suggestion. For example, a revised value chain could be made shorter through role integration of a smaller number of actors. Tu (2008) proposed that middlemen (brokers) roles within villages could be integrated into a trader's function by contract for a citrus value chain. The concept could be proposed after completing the descriptive case studies. Many studies point to the need for the introduction of technologies (Debello, 2007). For example, Badar (2014) recommended technologies for prompt information transfer among the value chain actors to improve collaboration and governance. The role of growers related to marketing channel choices influences citrus production (Siddique, 2015) and marketing processes (Akyem-Peprah, 2012).

Facilitators play roles in the capital, intellectual, and technological investment. For example, Manova (2014) describes the level of capital investment required to establish import/export trade in China from a global value chain perspective and to establish and manage a resilient produce chain.

2.8 Identifying Constraints

Obstacles to the smooth operation of a value chain are termed 'constraints'. Identification of such constraints forms the basis of a recommendation for improvement within critical case studies (Dhital et al., 2019).

Constraints can be internal or external for a given value chain. An internal constraint can be related to production, marketing, post-harvest processing, availability of technological interventions, input supply, post-harvest losses, storage facility, information flow, lower bargaining power of growers, transport distances (Woldesenbet, 2013), pests/diseases, knowledge gap, marketing information, credit access. For example, Akyem-Peprah (2012) provides an example of a value chain constrained by the cost of orchard/farm management, dominated by weeding, and tree damage by shaking during the harvest. Examples of external constraints include supply of cheaper citrus from other regions (Joshi & Gurung, 2009) or change in labour supply due to change in visa conditions.

In Nepal, the most dominant internal constraint to citrus value chains is the post-harvest loss of fruits, which is high given lack of packing, storage and cooling infrastructure (Olife et al., 2015b). Other weaknesses include scattered production, low-quality inputs, poor transport facilities, lack of credit, a short harvest window, irrigation problems, citrus decline and pest attack, labour issues, a communication gap between value chain actors, the inflow of foreign mandarins into the market (Pokhrel, 2011), improper harvest methods, handling, length of storage and pre-cooling practices (Akyem-Peprah, 2012). The education level of farmers represents a constraint, e.g., in technology adoption (Waqar et al., 2018) as does the involvement of traders with export experience (Shrestha, 2015).

2.9 Value Chain Analysis

All value chains have primary activities and support activities, as described in the modified Porter's value chain model (Porter, 1985) (Fig. 5).

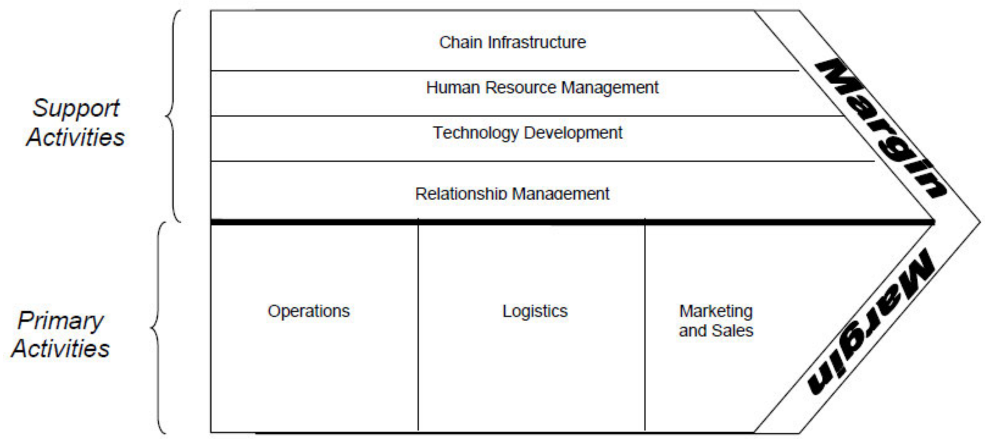

Figure 5: A Generic value chain (Modified) for the Value Chain Analysis approach (Source: Porter, 1985)

Various tools are used for value chain analysis, including chain mapping, interviews with the chain actors, screening critical issues at the actor and chain level and identifying performance indicators and targets (Attaie & Salazar, 2003). The performance indicators show the progress of the value chain towards a benchmark set by the value chain.

Case study methods are deemed suitable for identifying constraints and suggesting improvements in the value chains. A profitable/sustainable/resilient citrus value chain is likely to be buttressed by a range of support providers, e.g., providers of healthy nursery stocks, specialist orchard and packhouse machinery, agronomist advisory support, specialist packaging, phytosanitary advice (Badar, 2014), training (Dhital et al., 2019) and support of Market Information System (MIS) for the dissemination of market information within the value chain (Joshi & Gurung, 2009). Market/product diversification is a crucial resilience factor, which for citrus can include cultivation of early, mid, and late varieties, access to several markets, including processing. Resilient value chains include a research and development program enabling diversification (Olife et al., 2015b). In recent development, an approach for value chain analysis was used by Knez et al. (2021) with inclusion of domestic value chains focusing primarily in domestic products.

A summary of studies of citrus value chains used as a reference to this study or to analyse value chains regarding coverage, methods, constraints, and recommendations is provided in Table 1 below.

Table 1. A summary of related studies published on citrus value chains

COVERAGE	METHODS	KEY CONSTRAINTS	RECOMMENDATIONS	REFERENCE
Australia citrus general managers, owners, CEO of firms (Six firms)	Case studies, interviews, exploratory approach	Supply and demand mismatch, information risk, financial risk, natural catastrophes, regulatory requirements	Biosecurity management with strict quarantine measures, risk management strategies	Ali and Soosay (2015)
Nepal citrus 20 citrus growers, three VDCs	A semi-structured questionnaire, focus group discussion, orchard visit	Seedlings, rainfed system, pest diseases, improper post-harvest handling, limited access to chemical control measure	Grafting plants, training awareness, orchard management, nursery management, post-harvest handling	Acharya et al. (2011)
Pakistan citrus 120 citrus growers	Face-face interviews, SPSS Analysis	High input prices, small land parcels, middlemen monopolies	Regulate intermediaries in value chain through legislation, develop systematic marketing channels	Ashraf, Saqib, Hassan, Luqman and Rehman (2020)
Nepal mandarin 2 VDCs, 60 mandarin growers, four collectors, two	Survey, pre-tested interview schedule, face-face interview,	No adequate training, support and supervision, unorganised marketing system,	policies to fix market price based on cost of production, promotion of technology-based processed mandarin production	Shrestha (2015)

agro-input traders, two fruit nurseries, four technical service providers, four dealers, four wholesalers, four retailers, 20 consumers	focus group discussion, critical informant survey, SPSS, MS-EXCEL analysis			
Nigeria citrus Various papers, documents, and research	Review and analysis	Lack of value addition, post-harvest losses, poor road network, lack of infrastructure for storage and preservation, improved varieties, poor R&D funding, poor handling of fruits	Establish cold storage, reduce post-harvest loss, improved varieties, processing clusters, dedicated development of citrus value chain	Olife et al. (2015a)
Pakistan citrus 50 exporters	Interviews and questionnaires, value chain mapping, regression analysis	inappropriate fertilisers, citrus canker disease, poor post-harvest management, rootstock scion budding method/height, Role players – value chain actors?	reduce post-harvest losses (20-40%), improve productivity, adopt seedless varieties	Ahmad et al. (2018)

Pakistan Citrus 126 citrus growers (67 included in the paper)	Multivariate decision analysis technique, conjoint analysis, a survey by semi-structured questionnaires/interviews, face-face interviews	Urgent need of money, delay in payment, long time for picking fruits, harvest loss	Improving efficiency and effectiveness of citrus industry	Siddique (2015)
Nepal Mandarin 75 households, five different clusters	The survey, simple random sampling methods, semi-structured questionnaire, face-face interviews	Technical and socio-economic problems, lack of technical knowledge, input supplies, road and market access	Development of collection centres, frequent monitoring and training, input supply management promote the productivity of citrus	Dhital et al. (2019)
Bhutan Citrus Various papers and research	Review	Insect pest and diseases, weak input/service market, inadequate knowledge and skills, lack of access to and high cost of transportation,	Establishing a value chain forum, strengthening the linkage, increasing the quality and volume of production, positioning the brand image, creating awareness, capacity development,	Gyeltshen et al. (2015)

		post-harvest losses, lack of proper storage, unreliable market information and poor coordination, inadequate access to credit facilities, buyers' monopsony, frequent strikes in Indian border towns, low investment in research and extension, logistics, cross-functional drivers, weak coordination and linkage between support agencies,	establishing/strengthening the input market, market information system interventions	
Pakistan citrus processing industry, 33 exporters	The survey, questionnaire, analysis by descriptive statistics	Lower quality production, poor storage and packaging followed by transport, expensive freight, weaker government policies	Strengthen export promotion activities, export friendly and consistent government policies, setting up a cool chain, development of quality standards, the role of line development, incentives for exporters	Mahmood and Sheikh (2006)

Japan citrus Southwestern Japan	Research and development	Slope lands, high labour need, transport and spray difficulties, young generation moving away from the farm production system	Development of appropriate technologies based on computer programming, utilisation of new materials and processes	Morinaga (2002)

2.10 Conclusion

Small growers must target niche, often local, markets (Kolavalli et al., 2020). Small growers have additional constraints in developing countries which lack organisational and physical infrastructure (Orozco et al., 2021). However, niche export markets are developing, e.g., Fairtrade and organic citrus marketing (Mook & Overdevest, 2021) have expanded in the Netherlands and the US.

For a land-locked country like Nepal, road and rail infrastructure is critical (Pandey, 2020). The developing Pakistan to China horticultural trade presents an interesting parallel for Nepal (D. Adhikari & Y. D. GC, 2020; Arrfat, 2020). However, the decision to participate in a high-value chain comes with risks (Yaseen et al., 2020).

An alternative to retail citrus marketing is required in case of higher production and lower consumption or export. The prospects of juice marketing as an alternative were done (Neves et al., 2020). The sole involvement of the private sector is debatable (Adhikari, 2019), whereas the formulation of public, private partnership (Abdulsamad & Manson, 2019) by various citrus value chain actors and participants in the global value chain improvement is commendable.

Technologies for improvement in horticulture production and decision support (K. Walsh et al., 2020) are other factors in the advancement of value chains like citrus. A few technologies are gaining popularity in citrus, with a need to evaluate the applicability of a specific innovation for the citrus crop. Even remote sensing is utilised for risk mitigation (Benami et al., 2021), which shows technology development by specific folds compared to the last decade. Even though there are a few disruptive technologies (Krishnan et al., 2020) in developing country scenarios, developed countries are making significant progress with technology aiding the forecast of crop load and harvest timing (Anderson et al., 2021).

Value chain resilience is another crucial factor mentioned by Dong (2021) in the developing world, and the evolutions during a period are involuntary at times. COVID-19 was a significant factor in horticulture industries across the globe in the last couple of years, but there is a need to seek sustainability amid COVID-19 (Prinsloo & Matema, 2021).

In a nutshell, every value chain has ever-evolving constraints, and the actors must continually adapt their operations. Identification of constraints is key to action to improve. As implemented by Ugoh (2018), a walk of citrus chains would provide opportunities for the research to understand the ground scenario of what is happening and how the product has been handled or marketed. COVID-19 limited a proper value chain walk was not possible, but a presumptive/assumptive walk was practised in the citrus value chains of Central Queensland and Western Nepal.

3.0 Descriptive Case Study of Small-Scale Citrus Production in Central Queensland

Abstract

A descriptive case study based on semi-structured interviews is presented of the small-scale citrus farms, ‘By Citrus’, Lucht, and ‘Woodvale Park’. ‘By Citrus’ was the largest citrus producer in the Byfield district in the 1970s and 80s, and introduced innovations such as overhead irrigation, pack line technology Insect Pest Management (IPM), and marketing to southern central markets .A major value creator was production in windows when the market was in short supply. Value was lost with the development of early-season production in the Burnett and Emerald regions which also operate at a larger scale. The Lucht family has achieved an intergenerational transfer of citrus farming, although as an adjunct to other income. The major value creator is service to local IGA retailers, providing locally grown fruit of a ‘heirloom’ variety, Emperor, known to the local market. Value was lost with cyclone damage. Woodvale Park achieved a market niche and product differentiation with biodynamic certification, particular for lemons. Value was lost as production by competitors increased, decreasing market prices, restrictions on water supply in dry years, and cyclone damage. Common elements in each of these three small scale citrus producers included: (i) the need to find and defend a point of product differentiation that provides a rewarding market niche, (ii) the lack of resilience to a major event, such as a cyclone, and (iii) need for generational continuity.

3.1 Introduction

The Byfield and nearby areas of the Central Qld coast (Fig. 6) enjoy a higher rainfall than the surrounding areas, with an average annual rainfall of 1271 mm recorded for Byfield compared to 569 mm for Rockhampton annually, averaged over the period 2011-2020 (BoM, 2021; Chen et al., 2013). Byfield also enjoys a perennially flowing water supply, with an annual flow of 130 GL and a min daily flow of 15 ML (averaged over ten years). In contrast, the Fitzroy River has a massive annual flow of 6000 GL (Jones et al., 2016) but ceases to flow in the drier months.

Figure 6. Byfield region of Central Queensland, Australia (Source: Google Map, 2020)

The availability of water in Byfield attracted European settlement in the late 1800s. The product was initially marketed to nearby population centres. By the 1970s, Byfield citrus was marketed to Brisbane, Sydney, and Melbourne. However, the market advantage of the region was eroded with time, given the development of transport systems and irrigation systems elsewhere in the Burnett and Emerald regions. Further, restrictions on the extraction of water from Waterpark Creek in Byfield came into force in the early 1990s, coinciding with a series of periods of water scarcity. These forces, together with generational change, saw the industry fade in the region. Today only several small producers remain tapping niche markets.

Over supply of product to a market results in depressed profitability, squeezing out producers of smaller scale (Homburg et al., 2004). Niche marketing is a promising strategy for a small producer to avoid competition to capture a higher profit per item (Van Der Hope, 2008). This strategy relies on specialisation, flexibility, and a close customer relationship (Rosenbaum, 2004). Market niches for fresh fruit exist can be based on variety, flavour, place of origin, or production methods (Zeugner-Roth, 2006). For example, heirloom varieties or organic production can be used as a basis for the development of a market niche (Prónay, 2016).

This chapter provides descriptive case studies of three small-scale citrus production units, 'By Citrus', Lucht, and 'Woodvale Park', of the Byfield and the surrounding region of Central Queensland.

3.2 Methods

Case studies involve the documentation of a particular example or case. A case study can be characterised as explanatory, exploratory, descriptive, or critical (Yin, 2003). A descriptive case study was undertaken based on a semi-structured interview, following that of Tobin (2010). This work was undertaken under CQ University Human Ethics Approval number 0000022287. Informal encounters with the growers occurred at local grower markets. Participatory discussions were organised with the owners following an outline (Appendix 1) provided to the growers ahead of the meeting. A draft of the case study was provided to the growers for feedback and approval for the final report obtained.

Descriptions of the value chain operated by three producers were developed, with a focus on issues that both enabled and limited success in terms of economic, environmental, and social sustainability. The three producers were Lucht, the largest remaining citrus growers in Byfield, 'By Citrus', the largest grower in Byfield during the 1980s, i.e., the peak period of production in the region, and an organic producer, 'Woodvale Park' farm.

Common features

Fitzroy Nurseries

The main plant source for plants for all three producers was 'Fitzroy Nurseries' in Rockhampton (https://www.fitzroynurseries.com.au/). This nursery was established in 1953 by European immigrants from Dargel (German) and von Allmen (Swiss) families who worked as employees in a nursery in Bundaberg until 1952. From its start in 1954, Fitzroy Nurseries has become one of the largest sub-tropical nursery suppliers in Queensland. The nursery sources seeds from across the globe and from the customers. On request, certified propagation material can be sourced from AusCitrus (https://www.auscitrus.com.au/). Citrus seedlings were purchased as grafted plants, typically using rough or bush lemons and Troyer Citrange rootstock, with plants at about 14 months of age.

The advantages of sourcing plants from this nursery include:

- Proximity to the farming location
- Year-round availability of citrus plants
- Improved and updated varieties of citrus, with seeds/rootstock/scion/budwood sourced from 'Citrus Australia'
- Healthy nursery stock free from diseases and pests

Biosecurity protocols followed according to the Biosecurity Act 2015, and Biosecurity Regulations 2016.

Transport

Currently, there are two companies offering refrigerated transport from Rockhampton to the Brisbane markets, Rocky's Own Transport and Toll. The growers report Rocky's Own Transport is preferred for its flexibility in collecting loads, although it is more expensive. Shipments will be transferred from Rocky's Own Transport in Brisbane to toll or other carriers if servicing a more distant market. As implied in the name, Rocky's Own Transport is Rockhampton based. The minimum shipment is a quarter pallet. Loads less than 4 pallets must be delivered to depot, while larger loads can be collected from farm. Transport cargo can be held between 5 and 20^{o}C. An internal wall can be erected to create zones of different temperature. Generally, a booking is made at least the day before a load pick up the next day, with that consignment reaching the Brisbane market around 5 to 6 am of the following day. The company transports custard apple, pineapples, pumpkins, sweet potato, passionfruit, mango, and citrus from the Central Queensland region.

Packaging

The major suppliers of cartons in Australia are Amcor (https://www.truelocal.com.au/business/amcor-australasia/rockhampton) and Visy (https://www.visy.com.au/packaging/cardboard-boxes). Local growers use Amcor product. Amcor operates an office in Rockhampton for general packaging, but their fruit carton business is handled by the Amcor subsidiary Opal Packaging (https://opalpackagingplus.com/). Opal Packaging started in 1974 as Wayne Richardson Sales, with acquisition by Amcor in 2012. Cartons can be made of 3, 5 or 7 ply depending on the strength required. Boxes can be supplied flat or pre-erected, but freight on pre-erected boxes is prohibitive. Label printing requires a minimum 3000 unit run.

3.3 Farm Description

'By Citrus' Farm

Location

By Citrus is a 20 ha (~50 acres) production unit in Byfield, Queensland (Fig. 7) in the proximity of the Byfield creek and Water Park creek.

Figure 7: Farm boundaries of By Citrus farm 22°51'26.8"S 150°38'17.0"E (Source: Google Map, 2020)

History

Richter family

While immigrants to Australia predominately currently settle near the major urban areas (Rapson & Birrell, 2002) in the late 1800s immigrants fanned out across regional Australia in search of opportunity in agriculture, mining (gold rushes) and commerce (Hugo & Smailes, 1985). The Richter family emigrated from the Karlsruhe area of Germany to the Rockhampton region in 1889. At the time Rockhampton was in an expansion phase, buoyed by gold finds and acting as a port city and an administrative centre for the Central Queensland rangelands.

The family explored land options around Rockhampton before joining with several families to settle in the Byfield area. This location was chosen based on its higher rainfall and thus the potential for rainfed groups and proximity of Rockhampton market. It was judged to be suitable for bananas, Emperor mandarin, and common oranges production. Seedling citrus trees were planted on alluvial creek flat land, which were up to 30 ft (10 m) high in 1901. The second-generation pushed these trees out at 60-70 years of age, establishing orchards of small, easier to harvest trees.

The third generation (current owners) purchased land on the flats of Waterpark Creek in the 1960s. Although less than 100 km from Rockhampton, the region was remote in terms of services, with no mains electricity until the 1970s and only a dirt road to Yeppoon until the early 2010s.

Production of banana and papaya was continued on the hillside land, while establishing the creek front property. A house was constructed, and fruit a tree orchard was progressively established, achieving 4,000 citrus trees (Emperor mandarins, Imperial mandarin, lemons, Valencia, and some Joppa oranges) and 250 lychee trees by 1990, with an annual production of 14,000 (18 kg size) cartons of citrus fruit. The farm enjoyed a production window with little competition, and various production and packing innovations were introduced providing a period of profitability. The purchase price of the property was recouped in five years. However, other production areas came into play that eroded this market niche, and the fourth generation elected to leave farming and the Byfield region.

COD

The main production period of 'By Citrus' was within the period of operation of The Committee of Direction of Fruit Marketing (C.O.D.), an organisation controlled by growers. The COD was legislated as a statutory authority by the "The Fruit Marketing Organisation Act 1923", with operation commencing in 1924 (Queensland State Archives, Agency ID A10682[1]).

The COD acted for Queensland growers in running stores selling farm requisites, provision of cool storage facilities and pre-packing and packing facilities, insurance, control arrangements for canning, transport, and road distribution, fruit marketing and promotion, wholesale selling, retail outlets, and export and export development services. Prices were not set.

The COD organisational structure involved local associations reporting to the Sectional Group Committees (SGCs) for each of bananas, pineapples, citrus, deciduous fruits, other fruits, and vegetable-heavy produce growers. Two members from each Section and the director of marketing of the Queensland Government Department of Agriculture and Stock, later Primary Industries, formed the Executive Committee. Citrus farmers paid a levy of approximately 20 cents per case. Funds were used for research, development, and marketing alongside the running cost of SGCs.

The COD served to provide a range of services to an industry that consisted of many small producers. With the establishment of large producers and service providers in other areas, such as transport and retail, the need for the COD declined. The "Primary Industry Bodies Reform Act 1999" repealed the "The Fruit Marketing Organisation Act 1923", with a transitional period of statutory compulsory membership continuing until 2003. The registered business name of COD was changed from COD to Queensland Fruit and Vegetable Growers (QFVG) in 1999, with QFVG

[1] https://www.archivessearch.qld.gov.au/agencies/A10682 includes the details of fruit marketing organisation act related to COD.

restructuring from a statutory body to a company limited by guarantee in 1999. Nowadays, C.O.D., Growcom (https://www.growcom.com.au/), QFVG are all used as alternative names.

Features of Value Chain

Nursery stock

The main plant source for plants was 'Fitzroy Nurseries' in Rockhampton (https://www.fitzroynurseries.com.au/).

The advantages to 'By Citrus' of sourcing plants from this nursery included:

- Proximity to the farming location
- Year-round availability of citrus plants
- Improved and updated varieties of citrus, with seeds/rootstock/scion/budwood sourced from 'Citrus Australia'
- Healthy nursery stock free from diseases and pests
- Biosecurity protocols followed according to the Biosecurity Act 2015, and Biosecurity Regulations 2016.

Citrus seedlings were purchased as grafted plants, typically using rough or bush lemons and Troyer Citrange rootstock, with plants at about 14 months of age.

Seasonal production

Citrus varieties were selected to spread production from as early as January to as late as October. Meyer lemons harvest started in January, Lisbon lemons in February, Marsh grapefruit in March, Navel oranges in late March, Imperial mandarins until April May, Emperor mandarins May to August, Ellendale mandarins in late August, and Murcott mandarins in September finishing in October. Training, pruning, fertilising, and spraying continued after harvest. Lychee harvest occurred from late December to January into the beginning of February.

A market niche existed for Imperial mandarins because the warmer Byfield climate allowed 'By Citrus' to have fruit in the Melbourne market two weeks before any other producer. An average return for a half carton (9 kg) was $22-23 per carton, a very high price at that time. The later maturing varieties supported a market short on supply as the production of early varieties ended in August.

The Queensland-developed variety 'Ellendale', a large, orange-coloured mandarin, was later also introduced as a late-season variety. 'By Citrus' established about 500 trees. With a larger size, attractive colour, and a good keeping quality aided by the harvest in August, the fruit attracted a premium price.

This spread of varieties across the year gave diversification and income across the year. In contrast, another farmer in the region, Barry Nichols, produced only one variety. However, the year-round workload was hard to maintain.

Competition came with the advent of citrus production in the Central Burnett region. Golden Mile Orchards was established near Mundubbera and developed as the largest privately owned orchard in the southern hemisphere by the 1950s'. Golden Mile Orchards introduced 'Honey Murcott' budwood from the USA and developed its' production. The variety became the main mandarin of the season. As a sweet variety, it was also used in the export trade to the Asian market. Ellendale was also grown extensively in the Central Burnett region and was a mainstay of the export trade to Canada and European countries. Ellendale production from 'By Citrus' lost market advantage for late-season markets to Central Burnett region production.

Fertiliser

Blood and bone fertiliser were the main input sourced from meat works and COD in the early decades of 'By Citrus' production. In Byfield, later the farm converted to the use of a mineral NPK fertiliser.

Labour

Initially, labour was provided by family members. With the growth in farm production, additional farm labour was sourced by advertising and interview. At peak production, the farm employed seven seasonal staff, primarily international visa holders.

Mechanisation

The farm started with a tractor, a disk harrow, and a slasher. Another tractor was acquired, and a forklift attachment was constructed on-farm. As production increased in the 1970s, a cherry picker was acquired to aid the harvest operation. Cherry pickers were novel at that time. The machine had been used for display on farms around New South Wales. The machine was made in Australia under license from the parent company in Israel. A conveyor belt with fruit holding fingers was used to convey fruit from the harvest platform to a field bin, with the harvest platform operating up to 14 ft (4.5 m) above ground.

Water supply

The first citrus planting was established by hand watering. An irrigation system was progressively established from 1974, with water pumped from Water Park Creek using a belt drive from a tractor. A new irrigation system was also introduced, based on movable aluminium pipes with 25 sprinklers on each section. Pipes were shifted between rows every 3-4 hours, providing about an inch (25 mm) of irrigation water to each row. An orchard of 1000 trees was irrigated over one week. A ditch digger was hired to facilitate the laying of pipes and an overhead sprinkler system was installed. Later came a move to smaller ¾ inch diameter pipe and under tree mini sprinklers which each irrigated an area of around 2.5 m diameters. The pump could supply 800 mini sprinklers at a given time. Sprinklers were run for about 10 hours per day to irrigate the plot.

In the early 1970s, with the arrival of a mains electrical supply, an electrical pump was installed. This removed the need to commit a tractor to the pumping operation and to periodically refuel it. In 1973, a larger pump and pipes through the centre of the orchard were installed. Lateral lines ran from the centre pipe with individual sprinklers on 13 ft (3.9 m) risers placed 90 ft (27 m) apart. These sprinklers irrigated a 90 ft (27 m) diameter circle (Fig. 8).

Figure 8: Overhead Sprinkler in the citrus orchard (Source: Dipendra Aryal, 2020)

A dam of approximately 5 million gallons (1 ML) capacity was constructed in 1993, but this was only sufficient to maintain irrigation to 10 acres (4 ha) of orchards for 3 to 4 consecutive dry months. The dam was emptied several times over the years. Plans for a second dam were developed but were shelved following the introduction of the Water Resources Act of 1989[2] . This Act restricted farm rights to pump water from watercourses or to interfere with surface water flows. A water license from the Queensland government was required from the late 1980s with a scale installed in the creek dam for a minimum volume left after the council pumping. If the level of water was below a certain point, the farm could not pump the water and if the water was available, they had to pay for it.

Livingstone Shire Council (LSC) originally sourced water from Limestone Creek but shifted extraction to Waterpark Creek in the early 1990s. LSC was granted a permit to extract 20,000 ML per annum of water from Waterpark Creek. The early 1990s were a dry period[3] during which creek flow declined and town water use increased. During hot, dry periods, LSC town water use increased to 15 ML per day, matching the flow rate of Waterpark Creek.

Although the farm had been using water from well before LSC began extraction for the Capricorn Coast reticulated water supply. In the 1990s, 'By Citrus' received notification from the Department of Natural Resources (DNR) to cease water extraction from Waterpark creek. LSC had not imposed any restriction on town water usage at that time. With the farm dam at half capacity (2.5 ML), and 3,000 cartons of lemons on the trees, and 1,000 trays of lychees developing, the situation was difficult. Meetings with the local Government Member of Parliament were followed by the introduction of restrictions on town water use.

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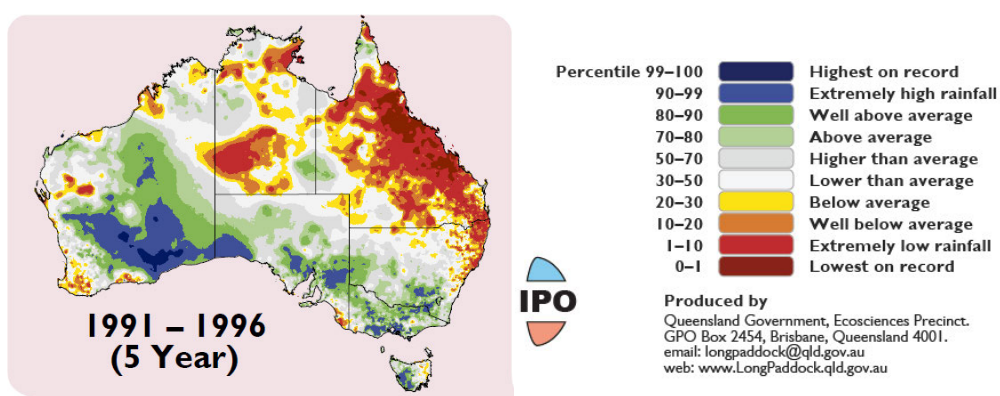
[2] https://www.legislation.qld.gov.au/view/pdf/inforce/1995-06-01/act-1989-112 includes the legislation on use of water resources.

[3] Extended dry periods in Queensland during the early 1990s included extremely low rainfall and a few locations with the lowest on record. (Source: Queensland Government)



Queensland Government

A compromise was reached with the DNR, with the farm decreasing irrigation from every week to every second week. However, if the creek water level fell to a set point, all extraction had to halt. These restrictions led to a decline in production. Some citrus was sequentially removed from production.

The options of creating a second dam were explored again. The Department of Environment initially declined a clearing request, based on assessment from inspection of aerial photographs of the presence of remnant native vegetation. Permission was provided after several years, but by this time the process of downsizing has reached the point where the second dam was not warranted. Over the next decade of downsizing, the rate of decrease of income was greater than the rate of decrease of expenses, such that operation was occurring at a loss. Further reduction in costs occurred, principally in labour hire.

Disease and pest management

In the first decade of production, the orchard was sprayed with copper oxychloride and finely ground sulphur. Copper oxychloride acts as a fungicide in control of melon nose, along with pruning of dead wood. Sulphur was used to control rust mites (Mauri mite). A water-soluble oil was used for the control of pink scale insects. The chemical Carbaryl (Manufacturer: Bayer Company, Germany) and later Supracide (also known as Methidathion and referred to as the 'super spray') was used to control grey grasshopper, red scale, white wax, pink wax, soft ground scale, soft black scale, and sooty mould. Applications were made twice a year, in early September and in December, after the harvest operation. Trees with fruits nearing maturity were not sprayed. Supracide was highly toxic and would negate the effectiveness of insecticides.

Biological control measures were introduced to Queensland orchards in the 1970s. Predatory wasps were acquired by 'By Citrus' from 'Bugs for Bugs' (Mundubbera, Qld.) for the control of the red scale. Predator wasp was first introduced in 1979 in Queensland (Citrus Australia, retrieved from https://citrusaustralia.com.au/news/latest-news/the-late-jack-parr-inducted-into-citrus-hall-of-fame, 2020).

Fruit fly was managed using pheromone lures and baits(https://bugsforbugs.com.au/product/fruit-fly-trap/). Lures attract gender-specific (either male or female) fruit flies in a trap and are drowned or killed whereas a bait consists of food (protein) with insecticide sprayed on the leaves and trunks which attracts all (male and female) fruit flies and kills them when they consume the bait. Temporary netting was also practised in citrus tree by farmers for pest exclusion (Fig. 9).

Figure 9: Netting for pest exclusion in citrus (Source: Dipendra Aryal, 2020)

Netted structures were installed in the 1990s for pest exclusion. A netted structure covering 3 ha of litchi costs $30,000 for the netting alone. The 2015 cyclone Marcia destroyed this infrastructure (Fig. 10).

Figure 10: Netted infrastructure destroyed by Cyclone Marcia (Source: Dipendra Aryal, 2020)

Grading/Packing/Processing

A packhouse and associated facilities were developed. Fruits were harvested into field bins to a weight of 500 kg. Field bins were tipped using a hydraulic system into a wash tank. Fruits were then moved by rotating brushes which also served to clean the fruit, removing black mould. Fruits were then treated with a fungicide in a dipping trough (Fig. 11), before further passage over brushes with softer bristles than in the washing process. A waxing process followed. Fruits were then size graded to eight drop points. Second-grade fruits were placed on a separate conveyor belt (Fig. 11).

Figure 11: Dipping trough for fungicide application (Source: Dipendra Aryal, 2020) and sSizing machine (Source: KB Walsh, 2020)

Graded fruits were initially packaged in bushels with a change to branded cardboard cartons in the late 1980s (Fig. 12). Initially, there was no mains power. The grader was operated using a hand-cranked diesel motor. Main's power was connected in 1989.

Figure 12: Bushels (left) and cardboard cartons (right) used for packing citrus by 'By Citrus' (Source: Dipendra Aryal, 2020)

Degreening/Cold room

Fruit leaving the farm was always orange due to the use of a degreening treatment. Initially, fruit bins were covered with a plastic liner, and ethylene gas produced from the reaction of carbide and water was introduced. Potato sacks were placed over the fruit to mitigate probable burn created by chemical condensation on the plastic. The carbide was bought from COD, which sourced the product from mines in Tasmania.

A degreening facility was constructed consisting of a lined room (Fig. 13). Carbide gas was used to ripen the fruits, with a hose supplying the gas into the room and a fan used for air circulation. Later, bottled ethylene was used. The room could accommodate twelve pallets in a single layer. Fruits were left in the room for up to 3 days, depending on fruit colour.

The Department of Primary Industries (DPI) initially provided a service of inspecting fruit for maturity at the start of the season through a sugar to acid ratio test.

Figure 13: Degreening room (Source: Dipendra Aryal, 2020)

A cold room was established which could hold about 600 cartons of mandarins. Fruits were stored within 600 returnable plastic crates of about a bushel in size (18 kg).

Transportation

The fruit was transported using a farm-owned truck in three or five-ton loads. Initially, fruits were transported from the farm to the Yeppoon railway station (Fig. 14) which was 40 km away. As production increased, the fruit was also trucked to Rockhampton (80 km), with forwarding to

Brisbane via rail or refrigerated road transport. The fruit was usually taken twice a week to Rockhampton market and twice a week to the railway in Yeppoon.

Figure 14: Yeppoon railway station, 1970. Queensland State Archives, Digital Image ID 1076737 (http://www.archivessearch.qld.gov.au/Search/ItemDetails.aspx?ItemId=1076737)

In the 1970s-80s, two-thirds of the length of the Byfield-Yeppoon road was gravel, but the Rockhampton-Yeppoon road was bitumen. By the late 1990s, the entire distance was bitumen. Given good packing of the fruit, with no loose fruit, there was no damage to fruits during road transport.

Fruits were originally shipped in wooden crates (bushel) and later in 18 kg cardboard cartons. The bushel contained a layer fewer fruits than the carton.

Fruit cartons were loaded by hand into the railway wagons during the first years. There were 30 cartons to a pallet. Later, the railway depot provided a forklift for unloading/loading. Cold rooms were available for the storage of pallets. The train wagons were not refrigerated. Truck transport from Rockhampton to Brisbane was refrigerated.

Responsibility for loss during transportation and costs of transportation to the wholesaler/retailer was placed on the grower. Wholesalers and retailers assumed responsibility for a consignment once produce arrived at their facilities. Stock loss infrequently occurred during the rail journey, typically involving the removal of a layer of cartons from a pallet.

Marketing and pricing

Produce was sold through COD Rockhampton, into COD Brisbane, COD Mackay, and COD Townsville, and to private agents in each of Melbourne and Sydney markets.

Peak production at 'By Citrus' occurred during the 1980s, with about 10,000-14,000 cartons (180 to 250 t) produced per annum. Initially, fruits were sold within Rockhampton, a city of about 50,000 people. Half a dozen other citrus orchards in the district, not quite the size of 'By Citrus' also supplied fruits to this market. A decision was taken by the growers to market fruit to Brisbane as a collective venture. Many growers would collect their production and send it to Brisbane rather than sending it alone because of lower production and higher transportation cost. By doing so, the growers could send their produce to the market in cheaper transportation costs.

All first-grade fruit was sold to the central markets in Brisbane while second-grade fruits were sold in the local market, roadside stores. There were no written agreements made with the market agents. Payments were generally made in a week, sometimes in a fortnight or even a month. However, agents held the upper hand in disputes, able to pay a lower amount than verbally agreed on an essentially unsubstantiated claim of lower quality than expected. The new code of conduct[4] was a talking point, but farmers undoubtably did not have too many options to choose from. If unsatisfied, the growers would move to another agent. 'By Citrus' shifted agents five times. The market agent in Brisbane who acted for 'By Citrus' was also the COD citrus delegate. A citrus delegate is a person who used to be a representative of the growers in the surrounding area and would go in meeting and discuss issues and help citrus industry grow altogether. Peter was also a citrus delegate for the Central Queensland area for an extended period. His visits as a citrus delegate assisted with the development of a rapport that supported the marketing relationship.

The price of fruit stayed constant for many years. From the mid-1970s to the early 1980s, $3.40 was received for an 18 kg carton. With growers reaching retirement age and a low incentive for a new generation to continue citrus production, other producers in the area ceased production and sold their properties. 'By Citrus' continued growth and increased production.

In the mid-1980s, the wholesale price per carton almost doubled, to $7.80. A year later, wholesalers were selling cartons at $10, and over the next 10 years, it reached $16, as growers exceeded the industry creating the shortage of supply. This provided a period of high profitability for the farm. In recent years, the price of citrus and mandarins is approximately $15-20 per kg in supermarkets (Coles, Woolworths) and $8-10 for limes (Source:

[4] A code of conduct is document including the agreed terms and conditions among both parties making an agreement on what to do and what not to. In terms of payment, the terms will include when, what method, and how much to pay.

http://www.ausmarket.net.au/images/Brisbane.pdf) which shows a drastic change of price over the years.

Second-grade fruits were not accepted by the central market. However, there was no juice processing or canning facility available, and the family did not have time or resources to diversify in this way. A pineapple cannery operated briefly in Rockhampton during the previous generation[5] (Pickett et al., 1988). The nearest processing plant was the Golden Circle Cannery in Northgate, Brisbane, but freight cost and the need to hold a share in the cooperative to process the fruits was a disincentive. The fruits had also to be clean; black spots on the fruits would not be accepted.

Downsizing of farm production occurred in recent decades. Currently, produce is marketed through farmers' markets in Yeppoon and Rockhampton. These markets are more tolerant of second-grade fruit.

Supply Chain Map

The supply chain actors described above are summarised in the following supply chain map (Fig. 15). During the peak years of production, majority of volume (55-60%) went through transport companies to urban consumers in bigger markets and rest was sold through COD and local amrkets whereas, 100% of marketable production goes to local markets of Rockhampton and Yeppoon in recent years due to decline in production.

[5] The COD purchased land for a cannery at Lakes Ck, near Rockhampton, in 1951. The cannery opened in 1953, processing mostly pineapple (up to 5,000 cases per week) but with intention to also process papaya and other tropical fruit. The cannery closed in 1957, supplanted by a freight subsidy to the Northgate cannery for central queensland growers. In 1964 the COD cannery in Northgate, Brisbane, became a separate business, known as Golden Circle. Golden Circle was acquired by Coca-Cola Amatil in 2007, then by Kraft Heinz in 2009. https://trove.nla.gov.au/newspaper/article/57242995.
https://trove.nla.gov.au/work/38971562?keyword=koongal%20cannery

https://digital.slq.qld.gov.au/delivery/DeliveryManagerServlet?change_lng=en&dps_pid=IE1411943

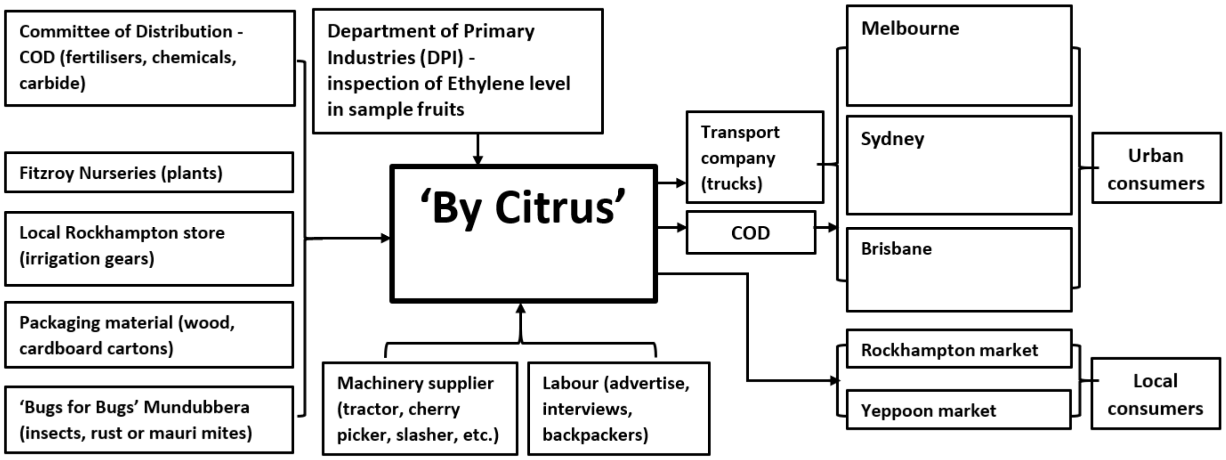


Figure 15: Supply Chain map of 'By Citrus' (Source: Own Sketch based on (Ahmad et al., 2018)

Key Issues

Infrastructure and farm technology

Improvements in the national road network and the availability of refrigerated transportation broadened the market for 'By Citrus' fruit. 'By Citrus' was proactive in adopting and developing relevant technology on-farm e.g., forklift, cherry picker, and adapting lures for fruit fly control, tree netting to limit bird damage, grading machine, and fungicidal treatment before grading. Many of these advances were innovative, in-house developed solutions, e.g., the forklift.

The accumulation of farm physical assets also brings with it the risk of loss and the need for continued cash flow to support maintenance. The high investment in netting structures increased the risk associated with cyclones. The Central Queensland region being cyclone prone, there is a risk that the netting structure may be damaged by cyclone increasing the risk of loss of bigger investments. Insurance schemes were considered but they were too costly.

Moreover, advances in road infrastructure and farm technology also led to an increase in the scale of operation possible for a given farm. Expansion at 'By Citrus' was limited in terms of availability of water and land, in contrast to the citrus growing areas in Central Burnett and later Emerald. The growth of alternative growing areas changed market dynamics: When 'By Citrus' planted 100 trees, the growers in the Burnett region would plant 10,000 trees. After 5-6 years of continual growth, the average price fell to $4-5 a carton of 9 kg imperial mandarins. Then 2PH[6] planted 180,000 plants in 2 years in Emerald. At one time 'By Citrus' had one or two hundred cartons in the Melbourne market while 2PH delivered 6 semi-trailers of fruits.

Generational Change

The rural to urban shift is a well-described global phenomenon (Meyerson et al., 2007). The next (fourth) generation of the Richter family moved away from the district and into non-farming careers. With water restrictions limiting the scale of operation, the profitability of citrus production has declined in the Byfield area, limiting the scope to attract an investor to maintain citrus production.

Markets for fruit

'By Citrus' enjoyed a period of high profitability when it was able to supply mandarins into a market short of supply, specifically Imperial and Emperor. The advent of Honey Murcott and Ellendale production in other growing districts removed this market niche later.

The central markets accepted first-grade fruits at a good price, but it was difficult to sell the second-grade fruit at a price above the cost of production. Second-grade fruit were sometimes dumped. So, the necessity of a processing facility was considered, which came into being with the establishment of the Koongal cannery[7]. Later, the cannery closed due to an imbalance in Southern and Central Queensland farmers' and industry peoples' interests and specific politics. The problem again is the loss of second-grade fruits due to the lack of a proper processing facility in local shires. This issue continues to the current day, with a contemporary attempt underway to develop a fruit processing plant in Yeppoon, focussed primarily on pineapple[8].

Forces of nature

Restrictions on water availability was a major contributor in the decline of the citrus enterprise. This decline was cemented by damage to infrastructure and trees by Cyclone Marcia 2015 (Davis,

[6] 2PH currently has 300,00 citrus trees on 550 acres (https://2ph.com.au/). The company was established in 2000. In June 2020 2PH was sold by the Pressler family to Costa P/L for $219 million (http://www.fruitnet.com/asiafruit/article/185591/costa-group-eyes-2ph-acquisition).

[7] https://trove.nla.gov.au/work/38971562?keyword=koongal%20cannery includes details on history, establishment and closing of cannery in Rockhampton.

[8] https://www.queenslandcountrylife.com.au/story/6536947/harvesting-a-win-from-yeppoon-pineapple-plant/ includes details on a new pineapple processing factory in Yeppoon.

2018). The cyclone damaged many of the central Queensland farms and properties around the Capricorn Coast.

Lucht Farm

Location

The Lucht citrus farm is a ~20 ha (~48 acres) production unit in Byfield, Queensland (Fig. 16), of which approximately 10-12 ha (~25-30 acres) is arable. The remaining land is too steep for cultivation.

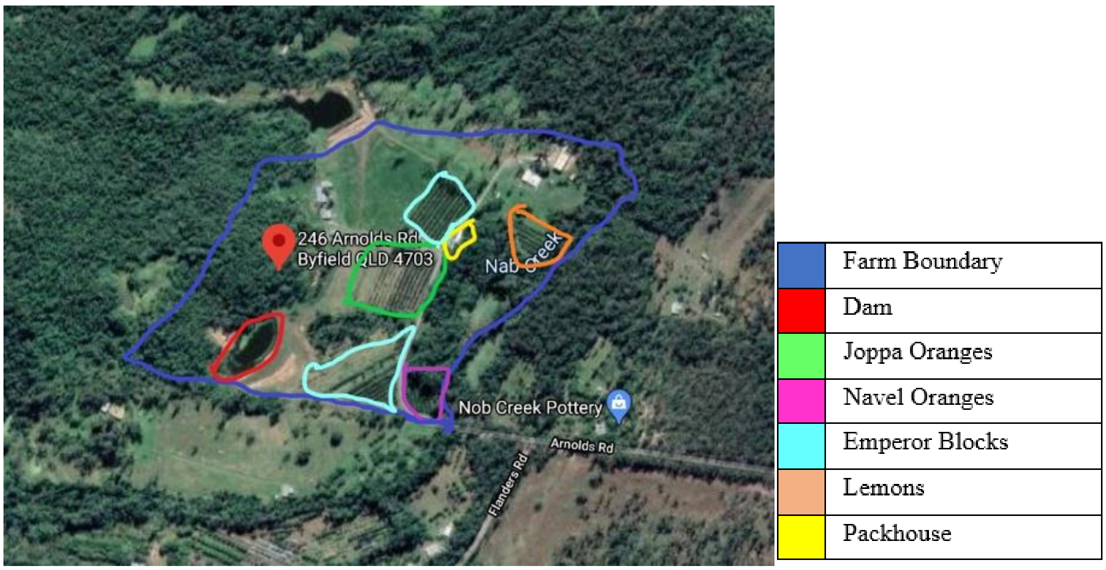


Figure 16: The farm boundary and components (Source: Google Map, 2021)

History of the farm

Lucht family and farm development

The Lucht family moved to the Byfield area in 1973. At that time, it was common for Byfield families to farm a hill block for banana or papaya and a creek flat block for Navel oranges or another citrus. Ted Arnold commenced citrus production around 1940 on the land now farmed by the Lucht family. Teds' son, John Arnold, who was born in Byfield in 1949 and went to the local school with Peter Richter (of 'By Citrus'), continued citrus production on this land. Claude Richter (Peter's father) bought the farm from the Arnold family in 1978.

The Lucht family bought the current farm block from Peter Richter in 1988. The farm consisted of four blocks. In 1999, one block was passed to each of three sons and the fourth block was held as a family trust block and kept as a bush block. Darren Lucht inherited land with 4000 citrus trees in 1999, the majority of which were Joppa oranges. The Joppa trees were removed in the 2000/01 season in favour of Navel oranges and Emperor mandarins and planting of 1000 trees occurred in the 2001/02 season. In 2015, cyclone Marcia destroyed almost 200 Emperor trees in the main paddock, which included most of the citrus trees planted before the Lucht family bought the property in 1988.

The farm currently has the majority of Emperor mandarins and Joppa oranges, Navel oranges, lemons, and grapefruit. One hundred emperor trees were planted in September 2002, and another 200 planted in August 2008, with an average annual production of 50 kg per tree.

Features of Value Chain

Nursery stock, losses, and current stock

As for 'By Citrus' and Woodvale or 'Mason', the main plant source for this farm has been 'Fitzroy Nurseries' in Rockhampton, Queensland (https://www.fitzroynurseries.com.au/). Plants were purchased in bare-rooted form.

Irrigation and fertilisation

Underground water and a dam provide water to the farm. Water extraction from the bore is not regulated, but the extractable rate is modest. The previous owners of the farm installed a dam and an irrigation ring main pipeline, in 1982. Following the purchase of the farm in 1988, income from pineapple crops was utilised to expand the capacity of the dam four-fold in 1993, creating a water body approximately 100 m by 50 m and 3-4 m deep. The dam is served by four drainage lines from the base of the mountain to the west, and there can be large overflows of the dam. An attempt has been made to raise the dam wall height modestly. Recognising the risk of water shortage in a dry year, an adjacent 20 ha block and its water resource has also been acquired in conjunction with a neighbour in 2017 to the south but the water is not used yet.

The irrigation system is based on a diesel-powered pump. The pump lacks a remote start option and requires refuelling through the night. Operation is therefore inconvenient given the distance from the house. A trial planting of avocadoes was installed in 1993. This was discontinued because of the need for more frequent irrigation, and the consequent labour requirement. Irrigation was discontinued on the citrus plantings in 2018. The system does not deliver sufficient pressure to the citrus planting adjacent to the house. The irrigation infrastructure remains in place, but an upgrade is required.

A block of 200 trees between the creek and the dam has been the most productive of the trees on the farm, likely due to higher water availability, flatter terrain, and location being used for vermin protection.

Fertigation based on fish emulsion fertiliser was adopted in 2005 following advice from agronomist Jeff Harvey from The Caves (a neighbouring suburb). Five litres of products were mixed with 200 litres of a mix of mineral fertilisers and introduced into the irrigation water stream. The trees could be seen to respond 'instantly' after the application, which was undertaken at the start of each month. The product cost was $40 for 20 litres at that time. In comparison, the fish emulsion product 'Charlie Carp' currently retails for around $100 for 20 litres, with recommended coverage of 2000 m^2 area (https://www.charliecarp.com.au/; doa 11/6/21).

Use of the fertigation system was continued until 2012, and partial use continued until 2018/19, ceasing when the supply of fish emulsion fertiliser (Fig. 17) was lost. The farm is currently neither irrigating nor fertigating.

Figure 17: Fish emulsion fertiliser tank (Photo: Dipendra Aryal, 2021)

Granulated nutrients have subsequently been used, being broadcast directly in-orchard. Heavy rain causing leaching of the applied fertiliser is recognised as a risk. However, it is felt that the citrus trees are responding well, with the largest crop the farm ever produced out of the main paddock achieved last year (2020 season).

Disease and pest management supplies

The main pests and diseases on the citrus crop are feral pigs, fruit piercing moth, citrus scale, and white louse scale. Fruit piercing moth is particularly attracted to Navel oranges, and losses of up to 100% of the cop are sustained. Alternaria ‘Brown spot’, citrus scale, and white louse scale (Fig. 18) were seen in the orchard, but the damage was not significant.

Figure 18: Left panel: Brown spot (Alternaria). Middle panel: Citrus scale in fruit. Right panel: White louse scale in citrus trees (Source: Dipendra Aryal, 2021)

A tractor-mounted spray system is used for chemical applications (Fig. 4). Previously, lime and sulphur spray were regularly used on the crop, and Supracide was sometimes used. Supracide is no longer registered for use on citrus from 2018 (https://myhealthbox.eu/en/supracide-400-emulsifiable-concentrate-insecticide/2214309; doa 11/6/21). Small amounts of copper spray are used, and other pesticides, such as dimethoate, are very sparsely used. Male fruit fly traps are used. The Navel orchard is maintained as a sacrificial crop (Fig. 19).

Figure 19: Navel block used as a sacrificial crop for fruit piercing moth (left), and Spray system, used as a tractor attachment (right) (Source: Dipendra Aryal, 2021)

The only interaction with the Department of Primary Industries (DPI)/ Department of Agriculture and Fisheries (DAF) was a farm inspection undertaken as part of the area-wide disease pest management during the 2004 citrus canker outbreak in Emerald (Gambley et al., 2009).

Yield estimation

The farmer estimates yield in terms of expected income, e.g., $50 a tree was achieved in the mid-2000s, while last year, $200 was achieved per tree. This income estimate involves a prediction of both fruit load and price, i.e., fruit production of 50 kg at $1.70 per kg equates to $85 per tree.

Harvesting

Fruits on lower branches are hand-picked from the ground while a ladder is used to access upper branches. Fruits are harvested using clippers. A forklift is used for the movement of field bins. Harvest of Navels typically begins in May. Emperor harvest begins the first week of June whereas, normally picking starts in the first week of May, which allows the sale of produce at the Mothers' Day market. Trees can be induced to flower early by bringing all interventions forward, including fertilising, watering, and pruning. Alternatively, harvest has been delayed to as late as November by irrigation and fertilisation and feeding plants to force a second flowering while allowing the first fruit to shed naturally in November. However, the timing of a second flowering risks exposure to rain events, resulting in flower loss and no crop. Also, a delay in harvest will result in a poor yield the following year.

Grading, packaging, degreening, and branding

A degreening facility was constructed (Fig. 20). Carbide was used to generate ethylene, with a hose supplying the gas into the room and a fan used for air circulation. One room could hold 12 bins at a time, i.e., around 5 tons of fruits. The facility was last used during the 'Fresh Care' accreditation of 2006.

Figure 20: Degreening and cold room (Photo: Dipendra Aryal, 2021) which was initially built to maintain a 10-15˚C temperature of bananas.

A washing and grading pack line, which was made in Adelaide Street in Brisbane having a telephone number only four digits long, was installed in the early 2000s. The pack line has not been used in the previous two seasons as fruits are packed directly into cartons in the field before transport to market.

The farm experience is that brushing on the pack line can improve the shininess of some varieties of citrus fruit, but on Emperor fruit, it causes irritation to the skin, with loss of shininess, while Navel oranges appear shiny without brushing. Brushing and cleaning are therefore not practised with these citrus fruits.

Labour management

Family labour is used for all activities, including harvest, packing, and marketing. The 12-week harvest window can exhaust the family resource. In peak harvest windows, top of canopy fruits, which require more time to harvest, may be left on the tree.

Marketing

Until the 1990s, the fruit was marketed both locally and to capital cities, through the Committee of Direction of Fruit Marketing (C.O.D.). Fruits have been sold into IGA since 1995, with fruit taken two to three times a week to Rockhampton and Yeppoon during the 12-week harvest window of Emperor mandarins. Fruits are now sold through farmers' markets in Yeppoon, Rockhampton, Proserpine, the IGA Dean Street, IGA Farm Street, The Barn in Yeppoon, and sometimes Emerald, through the Richardson Road IGA. In the harvest season, the order is collected on Monday morning from the IGA shops. Fruits are delivered to IGA stores in Yeppoon, Richardson Road, Dean Street, and The Barn in Yeppoon. The grower takes half a day off from business[9] on Friday to pick fruit for the Saturday markets and a Tuesday harvest was done for IGA. IGA in Farm Street accepts 1.4 tons supply of fruit per week.

The farmers market has a system of individual farmers having a stall (Fig. 21) to market their produce. Lucht believes that consumers are older Rockhampton residents who value the Emperor variety of mandarin for its flavour and freshness, despite its seediness. Lucht also believes customers recognise him and his friendly behaviour, and that the consumers also support the local market, even though the fruits are with similar prices to supermarkets. These consumers are regular through the season and repeat purchasers across seasons. Another consumer segment is 'value conscious', i.e., buying on price only. These customers do not recognise Emperor as a variety. Lucht believes that both groups of consumers do not comment about any marks or minor defects because their experience always had a quality fruit and taste inside, and as fruits are cheaper than in the supermarket, offering a bag (approximately 1/2 kg) of citrus for $5 and the stall operators become generous sometimes and add a few more pieces of fruit. The farmer also welcomes direct feedback on taste and appearance from consumers. Lucht's evaluation is that the farmers market has not changed much, and he is satisfied on how the market operates. He expects to operate the farm stall operates for the long term.

[9] The grower handles and manages another business in mowing equipment distribution and repairs; from where the total transactions last year was around 1.1 million dollars.

Figure 21: Byfield Emperor Mandarins Stall at Rockhampton Markets (Source: Dipendra Aryal, 2021)

A farming partnership with an agronomist/accountant neighbour with 300 citrus trees enabled documentation to gain 'Fresh Care' accreditation. This involved annual accreditation inspections requiring documentation of all inputs, including fertilisers and sprays, and detail of picking dates, and sale day. The accreditation was undertaken to allow the sale of fruit to Coles, however, Coles imposed additional requirements that prevented access. Coles required a larger volume of fruit, and the partnership was able to pledge 60-70 tons of fruit annually (30 tons from 300 trees from Lucht and fruit of an additional 30-40 tons from 400 trees of another farmer). After accepting Fresh Care certification, Coles required a suppliers' number, without a clear process explained, which was not mentioned before acquiring Fresh Care certification. This discouraged further activity.

The fruit was supplied to the IGA supermarket on Farm Street in Rockhampton from 2006 to 2010. The partnership was discontinued in 2011 and accreditation was left to lapse as farmers' market sales were going well without the need for accreditation. However, the fruit was accepted without accreditation by IGA in 2020 as there was a supply shortage in the Central Queensland region. The expectation is the same this year too.

The citrus varieties in production were selected to maintain a consistent production over the years. The mandarin variety, Emperor, was maintained as a market niche existed for this fruit as an ‘heirloom’ variety for the region with a dedicated customer base. Customer preference is based on the loose skin, juiciness, and strong flavour of this fruit, although the fruit has the relative attribute of seediness compared to the Imperial mandarin. To reinforce the niche marketing, customers are assured that the product they purchase at the market on that day was picked only the day before.

Boxes branded with the logo ‘Byfield Citrus’ were used when fruits were sent to capital city markets, but now second-hand boxes are used. When the fruits were not sold at the weekend markets, they were returned for storage in an airconditioned space in the past but now only fresh picking is done.

To gain insight into consumers purchasing local produce in a large retailer format, Barry Brookes, a pineapple farmer in Byfield region who direct markets to local Woolworths stores was interviewed (as citrus was out of season). Similar considerations would hold for Lucht citrus sales to IGA. The retailer uses Brooke’s pineapple in national promotions in the form of sales magazines and store posters, giving information about the farm. Produce is under the quality and assurance system ‘Fresh care’. Barry meets the store manager with every delivery, and runs in store tasting several times a year, receiving consumer feedback, and educating consumers about pineapple. The stock supplied to Rockhampton and Yeppoon stores is labelled as local produce, while produce can take one week to be transported to Brisbane and return to Rockhampton stores. There are return purchasers that buy fruit each week. Benefits to the store include flexibility in supply and fresher produce. Fruits are supplied each Monday and Thursday as a rule, but timing and volume can be adjusted on a day notice by the store. Stores also recognise that any produce issue will be dealt with promptly. The in-store demonstrations also allow the grower to define customer types by store, and target produce to those stores. For example, Allenstown shopping centre is characterised by professionals as customers, how prefer a smaller pineapple with crown on. Shopping Fair store is characterised by poorer families and pensioners, who prefer a larger pineapple without crown. Given the regular service, solid relationships have developed between grower and stores, with Woolworths supporting farm reconstruction after the 2019 fires, and managers sending get well cards when the farmer was in hospital recently.

Benefit to the grower is a much higher profit than sales through the market, to cannery (Golden Circle Cannery, Brisbane) or through the Tropical Pines in Yeppoon. For Brisbane markets, transport is Rocky's Own Transport. For example, for a pineapple retailed at $2 sent through the Woolworths distribution centre in Brisbane, $1 is the farm gate price, 40c is the cost of transport to Brisbane and back to Woolworths store, and 60c is the retailer margin. With direct sales to store from farm, farm gate return is increased to $1.60. The regular trips to Rockhampton are not 'wasted' in that they also serve in collecting farm input deliveries (equipment, chemicals).

'Sustainability' factors

All other Byfield citrus enterprises have closed, leaving this enterprise as the last significant producer. This has been enabled by the generation of off-farm income (running a small motor repair company, etc), sustained by a passion to grow to produce and to involve the next generation in production. Being a registered primary producer, and leasing motor vehicles, the farmer is also registered for taxation purposes.

Forces of nature

Cyclone Marcia caused significant damage to the orchard in February, 2015 (Born, 2015). Citrus trees were completely uprooted or blown over (Fig. 22). Surrounding trees above 4 meters in height were damaged severely. Approximately $60,000 worth of fruit was lost.

Figure 22: Darren and Heidi Lucht with their three sons (Michael – red shirt, Mason – blue shirt, and Lincoln – white shirt) on the farm after the Cyclone Marcia in 2015 (Source: Karin Calvert/Getty images®), and hail damage on citrus fruits (Photo: Dipendra Aryal, 2021)

Hail damage (Fig. 17) was another issue for the farm. This year there was a hailstorm when the fruit was small, with impact seen in the later stages of growth. Fruit internal quality is not impacted, but consumers' preferences change because of the outer look of the fruit (Fig. 23).

Figure 23: Mandarins in Rockhampton Market, May 2021 (Photo: Dipendra Aryal, 2021)

Periods of high temperatures are another issue, particularly for the variety Emperor which is susceptible to sunburn[10]. The risk period is from March or April onwards when citrus fruits reach a certain size and contain a certain acid or looseness in the skin and the days start reaching over 30^0C. Affected fruit are known locally as 'two o'clock fruit', in recognition of the time of day when fruits are most at risk.

The strong orange rind colour of Navels is impacted during the wet years, e.g., around 2006 or 2007. Fruits are a yellow, not orange, colour at harvest, leading to customer confusion about whether they are real oranges or not. The farmer had to convince the consumers to try the fruit. Therefore, the farm needed a degreening process to bring uniform colour in fruits.

Supply Chain Map

The supply chain actors described above are summarised in the following supply chain map (Fig. 24). In the previous generation (1970-90s), approximately 60-70% of production was transported to Brisbane through COD and the remaining volume was sold in local markets. Currently produce is sold through IGA and local market. Local markets on Saturday and Sunday; in Yeppoon and Rockhampton respectively, cover majority of consumption (estimated 60-70%) with the remaining volume goes through IGA.

[10] https://www.abc.net.au/news/rural/2015-03-23/sunburnt-citrus-dry-paddocks/6340682 reports sunburn in Mundubbera, Queensland.

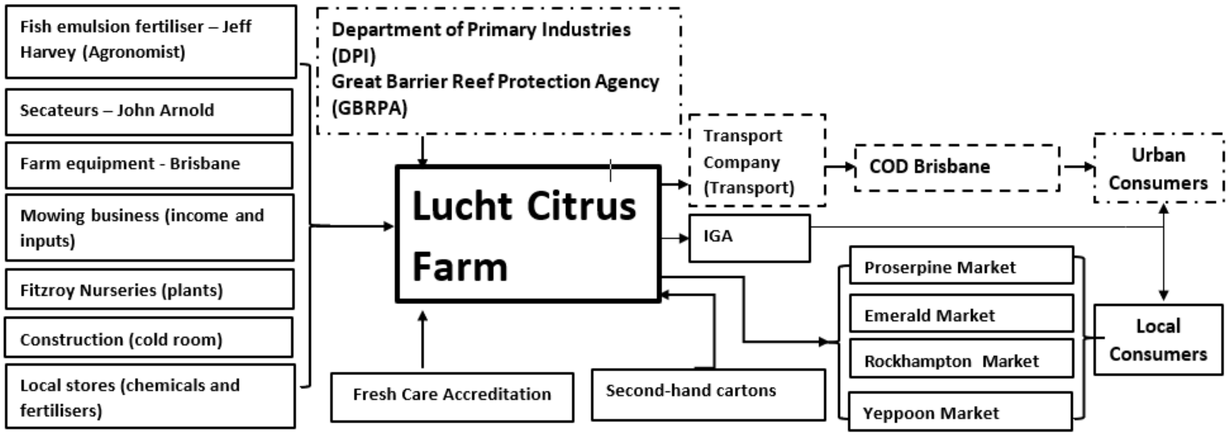


Figure 24: Supply Chain map of the Lucht citrus farm (Source: Own Sketch based on Ahmad et al. (2018))

Key Issues

Pruning, new plantings, and water infrastructure

Tree growth into the inter-row impeded access for the tractor and other vehicles (Fig. 25). Scheduling a major prune of every second row each year is being considered.

The trees of the main Emperor block planted in 2008 have been in their prime for four years now. With tree ageing and interest by the next Lucht generation, a new planting of Emperor mandarins is being considered, as is the planting of a passionfruit vineyard for diversification.

Figure 25: Impeded access in inter-rows (Source: Dipendra Aryal, 2021)

To support this expansion, irrigation infrastructure could be improved, e.g., with the installation of a solar-powered electric pump and potentially an uphill header/storage tank, which would need to be recommissioned.

Market Niche

The supply of local IGA shops is the key market for this farm. The Yeppoon and Rockhampton markets can be oversupplied with ‘backyard’ citrus, leading to depressed prices. A typical income per market day was $300 which was deemed to be not worthwhile by the farmer, but the farmer continued Yeppoon market sales last season because he was travelling to his auto-repair shop anyway and his son could be left to run the stall.

The farm has a low chemical usage in disease and pest control. If production increases, consideration should be given to progressing into eco-organic or organic certification schemes, if market advantage exists in pricing.

Forces of nature

There are several forces of nature impacting the farming profession in this region. Crop or weather insurance could hold value to support recovery from the forces of nature and losses related to those events.

Great Barrier reef Regulations

There have been several visits from representatives of the Great Barrier Reef Protection Agency (Authority, 2019), checking water quality and inputs to ensure operations comply with the reef protection legislation[11] (Gardner & Waschka, 2012). The fresh and marine water quality guidelines[12] are being reviewed recently as a stage 2 draft version is released to the public for suggestions with submission deadlines on 3 August 2021 (Source: Queensland Government, Department of Environment and Science).

Generational continuity

The next generation, especially the third and fourth children, Michael, and Mason, are becoming involved in the production, encouraged by the income the citrus fruits are making in a short 12-week marketing period. The interest of the new generation is a strong sign of sustainability. There is a belief that the citrus farm could provide a reasonable income for one family given if full-time labour input and diversification to include passionfruit and avocado crops.

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[11] https://www.legislation.qld.gov.au/view/pdf/bill.first/bill-2018-008 includes an Act to amend the Biodiscovery Act 2004, the Chemical Usage (Agricultural and Veterinary) Control Act 1988, the Environmental Protection Act 1994, the Fisheries Act 1994, the Nature Conservation Act 1992, and the Vegetation Management Act 1999 for particular purposes.

[12] https://environment.des.qld.gov.au/management/water/quality-guidelines provides the activity with water quality guidelines in Queensland.

‘Woodvale Park’ Farm

Location

The small-scale organic farm, ‘Woodvale Park’, is a farm of 10 ha (~25 acres) area on the Capricorn Coast, Queensland (Fig. 26).

Figure 26: ‘Woodvale Park’ farm 23°04'11.9"S 150°41'25.4"E (Source: Google Map, 2020)

History of the farm

The Woodvale Park owner came from a farming family, working as a teenager during the early 1990s on the parental conventional small cropping farm at ‘The Caves’ for approximately 10 years, producing vegetables and melons. He then ran a landscaping and mowing business in Rockhampton. The waste matter was disposed of at the parental farm, accidentally producing compost after a few years. The value of the compost was recognised in the vigorous growth of nearby pumpkins and melons.

Woodvale Park was purchased in the early 1990s, essentially as a hobby farm. Two experiences provided the impetus to embark on organic production. Conventional vegetable production was initially attempted but yields decreased over a few years of production. This decrease was attributed to the loss of soil structure and soil biology. During this period the farmer also had contact with individuals who displayed sensitivity to chemicals, and he became aware of a growing recognition of the potential toxicity of a range of plant protectant products (pesticides) used at that time in conventional farming systems. Conversely, the Department of Primary Industries (DPI) farm advisory services of the time stressed the adversities of organic production. The belief that organic farming would not provide enough production to sustain a living was also widely held by other local farmers.

A decision was made to convert to ‘biodynamic’ production, a more structured form of organic farming (Reganold, 1995). The transition from conventional to organic transition is recognised as a difficult period for both the farm and the farmer (Droogers & Bouma, 1996). Woodvale Park had a transition period without economic pressure as the farmer’s income was derived off-site. This grace period allowed time for experimentation. With the transition period covered and improving income, a decision was made to focus on certified organic citrus production.

During the early 2000s, citrus production involved 300 lemon and 200 mandarin trees, with an average production of 10 boxes per lemon tree (100 kg/tree, 30 tonnes total production) and five boxes per mandarin tree (50 kg/tree, 10 tonnes total production) in mandarin. Produce was sold through Sydney and Melbourne's wholesalers specialising in organic products, with good price premiums achieved over conventionally produced products. A price of up to $24 per box (9 kg) was achieved in this period, while conventional produce returned approximately one-third of that price. Profit was reinvested into increased plantings and labour-saving machinery (pickings aids, mulching equipment) and irrigation infrastructure, improving yields and farm efficiency.

Cyclone Marcia in 2015 impacted the farm severely, although initially only in terms of infrastructure (fences, roads) damage. Infrastructure recovery support was received through Government relief programs. However, the tree roots were damaged by tree movement during the cyclone, allowing Phytophthora infestation. Trees declined in health and production in the following years. In 2016, the decision was made to remove the trees. Given the increasing age of the grower, without children following into the business, and a long time from planting to production for citrus, replanting was not attempted, and a transition to vegetable production followed. By 2020, all produce was sold locally through informal (farmers’) markets. Although customers do not ask after certification status, Woodvale Park has maintained its certification status, despite the certification fees plus an additional cost of a one percent turnover levy. The compliance burden of organic certification is bigger as the record-keeping process is much higher for vegetables than citrus. With organic lemons attracting a high value in the current market there is an incentive to re-enter this market. However, the cost of re-establishing an orchard and the lag time to production has deterred the grower from this action.

The following sections describe features that made this system successful during the 2000s.

Features of Value Chain

Transport and market

Organic produce marketing was nascent in the 1990s, and those involved in it shared a camaraderie. 'Woodvale Park' produce was marketed through wholesalers dedicated to trading in organic products. This included "Back to Eden" (https://backtoeden.com.au/). This company is believed to have been the first organic wholesale business, operated by Lescott Joseph based at the Sydney market. Later, farm produce was also marketed through 'Fresh State' (https://www.freshstate.com.au/) operated by Peter Podolinsky, located at the Melbourne Market. Peter's father, Alex Podolinsky, established and registered biodynamics in Australia.

A camaraderie existed between small-scale organic producers, with growers uniting in a loose cooperative to improve production, marketing, and promotion. In the peak production period, cooperation existed with citrus growers as far away as the Burnett region particularly in terms of crop timing and marketing. The small-scale producers of the CQ coast would contribute to shared pallets for shipment. An effort was also made each year to follow the product from farm to market. This revealed the strengths and weaknesses of the postharvest pathway from the grower's self-analysis based on the learning and experience. For example, the trucking company used in the early years was found to be making long detours on the trip to Brisbane to make deliveries and pickups, with unloading and reloading of product. Lack of temperature control on non-refrigerated trucks was recognised as impacting product quality at the market. Time spent with marketing agents was also rewarded in terms of feedback on the relative importance of quality attributes to consumer demand. Feedback from marketers was also sought before entering a given market with a new product.

'Boom times' came during the mid-2000s when a 'detoxifying' diet based on the use of lemon juice gained popularity (Obert et al., 2017). This diet drove a higher demand and higher prices for lemons, particularly for organically produced lemons. These high market prices enticed other producers to begin organic citrus production. However, as there are 4-5 years between planting and production for citrus, Woodvale Park was provided with an extended period of high prices.

During periods of short supply, wholesalers urged shipment of 'any' produce. This short-term reward was avoided, realising that long-term brand damage could result. Currently, the farm utilises a niche of farmers' markets in Yeppoon and Rockhampton where a stall (Fig. 27)is set up every weekend and the products are sold by farmers themselves. As for Woodvale Park, there are a lot of organic products on offer alongside a series of citrus varieties (mandarin, limes, lemons).

Figure 27: Local Market stall of the Organic Farm at Rockhampton Markets (Source: Dipendra Aryal, 2021)

In recent years farm produce (citrus, lemon, limes, star fruit, broccoli, green vegetables, local honey has been marketed through the Rockhampton and Yeppoon markets, which occur weekly on Saturday and Sunday mornings, respectively. The market starts at 06:00 AM, with stall set-up around 05:00-05:30 AM. On the assessed day, approximately 60-70% of total visitors visited the Mason stall in Yeppoon market. Of these, approximately half bought products. Early market attendees were focussed on the organic status of the produce and were less price sensitive. Later attendees were less interested in the organic status and more focussed on price. Some consumers had been regular visitors for 20 years. Other customers had a connection to the farm through workshops offered there. In contrast, customers at the Rockhampton market were more price conscious than organic conscious.

Branding, certification, and traceability

Woodvale Park took advice from a professional marketer early in its' entry to organic citrus production. Organic (NASAA- https://nasaaorganic.org.au/) and Biodynamic certification were obtained, and a graphic was created as a brand and used on fruit cartons (Fig. 28). The first year represented a leap of faith, with a minimum purchase of 4000 printed cartons, enough for 40 tonnes of product, i.e., for several years of production at that time. This was a high cost for the farm during a 'start-up period'. However, the grower believes that the two investments of certification and labelling were critical to the success of 'Woodvale Park' citrus in the 2000s.

Figure 28: 'Woodvale Park' fruit packing cartons (Sourced from the farm, 2020)

'Woodvale Park' achieved NASAA certification in 1996. NASAA was adopted as this group offered a small farmer's cost-sharing scheme, with inspector travel costs shared between the 5-6 farmers on the Capricorn Coast also carrying NASAA certification, at that time. The biodynamic certification is also done by the same certifying body, with inspection and recommendation by the same inspector. Organic certification costs were only \$300 - \$400 per year in 1996 but had increased to around \$1500 per year in addition to a one percent commission on turnover in 2020.

During the period of peak production at 'Woodvale Park', there were twelve organic farms in the Central Queensland region. Currently, there are only three or four certified organic farms in Yeppoon, Bensons' Newby Organics being one of them. 'Woodvale Park' is on the verge of discontinuing organic certification because the farm is not sending the product to urban wholesale markets (e.g., Brisbane, Sydney, Melbourne) and the local market does not require official certification.

An additional levy of three cents per carton is imposed by the citrus growers' association (Australian Citrus), with raised funds matched by government subsidies to support research and promotion through the Rural Development Corporation scheme. This levy is collected on produce moving through central markets or from large retailers and is not collected on local market sales.

Nursery stock

Under organic certification, non-GMO planting material can be obtained from a conventional nursery (Bain & Selfa, 2017). Like the other two farms, the main plant source for 'Woodvale Park' is 'Fitzroy Nurseries' in Rockhampton (https://www.fitzroynurseries.com.au/).

In the later years, Woodvale park brought a few citrus lemon trees from a nursery on Sunshine Coast. Currently, the farm plans to plant 500-600 trees of different citrus varieties to sell fruits in the local market and diversify products throughout the season.

Input supply for Nutrient balance

In the 1990s there were few commercially available organic fertilisers. 'Woodvale Park' undertook compost preparation on-site, with a core input of cow manure from a Barmoya dairy mixed with green material collected on-farm using a forage harvester. Neighbour paddocks, roadside mowing, and lime were added to provide organic matter for compost. With repeated applications over years, soil organic carbon level is reported to have risen to 7-8% w/w and as high as 12%. Other factors to aid in this nutrient supply were legumes intercropping, pinto peanut grass, etc. Winter legumes like Woolly pod vetch dry out in summer and provide natural mulch to shade out weeds.

Approximately two tons of cow manure was used in the production of 20 tons of compost, per year. Other inputs included organic fertiliser (e.g., Blood & Bone, containing 8% N and 1.5% P, applied at approximately 1 ton per ha per year, Fig. 29), crusher dust from a local quarry, micronutrients from a local hardware store and organic pesticides. The farm has plans to buy rock phosphate in the future.

Figure 29: Left panel: 'Blood & Bone' fertiliser. Right panel: 'Bugs for Bugs' predatory mites to release in orchards (Source: Woodvale Park, 2019)

Disease/pest management

Without the use of plant protectant chemicals, an Integrated Pest Management (IPM) strategy is required. White scale was a major issue in the initial years of citrus production. Lime sulphur applications were initially used, achieving limited control. In 1990, approximately $900 was spent to acquire beneficial/predatory insects (useful bugs, mites, ladybird beetles, etc.) from 'Bugs for Bugs' (Mundubbera, Qld., https://bugsforbugs.com.au/, accessed 21/10/2020), and released in the orchard (Fig. 24). Further purchases and releases have been made, but the presence of a mixed groundcover is believed to have supported endemic populations of beneficial insects.

The fruit fly is a constant constraint for small-scale organic citrus fruit farms, with the thin-skinned mandarin cultivar 'Imperial' being particularly susceptible to fruit fly damage (Sutherst et al., 2000). Fruit fly infestation has led to the dumping of 'Woodvale Park' produce in the past. The Eureka lemon fruit was chosen for production as it has thick skin through which fruit flies are unable to oviposit (Sproul, 1976). Pheromone baits were also used routinely and effectively to minimise fly populations on the farm.

The physiological disorder of dryness in mandarin fruit, as described by Magwaza et al. (2013), was also a problem that differed in severity between years. No solution was identified for this disorder.

Irrigation and water

Woodvale Park citrus production was based on drip irrigation, with water drawn from bores. Between the early 2000s and 2020, Queensland faced two extended dry periods (Fig. 30) from 2001-2007, and 2012 onwards. Pumping by farms in the catchment is believed to have resulted in a drop in the water table level of approximately 20 m. As the irrigation pumps are not metered, there is no record of the quantity of water extracted.

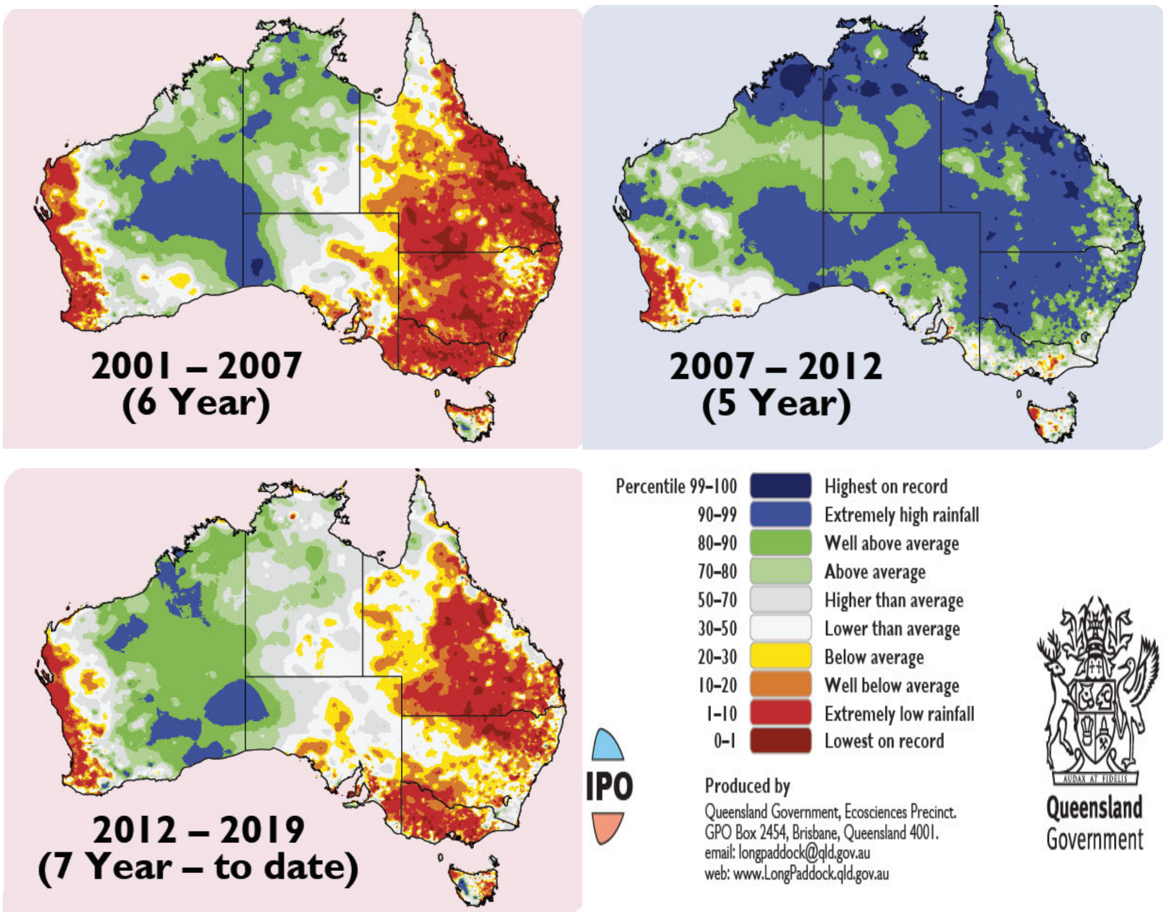

Figure 30: Queensland's extended wet and dry periods relative to historical periods (1889-2019); [Source: Queensland Government, Eco sciences Precinct (https://data.longpaddock.qld.gov.au/)]

Post-harvest technologies

A wooden diverging belt grader was initially used in fruit sizing, with visual grading for surface colour and blemishes. In 2010, a newer 'mechanical weight-tipping bucket' sizer [picture needed] was acquired to speed the grading process.

It was recognised that refrigerated transport would hold produce temperature but not lower it and that there was a risk of heat transfer in shared transport from produce loaded at ambient temperature. A cool store of around 20 m^3 volume, sufficient for storage of approximately 4000 kg or 4 pallets storage capacity was acquired in 2000, allowing produce to be cooled to a storage temperature of an average of 6-10 ˚C after harvest and before transport. Fruits typically require 24 hours to reach the set temperature once placed into the cold store.

Labour management

Casual and Willing Workers on Organic Farms (WWoOFers) provided harvest labour for Woodvale Park. WWoOFers are a labour source on many small-scale organic farms (Dufty et al., 2019), receiving board in exchange for work (usually 4 hours of labour per day with on-farm stay periods of 1-2 weeks on average according to Deville (2015). This ‘exchange’ is effective in a high labour cost scenario like Australia.

By the 2010s, however, WWoOFers were no longer primarily people with a background and/or interest in organic production but were better described as low-cost travellers. In the Woodvale Park experience, this group was not as dedicated and was harder to manage. Investments into labour-saving machinery followed. A cherry picker was purchased in the 2013-14 season. Using this, a single operator could harvest the entire farm. Other equipment followed, including a fruit sizer, tractors, and a forage harvester, all serving to reduce human labour requirements. However, even with mechanisation, as farm activity increases, more people are required (Commission, 2005). Further increase in tree plantings at Woodvale Park will bring the need to hire semi-skilled labour.

Labour saving technology

Woodvale Park made several investments to reduce labour requirements. A hydraulic picker (Fig. 31) and a grading unit were purchased by the farm, which were particularly effective in this respect.

Figure 31: A hydraulic picker at Woodvale Park (Source: Dipendra Aryal, 2019)

Market evolution

The supermarkets are a difficult customer for small-scale producers given their requirements (Fig. 32) for specific attributes (e.g., size limits and low tolerance of major and minor defect incidence) and their requirement for high volumes and consistency of supply. The entry of supermarkets into the organically certified produce market in Australia began in the 1970s, impacting the previously exclusive market of health food shops and home delivery businesses in urban centres (Lyons, 2007).

PRODUCT :	**CITRUS**
TYPE :	**Mandarin**
VARIETY :	**Loose**
GRADE :	**Organic**
GENERAL APPEARANCE CRITERIA	
COLOUR	*Uniform deep orange. Nil with > 2 sq cm .of light green tinge; limit of 10% of fruit affected.*
VISUAL APPEARANCE	*With bright bloom; Intact buttons, not torn or missing; segments easy to separate, 5% of dryness in consignment.*
SENSORY	*With smooth glossy skin, loose but not puffy, no foreign odours / tastes.*
SHAPE	*Round to slightly oval.*
SIZE	*40mm – 75mm.*
MATURITY	*Total soluble solids >8.5 Brix; with TSS to acids ratio >1:2; juice content >30 %.*
MAJOR DEFECTS	
INSECTS	*With Insects (e.g. mealy bugs), especially In navel or button, or >15 scales (red /brown spots).*
DISEASES	*With fungal or bacterial rots of the skin or flesh (e.g. Penkillium moulds, brown rot, soft rots).*
	With dark lesions on the fruit skin (e.g. Black spot, Septoria spot).
	With dark decay at the fruit core (Alterriaria).
PHYSICAL / PEST DAMAGE	*With cuts, holes, splits and cracks (that break through the orange outer layer and white pith layer through to the Juice sacs).*
TEMPERATURE INJURY	*With dark brown depressed lesions (chilling injury) or water-soaked flesh (freezing damage).*
	With pale, hard areas of skin (severe sunburn).
FOREIGN MATTER	*Nil foreign matter (e.g. glass, metal, hard plastic)*

Figure 32: Woolworths Produce Specification for Organic Citrus - Mandarin (Source: Woolworths, 2017)

Supply chain map

Features of the Woodvale Park supply chain described above are summarised into a supply chain diagram (Fig. 33). Key characteristics are the small scale and focus on organic citrus, particularly lemon. In the 2000s, approximately 40-50% of production went to Melbourne, Sydney, and Brisbane through transport companies with the remainder sold in local farmer markets. Currently all produce is sold through local farmer markets.

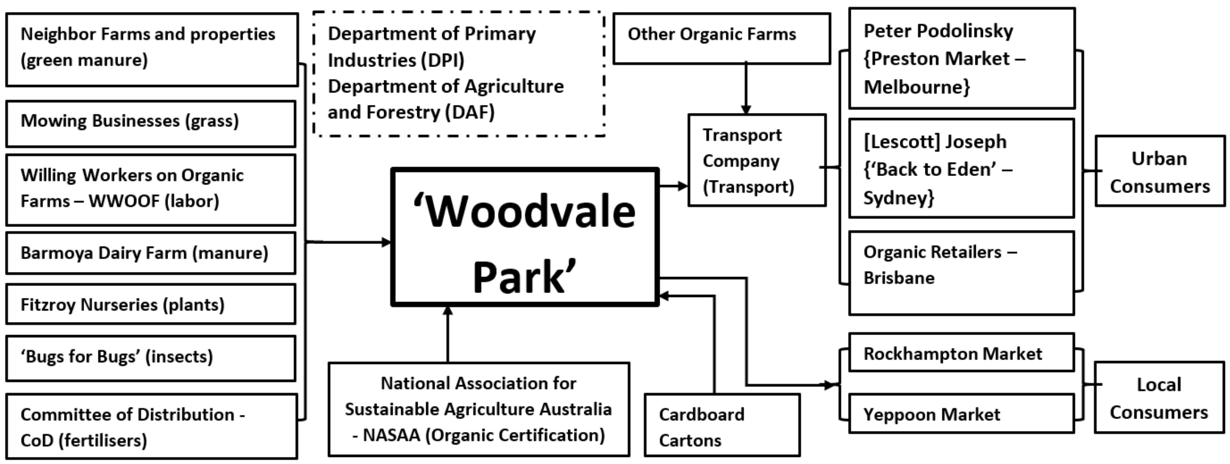

Figure 33: Value chain map of 'Woodvale Park' Citrus (Source: own sketch based on Ahmad et al. 2018)

Key Issues

Experience

Most production and marketing issues are multi-factor, and experience provides a knowledge base from which to judge new issues. The Woodvale Park farmer considers himself a better organic farmer than he was 20 years ago. Nutrient management was a primary issue at the beginning of the organic transition, while disease and pest management issues dominated later. With the DPI not offering advice in support of organic production, a key resource was the advice of the organic community.

Nutrient Balance

At a typical concentration of 1% w/w Nitrogen (N) and 1% w/w Phosphorus (P) in compost (Eghball, 2002), the use of 20 tonnes per year of compost equates to an input of approximately

200 kg N and 200 kg P annually. The input of one ton per hectare per annum of Blood and Bone across 5 ha will deliver 640 kg N and 75 kg P, for a total of 840 kg N and 275 kg P input per annum.

With citrus fruits containing 1% and 2 % w/fresh weight of N and P, respectively (Watson et al., 2002), approximately 300 kg N and 600 kg P were exported from the farm, annually. With inputs exceeding outputs, the farm was in an apparent net positive balance for nutrients. If leaching losses are low, reduced rates of inputs should be possible as soil fertility increases.

Market Niche

Success for Woodvale Park was tied to the servicing of a market niche that was rewarded with premium prices. This required a fit between the passion of the producer for organic production and the demand of the market, in this case for organically produced lemon. This fit was reinforced using organic and biodynamic certification, appropriate labelling of cartons, and the selection of marketers specialising in organic produce.

Organic certification

The global organic market is reported to grow in volume by around 20% every year (Aschemann et al., 2007), with reports of yearly increase of five billion US dollars (Sahota, 2009) and the COVID-19 pandemic is expected to increase this trend (Butler & Barrientos, 2020). A recent development saw the market grow significantly by 49% in the period of 2011-2017 (Luttikholt et al., 2019). Australia is a leader in organic farming in terms of area, production, and consumption (Aschemann et al., 2007). The evolution as a leading organic country is aided by isolation from cross-border pest and disease incursions (Bernzen & Braun, 2014), and the evolution of small-scale organic production zones and the development of market demand, niche markets associated with both small-scale production systems (Lockie et al., 2002), and also through large retailers who have introduced organic product lines (Willer & Lernoud, 2019).

Organic farming is intended to be a sustainable operation, although its scalability, i.e., its ability to 'feed the world' has been questioned, e.g., Vasilikiotis (2000). Herzfeld & Jongeneel (2012) consider that organic farming requires greater management and labour inputs than conventional farming. Documentation of successful and sustainable organic production-based value chains is therefore useful to inform the growth of this production system, however, several authors note that such documentation to be relatively scarce, e.g. Svotwa et al. (2009); Andersson et al. (2012).

Organic certification schemes in Australia began in the second half of the 1980s, with six schemes (see Table 2) still current (Gale et al., 2017). The National Association for Sustainable Agriculture Australia (NASAA) certification scheme began in 1986/87. The Biological Farmers of Australia (BFA) was established as a cooperative in 1987/88, began organic certification in 1992, changed its name to Australian Organic in 2012, and is currently the largest organic certifier in Australia.

Table 2. Organic and Biodynamic Certification Schemes and Standards in Australia

ORGANISATION	ESTD.	RELEVANT STANDARD
National Association for Sustainable Agriculture, Australia (NASAA)	1987	NASAA Organic & Biodynamic Standard 2016
Australian Organic	1988	Australian Certified Organic Standard (ACOS) 2016
Organic Food Chain	1997	National Standard for Organic and Biodynamic Produce
AUS-QUAL Pty Ltd.	1987	National Standard for Organic and Biodynamic Produce
Bio-Dynamic Research Institute	1957	Australian DEMETER Biodynamic Standard
Safe Food Production Queensland	2000	Safe Food Production Queensland Certified Organic

Source: Gale et al. (2017)

The use of the term ‘organic’ in the marketing of fresh produce does not require production under certification in Australia, as is required in some overseas countries, although Australian export of organic produce does require certification (Wynen & Fritz, 2007). The shift to a local market that accepts the informal claim of organic production has removed the need to maintain formal organic certification. In 2021, ‘Woodvale Park’ discontinued organic certification.

Disease and pest

Fruit fly can be a constraint for small-scale organic citrus production (Sutherst et al., 2000), with zero tolerance of presence in fruit in southern markets which are in the fruit fly free regions. Thick-skinned varieties of citrus with less potential of fruit fly infestation were selected by the farm, as suggested by Sproul (1976). This solution, however, impacts the production/market window.

The physiological disorder of dryness in mandarin fruit (Magwaza et al., 2013) was a significant issue in some years. The cause of this disorder remains unknown, and no remedy is available.

Transportation

Transport of produce to rewarding markets is often a limiting factor to small-holders (Kersting and Wollni (2012). The cooperation of growers to share transport, improvements in refrigeration and produce handling in transport, and improvements in the public road network have decreased the limitation which transport previously represented.

Resilience

Woodvale Park has faced three major challenges: (i) water supply in drought years, (ii) cyclone, and (iii) fire. The modest scale of production and heavy use of water-saving features such as mulch has mitigated water supply issues, although a drop in water table increases pumping costs.

Cyclone Marica was a category five cyclone that crossed the Queensland coast at Byfield and proceeded on a southwest path, taking its eye within 10 km of Woodvale Park in 2015. The cyclone impacted Central Queensland's farming sector in multiple ways, as reported by Davis (2018). The cyclone was a turning point for the citrus enterprise at 'Woodvale Park'. In hindsight, the grower believes he should have removed the existing citrus planting and replanted, rather than trying to rejuvenate the trees. New varieties of citrus could have been planted, chosen to meet future market demand. However, given the time required to establish a new orchard and the increasing age of the farmer, without a following generation on the farm, the decision was taken not to replant.

The Woodvale area was a declared natural disaster area following fires in 2019[13]. Increasing groundcover density in small holder blocks in the area created high fuel loads which sustained widespread fires and significant damage to property and other orchards in the area. Woodvale Park managed the fire with good firebreaks (Fig. 34) and unplanned success. The farm manages a firebreak on every side of the farm before the bushfire season under the permission of the local fire and emergency office.

[13] https://www.daf.qld.gov.au/business-priorities/agriculture/disaster-recovery/natural-disaster/activated-areas includes areas around Woodvale Park, Livingstone Shire Council impacted by bushfires in 2019.

Figure 34: Farmer creating a fire break with controlled fire (Source: Woodvale Park, 2019)

For the overall development and sustainability of the small-scale organic citrus value chain, certain aspects need improvement. The suggestions for the overall development of small-scale organic citrus production systems could be articulated in a few bullet points below. However, these improvements could vary in different locations or scenarios, the applicability of suggested interventions could be generalised in most of the small-scale organic citrus value chains.

3.4 Conclusion

Learnings

Value chains are not static, but rather evolve with time. The Richters of 'By Citrus' were progressive conventional farmers, adopting and adapting technology as it became available. Their ambition to be the largest citrus producer in the district was achieved by the late 1980s, with 'By Citrus' a well-recognised brand enjoying market success. The importance of market pricing and timing is illustrated by the success enjoyed by 'By Citrus' in the 1980s when prices rose sharply following the exit of other small growers, but before the entry of the large growers of Central Burnett and Emerald. A similar story was told of the Yeppoon pineapple industry, with the Atkinsons increasing planting even as many small growers left the industry. After some years, the demand for pineapple rose, driving prices higher from the remaining producers.

However, production limitations, in terms of land and water availability, decreased 'By Citrus' competitiveness relative to emerging production areas. At this point, the operation could have shifted to target a niche market, if such a target could be identified. Alternatively, the Byfield site could have been sold and citrus production resumed on a larger scale in the developing Gayndah-Mundubbera or Emerald areas. The latter strategy would have involved scaling up from 4,000 trees to 20,000 trees, requiring debt financing.

For 'Woodvale Park', an early dedication to organic production led to the development of a successful niche market through the 2000s. An increase in organic production elsewhere eroded the market price, leaving the operation vulnerable to shocks such as drought periods and cyclones. However, for Lucht, there was a significant amount of off-farm income coming from another business, which assisted the owners to maintain the citrus farm as a hobby farm – where he developed his passion from his early childhood. The attempt to maintain the farm's heirloom variety, Emperor, is also commendable.

The common themes for all three producers were (i) realizing a rewarding market niche; (ii) water supply; (iii) cyclone recovery; (iv) generational continuity.

Areas for improvement

Topics for consideration to improve the sustainability of small-scale citrus value chain are:

- Branding to create excitement and curiosity among the consumers.
- A range of new niche products, e.g., ginger, turmeric as intercrops, and other small fruit crops and the potential for sale of compost as an additional product from Woodvale Park.
- Diversification to different citrus commodities (Nawaz et al., 2012) to widen the production window and address different market niches.
- Crop and weather insurance could be considered. A horticultural insurance scheme is recommended as appropriate for both family-owned and corporate orchards, regardless of size (Hatt et al., 2012b). Fruiting tree crops on the tree can be insured for fire, hail, frost, and windstorm, with most policies including a variety of additional benefits including replanting and reestablishment costs, firefighting and mitigation expenses, removal of debris, and loss orchard infrastructure. Alternatively, insurance can be taken against a particular weather event occurring, rather than the damage caused by an event. (Hatt et al., 2012b) summarises the common insurance options available in Australia as:
    A. Traditional Insurance Products
        - Named Peril – frost, hail, fire damage cover
    B. Index-based Insurance Products
        - Weather derivatives, e.g., CelsiusPro

- Yield index insurance, e.g., YieldShield

Of these issues, that of insurance options will be explored in a critical case study.

4.0 Descriptive Case Study of Export Orientated Citrus Production in Southern Queensland

Abstract

A descriptive case study of large-scale, export orientated citrus production in the Wallaville region of Queensland, Australia area is presented. The methodology employed was a case study research using semi-structured interview with staff from farm, packhouse, labour supply company and quality control. Production in this location was based on access to water and reasonably priced land. The current operators are diversified in production across different fruits or commodities and even different varieties among those fruits vertically through the value chain. About half of the crop is exported and half is marketed domestically. Key constraints identified included labour shortage, water restrictions for irrigation, disease and pest control, estimation of harvest timing and yield and market price volatility.

4.1 Introduction

Australian citrus covers 28,000 ha land involving 1900 growers in the production of 715,000 tons of fruit and has increased by 25% compared to 2014 (CitrusAustralia, 2020). Australian production is centred on the Murray valley (21%), Queensland (20%), Riverina (30%), Riverland (20%) and others (4%), covering 5,714 ha, 5,703 ha, 8,510 ha, 5,518 ha and 1,014 ha respectively (https://citrusaustralia.com.au/growers-industry). Production in the Murray valley is 65% Navel, 24 % mandarins, 6% Valencia and common types and 4% lemon and limes. Riverina production is 50% Valencia and common orange types, 42% navel, 5% mandarin and 2% lemon and lime fruits. Riverland production is 50% Navels, 26% mandarin, 18% Valencia and common types, 5% lemon and limes and 1% others. In comparison, in Queensland production is 72% mandarin, 24% lemon and lime, 2% Navel and 2% others. In total, approximately 535,000 MT of orange and 175,000 MT of mandarin/tangerine are produced (Flake, 2019).

Approximately 40, 37 and 23% of the orange fruit produced in Australia are processed, exported and consumed domestically, respectively (Flake, 2019). Of mandarins, 50% are consumed domestically and 50% are exported, primarily to China, Thailand, Vietnam and Indonesia. Overall, approximately one third of citrus production is consumed in domestic markets, mainly through the supermarket chains. Around 20,000 MT of oranges are imported from USA and Egypt are imported to support domestic fresh fruit consumption in summer months (Flake, 2019).

The typical citrus value chain involves engages major value chain actors and are networked to numerous other actors as supportive cast to improve the value of the product. Production and marketing constraints evolve continuously, and the strength of a value chain network is manifest in its ability to adapt to such change, typically supported by technological advances. To realise the effective value of technological advances, Badar (2014) pointed the importance of collaboration among the value chain actors. In general, the distant market value network will be complex. Australian export strategies keep evolving in concert with global phytosanitary and food quality standards. Export of Australian citrus to China is permitted under a phytosanitary agreement between the Australian Government and the People's Republic of China.

4.2 Methods

A semi-structured interview was conducted with the farm manager and packhouse manager from two export oriented citrus industries, and a labour supply contracting firm manager. The interview was based on a pre-defined question set, adjusting questions according to the scenario and narration by the interviewee.

The current exercise profiles two large-scale citrus farms with approximately 326 ha of cultivation area in Wallaville, Queensland (Fig. 35).

Figure 35: Location of the farms in Queensland (top left), The Australian Tree Crop Map (ATCM) of citrus cultivation in selected farms (top right and bottom) Top panel: Spencer Ranch (265 ha). Bottom panel: Abbotsleigh Citrus (170 ha). Source: Google Map, 2021 and ATCM viewer, 2021.

4.3 Farm Description

'Spencer Ranch'

Ian and Pam McLennan[14] purchased land in use for small crops and cane production in 1978, and began an annual increase of citrus plantings, reaching 85 ha in 1988/89 when the property was sold to Craig Spencer, of the 'Carter and Spencer' marketing group. 'Spencer Ranch' (https://www.carter-spencer.com.au/spencer-ranch) expanded in the following year with purchases of two neighbouring farms were purchased. With additional plantings, the farm now has a total of 265 hectares and 62,500 citrus trees.

Citrus harvest from the Byfield region is effectively the first fruit on market each season, but the volume of production from this area is trivial. Production from the Wallaville area begins earlier than that of Mundubbera and Gayndah. However, a range of growing techniques including use of growth regulators has allowed the production window to be stretched, such that the effective harvest time difference between Wallaville and Mundubbera is now only one week. Similar techniques could be used at Spencer Ranch to bring harvest forward, but a decision was made to avoid such practices as they can negatively impact fruit quality.

14 https://www.facebook.com/thepricklypineapplewhitsunday/photos/a.231797487016897/1396787353851232/?type=3 mentions the owners of 'Early Bird Citrus' in Wallaville (Gin Gin) as Ian and Pam.

A few varieties are grown to extend the harvest window. Additional crops have been considered, but avocado and mango yield was variable on a biannual or tri-annual basis in this region. Continued consideration is given to other crops, such as macadamia and pomegranate, but to date, the management decision is that citrus provides the best fit for profitability, with economy of scale in growing and packing.

'Carter and Spencer' has been a fruit wholesaling and exporting company in Australia for approximately 85 years. The driver for Craig Spencer in entering citrus production is the philosophy that people increasingly want to know the history of their food. This trend is further advanced in Europe and USA.

Value Chain Features

Multiple varieties and diversification

The production of a range of citrus commodities, e.g., lemons, limes, mandarins, and oranges, and varieties of those commodities, enables an extended harvest window, improving farm and packhouse infrastructure use. In each year, mandarin production begins with the Fremont variety and continues to Imperial Mandarin, then Ivanna Mandarin and ends with Honey Murcott in June, providing a harvesting and packing window of six months per year. This window is extended to 11 months per year by production of other citrus commodities. For example, lime harvest begins in April/May and continues until November, orange harvest begins mid-April and, inclusive of Washington navels and Valencia, continues until October, while lemon harvest also continues until October. The month of October is the month of maintenance, for farm infrastructure such as infrastructure and for pruning and for the packhouse and cool rooms.

Consideration was given to establishment of tourist cabins along the riverbank for use in farm stay or work experience programs. Favourable factors included ease of access, being on the Bruce Highway, and feedback from surveys run at city markets indicating purchasers of fruit from the farm were interested in such an experience. However, the process of approvals was daunting, and the experiences of the Koorana Crocodile farm which attempted a similar activity led to a decision not to proceed with this venture.

Labour

Labour is hired directly by the farm, with organisation by a Childers firm that supplies accommodation and transport to farm from Childers. Labour management is regarded as the largest management issue, evident at multiple levels through the business, including field, packhouse, administrative and managerial levels. With high cost of labour, the farm runs a team in which every person has a defined non-redundant role. Backpacker labour can be unreliable in that staff may quit anytime, even simply not turn up, without notification. The average term of employment of staff is 15-18 months. A similar issue is believed to pertain at retail level also. Training of staff can take months, so continual introduction of new staff is a major challenge.

Labour costs has risen steeply in recent decades and award conditions have tightened. For example, the Horticultural Award, effective as of 1 July 2021, awards a base rate of $20.33 an hour plus on costs, with casual workers now also entitled to overtime after 12 hours work in a day or after 7 pm[15].

Since COVID-19 began, backpacker numbers have been decreasing as people returned to their home countries, without replacement.

Water and fertiliser

The 1978 farm established underground asbestos pipelines. A ten-year plan executed in 2016 continues a program of addition of water sources and extension and replacement of irrigation lines. Soil moisture probes are used to inform irrigation scheduling.

Water is sourced from the Paradise Dam through the Burnett River. Previously there was a set volume allocation, but now there is a base water allocation based on farm area and a market to purchase further water, if available. The lowering of the Paradise Dam wall in 2019 and consequent reduction in water storage from 300 to 170 GL is a major issue for farm expansion and indeed viability of the farm in dry years. Further citrus plantings planned for 2020 were cancelled. A class action (http://www.marlandlaw.com.au/paradise-dam-class-action/ doa 31/7/21; https://paradisedamclassaction.com.au/; doa 31/7/21) has been brought against the state government on the basis that allocations were sold on assumption of water availability.

The cost of electricity has increased 174 % in the last three years, with impact to cost of water pumping and packhouse operations. On farm solar electrical generation is being expanded.

A different approach is taken for fertilisation to traditional citrus practice. Rather than quarterly or monthly application, fertigation occurs fortnightly and sometimes weekly depending on the time of the year and tree demands, with the aim only the current requirement of the tree. Fertiliser is

[15] https://www.fairwork.gov.au/employee-entitlements/hours-of-work-breaks-and-rosters/hours-of-work/when-overtime-applies#2169-2185 provides details of ordinary working hours as 7 am – 7 pm and casual employees are subject to overtime if they work more than 12 hours a day or more than 304 ordinary hours in an 8 week period.

now primarily sourced from European producers. Cheaper product from China was found to be inconsistent across 10 years. In one case, analyses on potassium content gave 23 and 14 % w/w for samples taken from adjacent pallets. The increasing expense of fertilisers has driven more effective use of fertilisers. This has been one of the easiest cost reduction measures to implement.

Disease and pests

Specific staff undertake weekly crop monitoring following transects on the perimeter of the farm as well as through the orchard. As fruits begin to mature, fruit fly bait is placed each week. If pressure is high, yeast extract with insecticide is sprayed onto trees. Fruit piercing moth was a massive problem across quite a few regions last year, with similar damage done mandarin and orange varieties. The prediction of pest movement is seen as critical and the farm has enjoyed success spraying blocks which could have been affected from moth entering from neighbouring farms, as detected in the monitoring program.

Accreditation documentation

Documentation associated with quality assurance for both domestic and export markets began to increase from the 1990s. At one stage the farm was keeping six sets of documentation to satisfy the requirements of six marketing channels. A single document was created combining requirements of all markets, from Fresh Care accreditation to export market pest inspections.

Fruit fly chemical treatment records are audited to enable marketing into South Australia and Western Australia. There must be absolute certainty on alignment of batch numbers to chemical treatments, with phytosanitary certificate and transport documentation. Any mishap would result in a verification suspension and likely economic losses.

In orchard phytosanitary inspections occur monthly irrespective of whether the fruit is ultimately marketed domestically or exported as it is not certain what market the crop is intended for until harvest. As export markets can differ in inspection requirements, e.g., The Philippines and Vietnam requirements differ to those for Thailand or China, the monitoring and inspection program covers notifiable pests of all markets (Spreen et al., 2020).

The export season runs from June to October. Usually, 150 bins per day are processed, with five shipping containers packed over a 48-to-72-hour period. Once a container group is ready, the quality assurance team on farm/packhouse will randomly choose and cut six hundred pieces of fruit for inspection. If clear of infestation, the inspected fruit lot are isolated and stored, with the shipping containers locked and tagged ready for shipping/export. If there is infestation, the lot is rejected and is shipped back or dumped whichever is relevant in case-by-case basis.

More recently, the *Environmental Protection Regulation 2019*[16] requires documentation and justification of fertiliser purchases and amount in Queensland. An audit of an area occurs approximately every six months, e.g., on chemical usage, water usage, phytosanitary inspection. Many farms assign a person to organise records just before audit, but the approach adopted at this farm is to continually manage records, such that no additional preparation is required for audit.

Yield estimation and harvest

Production is maintained across ten months of the year, but production volume varies across the harvest period, reflecting tree size, flower initiation, pollination, etc. Fruit load estimation prior to harvest is important for harvest resourcing and marketing. Frame counts are used, with manual count of the number of fruits in a cubic meter of canopy. Several frame counts are made per block and averaged. This number is then multiplied by an estimate of canopy volume, taken as canopy height by width by length. The work is done by a manager with experience of the technique (in this case, 21-year experience).

Harvest timing is informed by monitoring of fruit juice Brix levels, with harvest occurring when a minimum Brix specification is achieved. Multiple fruit are sampled from each block. Titratable acidity is checked on some juice samples, using titration or by conductivity tests. Fruit external colour is assessed by eye. If fruit are externally green when at harvest maturity, a decision must be made whether to delay harvest to allow colour development or to harvest and degreen the fruit.

Records kept of previous harvests by the previous manager and by the previous owner also inform the decision to pick. Generally, harvest timing estimates are accurate plus or minus one week.

Postharvest

Fruit brought from the orchard in field bins are unloaded into a water tank. From here fruit are automatically processed. Fruits are washed several times, with a first wash using chlorinated water followed by washes of fresh water and a fungicide treatment. A waxing process follows. All current markets allow use of wax where fungicide is used.

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[16] https://www.legislation.qld.gov.au/view/html/inforce/current/act-1994-062#sec.80 includes details on how to manage nutrients in the farm and what to record.

A colour camera system is employed on the pack line, with fruit rolled during passage through the field of view of the camera to enable inspection of the whole surface of each fruit. A machine vision system trained to identify and detect external defects is used in sorting of fruit. Human inspectors view fruit after the automated sorting. Staff are kept aware of fruit defect issues, with training referring to a citrus defect poster placed in the staff room. Defects of concern include rots and moulds, physical damage, dark blemishes, water damage, insect damage, malformed fruit, bleaching, superficial physical damage, and presence of scale.

Fruits are also sorted using a weight grading system. A brand sticker is automatically applied to individual fruit. Fruits are packed into cardboard cartons and stacked onto the pallets, then plastic wrapped before loading to containers or trucks. Pallets may be held in a cold room for storage before transport. The export consignment undergoes cold treatment and disinfestation before they leave the port and mostly done during transit or freight ships.

Insurance

The farm has a budget for self-insurance, with funds aggregated to a separate account to cover losses ranging from vehicle accidents to pack house fire and crop losses. Insurance is purchased for pumps and physical buildings, but not for any mobile asset.

Markets

A bad experience with fruit by a consumer will result in loss of future custom, with a long period before the consumer will try the fruit again. This marketing experience informs a focus on consumer experience linked to the brand, to support repeat purchases. The use of multiple varieties, giving production over nine months of the year also supports brand recognition.

The farm supplies Coles, Woolworths, Aldi, and Costco, domestically, and Costco, China, and a Thailand group, internationally. Fruits are exported through the KCTT (Korea, China, Thailand and Taiwan) protocol, in which the same requirements are used for all four export destinations. The farm has also adopted the same protocols for fruit destined for the domestic market except for cold treatment disinfection. This operational consistency avoids confusion between consignment treatments in daily operation, e.g., between consignments destined for Costco, Sydney or Costco, China. For example, a 600 fruit per batch insect and pest inspection is applied to all consignments.

For export consignments, fruit batches that pass inspection go into refrigerated storage and/or transport to an approved container loading facility in Brisbane. All pallets are clearly marked with product and market detail, with linked documentation the history of the produce. Fruits are transported in a temperature-maintained trucks and shipping containers from packhouses to the transit point and during the export shipping. The process generally takes between 1-2 days from packhouse to export point, and a few days (air freight) to weeks (by ship) time to reach the destination market. Air freight is used for fruits which undergo fumigation or any other rapid disinfestation processes. Cold treatment disinfestation is carried out in-transit while travelling by sea, e.g., 3^{o}C for 16 days for lemons exported from Australia to China. Fruits are inspected again at the destination market before dispatch to warehouses and distribution centres and finally to the retail markets and consumers. The fruit should retain a shelf life of 2-3 weeks at time of purchase.

Supply Chain Map

Features of Spencer Ranch supply chain described above are summarised into a supply chain diagram (Fig. 36). Key features include supply of supermarket chains and export markets. All production is transported to Brisbane, with approximately 40 - 50% then exported, 45-50% sold directly to large retailers and 5-10 % sold to the Brisbane markets or local markets.

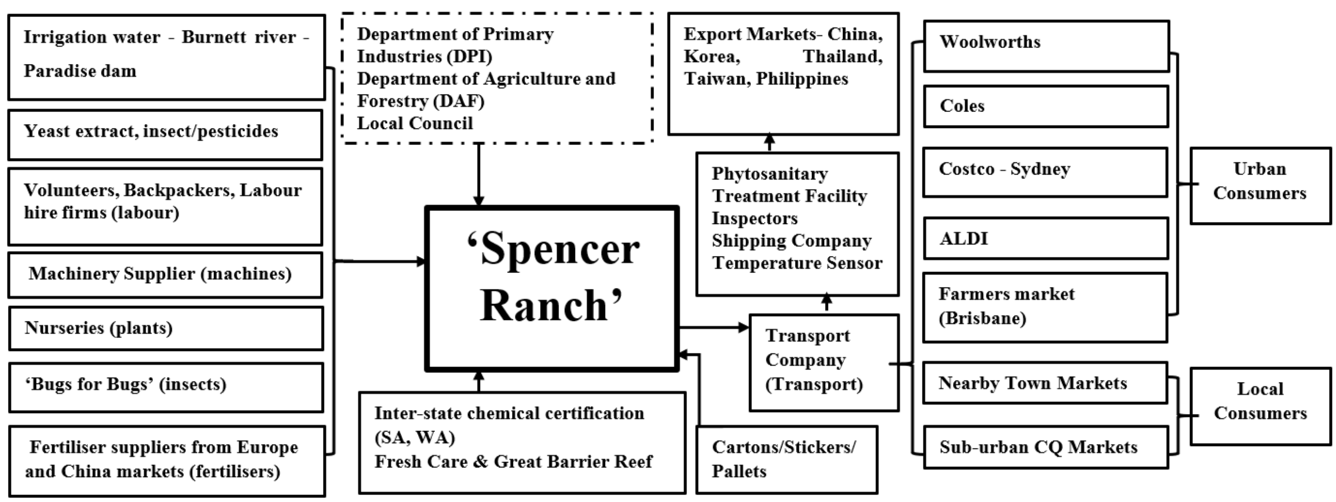

Figure 36: Supply chain map of 'Spencer Ranch' (Source: own sketch based on Ahmad et al., (2018))

'Abbotsleigh Citrus'

History of the farm

Abbotsleigh Citrus (https://www.abbotsleigh.com.au/) is a producer of citrus fruits located in Wallaville with about 60,000 trees of citrus planted over 170 ha. The farm has been co-owned and managed by the Campbell and McMahon families since 2003. In 2014, a strategic partnership[17] was formed with Seven Fields (http://www.sevenfields.com.au/), a like-minded grower and packer in premium Australian citrus and mangoes. With involvement of the same family members, common goals were shared between the two businesses. A focus was given to sustainable production, including use of organic fertiliser (compost) produced on the farm. In 2001, 20 ha was planted to blueberry for product diversification. The Abbotsleigh Citrus business was acquired[18] by the Nutrano Produce Group Ltd. (https://nutrano.com.au/) in 2016.

Value Chain Features

Labour

The farm requires a low number of permanent staff for the whole year, and a larger number during the peak season of harvest and packaging. This extra staffing is a mixture of backpackers, seasonal labourers and 'holidaymakers'. Staff can be sourced from several labour supply companies.

Agronomy

Drip irrigation has been installed for water use efficiency. Precise application of water and fertiliser through fertigation is claimed as a major contributor to higher fruit yield and lower inputs compared to surface irrigation and traditional fertilization in citrus. Training and pruning are undertaken each year after harvest.

Disease and pests

The farm has bio-security protocols aimed at restricting diseases and pest spread. Farm visitors are not permitted to use their own vehicles on farm. Currently the major pests of concern are fruit fly and gall wasp (Fig. 4). Queensland Fruit Fly (*Bactrocera tryoni*) and Mediterranean Fruit Fly (*Ceratitis capitata*) are phytosanitary pests listed in export protocols with many countries. Pest management is focussed to biological methods, with chemicals used only if the pest populations exceed a threshold level. For example, predatory mites from 'Bugs for Bugs' (Fig. 37) are used for control of leaf mites and other pests. Agricultural mineral oil (AMO), a petroleum oil derivative, is used as a spray, acting as a suffocating or behaviour altercation agent. Pests are not known to develop resistance and the chemical compound is broken down within weeks. A higher volume application is better than application of a higher oil concentration.

[17] http://www.sevenfields.com.au/media/16125/2015%20company%20profile.pdf provides detail about the two companies Abbotsleigh Citrus and Seven Fields.

[18] https://www.abbotsleigh.com.au/ mentions acquisition of Abbotsleigh Citrus by Nutrano Produce Group Ltd.

Figure 37: Left panel: Eggs of citrus gall wasp. Right panel: Predatory mites used for pest management from 'Bugs for Bugs' (Source: Dipendra Aryal, 2019)

Postharvest

Ethylene is used for skin degreening of physiologically mature fruits. The degreening rooms feature movable curtains, adjustable to the number of field bins, and fans for gas circulation (Fig. 38). If colour is acceptable, bins are unloaded into a water bath and pass human inspection for obvious defects or foreign objects before singulation to a cup conveyor. Fruit pass through a washing, drying and treatment tunnel. An antifungal chemical 'Citrus Wash' (Fig. 5) is added to the water wash.

Figure 38: Top left: De-greening room; Top right: citrus wash stock; Bottom left: unloading of field bins; Bottom right: singulation of fruit to six lanes for colour and weight sorting. (Source: Dipendra Aryal, 2019)

Fruit then passes an optical sorter (Spectrim, Compac, Auckland, New Zealand), with fruit rolled in passing the cameras to enable view of all sides of the fruit (Fig. 39). Approximately 200 images are acquired per second. Red, green, and blue (RGB) and far-red images are acquired, the far-red image improving detection of bruises. In addition to simple colour grading, the machine vision system can be trained to recognise skin defects, with automatic grading to a user set specification on defect level. This system requires a trained operator to monitor performance and retrain the system as needed, however overall, the technology has resulted in a large saving on human labour for fruit inspection, and results in a more consistent product.

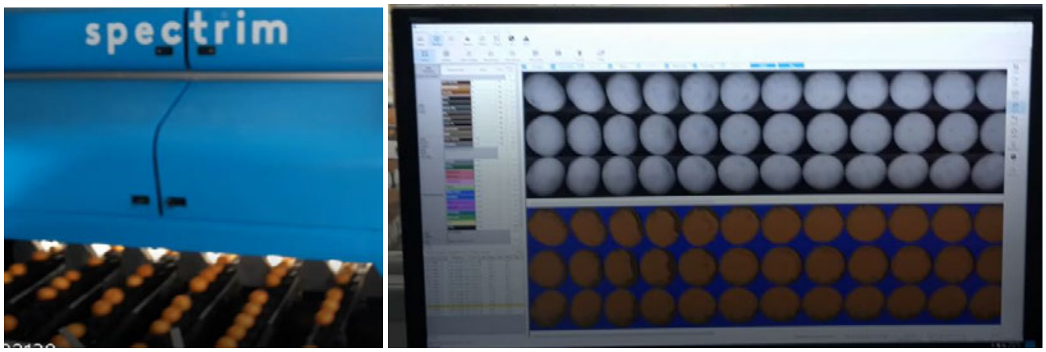

Figure 39: Left panel: singulated fruit passing into the camera box for optical sorting; Right panel: user interface showing far red image above RGB image (Source: Dipendra Aryal, 2019)

After optical sorting fruit may be subject to a fungicide treatment, with Dimethoate 400 typically used (Fig. 40). Washed fruit pass through the waxing chamber (Fig. 40). Waxing reduces fruit transpiration, thus slowing weight loss, extending shelf life, and maintaining freshness and fruit appearance. Another benefit of waxing after chemical treatment is that it acts as a carrier of fungicide because the fungicide is miscible with the wax. This prevents stem-end rind breakdown, maintaining the quality of fruit and extending shelf life.

Figure 40: Left panel: dimethoate used in treatment of citrus fruit before waxing; right panel: waxing of fruit (Source: Dipendra Aryal, 2019).

Singulated fruit are also sorted on weight and branded with a sticker (Fig. 41). Fruit sorted on weight and colour drop to cross belts for human packing to cartons. Packers represent a last line of defence for removal of defect fruit. Training aids for recognition of defects are present to remind the human packers (Fig. 41).

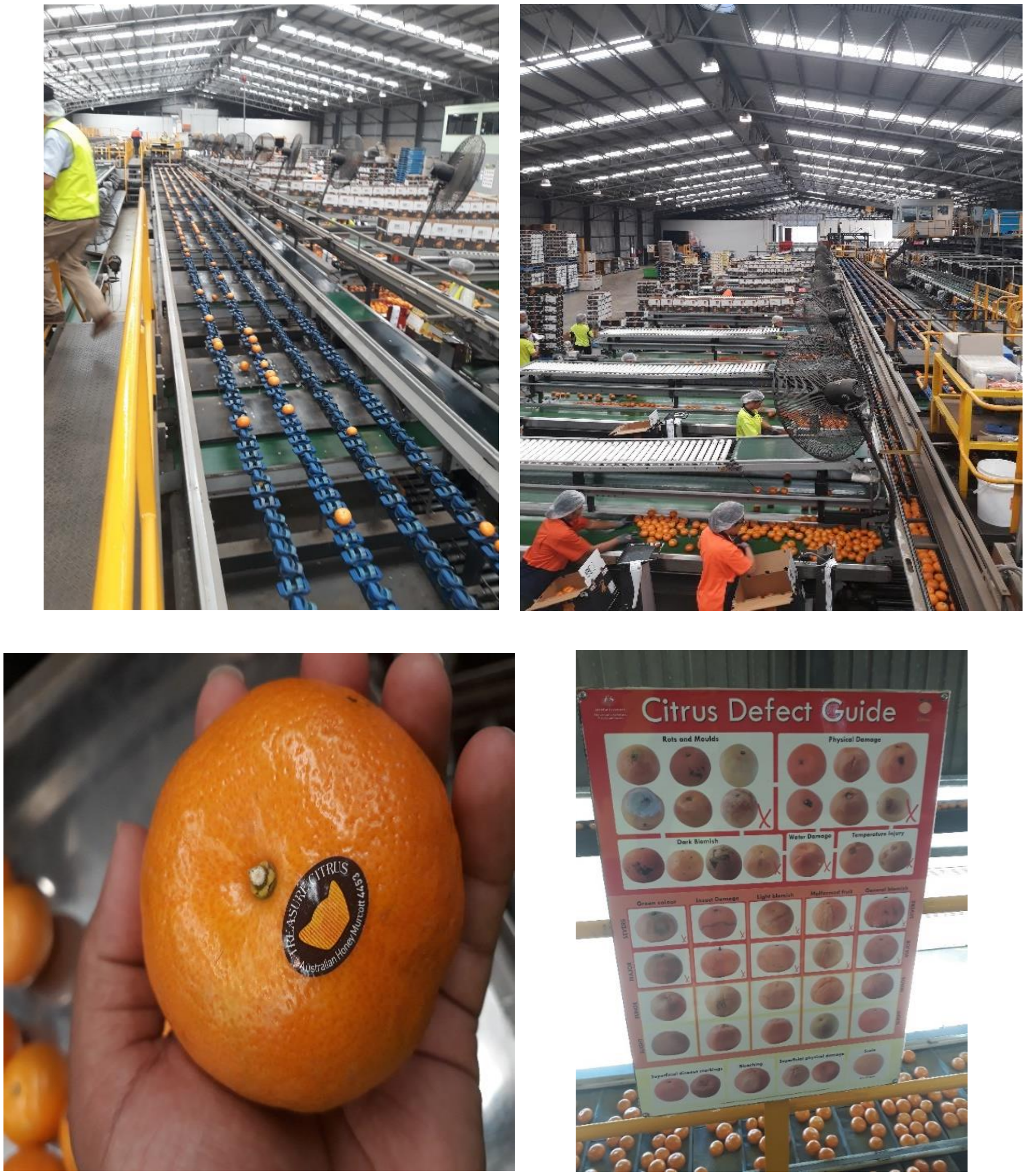

Figure 41: Left panel: weight based citrus fruit grading lines; Right panel: packing of graded fruits; Bottom right panel: Branding of individual fruit with sticker; Bottom right panel: Citrus defect guide (Source: Dipendra Aryal, 2019)

Two sizes of cartons are used, one holding 10 kg and the other 15 kg of fruit. The cardboard of the cartons is a good insulator, minimising heat transfer from outside. The cartons are sturdy, enabling stacking on a pallet. Each pallet contains either 64 or 80 cartons, for 15 and 10 kg cartons, respectively (Fig. 42). The pallets are then held in cool store before transport. Cold treatment disinfestation is done in transit and during the freight once the fruit consignment arrives at the port.

Figure 42: Left panel: fruit packed into cartons; Right panel: palletised cartons (Source: Dipendra Aryal, 2019)

Insurance

Crop can be lost to strong winds, hail, frost, smoke taint, or drought. The farm self-insures for such loss.

Markets

Fruit with minor bruises or injuries can be marketed domestically, but only blemish free product is directed to the export market. The export market provides a higher price for product than the domestic. In addition, production exceeds the capacity of the domestic market. Citrus fruit are exported mainly to China, Thailand, Indonesia, and many Middle East countries.

Supply Chain Map

Features of Abbotsleigh Citrus supply chain described above are summarised into a supply chain diagram (Fig. 43). Key features include supply of supermarket chains and export markets, mainly Asian and Middle east countries. Majority of volume (55-60%) is supplied from the farm to the export market whereas, remaining 40-45% volume is supplied to the domestic markets and approximately 5% is damaged by minor injuries and bruises which are sold locally.

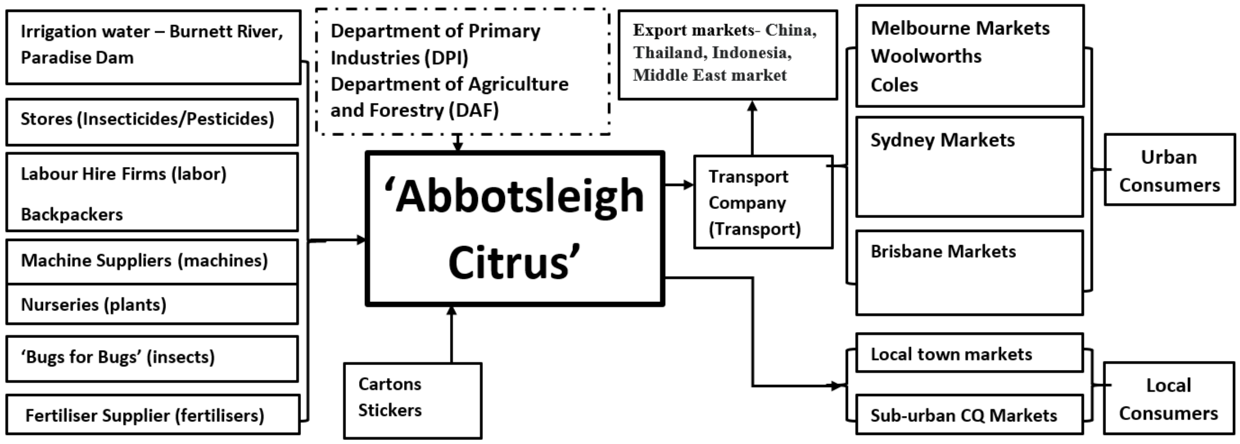

Figure 43: Supply chain map of 'Abbotsleigh Citrus'. Source: own sketch based on Ahmad et al., (2018).

Global Harvesting P/L – labour hire

History

The owner/manager, Basu Dev Dahal, came to Australia 26 years ago as a visitor and worked as a fruit picker in grapes and citrus and progressed to farm supervision roles. The family was ready to purchase a business in Brisbane in 2008 but a fall in stock market prices eroded their resources. This change in circumstance led to the motivation to create a labour hire contracting business. The business began in operational from July 2014 and initially serviced only citrus producers, with a large seasonal fluctuation in work. With addition of a contract to service a large blueberry farm, work across the year increased. Global Harvesting P/L (https://harvestingservices.com.au/) is now one of the largest employers in the Burnett region.

In its first year of operation the company employed 50-60 people but before 2014, 14-16 people started working in a group as 'Dahal Services', 'Dahal Pty', with the owner acting as a gang supervisor himself. He continued working as a supervisor for several years but as the business expanded, he employed people for these roles. The company now services most crop management tasks, including planting, pruning, harvesting, farmhand duties, weeding, driving, supervising, and packing, with activity year-round. The business model involves supply of labour to farms, with conditions and pay at a level that entice workers to stay. The farms have an assurance of getting efficient workers without management difficulties.

COVID-19 has, however, impacted operations significantly. The number of people working in a group has decreased from 250-300 (maximum 350 at a time) 140-150, sufficient to support basic operations, while some activity has been suspended, e.g., the company could not supply labour for vegetables during March and April 2020.

Business model and regulations

The company contracts an agreed service to a farm. Typical services are planting, fruit picking, packing, training, pruning, spraying, and higher positions such as supervision. Services are provided to vegetable, citrus, blueberry, grapes, and mango farms. Citrus harvest work occurs across nine months of the year, with lemon harvest work starting in January and late mandarin varieties harvest work ending in August/September. Blueberry crop work continues for five to six days a week during the peak harvest season.

The company recruits and trains workers and pays for work based either on piece work or an hourly basis. Piecework is assigned by paying a fixed rate of amount per unit of work done, for e.g., $100 per bin of citrus fruit. Based on their experience and capacity, workers are offered full-time or casual work paid on an hourly rate but most work is done under the piecework payment system. The piece rate is adjusted for different crops and growing conditions. For example, the payment for blueberry harvest ranges from $2 to $8 / kg depending on the variety and the quantity and quality of fruit on plan. Other conditions may be offered, depending on the workers quality. Some people make more money on piecework than on a per hour rate. All workers must have an Australian bank account with payments going through a payroll system.

When the company was started there was no regulation on labour hire service. Since 2016, a labour hire licence (https://www.labourhire.qld.gov.au/) has been required in Queensland, with conditions deemed tough in the firm's experience. As part of these conditions, the company must verify Australian citizenship or right to work visa status of all employees. The company also awarded a license to operate in Mildura, Victoria in 2019/20. It was intended that the company would arrange worker movement between states, but COVID-19 travel restrictions prevented this after 2020. In few other states, there are no licencing requirements[19], for example Northern Territory, Tasmania, Western Australia, Australian Capital Territory. The company hopes to expand to all states and territories in the future.

[19] https://legalvision.com.au/labour-hire-license-laws-australia/ mentions only Queensland, Victoria and South Australia have labour hire license requirements.

Relevant Work Cover, public liability, and professional indemnity insurance is maintained. A given farm can negotiate an enterprise bargain with their workers, which workers must perceive as offering conditions better than the prevailing Horticultural Award at the time of negotiation. Thereafter the enterprise bargain holds for its agreed duration, even if a new Horticultural Award is enacted, unless specific action is taken. With many farms on enterprise bargains, the company sometimes has to deal with more than ten workplaces agreement at one time. The firm signs the contract with the farm for a service and provides the service by using labour under the firm's rules and regulations. There is minimum bargain or deal of labour with the farms or enterprises.

Diversity of labour

Approximately 10% of those employed come from Australia and New Zealanders. International staff come from many counties, principally Nepal, Europe, Korea, Japan, and some Pacific Islanders. People contact the company both while overseas, before coming to Australia, and once in Australia. Those on working holiday visas ('backpackers') are mostly from Europe, Korea and Japan. Those on student and student dependent/spouse visas are mostly from Nepal. Initially the company was largely reliant on backpackers, but the largest pool was Nepalese, pre-COVID-19. Post COVID-19, the backpacker force has disappeared as people returned to their home countries without entry of fresh workers.

Some tasks require a greater skill level. The company will sponsor people functioning well with such tasks for a sub-class 491 four-year skilled regional work visa followed by application for permanent residency. All applicants are vetted through the same interview process. Applicants are screened for their health and visa status and assessed on their readiness for hard work. Different applicants may be selected based on duties required, e.g., outside work or packhouse work. Spraying is a more technically demanding and higher paid task, undertaken by a relatively constant group of workers returning each year.

As a generalisation, the Nepalese and Japanese are effective workers. These workers aim to amass money and a likely to be of longer duration employment. The company also has a license for the Pacific Islander Scheme as of now, recently employed an islander and approved seasonal worker program recently.

The Working Holiday visa allows holders to work six months for one employer and then they must change the employer. Post covid, visa conditions have changed such that working 88 days for an employer enables a right to work another year in Australia, while working another six months, enables the right to work a third year. There visa allows for work on any farm at any location in Australia and is intended to be attractive to travelling wishing to 'see the country'. Because of the 'six months with one employer' rule, staff will leave the company for a time for other work or travel and then return.

Training

The main task of the company is logistical, to arrange provision of the right number of staff to the right locations at the right time. With work across many farms and tasks, communication to, and training of, workers is critical. Senior staff must guide the gang supervisors who must lead their workforce into varying tasks and locations. Continued interaction with farm management is also essential, as, following market requirements, farm instructions may change within a day. For example, a select harvest of fruit of a certain size and colour may be required, or a strip pick of all fruit.

Each worker is inducted to each task, and training is refreshed each day. Workers tend to avoid certain steps, so continued reminders are necessary. With piece rate paid on number of buckets and bins filled, fruit quality can be compromised in the haste to harvest.

Services provided to workers

The company arranges accommodation for those working for longer periods. Rent is deducted from pay. Currently, accommodation is only arranged for longer staying workers as they do not have inclination to live elsewhere and prefer a house. Other workers stay in caravan parks and campsites as backpackers.

A pool of three buses and several cars is used to ferry workers between their accommodation to farm. Some workers use their own transport. The firm provides the labourers free transport within the workplace farms- from accommodation to farm and vice versa but does not cover initial transport costs for travelling to and from the work region at the start and end of the season.

Citrus labour

The piece-rate for citrus harvest varied between \$60-\$250 per field bin (holding capacity of 500 kg of fruit), depending on the density of fruit on the harvested trees. Each worker has their own bin to fill, and the supervisor keeps a tally of bins picked. A canopy with a high fruit load and fruit close to low to the ground is easier to pick than a canopy with scattered fruit located higher up the tree. Selective pick on colour and size is slower than a 'strip' pick. The manager must judge an appropriate piece rate to ensure the average efficient makes sufficient income for the day and embed this price into the contract between the company and the farm.

No technology has been used to estimate labour requirements, to date. Experienced staff from the farm and from the company look at the crop and predict production level. The number of workers required is based on the estimate.

4.4 Common issues

The following issues were identified as common concerns across the players involved in export orientated, large scale citrus production.

Insurance

Insurance is available on infrastructure such as farm buildings and tractors. There are a few weather derivatives products available that can be used as crop insurance (e.g., CelciusPro, https://www.celsiuspro.com/, doa 06/08/2021) but these products were not used in the two case examples. Rather, as the enterprises belong to diversified groups, in terms of multiple production sites and/or vertical integration, the risk is internalised, i.e., the farms self-insure on crop loss, with deliberate budgeting for this internal insurance recommended.

Labour

Large-scale citrus farms require a large human resource for production, harvest, processing, packing and transport. Existing operations can be constrained by lack of appropriate labour. This situation has been incrementally developing over the last decade, with declining participation of Australians. This situation is likely due to a demographic shift of the Australian population to city areas and a shift of large citrus production areas to more remote, less populated areas (Robinson, 2014).

Several government schemes have targeted the harvest labour issue. Working holiday makers have a significant role in Australian horticulture sector (Reilly et al., 2018). For example, backpackers from certain countries can have their working holiday visas extended conditional on working three months (or 88 days) in agriculture (https://immi.homeaffairs.gov.au/visas/getting-a-visa/visa-listing/work-holiday-417 doa 28/08/2021). However, uptake of the scheme can vary with condition changes. For example, numbers dropped in response to a change in taxation rate in 2018 (removal of tax free threshold, https://www.ato.gov.au/Individuals/Income-and-deductions/Offsets-and-rebates/Low-and-middle-income-earner-tax-offsets/). Also, the recent Australian-UK trade agreement removes the necessity of farm work (https://www.smh.com.au/politics/federal/farmers-demand-new-visa-after-losing-uk-backpackers-under-trade-deal-20210616-p581il.html) for working holiday visa extension by UK residents. In the Seasonal Worker and Pacific Islander Schemes, growers bear airfare and other costs, but access workers likely to return over multiple seasons, thus developing skills and knowledge of operations (https://www.dfat.gov.au/geo/pacific/engagement/pacific-labour-mobility, https://www.dese.gov.au/seasonal-worker-programme). A call for submissions on the review of these program closed on 18 July 2021 (https://www.foreignminister.gov.au/minister/marise-payne/media-release/submissions-invited-streamlined-pacific-labour-mobility-initiative). As an outcome of this review, a new agricultural visa was announced starting at the end of September 2021. This visa allows foreigners to work in the farm, forestry, meat and fisheries sectors and provide a pathway for permanent residence (https://www.abc.net.au/news/2021-08-23/new-working-visa-for-farms-begins-next-month-permanent-residence/100398052, doi 30/08/2021). South-east Asian countries are targeted, likely Vietnam, with the country to be included based on bilateral agreements (Sulivan, 2021).

However, with current quarantine limitations on entry of people into Australia, the impact of this visa on the labour shortages of the current season may be limited. COVID-19 pandemic has restricted access to international labour, highlighting the fragility of reliance on international labour. This has resulted in efforts to encourage labour mobility within Australia to address farm labour needs. The Queensland Government 'Back to Work in Agriculture Incentive Scheme' provides $1,500 in relocation support (https://www.qld.gov.au/about/pickqld/pickqld-bonus) while the Australian Government Relocation Assistance provides up to $6,000 for Australian job seekers and up to $2,000 for international job seekers (https://jobsearch.gov.au/harvest/workers/relocation-assistance).

Labour represents a large proportion of total citrus production costs (40% quoted in https://www.pc.gov.au/inquiries/completed/citrus/submissions/australian_citrus_growers_acg/sub072.pdf, doa 1/8/2021, 50% of total growing cost quoted in https://www.aph.gov.au/DocumentStore.ashx?id=16dc9758-3cf6-44d2-b49f-3bcd23fa56b0&subId=5561, doa 1/8/2021). The Horticultural Award which came into force on 1 July 2021 provides a minimum rate of $20.33/h, with higher rates for afternoons, nights, and public holiday shifts (https://www.fairwork.gov.au/ArticleDocuments/872/horticulture-award-ma000028-pay-guide.pdf.aspx; https://awardviewer.fwo.gov.au/award/show/ma000028; doa 1/8/21). Overtime rates of $30.50/h applies on Monday – Saturday shifts while the Sunday overtime rate (outside of harvest period) is $40.66/h. For positions such as leading hand, first aid or wet work, there is a different calculation algorithm called PACT – Pay and Condition Tool (https://calculate.fairwork.gov.au/). Australian farm labour pay rates are possibly the highest in the world. For example, other large citrus exporting nations such as the USA, Brazil and South Africa have unskilled labour rates of $9.82[20] per hour, $1.86[21] per hour and $2.02[22] per hour, respectively. Thus, Australian exports cannot compete on price with competitor product.

Labour availability and demand changes every year, with management complications as workplace rules and regulations change. The interviewees feel that labour management becomes harder every year. As a rule, farms are employing a fewer number of higher quality people each year.

There is therefore a strong driver for Australian export orientated citrus producers to adopt labour saving innovations. Automation technology continues to advance for packhouses, with all steps now automated, from bin tipping through produce inspection to packing of cartons and palletising (e.g. Compac; https://www.compacsort.com/, and MAF; https://www.maf-roda.com/en/page/palletizing.php) and continued adoption by the Australian industry is expected. Automation of harvest represents a new challenge.

Water

For a perennial crop such as citrus, certainty of access to water is a pre-requisite to farm operation. Change in water availability for the Wallaville producers inherent in the reduction of the height of the Paradise dam represents a fundamental challenge to long term expansion and viability. The progress of the class action and the potential for an engineering solution to restore dam capacity will be important to these producers.

Pest and disease

As an island continent, Australia enjoys freedom from a range of citrus diseases and pests, e.g. citrus canker. For those pests and diseases that are present a range of mitigation measures are possible. The price, however, is eternal vigilance, to allow actions to be taken at an early stage. Strong monitoring programs are therefore essential.

[20] https://www.dol.gov/agencies/whd/minimum-wage/state mentions minimum pay of USD 7.25 per hour; current conversion rates applied.

[21] https://www.in.gov.br/materia/-/asset_publisher/Kujrw0TZC2Mb/content/id/57510734 details BRL 4.54 per hour of labour; current conversion rates applied.

[22] http://www.labour.gov.za/employment-and-labour-minister-tw-nxesi-announces-minimum-wage-increases includes R20 per hour for labour in South Africa; current conversion rates applied.

Product quantity and quality

With new year-round production, accurate estimation of crop load quantity and harvest timing is a key management requirement, e.g., for estimation of labour needs.

As Australian export citrus cannot compete on price, it must compete on quality. Factors impacting quality include (i) growing conditions, e.g., eliminating wind rub and other conditions causing external defects; (ii) pests and diseases of phytosanitary concern; (iii) timing of harvest; (iv) postharvest treatment, from sorting to remove defects to storage conditions that maximize shelf life.

4.5 Conclusion

Citrus production is a mature industry in Australia, and well established in the Burnett region since the 1970s. There is concern from players interviewed that the level of innovation in the industry has dropped off, with the citrus industry judged to be "at least 10 years behind when compared to the apple industry". The macadamia industry, which has expanded rapidly in recent years, is considered to have a high level of innovation adoption.

A summary of suggested innovations matched to issues arising from the description of operation follow:

(i) labour supply – continued innovations in mechanisation can be applied to both packhouse and harvesting, e.g., Ubot (https://www.ubotcitrus.com/, doa 31/7/2021).

(ii) disease and pest monitoring – automated monitoring aids are being developed, e.g., iMapPESTS (https://imappests.com.au/, doa 06/08/2021).

(iii) documentation of practices – easy to use, online farm information management system (FIMS) and decision support tools are required that integrate functions, e.g., labour management, irrigation control, chemical usage (e.g., FarmInOne, https://farminone.com.au/, doa 31/7/21).

(v) harvest load – machine vision tools for 'automated' assessment of fruit number and size are becoming available, e.g., Plantai (https://plantai.net/, doa 31/7/21). Of those interviewed, the labour-hire firm manager expressed highest interest in such technology.

(iv) harvest timing – accumulated heat units are related to fruit maturity and can be estimated from on-site temperature records (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/218972/Calculating-heat-units-for-citrus.pdf). Also, technology exists for rapid non-invasive measurement of Brix (http://www.sunforest.kr/category_main.php?sm_idx=168). Such technology coupled to capability to log data directly to a farm management information system would support farm management in the decision on when to harvest.

Of these potential innovations, the precision horticulture tool of a rapid non-invasive measurement of Brix will be evaluated in a critical case study.

5.0 Descriptive Case Study of Citrus Production in Western Nepal

Abstract

A descriptive case study based on semi-structured interviews and a web-based survey- Qualtrics, is presented of a typical citrus production system in western Nepal's mid-hill region. The methodology involved interviews with the farmers, traders, wholesalers, exporters, and support providers and a survey among government officials to identify the primary value chain actors, their roles, and critical constraints within the value chain. The sustainability of production and export is also discussed among the participants. The development of the enterprise is explored, with the main features of the value chain briefly described. Key constraints included small land holding, improper planting materials, lack of citrus specific inputs, lack of irrigation water, diseases, pests, inadequate post-harvest handling, marketing, export, and climatic conditions, which suppressed the expansion of the citrus industry in the region. The potential for a viable citrus value chain in a developing country setting is discussed.

5.1 Introduction

The citrus industry tops the fruit crop industry in Nepal's cultivated area and production in approximately 50 (out of 75) districts (D. Adhikari & Y. GC, 2020). The citrus industry remains restricted in quality and market, preventing the nation from becoming an exporter. Due to the parallel ripening patterns of the mandarin cultivars, the market window in Nepal lasts only a few weeks, leaving farmers without additional options to market fruit outside this timeframe.

In Nepal, citrus is cultivated throughout over 33,897 ha of land, with 259,191 tons of fruit (MoALD, 2020). Mandarin (commonly called as 'Suntala' in Nepali) orchards cover 22,060 ha and contribute 174,868 tons of production, while sweet oranges (commonly called as 'Junar' in Nepali) and lemon (commonly called as 'Nibuwa' in Nepali) is cultivated on 5,145 and 1,010 ha, respectively, producing 50,518 and 7,121 tons of fruit, respectively (MoALD, 2020).

The AusAID/PSLP project of 2012-2016 addressed several issues in the mandarin supply chain in Nepal with attempt to improve industry sustainability. Several Nepalese farmers were presented an opportunity to visit and study the Australian and Thai citrus industries within the project period. The project identified various technology gaps and suggested that the industry be more economical, feasible, and sustainable. However, no formal evaluation is done as part of recommendation and technology adoption.

The increasing demand for fruit in metropolitan regions and accessibility of the global markets provides a foundation for developing the citrus value chain in Nepal. Supply of either of these markets requires a focus on quality and consistency in supply, which has limited development to date (D. Adhikari & Y. D. GC, 2020).

5.2 Methods

A descriptive case study was selected, where 20 growers were selected from two regions profiling a typical citrus farming cluster in Nepal's central citrus production regions – Syangja and Parbat (Fig. 44). The original involvement of growers in the two areas was based on an open invitation to participate distributed by the Ministry of Agriculture Development (MOAD), Department of Agriculture (DoA), and the Micro Enterprise Development Programme (MEDEP) during the project operation in 2013 and 2015. Semi-structured interviews were conducted in two regions with randomly selected willing interviewees including 20 growers, two traders, two wholesalers, and support providers on both years at field sites in Nepal using an interview guide and question prompt (Krauss et al., 2009), allowing for diversity between locations, scenarios and situations of the interviewees. Government officials from different departments were surveyed using Qualtrics (https://www.qualtrics.com/) as Carnaby and Harenberg (2013) also used. The offices and departments were selected as stakeholders in citrus production, research, pest management and export, with the officers were self-selected based on their roles and positions in the respective government institution. Due to travel restrictions amid COVID-19, the face-to-face interviews were impacted, and hence virtual methods of interviews were utilised (e.g., Zoom, telephone, teleconference, Viber-in case of a few remote Nepalese growers).

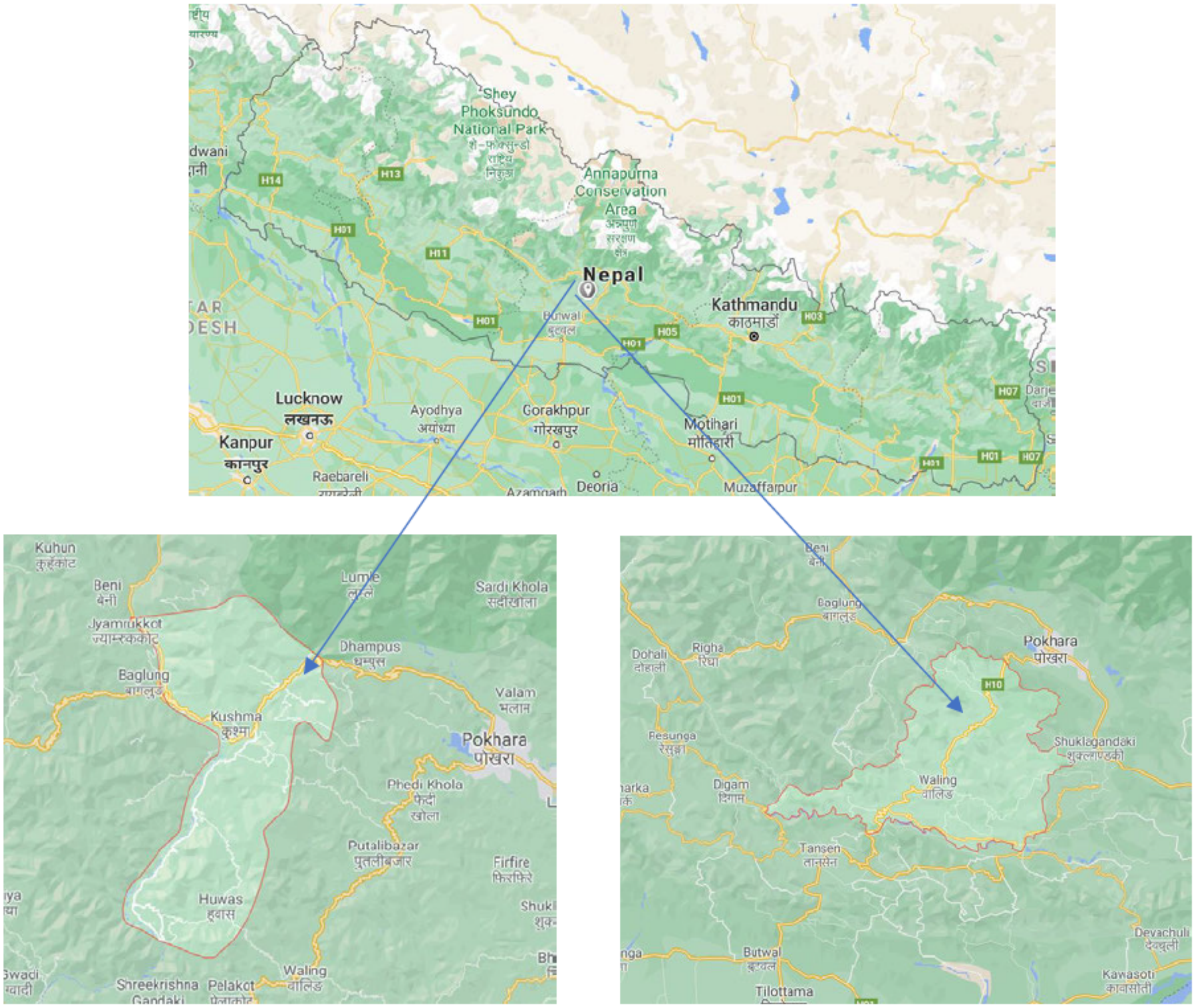

Figure 44: Location of a typical citrus farming region in western Nepal – Syangja and Parbat (Source: Google Maps, 2020)

The method of analysis selected for this case study was the procedure of qualitative methods incorporating thematic analysis and the data-focused deductive approach of Crabtree and Miller (1999). This approach complemented the research questions by allowing the process of deductive thematic analysis (Fereday & Muir-Cochrane, 2006). A theme may be initially generated deductively from theory and a priori research (Boyatzis, 1998).

The NVivo software program assisted in categorising and arranging the data set. The software supported working efficiently with large amounts of text, thus enabling depth and complexity of analytical organisation of collected information from growers. The credibility of the analysis was additionally enriched by having the researcher and one of the supervisors analyse the data. The data sets were worked through systematically, giving comprehensive and equivalent attention to each data element. Individual data extracts were coded as many times as applicable and into as many different themes as considered suitable (Nowell et al., 2017).

> *"Deductive approaches involve using a structure or predetermined framework to analyse data. Essentially, the researcher imposes their structure or theories on the data and then uses these to analyse the interview transcripts"- Seale (1999) (page 45 and 135).*

A wide diversity of concepts was covered in the interviews, so at the outset, the theoretical frame to approach comprehensive, upper order codes to help categorise the data was employed. The data was coded into various categories (Appendix I) to organise the information as value chain features. These deductive codes frequently shaped vital themes: some tallied with interview questions and were characterised as parent nodes in NVivo. NVivo and written manuscripts of the coded data in every theme were used to create subthemes as necessitated (Nowell et al., 2017). This coding was used to categorise similar information in specific topics depicted as value chain features in description. Because of a high number of transcripts from ten different growers from two regions over three different years, it was deemed useful.

5.3 Features of Value Chain

Small-holder production

One of the critical features of Nepalese small-holder farms is the terrain (Fig. 45) incorporating a subsistence farming system, where the growers tend to grow as many seasonal crops as possible for living and in preparation for winter. The concept of commercial farming is still not dominant amongst these small-holder farmers. The average landholding of small-holder citrus farmers in the western mid-hills of Nepal is very low with most farmers having less than one hectare of land. Nevertheless, the majority of Nepalese mandarin production comes from the small-holders of the western mid-hills. Land fragmentation is one of the primary reasons behind this situation, as the landholding continues to fragment generation after generation. The landholding is also dependant on the economic and social class of the people.

Figure 45: Citrus trees in the mid-hill region of Nepal (Source: https://blog.gfar.net/2016/03/02/yap-proposal-84-rejuvenating-declining-citrus-orchard-madan-poudel-nepal/, doa 30/08/2021 with permission)

Transport and markets

In some regions, transportation is difficult, as there are only a few resources for the proper packing of citrus fruits. Local resources like straw or banana leaves are used as cushioning materials for the fruits when they are heaped in the back of a truck (Fig. 46). When they arrive at the market, the fruit is tipped into different containers or plastic crates and sold in this manner. This system creates pressure on the bottom fruit and impacts quality. Many farmers cannot afford to own trucks; hence they must rely on transport companies for trucks and vehicles. The farms that can afford transport and are innovative have started to transport citrus fruits in cartons (Fig. 46). The carton packaging protects the fruit and provides a better product quality for sale at the markets.

Figure 46: Citrus fruit transportation in a heap by truck - left (Source: https://kathmandupost.com/money/2019/12/05/farmers-expect-orange-biz-boom-this-season, doa 30/08/2021, no copyright information); transported in cardboard cartons – right (sourced with permission: Triputra Bagwani Farm, 2020)

Branding and Packaging

Traditionally, packing citrus fruit is done using bamboo baskets and plastic crates (Fig. 47). Some of the more extensive and advanced farms even use cardboard cartons to pack fruits. Due to the increased accessibility of roads to remote parts of Nepal, plastic crates have gained popularity. Easy to carry and easy to load and unload to and from the truck make them famous. Each plastic crate is stacked and covered with a tarpaulin to provide shade and prevent the entry of dust and rain.

Figure 47: Packing citrus fruits in plastic crates before transport (Source: https://myrepublica.nagariknetwork.com/news/technicians-bringing-citrus-fly-infestation-under-control/, doa 30/08/2021, no copyright information)

In addition, there was a reported rental cost of plastic crates used for marketing and several labours utilised to collect and store the crates from the retail market. This circumstance commended a few farms to start packing their fruits in cardboard cartons (Fig. 48). The activity was reported to have provided significant improvements in fruit quality when they reached the market; however, the additional cost of the carton was not easy to recover for the farms using them. The wholesaler pays the labour to gather and keep records of plastic crates used for moving and marketing citrus. Nevertheless, the retailers will bring them back to the sales yard of the wholesaler the next day.

Figure 48: Packing citrus fruits in cardboard cartons used by a private farm (sourced with permission: Triputra Bagwani Farm, 2015)

Nursery stock

Most citrus plants in small-holder farms are plants raised locally from stock at the farm. Previously a large portion of plants used to be propagated vegetatively – by layering the branches of a tree, and now the concept of the nursery-raised seedling is gaining popularity. The use of grafted plants is increasing in popularity among growers because of their size, quick output, ease of management, input requirements, and consistency in production. The local plants are enormous and are challenging to harvest, train, prune, and spray with chemicals for disease/pest control. Often, when the number of plants available from local nurseries within the district is scant, the planting materials are sourced further outside the district (mainly from the Palpa citrus farm). The Plant Quarantine and Pesticide Management Centre (PQPMC) in Kathmandu is responsible for inspecting and approving inter-district planting material.

Nutrient balance

Nutrient sources are obtained from mainly local products, including farmyard manure, cow or buffalo urine, green mulch, forest mulch (dry leaves collected from the forest nearby), and NPK fertilisers sourced from farmers' cooperatives. The system of preparing the farmyard manure is undertaken by decomposing the leftover fodder, grass, mulch, and other green grass along with the cow or buffalo dung in a pit frequently aided by biogas slurry (in the case of the Syangja district). When the manure is prepared, it is taken out of the pit, left for a few days to dry, and then carried manually by people in a hand-woven bamboo basket (Fig. 49). However, with the migration of people from village regions, labour scarcity is forcing farmers to leave the land fallow. Farming continues where road access is more straightforward, allowing tractors to transport manure and other inputs to the field and transport harvested produce to storage on the farm.

Figure 49: A woman carrying farmyard manure in a bamboo basket on her back (Source: Dr. John Tyman, accessed from http://www.johntyman.com/nepal/16.html, doa 30/08/2021)

Government subsidies are available for various inputs, including Bordeaux mixture on the canopy and Bordeaux paste on the trunk for pest and disease control. The Prime Minister Agriculture Modernisation Project (PMAMP) and the Citrus Zone or Super zone facilitate such subsidies. Disease and pest management is also supported by the Agriculture Knowledge Centre (AKC) and the Plant Protection Directorate (PPD), which provide technical resources and a small number of funds for pest and disease control mechanisms.

Irrigation and water

The mid-hill region of Nepal is dependent on rainfall for farming (Adhikari, 2018). Citrus is grown in the upland, where water is not readily available in many districts. Also, the harvest season matches the dry season when there is no rainfall. Once the fruits are harvested, and the orchard is supplied with manure and mulch, the farmers must wait for rainfall to supply nutrients to the roots. Delayed rain will push the flowering to later, and fruiting in the next season is impacted. Some farms in Syangja and Parbat installed a drip irrigation system in citrus orchards (Fig. 50) in 2015, with these systems are still functional in Syangja in 2021. In the case of Parbat, the community shared a common source of water. The irrigation system created disputes among the growers resulting in the discontinuation of the system. In Syangja, the whole operation is owned by a single farm.

Figure 50: Installation of drip irrigation systems in citrus orchards of Syangja (left) and Parbat (right) Source: Dipendra Aryal, 2015.

Post-harvest technology

After harvest, fruits are transported to a grading room. Fruits are tipped from baskets onto the floor and graded into various sizes by human hand. The floor would sometimes be just plain earth, sometimes covered by grasses or straw, and in improved cases, the fruit may be placed on a tarpaulin. Many people sit around the pile of fruits to hand grade fruit according to quality to different baskets or plastic crates (Fig. 51). In a 2020 development, a farm of Syangja installed a fruit grader sourced from India.

Figure 51: Grading fruits in Nepal, a fruit grader (sourced with permission: Triputra Bagwani Farm, 2020)

Labour and harvesting

The harvesting of citrus fruit on seedling trees is complicated, involving large trees on steep land. The harvest crew/labourers must climb the trees to pick the fruit. Workers in the tree harvest fruit into small hand-woven bamboo baskets tied with a rope and hung on one of the tree branches. When the basket is complete, they lower it skilfully to a co-worker who tips it onto the ground or into one of the more extensive bamboo baskets. The more giant bamboo baskets are used to carry the fruit to the grading floor, or in very few cases, to a packhouse. This basket is carried on the back and using a head support strap (Fig. 52). The fruit was pulled from the plant, resulting in tearing of the skin and reduced shelf life. Recently, the method of using secateurs or a pruning saw for harvesting fruits with leaves/stems is also gaining popularity. Labour availability has been comparatively easy until recent years.

Figure 52: Carrying citrus fruit in a bamboo basket (Source: https://olgarani.blogspot.com/2012/04/bamboo-wonder-tree.html, doa 30/08/2021)

Market evolution

The primary wholesale marketing outlets of the regions selected for this case study are Kalimati Kathmandu, Pokhara, and Butwal. When the fruit arrives at the wholesale market in those destinations, small retailers from around the city or town will buy the fruit from the wholesalers or the traders and sell it in small amounts in small retail shops (Fig. 53). Those retail shops would be fruit shops with many types of fruit available for customers. Furthermore, many mobile merchants (or fruit vendors) sell the fruit and move around the city in small vans, carts, and bicycles (Fig. 53). In local areas, people have started selling produce at highway markets (for example, on the Siddhartha highway) and village (semi-urban) markets where the people will buy citrus fruit during travel.

Figure 53: A retail shop in Kathmandu Valley, Nepal (https://www.facebook.com/rimalfruitraders/posts/d41d8cd9/122001235946361/) and a mobile fruit stall mounted on a bicycle (Source: https://www.goingsomewhereslowly.com/2015/03/scams-in-kathmandu/)

Government support

The new (2019) republican structure of local, provincial, and federal government systems has support available for citrus growers at a local government level as rural municipalities and municipalities, local support as state government and ministries, and federal government support as departments and research centres. A range of government institutions provides services at all local levels- local, provincial, and federal. A survey (see Appendix E) involving officers from nine government offices indicated a minimum age of 21 to a maximum of 43, providing government support for a minimum of 2 years to a maximum of 17 years among the participants. The education level of those government officers ranged from undergraduate to PhD degree. The majority in the survey were scientists and researchers, followed by agriculture development officers.

Supply chain map

The description of features in the previous section are summarised into a supply chain diagram as follows (Fig. 54). The majority (approx. 80%) of small-holder mandarin production in the mid-hills of Nepal depend on traders to buy and marketing their produce. The farms that engage in direct trade are comparatively bigger (30-40 tonnes/year) and can afford to hire transport vehicles. Of fruit sent to wholesale markets, approximately 35-40% is directed to Kathmandu, 20-25% to Pokhara market, 25-30% to Butwal and ~10% to highway or village markets.

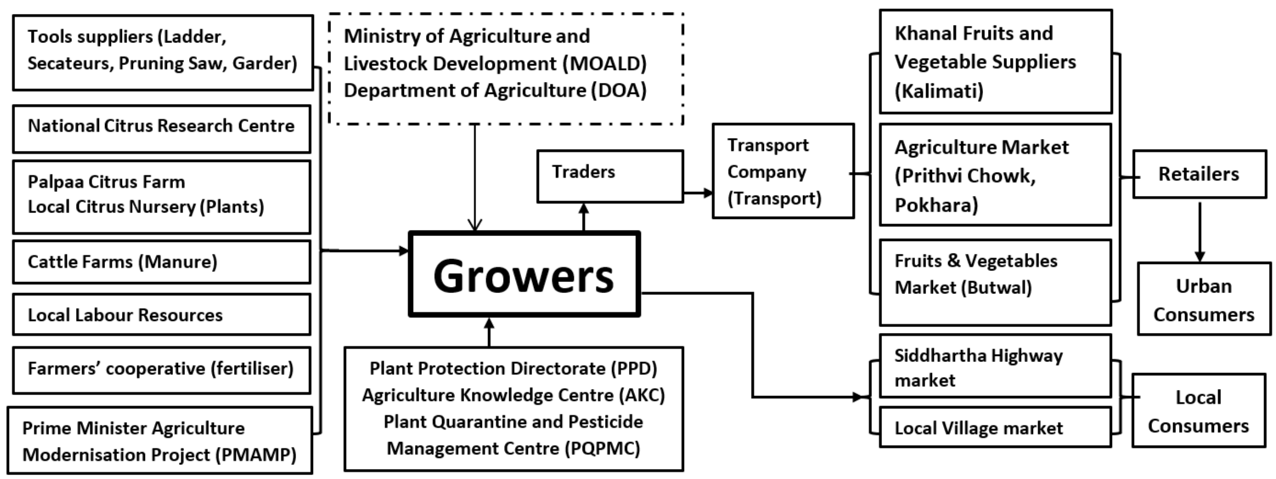

Figure 54: Supply chain map of a typical Nepal citrus value chain (Source: own sketch based on Ahmad et al. (2018))

5.4 Key Issues

Small landholding

Land fragmentation is a vital issue in the Nepalese farming system. The average landholding of farmers is around 0.8 ha (Shrestha, 2012). Each landholding becomes smaller with each generation unless the family can afford to extend the landholding by purchasing more land. Small-holder growers cannot afford to sell their fruit by themselves because of the resources required to manage harvesting, packing, and transportation. Small-holder growers thus rely on traders and intermediaries to harvest and market their fruit.

Improved varieties

Most small-holder farmers' orchards are grown or raised locally from the seeds of fruits consumed at home. There is poor availability of improved citrus varieties due to fewer nurseries across the country producing the improved varieties (Bhandari et al., 2021).

Citrus specific inputs

Citrus-specific inputs such as mineral nutrients, disease/pest control chemicals, and post-harvest treatment chemicals are unavailable in Nepal. Small-holder farmers use locally available inputs; for example, cow dung, compost, green matter as mulch, and sometimes a paint of Bordeaux mixture if a subsidy is available (Regmi et al., 2020). The larger farms manage the orchard on a more frequent basis.

Irrigation system

The mid-hill region of Nepal, where citrus is dominant, is rainfed, with less irrigation available in most locations (Belbase et al., 2020). Due to the unavailability of irrigation water around the year, farmers must depend on rain to supply or dissolve nutrients in the soil/water to initiate new growth (flush) and flowering after harvest. Drip irrigation materials are available but not affordable to most growers in the region, given the low returns currently achieved. The dry season pushes the harvest later in some citrus varieties, where alternate bearing symptoms are seen. Also, the tree's health is severely impacted due to a lack of water in the dry season.

Diseases and pests

Citrus decline, dieback, citrus greening, and Phytophthora root rot are the major citrus issues in Nepal (Lama, 1996). Due to heavy rainfall during the monsoon, the drainage or leaching causes root rot and sometimes even stem rot in the tree's trunk. The fruit fly is a significant pest and has caused heavy damage through fruit drop and thus economic loss to the farmers. Leaf miner is an emerging pest in new plants and new flushes of old plants.

Climatic conditions

Heavy rainfall during the monsoon, hailstorms and drought during the dry season are primary climatic conditions causing problems for citrus farming. The monsoon season and hailstorm occur during the early days of flowering and fruit set in Nepal’s citrus season, which causes significant loss of flowers and fruits. Hail damage of set fruits [even at an early stage] results in scars and marks (Kaska, 1989) visible in mature fruit. These defects result in loss of value, although the internal quality is not compromised.

Harvesting tools and techniques

Harvesting is rough and risky with tall trees and old branches. The fruits are harvested into a bamboo basket that squeezes the fruit sometimes due to the heavy load, causing the fruit skin/rind to rupture, compromising shelf life and quality. Also, the trees face significant stress from pulling and twisting branches during harvest (Savary et al., 2010) to drop the fruit from the branch/tree. The harvested fruits are stored in bulk in a heap, sometimes resulting in a significant anaerobic condition and fermentation. This situation creates a foul smell in fruits and results in lost sales.

Post-harvest handling

Heaping or piling fruits after harvest cause pressure on the fruit located at the bottom of the pile and may cause rind rupture, affecting the shelf life and quality of fruits. Post-harvest fungicide treatments are not practised in Nepal, impacting shelf life (Rokaya et al., 2016). Fruit grading on the open ground results in soil and grass residues in the fruit, negatively impacting consumer interest. These poor handling practices result in quality deterioration before the fruit reach the market.

Branding and packaging

Small-holder farmers do not have the resources to access wholesale markets by themselves, and in many cases, prefer not to be involved in marketing. Most farmers prefer to sell their crops to traders or mediators who harvest, grade, pack, and transport the fruit. In consequence, branding and packaging are rare among citrus growers in Nepal. Only a few larger growers now do their branding and packaging in cardboard cartons. This activity makes consumers wary of mixing fruits from different growers; and therefore, by extension, they do not understand the quality of the fruit on offer in the market.

Transportation

In the steep terrain used for citrus production, there is often a distance between the point of harvest and the road. Harvested fruit is either carried by humans or transported across the country by utility vehicles or tractors. Citrus production occurs primarily in rural regions with only recently constructed unsealed roads are available, while highway networks or bitumen roads serve a few citrus-producing regions. Further, there are no specific trucks and vehicles for the conveyance of citrus fruits, including no refrigerated transport.

Thus, both the roads and conveying vehicles are unsuitable for keeping the fruit undamaged during transport.

Marketing

The primary issue concerning growers is the marketing element of their enterprise because the price of citrus is never fixed or constant. One of the primary reasons behind the unrest in marketing is the subsequent ripening of citrus fruits. Due to similar varieties and growing conditions, almost all citrus fruits ripen at a similar time of the year. This event results in a flood of fruit in the market, thereby significantly dropping prices. There is neither a proper marketing system to make the fruit sold from a single market window nor a proper price-setting mechanism to assure a peak price of fruit for the growers.

Lack of export

No Nepalese citrus is exported. If the export channels are developed, the market pressure within the country would be eased. The export venture could also provide more financial benefits to the growers and could provide a driver for adopting practices that benefit the domestic value chain by meeting phytosanitary protocols (Agreement, 2012) and improving citrus quality.

5.5 Conclusion

The common issues mentioned by the growers during the interview were market, quality, export, harvest, production, and many others, as displayed by the word cloud (Fig. 55) created through NVivo.

Figure 55: Word cloud of most used words and phrases related to the critical issues during interviews (Source: NVivo analysis)

Suggestions for improvement in the Nepal citrus value chain include:

- Increase landholding by the purchase of land in areas suited to citrus production while treating the citrus industry as a primary business
- Adopt a range of improved varieties to diversify and extend the harvest window
- Manage irrigation year-round by building dams or rainwater harvest systems rather than relying on rainfall
- The use of nets and hail/frost protection of citrus in some cases
- Improvement of harvesting practices through the use of secateurs, gloves, bags and three-point ladders
- Proper cleaning, grading, and packaging of fruit before transporting to market
- Product branding and packing in a safer packing material
- Transportation in safe vehicles with genuine care for the fruit quality
- Development of an export market

The growers and stakeholders supporting citrus production and marketing are interested in the notion of citrus export. A primary issue is the concise market window due to the parallel ripening pattern of citrus varieties available in the region. With over-supply of the local market, prices stay low. There is potential to improve returns through the development of an export market. Improved profitability would provide resources to tackle other issues, from irrigation to available varieties. A recently established government system supports grower groups capable of exporting produce out of the jurisdiction.

A critical case study was therefore undertaken on this topic as a potential of citrus export to Tibet.

6.0 Evaluation of Crop Insurance Options for Small-Scale Citrus Production

Abstract

A review of insurance options in general was undertaken, in context of relevance to fruit tree crops. The insurance needs of small-scale citrus producers in Central Queensland are described, with cyclone, drought, hail, and fire being the major risks. The insurance market has two relevant products, crop insurance and event insurance. Several insurance providers are available for crop insurance, with premiums ranging from 6-11 % of crop value. However, while broadacre crops are relatively easy to value, valuation of the crop load of a tree crop such as citrus is difficult to document. New technologies in fruit load estimation will aid such estimations. Event insurance involves a 'bet' on the incidence of an event and can be made irrespective of crop value or loss. However, actuarial estimation of the probability of the weather event is based on the nearest BoM station record and the process to produce a quotation on a specific criterion is cumbersome. Nonetheless, an event-based policy is recommended as the best option for small scale citrus producers.

6.1 Introduction

Most farms hold insurance on infrastructure such as houses, sheds, vehicles, and machinery. This chapter focusses to a discussion of insurance of the crop itself. While risk exists in all commercial activity, the agricultural industry is regarded as experiencing high risk and volatility (Fig. 56), with the volatility index of agriculture being almost double that of other industries regarded as volatile, such as services (ABS, 2011). 'Who would be a farmer' is a common refrain on hearing of crops lost to natural events. With income dependent on sale of the final harvested crop, an event at any point in the growing period can be disastrous (Hazell, 1992). Even greater risks apply in perennial crops such as citrus, with damage to trees impacting yield in future years as well as the current year (Martin, 1996). This outcome was documented in the case studies of small-scale citrus producers, with all three producers significantly impacted in subsequent years following cyclone Marcia in Feb 2015. Other producers in the area were significantly impacted by fires in Nov 2019, while a major hailstorm impacted the Yeppoon to Rockhampton area in April 2020.

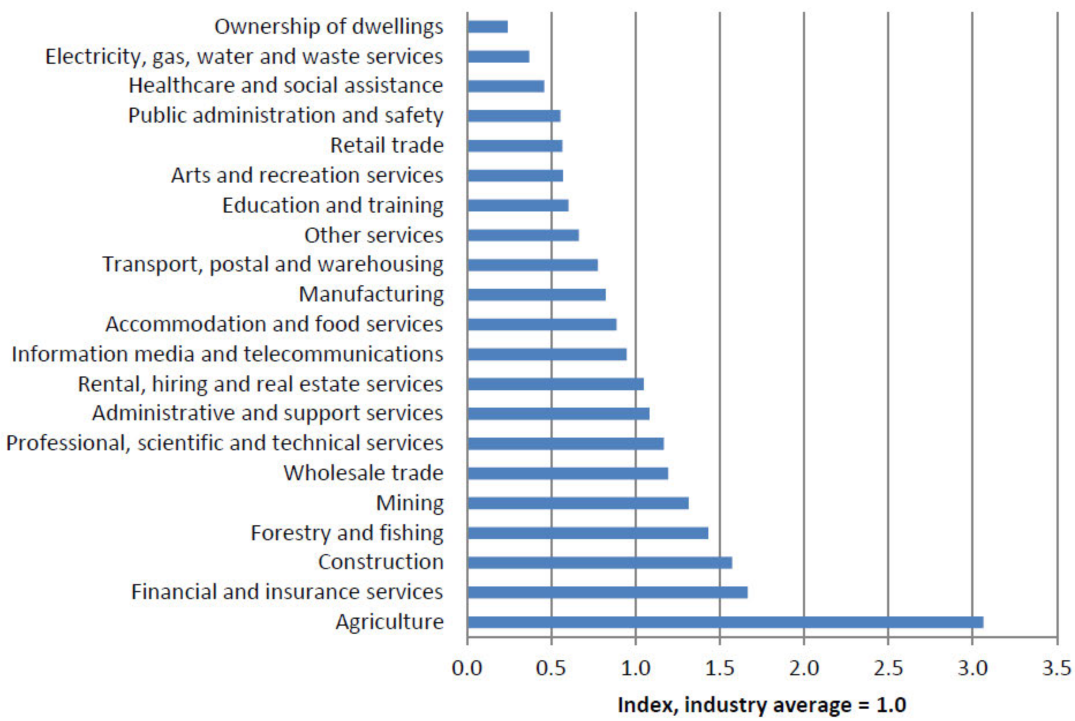

Figure 56: Industry output volatility, 1975-2011 (Source: ABS (2011)

Indeed, there has been 6 declared disasters in the Central Queensland area in the past 10 years (2 flood, 2 fire, 1 cyclone and 1 hail event). Recovery from one disaster event can take years, rendering enterprises more at risk should further disaster events occur.

Insurance is a means to de-risk an enterprise (Kimball, 1988). Smaller risks can be managed more efficiently via savings or borrowings, i.e., credit (Hatt et al., 2012a). Agricultural insurance is appropriate to mitigate the impact of rare and extreme events (Fig. 57). The Australian risk management market has been growing constantly (Hatt et al., 2012a).

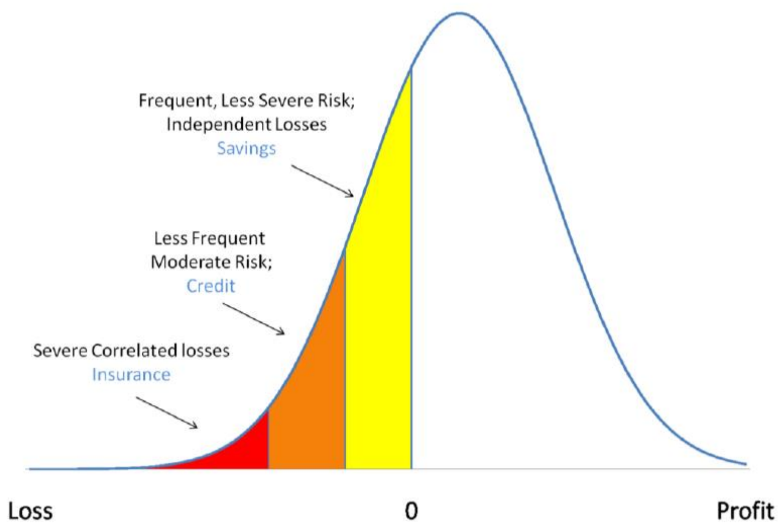

Figure 57: The role of insurance; Source: DAFWA (2011)

Farm production risks can be defined as yield (quantity) and price (value) risks. For several types of agricultural commodities futures contracts are available. These contracts eliminate price risk, i.e., the risk of a drop in the nationwide price of the crop, but they do not protect against quantity risk, i.e., failure to grow the expected amount of crop.

Product prices are not in control of farmers and are systemic, and thus easily measured. Yield risks are less systemic than price risks, meaning they are localised, and all farmers are not affected the same way. For example, farm specific soil types or a poor management practice by a farm manager can impact farm yield. Australian fruit tree farmers can mitigate yield risks using:

- Variety selection and diversity
- Location diversification, with farms in different climate regions
- Irrigation improvement for efficient use of water
- Infrastructure, such as hail nets and fire breaks
- Use of climate forecasts

Farmers have more knowledge of potential risks and expected farm yields than insurance companies. Insurance companies cannot easily identify low and high-risk farmers and set their premiums accordingly. In contrast, farmers have no better knowledge of price changes than the market. These issues complicate the offer of crop yield (as opposed to price) insurance. For example, if the insurance product is not compulsory, good farm managers with lower risk will tend to withdraw from the system.

The cost of insurance

The insurance price depends on likelihood of pay out, company overheads, ready access to capital cost and profit (Skees et al., 2008). The cost of risk is the expected farmer claim over the contract period. Administrative cost comprises information, loss adjustment and delivery costs. The cost of ready access to capital includes the cost born by insurer to provide loss covers in case of a systemic risk where many clients make a claim at the same time. Those companies transfer their risk to global insurers or reinsurers in a premium, which adds to price (Mills, 2009). Pure risk is the major component of risk cost, which may include ambiguity loadings. Pure risk was estimated by Hatt et al. (2012a) for wheat, lupins and canola in broadacre regions across Australia using the farm survey data. Hatt et al. (2012a) even noted that insufficient data existed to estimate risk for Australian horticultural crops, although loss ratio[23] from overseas could be a reference.

Insurance premiums decrease as participation rates increase, and are lowest for compulsory insurance schemes (Table 3) (MPCI Task Force (2003) (Force, 2003).

Table 3. Average premium rates, eight Western Australia shires – MPCI Task Force estimates

Take-up rate %	40% coverage	65% coverage
10	3.2	9.0
20	2.2	7.0
30	1.6	5.8
40	1.3	4.7
100 (compulsory)	0.5	2.5

Note: Premium rates are a per cent of agreed crop value. Results are for a 60 per cent loss ratio. Data source: MPCI Task Force 2003

Farmer demand for insurance

Uptake of crop insurance policies in Australia is low. A MPCI project involving grain farming in Western Australia achieved only 18% of uptake after three years (DAFWA, 2009). Khuu and

[23] Loss ratio is calculated as the ratio of total insurance payouts to total premiums.

Weber (2013) note that in a survey <5% of dryland crop farmers in Western Australia were willing to pay a commercial insurance premium, and suggested that government support in disaster periods may have diminished the demand for crop insurance. Murphy et al. (2011) suggest other reasons for low demand to include:

- Undervalue insurance as people see less likelihood of unprecedented events
- Daily needs are in priority for farms in low income or developing countries
- Less understanding and less familiarity about insurance
- Increase in price due to ambiguity loading due to lack of sufficient data
- Time consuming for index markets to mature

The problems of adverse selection, moral hazard[24] (Roll, 2019) and systemic risk increase also complicate the offer of an index based insurance products, adding on basis risk (Hatt et al., 2012a). The administration and reinsurance cost for index-based insurance products can impact demands for those products (Table 4).

Table 4: Product comparison, selected insurance price and demand factors (Source: ABARES, 2012)

Product	**Administrative costs**		**Reinsurance costs**		**Farmer demand**
	Adverse selection	**Moral hazard**	**Loss adjustment**	**Systemic risk**	**Basis risk**
Named peril	Low	Low	Moderate	Low	Low
Multi-peril crop insurance **a**	High	Manageable	High	High	Low
Multi-peril crop insurance **b**	Low	Manageable	High	High	Low
Mutual fund a	High	Manageable	High	High	Low
Mutual fund b	Low	Manageable	High	High	Low
Weather derivative	None	None	Low	Manageable	High
Yield index	None	None	Low	Manageable	Moderate
Area yield index	Low	Low	Low	Manageable	High

[24] Moral hazard exists when decisions made by the insured person change as a result of having insurance.

Note: **a** Voluntary scheme. **b** Compulsory scheme. The only important difference between the mutual fund and multi-peril crop insurance schemes is that mutual fund schemes do not need to make a profit.

The presence of a government subsidy on premiums is a major driver for farm insurance uptake overseas (see later section), but such subsidies are not available in Australia.

Insurance Schemes

Insurance schemes are categorised to traditional and index-based products (Hatt et al., 2012a). Traditional insurance products usually cover the perils of frost, hail, fire, pests, and diseases in terms of loss of revenue, whereas index-based products involve a 'bet' on the occurrence of a certain environmental condition related to yield such as temperature, windspeed and rainfall. The pay out of traditional insurances is based on assessed yield of individual farmer. Some products involve a pay-out based a comparison of individual farm yield to or region-based yield. The index-based insurances pay out on a weather criterion. All existing products largely target broadacre cropping rather than horticulture.

6.2 Traditional Insurance Products[25]

Named peril insurance

This insurance scheme provides protection against specific perils like frost, hail, fire, etc. The loss of crop from the insured perils must be agreed upon by both parties, following a process of assessing the loss. A moral hazard exists in that the farmer has incentive to mask loss from other causes behind a loss to the names peril.

Multi-peril crop insurance (MPCI)

In this yield insurance product, multiple perils are included, and payments are based on yield losses due to included perils. Both parties, grower, and insurer, agree on expected yield and price per ton. This insurance product is easier to implement in large production areas with many farming units, where there is an establish average area yield, e.g., 2 ton per hectare wheat. Pay-out is based on the yield loss at the market price per ton prevailing at time of harvest. These schemes do not operate in Australia (Hatt et al., 2012a).

[25] http://agriinsurance.com/Agri-Insurance-News/Agri-Insurance-Options-in-Australia.html provides options of farm insurances in Australia.

Crop revenue insurance

This product is like MPCI, but it covers loss of revenue resulting from either a drop in yield or a price per tonne. Thus, the cover includes both decrease in yield and price per ton. This cover protects growers from both yield and price risk. These schemes are not popular in Australia, with insufficient take ups to maintain the business for insurers (Hatt et al., 2012a).

Mutual funds or farmer pool

These products are not legally insurances but can serve like an insurance product. A mutual fund is raised from member growers with the pooled income invested, to be withdrawn when a farm faces a loss due to a trigger event. These products are not in current use in Australia (Hatt et al., 2012a). The last product in this category used in Australia was the CBH Mutual Scheme, which was developed by a group including Willis Australia (https://www.willistowerswatson.com/en-AU/), Western Australian Farmers' Federation, unspecified banks, Department of Agriculture and Food, PlanFarm (https://www.planfarm.com.au/). This scheme was prioritised in wheat and barley crops in WA for members of CBH Mutual. An example by Willis (2011) on how this scheme operated is attached in Appendix F.

6.3 Index-based Insurance Products

The index-based products can be classified as weather derivatives, yield index insurances and area yield insurance (Hatt et al., 2012a). An event index can be as simple as a rainfall or temperature target during a growing season, e.g., pay out if temperature exceeds 40°C for a specified time, or more complex, e.g., involving several variables such as climate data and local-level yield data.

Governments have a role in supporting data collection and management to support implementation of such indices. More user-friendly access to climate data can help farmers make efficient decisions to minimise risks (Hatt et al., 2012a). The Queensland Farmers' Federation[26] (QFF) have planned to develop an index-based insurance product in collaboration with the University of Southern Queensland (USQ) developing a project[27].

Weather derivatives

These products involve a 'bet' on variables such as rainfall or temperature. These derivatives are based on weather station data, with a sufficient historical record required to development an index

[26] QFF have an insurance product for farms in this link https://protect-au mimecast.com/s/gYJNCwVLY6fO8zm0cq1btf?domain=qff.org.au/ with details.

[27] https://protect-au mimecast.com/s/FTqjCvl0X6HBNj5OsQVLHw?domain=usq.edu.au have a project on crop protection details from USQ.

(Barnett & Mahul, 2007). A subscriber selects a weather station based on their location. A pay-out is obtained if the temperature or rainfall goes below or above the pre-specified amount over a pre-specified period of time, based on actuarial odds determined by the insurer (Hatt et al., 2012a). These products are therefore easy to administer, requiring no assessment of crop value or loss. As for a horse race bet, the 'wagered' amount can be of any value.

An example of weather derivative offered in Australia is that offered since 2010 by CelsiusPro Australia from 2010 (https://celsiuspro.com.au/). CelsiusPro Australia is part of the Swiss Company CelsiusPro AG, founded in 2008. The company is specialised to develop and deliver weather derivatives. It is also operational in Europe and North America, with activity in a range of sectors, including tourism, construction, transport, energy, and agriculture. In Australia, all their weather derivatives products are based on publicly available data from the Bureau of Meteorology. A wide range of insurance services/certificates are available, including:

i. Rain day – if the daily rainfall is higher than specified at farm level on a given day
ii. Dry day – if the daily rainfall is lower than specified at farm level on a given day
iii. Frost day – if the daily minimum temperature is lower than specified at farm level on a given day
iv. Heat day – if the daily maximum temperature is higher than specified at farm level on a given day
v. Dry season – if the cumulative rainfall during a particular period is below than specified at farm level
vi. Rain season – if the cumulative rainfall during a particular period is above than specified at farm level
vii. Dry spell – if a dry spell occurs; where the dry day sees rainfall below specified threshold for a minimum number of consecutive days.

Participants do not need to make a claim. Pay-out is automatic, based on data from the Bureau of Meteorology (BoM). There is a need to establish more weather stations to make it possible for more accurate interpolation of data to a particular location.

Yield index insurance

For this product, insurance is taken on a forecast value of a crop. If the actual yield is lower than the original forecast due to events out of grower's control, the farmer receives a pay-out. A 'moral hazard' exists in that farm mismanagement can occur.

An example of yield index insurance is YieldShield[28] which was functional from 2009 in Australia (Hatt et al., 2012a). The product was apparently discontinued from 2018[29] due to low take up and the trademark was not renewed. It was offered by the Primacy Underwriting Agency (https://pum.com.au/), which combines traditional named peril insurance (on hail, fire, etc.) with yield indexes for wheat and grain and sorghum crops. Oz-Wheat and Oz-Sorghum were index models developed under the YieldShield banner. These products integrated data on climate, crop phenology and crop management practices, with calculation of parameters such as soil water balance and a crop water stress index. A linear regression was used to predict yield from the local stress index (Fig. 58).

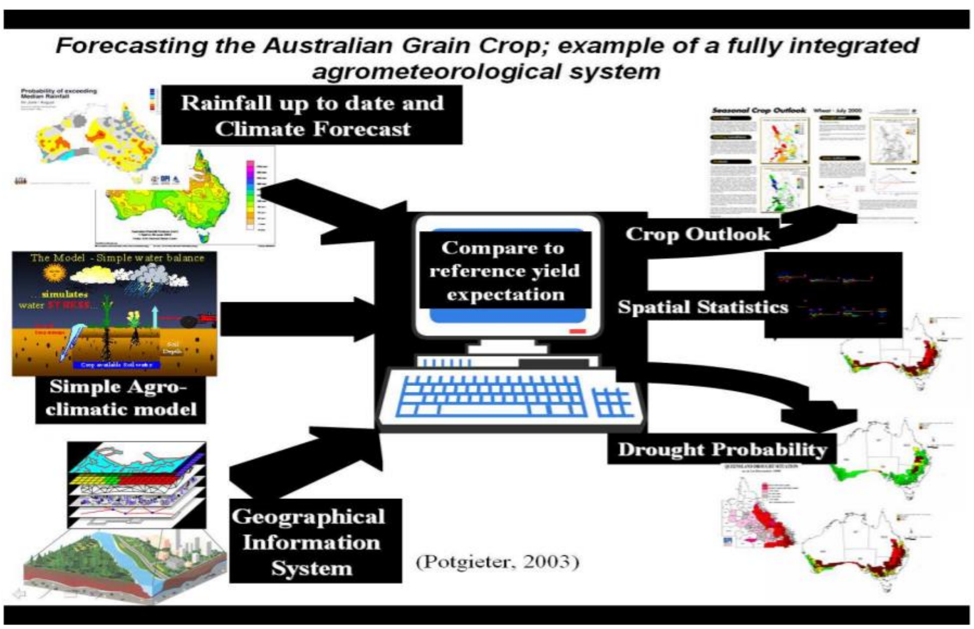

Figure 58: An example of an integrated agrometeorological system (Potgieter, Everingham, & Hammer, 2003)

[28] https://www.trademarkelite.com/australia/trademark/trademark-detail/1228644/YIELDSHIELD provides information about the status of YieldShield in Australia which is not renewed by paying the membership fees.
[29] https://search.ipaustralia.gov.au/trademarks/search/view/1228644?q=1228644 YieldShield trademark renewal fees were not paid from 2018 and was removed from the register published.

The following inputs are used in estimation of the insurance premium:

a. Shire-level average yield data
b. Climate-related factors
c. Timing of planting
d. Crop phenology
e. Crop management practices

Sophisticated protocols exist for forecast of yields of the broadacre grains industries, including use of time series satellite vegetation index imagery (Zhang et al., 2010). These protocols can operate at a continental scale. Such pre-harvest crop load estimation tools yields are used in trading, e.g., as offered by https://geosys.com/commodities-trading-logistics/.

Benami et al. (2021) report the use of weather and satellite data to lower the cost of yield estimation for index insurance, compared to field-sampling-based campaigns. However, remote sensing of vegetation health is a relatively poor indicator of tree crop yield, with better estimates achieved through manual count of a statistically relevant number of trees or by machine vision-based estimation, as reviewed by Anderson et al. (2021).

Area yield index insurance

This product is in between traditional and index products of insurance. It is based on local region yield levels. Growers receive a pay out if the average yield in the region is lower than a pre-specified average yield in the same region, irrespective of individual farm yield. This arrangement provides incentive for good farm management. These schemes are not available in Australia (Hatt et al., 2012a).

6.4 Insurance overseas

Named peril agricultural and MCPI insurance schemes on crop yield are common internationally with 100% availability in 21% of high-income countries (Table 5). All developed countries offer named peril insurance products while index schemes are less common and majority of them are at initial stage according to the World Bank survey (Mahul & Stutley, 2010).

Table 5. Number of yield and index-based crop insurance schemes.

Countries by development status	Number of countries %	Named peril %	MPCI %	Crop revenue %	Area yield index %	Weather index %
High income	21	100	48	5	10	10
Upper middle income	18	67	72	0	11	17
Lower middle income	20	45	85	5	25	35
Low income	6	50	17	0	17	33
Total	65	69	63	3	15	22

Data source: World Bank 2010

Subsidies are provided for crop insurance premiums by many high-income countries (Table 6) but not Australia, New Zealand, Sweden, Germany, Hungary, Czech Republic, Netherlands, and Greece (Mahul & Stutley, 2010). The level of government subsidies ranges from 52% in Canada, 67% US and 61% in Italy. Government subsidy for insurances began in 1930s when the US Federal Insurance Program was introduced during major droughts, with support continuing to the current day (Barnett, 2000). Government subsidised multi-peril crop insurance products grew in Latin America but then terminated in the due to poor performances. The USA, Portugal, India, the Philippines, and Spain tried to restructure national programs by introducing public-private partnerships (PPP).

Table 6. High-income countries with subsidies for crop insurance premiums (Source: World Bank, 2010)

Country	Fixed subsidy (%)	Variable subsidy (%)	Special subsidy for small and marginal farmers
Australia	n/a	n/a	n/a
Austria	50	0	Yes
Canada	0	0-100	No
Cyprus	50	0	No
Czech Republic	0	35-50	n/a
France	35	35-40	Yes
Israel	35	35-80	No
Italy	66	0	No

Japan	50	0	No
Portugal	0	45-75	No
Slovenia	0	35-50	Yes
Korea	50	0	No
Spain	0	4-75	No
Switzerland	0	0	No
Unites States	0	35-67	No

Crop insurance premiums vary from 3.5 to 10.3 % of crop value in Japan and Canada respectively. All schemes are voluntary, except in Japan where the compulsory schemes apply in wheat, rice and barley (Mahul & Stutley, 2010). The development of index insurance in developing countries has been supported by the World Bank, e.g., in India and Mexico (Barnett & Mahul, 2007). Weather index insurance was introduced in 2003 in India, with 250,000 policies sold in 2005-2006 (Barnett & Mahul, 2007). As noted (table 7), a number countries subsidize farm insurance, but this does not exist in Australia. In the absence of significant government support, (Hatt et al., 2012a) suggest insurance schemes are not likely to be viable.

6.5 Insurance for Horticulture

Fruit tree crops and the trees themselves can be insured for fire, hail, frost, and windstorm damage in a few countries. Policies can include a variety of additional benefits including replanting and re-establishment costs, firefighting and mitigation expenses, removal of debris, replacement of orchard infrastructure such as netting, harvested fruit, grading penalties, and restricted access costs (Hatt et al., 2012a). Cost depends on the type and age of the trees, their location, and the perils to be insured. This cover can be expensive, especially if frost cover is required (Hatt et al., 2012a).

Such insurance policies are government subsidised in the US and are widely held by orchardists there. Fruit load and tree evaluation services based on machine vision and LiDAR have become available to provide rapid orchard assessment for insurance evaluations (e.g., Agerpoint, https://www.agerpoint.com/).

Hatt et al. (2012a) notes that in the non-subsidized Australian market there is a very limited number of insurers and a product offer that tends to be change often and recommends that insurance policies should be reviewed on an annual basis. A broker like AgriRisk[30] that has access to a variety of insurers can manage this process for interested parties. Governments and industry organisations can assist in increasing awareness of insurance options as one part of building capacity to manage risks. For example, insurance was discussed in Growcom[31] (https://www.growcom.com.au/) organised bushfire relief workshops in Central Queensland.

6.6 Insurance for CQ small scale citrus producer

Consider the case of a small-scale citrus producer in CQ interested in cover to mitigate loss of income from loss of crop due to hail, cyclone, or fire. The producer has 500 trees in 20 ha producing 25-30 ton of fruit per year, with a farmgate price of approximately $100,000.

The producer could seek a weather index, e.g., with pay-out of $100,000 in event of a inclusion in a government Declared Disaster Area due to hail, cyclone or fire (https://insurancecouncil.com.au/consumers/help-in-disasters/), or in event of some specific weather event associated with hail, cyclone or fire, such as a 10 min mean windspeed over 100 km/h. Actuarial data would be used in calculation of risk, e.g. https://acquire.cqu.edu.au/ndownloader/files/25842647 history of cyclones on the Capricorn Coast.

Alternatively, the producer could seek a product that placed a value on the crop. Pay-out would be based on current production area and a historical average yield for the producers' farm or a regional average. To base cover on producers' yield requires third party verifiable data on previous and current yield, which does not exist in Australia. As noted earlier, in the US there are third party yield evaluation services that support insurance claims. To base cover on a regional average production is problematic, given the low level of citrus production in the CQ coast and the niche operations. Use of a regional average can also inappropriately subsidises a manager with generally below average yields and penalise a manager with above average yields.

The following insurance groups were contacted to supply a quote for this case: Nutrien Ag Solutions (https://www.nutrienagsolutions.com.au/), Agririsk (https://agririsk.com.au/),

[30] https://agririsk.com.au/ provides options for insuring horticulture, viticulture, cotton, broadacre, poultry and others.
[31] https://www.growcom.com.au/portfolio/bushfire-recovery-and-resilience-in-horticulture-industry-central-queensland-pilot-project/ provides information on pilot project related to bushfire relief and resilience schemes.

Queensland Farmers Federation (https://www.qff.org.au/), and WFI insurance (https://www.wfi.com.au/).

Of these insurers only WFI, which have an agent in Central Queensland[32], QFF, and Nutrien Ag Solutions responded. WFI did not have any product in offer for fruit crops whereas QFF is still in product development phase. Nutrien recommended a farm insurance product (https://www.nutrienagsolutions.com.au/insurance/insurance-products/farm-insurance) that covered infrastructure, machines, and crop. In addition, a weather parametric insurance product (Appendix G) was available from Nutrien Ag covering high and low temperature or rainfall high rainfall and hail events. Premium amounts are determined on case-by-case basis.

The insurance provider estimated a premium price around $20,000 against multi-perils for a crop valued at $500,000. This represents a premium of 4% of asset, i.e., equivalent to full value once in 25 years. Potentially growers in the region could aggregate to achieve this total value, sharing the premium cost.

Alternatively, growers could elect for a weather index. Relevant indices to cover a fire or cyclone vent would be:

i. Mean temperature in selected period
ii. Maximum temperature
iii. Minimum temperature
iv. Rainfall
v. Average rainfall in selected period

For instance, there was a huge bushfire around Cobraball region in November 2019. Leading into the event, the mean temperature of the month around that region was 28.1^0C with a maximum of 34.9^0C and minimum of 13.6^0C. There was a significant decrease in rainfall; only 0.2 mm recorded in November 2019, compared to average of 66.1 mm. If there was an insurance product quoting let say a cover of $500,000 for 1 month period (November 2019) with parameters nominated at <2mm rainfall and >34^0C temperature, what would the premium be? Is an interesting question for the CQ growers. An indicative premium of 7% of crop value was given, allowing assumed estimates of premiums and pay outs (Table 7).

[32] An agent is designated for Central Queensland region by WFI https://www.wfi.com.au/find-area-manager/profile/rikky-lynne-sands for farm insurances and others.

Table 7. Premium cost and pay out calculation based on yield and price of insured crop

Yield ton/ha	Variance from average	Five-year average ton/ha	Trigger yield (75% of five-year average)	Fruit price per ton	Premium cost (7% - cover 75%)	Pay out $/ha
20	10%	15	11.25	$2000	$140	$1500
10	-62.5%	16	12	$2200	$154	$1650

Modified from https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/02/multi-peril-crop-insurance-what-is-the-business-case

6.7 Conclusion

The volatility of risk in agricultural production has hampered the development of an unsubsidised insurance product in Australia. Given Australia is a country with a strong agriculture sector, development of these risk mitigating tools is important. It would be easier for the government and insurance companies if the insurance scheme was mandatory. An incentive to join a farm insurance scheme could be provided as is done for medical insurance (reduced taxation rate if a person belongs to a medical health insurance scheme). One possibility is to reduce disaster relief, with of funds to subsidise insurance.

The low demand for traditional insurance programs has resulted in the offer of index-based insurance products. Improvements in the BoM network of monitoring stations is important to improve the relevance of weather indices to a given farm. It appears that the current best option for a Central Queensland small scale citrus farmer interested in mitigating risk on a cyclone, fire or hail risk is to seek a weather-based index on criteria related to these events.

7.0 Evaluation of Technology for Rapid In-Orchard Assessment of Mandarin Brix

Abstract

Three portable devices based on near-infrared spectroscopy (F-750, SunForest H-100C, MicroNIR^{TM}) were evaluated for non-invasive estimation of Soluble Sugar Content (SSC) of intact mandarins, relative to destructive Brix measurement of extracted juice using a refractometer. Better results were obtained for tight skin variety like Imperial (RMSEP of 2.51) and Afourer (RMSEP of 0.43) compared to loose skin varieties like Emperor (RMSEP of 0.53). The SunForest unit returned the best result of the three instruments, but could not be used in direct sunlight, and the result of the prediction of the independent test set (R^2 of 0.66, RMSEP of 1.16 %SSC, bias of -0.42 %SSC) was too poor to support a recommendation for use of the current technology in a citrus value chain, given the variation in harvest populations was <2 %SSC in 4 of 5 populations assessed in this study. Instead, it is recommended that the current destructive method be undertaken with a sample number based on attribute variation, with fruit sampled using a systematic uniform random sampling strategy.

7.1 Introduction

The timing of harvest of citrus crops is based on an evaluation of fruit maturity in context of fruit Brix (soluble sugar content, SSC, measured of juice using a refractometer) and titratable acid (TA) levels. The BrimA index (SSC minus a constant times acid level) (Jordan et al., 2001) to replace use of a SSC:acid ratio as a maturity index (Stevens & Baier, 1939). This metric has been adopted by Citrus Australia within the Australian Citrus Quality Standards (https://citrusaustralia.com.au/growers-industry/citrus-quality-and-maturity). Product specifications on citrus commonly include a minimum SSC level and may now include a BrimA value.

The measurement of SSC and TA using a refractometer and titration, respectively, requires extraction of juice, i.e., destructive sampling. The cost and time requirement of this task limits the number of fruits a grower is willing to assess. The use of a portable, non-invasive technology that could assess SSC and TA levels of fruit on tree would be advantageous to grower assessment of harvest maturity. Such a measurement could be coupled to a geolocation and results displayed in a Farm Information Management System to guide the order of harvesting.

Near infrared (NIR) spectroscopy has become a popular tool for non-invasive assessment of fruit internal attributes in the last few decades (Greensill & Walsh, 2000; Zude, 2003; Zude et al., 2006). Kawano (1994) predicted citrus soluble solids from NIR spectra using partial least square regression analysis. (Zude et al., 2008) used a prototype NIR technology in field, noting SSC to plateau as citrus fruit reach harvest maturity. Grading lines now incorporate NIR technology, with on-line sorting of citrus Brix and acidity claimed e.g., Aweta (https://www.aweta.com/en/), MAF (https://www.maf-roda.com/en/page/packing.php). Several manufacturers have released generic handheld NIR units that can be used in field, and two manufacturers have released handheld NIR instruments targeted to the fruit industry, the F750 and F751 from Felix Instruments (Camas, WA, USA) and the H-100C from SunForest (Incheon, Korea).

A portable NIRS sensor would allow for assessment of fruit on tree, better supporting estimates of spatial variation in the orchard. Hand held technology is likely to be less accurate than the technology used on pack lines or in laboratory, given variation in ambient temperature and light levels (Golic & Walsh, 2006; Sánchez et al., 2003). However, the technology continues to improve, and portable NIRS technology is now employed extensively in the Australian mango industry (Walsh et al., 2020).

Such a tool holds promise for rapid non-invasive estimation of fruit attributes, but it must be used in context of a sampling strategy. The number of fruit (n) to be tested should be set in relation to sample variability (standard deviation, SD), as:

$$n = (t.SD/e)^2 \qquad \text{eqn. 1}$$

where t is the t statistic for an accepted probability, e.g., 1.96 for 95% confidence, and e is the accepted error as mentioned by Walsh et al (2020). For example, if the SD of the population is 2% SSC, then 64 randomly sampled fruit should be assessed for an accepted error of 0.5% SSC, for 95% confidence in the result. Further, there can be several flowering events across a farm, or within tree. These flowering events produce populations of fruit that are on a maturation 'trajectory' and should be assessed as independent populations. The populations are sometimes referred to as 'maturity zones.

The current exercise was conducted to evaluate three instruments for non-invasive assessment of SSC in citrus fruit, in context of recommendation for an Australian citrus exporter. As the review of Walsh et al (2020) criticises published work in which evaluation of NIR technology is based on test sets represented in the calibration set, a ‘real world’ evaluation scenario was undertaken, with device calibration based on different harvest populations of fruit than the test population.

7.2 Materials and Methods

Sample collection and Brix measurement

Citrus fruit of a range of mandarin varieties, maturity stages and sizes were sourced from multiple stores/producers. A range of tight skin varieties (e.g, Afourer, Imperial, Amerotti, Murcott) and loose skin varieties (e.g., Emperor) were experimented. The first population was comprised of 20 Afourer fruit and 10 Emperor fruit sourced from Woolworths and Lucht’s farms respectively. The second population was comprised of 30 Afourer fruit, with 10 fruit obtained from each of three retailers (Aldi, 10 small fruit, Coles, 10 mixed sizes fruit and IGA-Drakes, 10 large fruit). The third population also consisted of 30 fruit, with 10 Imperial fruit from Aldi, 10 Afourer fruit from IGA-Drakes and 10 Afourer fruit from Coles. The fourth population consisted of 10 Amerotti fruit, 10 Emperor fruit each from Mason’s farm and Lucht’s farms. All 120 fruit were used in calibration of the NIR instrument. A fifth population used as a test set consisted of a mix of 10 fruit of each of Afourer, Imperial, and Murcott varieties sourced from above mentioned stores.

Fruits were marked at two opposed points on the fruit equator. Spectra were acquired of fruit equilibrated to approximately 10, 20 and 30^{o}C. Fruit external temperature was measured using an Q1370 infrared thermometer (Dick Smith Electronics, Melbourne, Australia). After spectra were collected, fruits were halved, and a 20 mm diameter core was taken at the marked location on the fruit. The core was juiced by manually squeezing and Brix determined using a RFM 320 refractometer (Bellingham + Stanley, Kent, UK).

Spectroscopy

Spectra of fruit were acquired using each of three handheld spectrometers (Fig. 59). The F750 (s/n 17057; Felix Instruments, Camas, WA, USA) operates in the wavelength range 400-1100 nm and employs a per sample referencing procedure that is claimed to allow operation in full sunlight. The unit is marketed as for use with any thin-skinned fruit commodity. The SunForest H-100C (Korea) operates in the wavelength range 700 – 950 nm and is designed to be used specifically with citrus fruit. The Micro-NIR^{TM} (USA) operates in the wavelength range 900 – 1700 nm and is a generic portable spectrometer, not targeted to the fruit industry.

Figure 59: F-750 (left) SunForest (middle) and MicroNIR (right) devices.

Single spectra were acquired of each marked point on the fruit, giving two spectra per fruit, using each of the three handheld spectrometers. Spectra of the four populations used in calibration were acquired indoors, under fluorescent lighting. Spectra of the fifth population were acquired outdoors in a shaded area, i.e., under diffuse sunlight. Work is a direct sun exposed area was discontinued as the SunForest unit failed to record under such conditions, reporting an error condition.

Chemometrics

PLS regression was undertaken using The Unscrambler X (Camo, Norway). Spectra were pre-treated with mean centring and a 9-point second order polynomial 'Savitsky Golay' second derivative. Cross validation was based on use of twenty groups. The number of factors was based on that automatically selected by The Unscrambler software with manual confirmation based on with the 'smoothness' of the plot of regression coefficients.

The population of 120 fruit (240 samples) was used in calibration of the devices, with an independent population of 30 fruits used in testing.

7.3 Results and Discussion

NIR-SSC estimation

Fruit Brix varied between 6.9 and 15.2^o, with an average of between 10.30 to 13.49^o across populations and a standard deviation (SD) of between 0.87 and 2.39 across the five populations was achieved (Table 8).

Table 8. Statistics of reference SSC values

Population	Sample size	Average	SD	Max	Min

1	30	12.13	1.86	14.9	8.8
2	30	13.49	0.87	14.8	10.6
3	30	12.45	1.73	15.2	9.2
4	30	10.30	2.39	14.8	6.9
1-4	120	12.09	2.12	15.2	6.9
5	30	12.36	1.72	16.5	8.5

Example spectra of fruit recorded in laboratory (left panels) and outdoors (right panels) are shown in Figure 60.

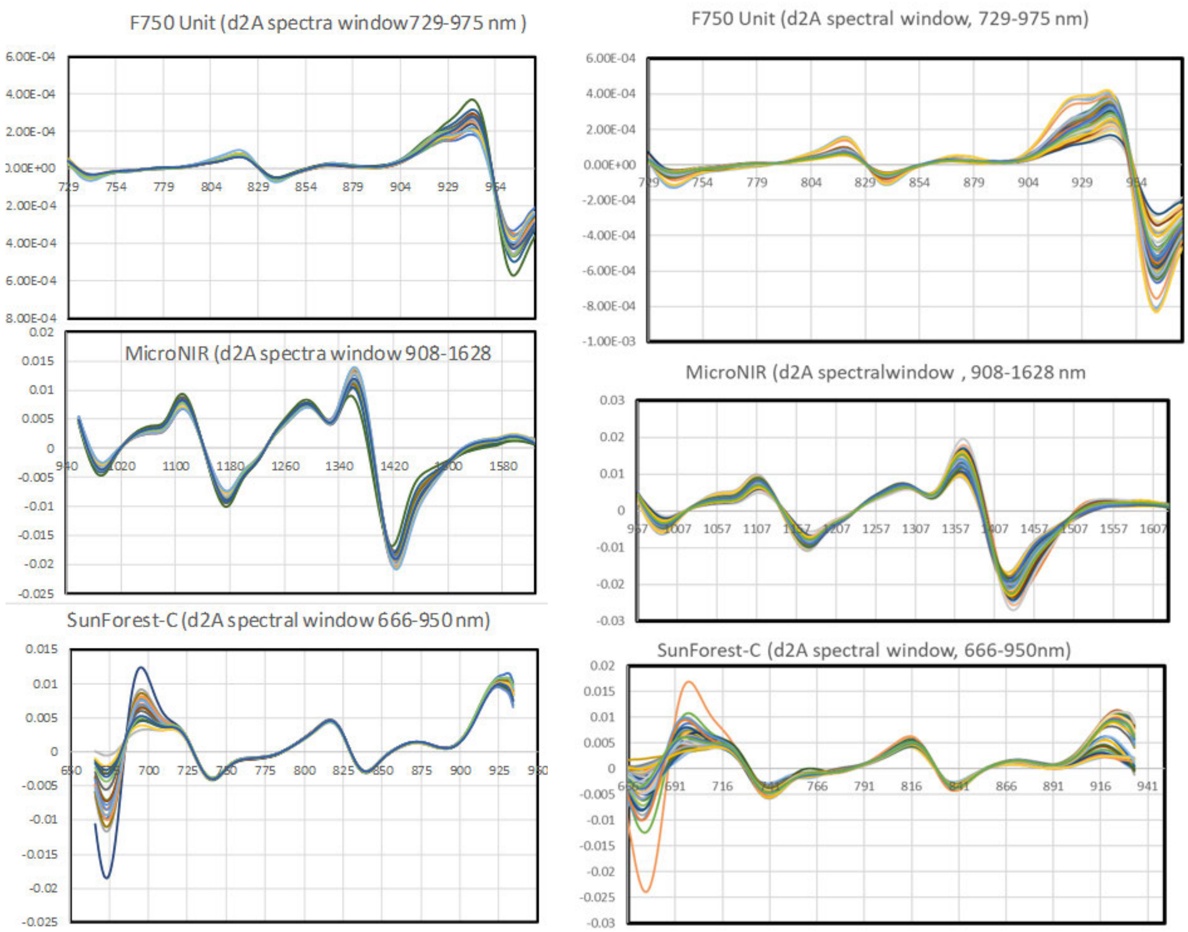

Figure 60: Second derivative of absorbance spectra of mandarin fruits recorded by F-750 (top), MicroNIRTM (middle), and SunForest (H-100C) (bottom). Spectra were acquired indoors (left panels) and in shaded field conditions (right panels).

The three devices were calibrated using the population of 120 fruits. The best cross validation result was achieved with the SunForest unit (Table 9).

Table 9. PLSR calibration (Cal) and cross validation (CV) statistics for a model developed for each device (120 fruit calibration population, fruit scanned in laboratory condition ~20^{0}C). #f refers to the number of latent variables used in the model.

Device		**Slope**	**offset**	**RMSE**	**R^2**	**#f**
F-750	Cal	0.83	1.98	0.86	0.83	7
	CV	0.81	2.18	0.98	0.78	
SunForest	Cal	0.87	1.50	0.50	0.87	9
	CV	0.86	1.67	0.55	0.86	
MicroNIR	Cal	0.87	1.50	0.74	0.87	6
	CV	0.87	1.57	0.78	0.86	

The best cross validation result for a model developed on the test population was again achieved using the SunForest unit (Table 10).

Table 10. PLSR calibration (Cal) and validation (CV) statistics of population 5 (fruit scanned under diffuse sunlight).

Device		**Slope**	**offset**	**RMSE**	**R^2**	**#f**
F-750	Cal	0.72	3.44	0.90	0.72	8
	CV	0.58	5.27	1.27	0.46	
SunForest	Cal	0.94	0.71	0.41	0.94	9
	CV	0.93	0.85	0.56	0.89	
MicroNIR	Cal	0.80	2.48	0.75	0.80	9
	CV	0.71	3.55	1.00	0.65	

The SunForest unit also returned the best prediction result of the three devices for the test population using a model developed on the calibration set of 120 fruit (Table 11).

Table 11. PLSR Prediction (Pred) statistics of citrus Brix

Device	**Cal set POPs**	**Pred set POP**	**SD**	**R^2_p**	**RMSEP**	**Bias**	**SDR**
F-750	POP 1-4	5	1.72	0.36	1.99	1.36	0.86
SunForest	POP 1-4	5	1.72	0.62	1.16	-0.42	1.48
Micro NIR	POP 1-4	5	1.72	0.39	1.87	-1.04	0.91

Fruit sampling

To obtain a measure of SSC that represents an orchard, an adequate number of representative fruits must be sampled. Given a SD of 2 %SSC and an accepted error of 0.4% SSC, the number of fruits that should be sampled to estimate the average SSC of fruit in an orchard at a 95% confidence level can be calculated using equation 1 to be 96.

For a sample of fruit to be representative of the orchard, fruit should be sampled randomly from within the orchard. However, locating random locations is difficult in practice. Instead, it is recommended that using a systematic uniform random sampling strategy. For example, if 96 fruit are required from an orchard with 1,000 trees, one fruit from every 10^{th} tree, with fruit taken from a different canopy side and position on each tree.

7.4 Conclusion

Of the three instruments, the SunForest (H-100C) instrument performed best for non-invasive assessment of mandarin SSC in shaded conditions. However, the device could not function in direct sunlight. Further, while the calibration cross validation results were encouraging (R^2 of 0.86 and 0.89, and RMSECV of 0.55 and 0.56 %SSC for two exercises, respectively), the result of the prediction of the independent test set (R^2 of 0.66 and RMSEP of 1.16 %SSC) was poor given the variation expected in future test populations (SSC SD was <2 %SSC in 4 of 5 populations assessed in this study).

In conclusion, this technology has documented value in harvest maturity assessment of thinner-skinned fruit types, but its use with mandarin or other citrus fruit is not recommended. The poor result is ascribed to the relatively thicker skin of mandarin. Sampling of a fruit number related to the level of attribute variability, using a systematic uniform random sampling strategy is recommended.

DECLARATION OF CO-AUTHORSHIP AND CO-CONTRIBUTION

Title of Book Chapter: Potential for Export of Citrus from Nepal to Tibet

The following chapter focusses to explore prospects for citrus trade into China, Tibet and is under peer-review for publication by NEPAFE- https://nepafe.org.au/ in preparation for the **Springer Book Series – "Achieving food, nutrition, and livelihood security: Principles and practices for sustainable farming systems in Nepal".**

NATURE OF CANDIDATE'S CONTRIBUTION, INCLUDING PERCENTAGE OF TOTAL

In conducting the study, I was responsible for forming the research question, collating literature, collecting data, interviewing Tibet-Nepal traders, importers/exporters, analysing available resources, drafting the paper.

This publication was written by me as a primary author and my contribution was 70%.

NATURE OF CO-AUTHORS' CONTRIBUTIONS, INCLUDING PERCENTAGE OF TOTAL

My co-author, Prof. Kerry B Walsh (k.walsh@cqu.edu.au), contributed to the paper by adding more information on relevant topics, his knowledge and expertise on the field, with additional wording and formatting on the draft covering 15% of the work. Other co-authors Dr. Phul Subedi (Central Queensland University, Australia; Email: p.subedi@cqu.edu.au) helped to find the platform for publication, shared available resources for reference, and helped with his knowledge and experience about Nepal communicating with importers and traders contributing 10%, and Sabnam Shivakoti (Government of Nepal, Ministry of Agriculture and Livestock Development; Email: shabnam.shivakoti@gmail.com), contributed with her policy level knowledge and expertise comprising 5%.

8.0 Potential for Citrus Export from Nepal to Tibet

Abstract

Citrus production is important to the economy of the mid hill areas of Nepal, bringing an estimated return of more than 5 billion rupees. However, the industry has been characterized by low profitability, with fragmented and short value chains delivering product of variable quality to local markets. The prospect for export of citrus from Nepal to the Tibet Autonomous Region is explored, based on the foundation of a phytosanitary agreement between China and Nepal, effective from 13 October 2019. A critical case study approach is adopted, based on information from actors in the current value chain. The potential market is described in terms of price and volume. A potential supply chain is described in terms of actors and pathways, including production areas, transport corridors and procedures for disease pest management, cold treatment disinfestation, and other phytosanitary protocols. Policy recommendations are made to allow small-holder farmers to participate in such a value chain, to achieve higher profit and improve livelihood security and to support the nation to achieve sustainable development goals (SDGs) related to poverty, hunger, economic growth, and industry, innovation and infrastructure related to citrus export.

Keywords: Citrus, Export, Livelihood security, Phytosanitary, Small-holder, Supply chain, SDGs.

Introduction

Citrus is a major fresh fruit globally. Global orange production for 2018/19 was estimated at 54.3 million tons, with annual production increased continuously over the last eight years (USDA, 2019). Global mandarin/tangerines production was estimated at 32 million tons, with China contributing 22 million tons (USDA, 2019). However, China still depends on imports for nearly 20% of the citrus consumption (USDA, 2019). This situation opens an opportunity for Nepalese farmers and exporters to serve the Chinese market.

China is aggressively pursuing trade opportunities worldwide for fruits, often trading rights of import of some commodities for the right of export of others (Reporter, 2019). Recent examples include: (i) an agreement on the export of melons from Brazil to China was finalized in November 2019 during the visit of Chinese President Xi Jinping to Brazil (Maxwell, 2019); (ii) a Chinese delegation visited Chile in late 2019 to inspect citrus orchards and packhouses, a step towards protocol approval for export of citrus from Chile to China (O'Callaghan, 2019b); (iii) In late 2019, Chinese inspectors monitored the Cambodian mango industry in terms of pest control and chemical pesticides use and recommended Cambodia to be eligible to export fruit to China (O'Callaghan, 2019a).

A trade agreement unlocks the door to trade, but much further work is required to open and maintain a profitable trade. For example, an Australia – China free trade agreement which included rights of export of Australian citrus to China was enacted in late November 2014, in the 21st round of negotiations which spanned almost a decade (Qi & Zhang, 2017). Australian citrus covers 28,000 ha of land involving 1,900 growers in the production of 715,000 tons of fruit (5-year average) worth AUD $627 million (Plant Health Australia, 2019). The value of Australian citrus exports to China increased from AUD $202 million in 2014 to AUD $435 million in 2018 (CitrusAustralia, 2018). There is a certain drop off percentage (16% drop of oranges in 2019/20) export due to COVID-19 pandemic but Australian citrus producers have consistently worked at developing this export market, changing varieties, agronomic practices, and marketing strategies (*Landline*, 2013). For example, Australian producer group regularly visits Chinese markets to monitor market status and quality standards to further develop strategies that maintain a higher price for their produce (O'Callaghan, 2019c).

Citrus has been promoted as a cash crop for the mid-hill districts of Nepal, with the Lumle Agricultural Research Center active in this area in the 1980s. Amongst fruit trees cultivation in Nepal, citrus is a number one in terms of area coverage, production, and income for mid-hills farmers. Citrus was cultivated in 42 districts with total land coverage of 46,412 ha, productive area of 28,406 ha and annual production of 271,908 tons of fruit (MoALD 2020). Of this production area, mandarins cover 27,951 ha contributing 177,381 tons of production, while sweet oranges and lemon are cultivated on 6,646 ha and 1,114 ha, respectively, producing 43,061 tons and 6,075 tons of fruits respectively (MoALD, 2020). This makes citrus the most cultivated and highest producing fruit crop in Nepal covering around 32% share in cultivation area and 37% in production. However, all production is consumed domestically, and all production occurs within a relatively narrow window of October to January. In consequence of this domestic consumption, increase in production results its price decline. This calls for an opportunity to export the product so that increase in production does not result in decline in price. A potential export market is Tibet - a proximate market - where a typical price for mandarins is NPR 200/ kg.

China and Nepal ratified an agreement in late 2019[33] that allows export of citrus from Nepal to Tibet on condition that phytosanitary measures are respected, especially in the context of the problem caused by fruit fly species and other diseases/pests. A National Preparatory Working Group (NPWG)[34] was also established to develop a protocol for the implementation of the agreement (MoALD 2019). China is also taking the problem of fruit fly species seriously in trade agreements with other countries. These agreements are briefly reviewed in this chapter, with treatments proposed that comply with these parallel agreements. Such an approach can avoid the need to invest in further research for the development of new protocols.

This Chapter also explores market and pricing details in Tibet, the likely treatment and transport pathways, and costs to establish a likely return on investment and sustainable pricing on citrus fruit. With such information, this Chapter is expected to help National Preparatory Working Group, which was formed by Government of Nepal to prioritize and work on export trade. A critical case study approach is adopted, based on information from actors in the current value chain with the potential market in terms of price and volume. The potential is explored in terms of the actions needed to meet the phytosanitary conditions of that agreement, likely transport pathways and value chain actors and market size and value. It is also hoped that this information will inform growers and traders considering investment in such a trade and benefit relevant government agencies considering actions to facilitate such trade.

Livelihood improvement and sustainable development goals

Poverty alleviation directly targeted to disadvantaged groups often produces only a localized and relatively short-term benefit. In contrast, lifting economic activity of the whole population can have generalized and long-term benefit to rural peasant and disadvantaged groups. China offers an example of the success of such an approach.

The removal of barriers on international trade results in improved market efficiencies and thus increased economic output and improved livelihood security (Victor, 2007). However, the removal of barriers can be initially disruptive if imports displace non-competitive domestic production. It is argued that in the longer-term economic effort shifts to sectors that are competitive in international markets, with efficiency of that sector improved by access to the best

[33] https://www.fmprc.gov.cn/mfa_eng/wjdt_665385/2649_665393/t1707507.shtml includes the joint statement between the People's Republic of China and Nepal dated 2019/10/13

[34] This NPWG group was formed in 2020 by the Government of Nepal, Ministry of Livestock and Agriculture Development to prepare an action plan for implementation of the protocol.

supply of inputs, whether that be domestic or imported. This improves the general welfare of the country (Victor, 2007).

International horticultural trade has grown dramatically in recent decades, with notable increases in trade between South American and African countries and the relatively wealthier northern hemisphere countries (Barrientos et al., 2003; Olaitan et al., 2019). Such trade has contributed to livelihood improvement across the globe. Successful trade can result in improved rural economies and enhanced livelihood, but success requires correct choice of commodity and improved practices in horticulture value chains that deliver product quality at reasonable prices (Kumar & Gupta, 2015).

A useful example is provided by the Swift Co., Ltd. group in Thailand as a sustainable fresh produce business practice (Suthavivat, 2018). A group of managers out of the airline industry in Thailand established grower groups focused on air freight export of asparagus and mango fruit. The increased profit from the export markets supports a range of benefits to the small producers as part of ethical business[35]. They have also managed to maintain a traceability system even if the produce is gathered from group contract farming (Deyi, 2005).

A similar grower co-operative model could be used to support citrus export from Nepal, with the aim of higher returns to Nepalese citrus enterprises. This aim addresses SDG goal 1, poverty reduction, hunger (goal 2), economic growth (goal 8) and is relevant to industry innovation and infrastructure (goal 9) (Liu et al., 2015; Stevens & Kanie, 2016).

Nepal has two neighboring countries each with populations over 1 billion. At present export of citrus product (fruit, fresh or dried) to India is valued at only $USD21,000 (https://trendeconomy.com/data/h2/Nepal/0805; doa 21/07/2021), and no citrus is exported to China. Citrus export to India is problematic as India produces citrus in the same period of the year as Nepal. Though, Nepal exports citrus through formal and informal sources, Indian market does not entertain a huge quantity of export either it be citrus, other fruits or vegetables. In addition, the official export channel is not open with distinct protocols in place compared to China which have specific protocols and clear description in place. This chapter focusses on prospects for citrus trade into Tibet, China.

[35] http://www.thaifreshproduce.com/en/company-overview/ethical-business/

Prospects of Nepal to China citrus trade

China is a major importer of citrus. The import of citrus to China is expected to exceed export by 4,650,000 metric tons (Chunjie, 2000) by 2030 AD (Table 12). In recent years, with the increase of disposable income of Chinese residents and the increase in the living standards, Chinese quality of life has also risen steadily, subsequently the demand for fruit continues to increase. Data shows that in 2020, China's citrus market demand was 48.22 million tons with average yearly increasement rate of 10.91% (Table 1). The China Commercial Industry Research Institute predicts that the market demand for citrus in China will reach 51.568 million tons in 2021 (data not shown). Liu Jiang (2000) reported that the per capita demand of total fruit, apple, and citrus in China in 2015 was 60.0, 16.0 and 11.7 kg per person per year with total demand of 87.1, 23.2 and 17.0 million tons, respectively. The per capita demand was projected to increase to 93.6, 20.0 and 16.0 kg per person per year with total demand of 149.8, 32.0 and 2.56 million tons, respectively in 2030.

Table 12. Estimated balance of fruit supply and demand in China (units of 10,000 ton).

Fruit type	Items	2015 Actual	2016 Actual	2017 Actual	2018 Actual	2019 Actual	2020 Actual
All fruit	Consumption	24654	24441	25337	25904	27665	28956
	Production	24525	24405	25424	25688	27401	28692
	Difference	129	36	-87	216	264	264
	Share in Demand	0.52	0.15	-0.34	0.83	0.95	0.91
Citrus	Consumption	3547	3527.7	3786.3	4093.1	4539.8	4822.5
	Production	3617.5	3591.5	3816.8	4138.1	4584.5	5121.9
	Difference	-70.5	-63.8	-30.5	-45	-44.7	-299.4
	Share in Demand	-0.02	-0.02	-0.01	-0.01	-0.01	-0.06

Source: China Business Intelligence Network (https://www.163.com/dy/article/GN07PV2P051481OF.html)

China is a potential market for Nepalese citrus fruit. Goods can be exported to China from Nepal through India, transiting by sea via the Indian port of Kolkata. However, custom issues and shipping time have precluded such export.

The direct export of Nepalese citrus to neighboring Tibet region is a more achievable goal. Under the 'Protocol on Implementing the Agreement on Transit and Transportation between Nepal and China' (MoALD 2019) which became effective in February 2020, Nepal can export through six dedicated transit points between Nepal and Tibet. Also, an MoU was signed between Nepal and China on the 13 October 2019 to undertake a 'Feasibility Study of China-Nepal

Cross-Border Railway Project' (Pandey, 2020). These agreements are indicative of increasing trade prospects.

Nepal boasts a comparative distance advantage in the supply to the Tibet market, even relative to the citrus production areas of China. Tibet has negligible citrus production and relies entirely on the import. While Tibet is a modest market, with a population of approximately 3.3 million, the major urban centers hold market promise, with a population of around 1 million in Lhasa and 0.7 million in the Shigatse area. Within the population, relatively well paid ethnic Chinese government employees and military and a rising middle class are target markets for a slightly more expensive product offer (Fischer, 2011).

At the consumption rate of 2015, the annual market for citrus in Tibet would be around 8,190 metric tons for Shigatse, 11,700 metric tons for Lhasa, and almost 38,610 metric tons for Tibet as a whole. This amount is equivalent to 15% of the current citrus production of Nepal; 246,269 MT in 2017 (Knoema, 2020).

Nepal – China phytosanitary agreement on citrus

A phytosanitary trade agreement for the export of citrus from Nepal to Tibet was first enacted in 2012. This protocol was the first such agreement entered into by Nepal government for the export of agriculture products with another government, and therefore presents a model for establishing similar specific trade agreements for other products.

This agreement lapsed at the end of its two-year life. No exports occurred in this period. The agreement contained a clause requiring "the fruit (to be) from an area free of pests and diseases" (Table 13). This condition could not be met as the listed pests, including the fruit fly species, *B. dorsalis*, *B. zonata*, *B. cucurbitae*, *B. tsuneonis*, and *B. correcta*, are endemic in citrus production areas of Nepal. Various protocols were developed for survey and surveillance of disease and insect pests, orchard management, pest control, farmer, and orchard registration.

Table 13. List of pests and diseases included in various phytosanitary agreements for the export of citrus fruit to Tibet/China

Pest/disease	Nepal to Tibet 2012 (*Citrus reticulata, C. sinensis, C. limon*)	Nepal to Tibet 2019 (*Citrus reticulata, C. sinensis, C. limon*)	China to Mexico 2014 (*Citrus reticulata, C. sinensis, C. hybrids, C. maxima, C. grandis*	Egypt to China 2006 (Citrus fruits)	Australia to Thailand 2011 (*Citrus reticulata, C. sinensis, C. limon*)	Pakistan to China 2005 (*Citrus reticulata, Citrus sinensis*)
Xanthomonas spp. pv citri						
Citrus Greening disease						
Bactrocera correcta						
Bactrocera cucurbitae						
Bactrocera dorsalis						
Bactrocera tsuneonis						
Bactrocera zonata						
Bactrocera minax						
Bactrocera tryoni						

A new agreement (MoALD 2019) was signed on 13th October 2019 during the visit of Chinese president Xi Jinping to Nepal. This agreement allows for the export of "pest-free product", i.e., the product and not the production area must be free of designated pests, with the product to be from designated production areas and packhouses practicing control measures. The agreement is set to automatically extend in its current form unless the parties enter negotiations for alterations.

The agreement, however, does not stipulate the disinfestation treatments to be used for elimination of the listed pests. These conditions must therefore be proposed to, and agreed by, Chinese authorities. The Nepal-Tibet agreement involves the same fruit fly species as is covered in the China-Mexico, Pakistan-China, and the Egypt-China agreements (Table 2).

The phytosanitary rationale for Chinese requirements

Citrus greening disease (or yellow dragon disease), citrus canker and several fruit flies listed in Nepal-Tibet agreement are already present in China, including the Chinese provinces neighboring Tibet. *Bactrocera dorsalis* and *B. minax* are present in the neighboring provinces of Sichuan and Yunnan (BiosecurityAustralia, 2009) (Figure 61). *Bactrocera cucurbitae* and *B. correcta* were recommended to be monitored in Yunnan (a neighbor province to Tibet), Guangxi, Hainan, and Guangdong provinces (Qin et al., 2015).

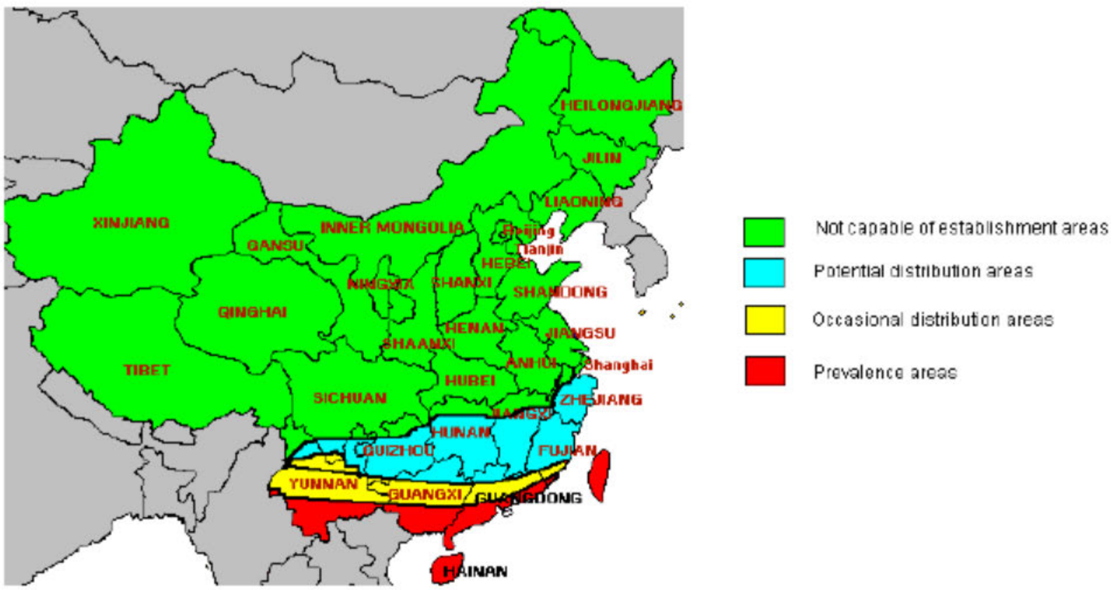

Figure 61. Distribution and potential establishment areas for Bactrocera dorsalis in China (Source: Biosecurity Australia, 2009)

The pests included in the Nepal-China agreement are unlikely to occur in Tibet, given its climate. *Bactrocera dorsalis* and *B. minax* are reported as not present in Tibet (CABI, 2019). The possibility of the establishment of fruit fly in three low altitude pocket areas in Tibet of relatively milder climate was considered (Yu Hui, 2011), with Chayu (900 km east of Lhasa) being reported as a moderately suitable district for the fruit fly species *B. zonata.*

Given that these pests and diseases occur in China and are unable to establish in Tibet, the requirement for product free status in the Nepal-Tibet trade agreement could be questioned in future negotiation rounds.

Treatments for fruit fly control

Conditions (cold treatment durations) are slightly harsher in the China-Mexico agreement than the Egypt-China agreement (Table 14). Nepal should propose the conditions of the Egypt-China agreement for the Nepal-Tibet trade because of lower holding day (only 16 days) requirement in this agreement compared to others.

Table 14. Cold treatment temperature ranges for fruit fly in citrus, as stipulated in trade agreements.

Protocols	Temperature range (°C)	Duration (Days)	Fruit fly species
Egypt-China (2006)	<0 0-0.55 0.55-1.11 1.11-1.66 1.66-2.22	10 11 12 14 16	All economically significant Tephritidae fruit flies (*Bactrocera zonata* included)
China-Mexico (2014)	<1.11 1.11-1.67 1.67-2.22	14 16 18	*Bactrocera correcta, B. cucurbitae, B. dorsalis, B. tsuneonis*
Pakistan - China (2005)	<1.67 <2.22	17 22	*B. zonata, B. dorsalis,*
Australia – China (2017)	<1.00 <2.10 <3.00 <3.00	16 21 18 16	*B. tryoni, Ceratitis capitata,* Queensland fruit fly, (total 20 pests of quarantine concern for China). 3^0 for 16 days is valid only for lemons.
Nepal-China (2019)	n/a	n/a	All five species mentioned above in Egypt-China, China-Mexico, Pakistan-China protocols

Potential market

The main potential markets for citrus in the Tibet region are the urban areas, which are relatively close (848 km) to the Nepalese border. The population of the urban region of the capital Lhasa is approximately one million. Shigatse, which is on the Nepal to Lhasa transport corridor, holds a population of 0.7 million. Lhasa has a large resident population of Han Chinese who fill government and military roles. The potential for premium pricing for the more affluent local middle class and higher paid ethnic Chinese government workers and military should be explored.

Trade border between Nepal and Tibet was not regulated until early 1960s (the Sino-Nepal boundary agreement was enacted on 21 March 1960). Nepalese citrus fruit was transported through the border crossing at Zhangmu to Lhasa and other parts of Tibet. According to a trader who was involved in that trade (Buddha Ghising, *pers. comm.*), competition with fruit from mainland China came after the railway between Xining and Lhasa came into operation in 2008.

Nevertheless, Nepalese fruit always achieved a minimum price of 5 RMB per kg (NPR 100 per kg).

A market study tour visited the markets of Shigatse and Lhasa during the period 13-19 December 2013 (DMEGA, Parbat 2013). The Lhasa market price for citrus was recorded at 16 Yuan (260 NPR; 3.33 AUD)/ kg for seedless and half that price for seeded fruit. A price of 12 Yuan (195 NPR; 2.5 AUD), 10 Yuan (162 NPR; 2.07 AUD), and 8 Yuan (130 NPR; 1.66 AUD)/kg for Nepalese A, B, and C grade seeded citrus, respectively, was recommended. The 2020 market prices for oranges in Beijing are 3.96 Yuan per 0.3 kg bag (13.18 Yuan/kg) (Numbeo, 2020). A trader based in Lhasa, contacted in August 2021, reported citrus fruit remains the most popular fruit in Tibet, with around 300 tons traded per day in the Lhasa market at a typical price above 5 RMB/kg. It was also noted that premium price was paid for 60-80 mm diameter citrus fruits. According to the trader, the Nepalese fruit were larger than the fruit from mainland China, providing opportunity for export into Tibet. It is recommended that the Nepal embassy in Tibet collect seasonal prices and volumes of citrus sales in Lhasa and Shigatse.

Treatment options

To meet the phytosanitary conditions in the Nepal-China agreement, the product must be treated to be fruit fly free. The Agreement does not specify treatments; it only states that "the treatment should be done according to international standards". Methyl Bromide fumigation is a short and effective fumigant (for an example protocol see (DAF, 2015), but this treatment is being phased out worldwide due to the toxicity of the chemical. Low-temperature treatment (Table 14) may be presumed to be acceptable under the Nepal-China agreement.

Mandarins and lemons are considered 'soft' citrus, being less tolerant of low-temperature conditions compared to sweet oranges. In Australia, mandarin fruits are held at 2.5-3°C for 16 days to achieve fruit fly pest-free status for the product. Mandarins from the southern cooler regions are cooled directly to 2°C whereas fruit from warmer northern regions are initially held at 7°C for 24 hours and then cooled to 2.5-3°C. Mistakes made in the de-greening process, in terms of holding fruit at higher than recommended temperatures or ethylene levels, render fruit more vulnerable to chilling compared to fruits de-greened with 5 ppm ethylene at 24°C (*pers. comm.* Noel Ainsworth, DAF, Australia).

The procedures used in Australia to bring the fruit temperature down are recommended for use in Nepalese export to Tibet, i.e., fruit should be brought to 7°C for approximately 24 hours to cold harden, then chilled to 3°C within 48 hours. This would normally be done in a forced-air chilling room (Rao, 2015). The design of a typical forced air cold room is described by (Ferrua & Singh, 2009). A typical establishment cost for a unit capable of holding fruit equivalent to two 20 ft shipping containers is AUD$4600 (HomeGuide, 2020). If this facility is lacking, modest volumes of fruit could be treated using an ice water bath.

After reaching 3°C, fruit can be moved to shipping containers (Fig. 62) to hold this temperature for the required treatment period of approximately 16 days (Table 14). Refrigerated shipping containers can hold temperatures as low as -20^{o}C, however, the product entering container must already be at the desired temperature, i.e., the container cannot lower the temperature of the product. Given the use of a forced-air chilling room treating two shipping containers of fruit every 48 hours, use of 16 shipping containers is recommended, with loading of two containers every second day for a 16-day treatment period.

Figure 62. Right panel: Refrigerated container (20ft) capable of holding 24 tons of fruit. Left panel: insertion thermometer with data logger.

The major running cost of such a facility is electricity. The electricity required to maintain a 120 m^3 cold room at 7°C for approximately 24 hours and 3°C for 48 hours is estimated at 149 kWh/day (Evans, 2017). At a cost of AUD$0.15/kWh, this is a cost of $7.44 per container per day or AUD$0.00075 per kg of fruit per day. The electricity required to operate a 20 ft shipping container at 3^{o}C is estimated at 50 kWh/day (Evans, 2017). At a cost of AUD$0.15/kWh, this is a cost of $120 per container over a 16-day holding period or AUD$0.012 per kg. The total electricity cost for cold storage treatment is thus estimated at AUD$0.012/kg.

Internal fruit temperature should be logged using an insertion thermometer (InstrumentChoice, 2020). To comply with Nepal to Tibet agreement, temperature records would need to be maintained and subject to an on-site inspection by MOALD/PQPMC assigned quarantine officers.

Transport options

There are six entry points to Tibet from Nepal, but only two are suitable for substantive vehicle traffic. These crossing points are at Tatopani and Rasuwagadhi (Fig. 63). Dry ports are under construction at both crossing points. At Rasuwagadhi, the 8.5 ha dry port will have parking space for 350 trucks and associated containers, with 5000 m^2 land set aside for a five-story administrative building (quarantine office, customs office, banks, and post office). Two customs clearance areas on 2080 m^2 land with a 750 m^2 warehouse are included in the plan (Devkota, 2019). The dry port construction was slated to be ready by May 2022, but the work is on hold[36] due to COVID-19 outbreak. For citrus from the Syangja production area, both routes present a similar distance, at ≈1289 km via Galchhi-Rasuwagadhi and ≈1234 km via Kathmandu-Tatopani. For Sindhuli citrus, the Tatopani route is shorter, at 1050 km (Fig. 3).

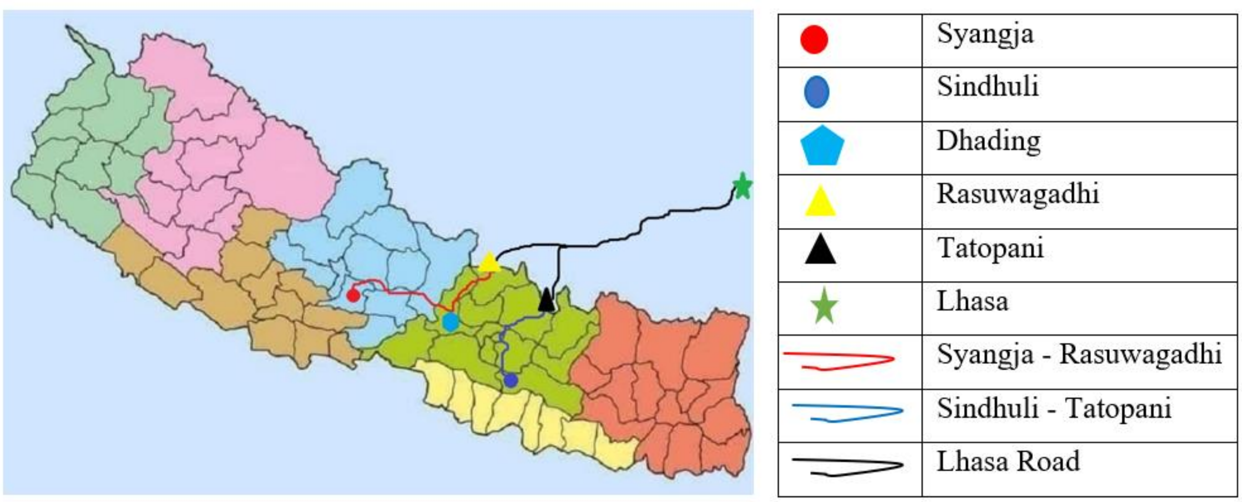

Figure 63. Main citrus production areas (Syangja and Sindhuli) and border exit points (Rasuwagadhi and Tatopani) to Lhasa, Tibet. Map source: Google Maps (2020)

With an existing trade imbalance, many trucks importing goods from China to Nepal return empty to the border. Trucks are closed bodies, with goods protected from sunlight and rainfall, but there is no use of refrigerated containers. There is a large trade in apples from China through

[36] https://kathmandupost.com/money/2021/03/19/construction-of-rasuwa-dry-port-on-hold-since-virus-outbreak provides information related to the pause in dry port construction due to COVID-19 outbreak.

Tibet into Nepal and India, and the use of these trucks in backloading citrus from Nepal to Tibet should be considered (*pers. comm.* Mr. Buddha Ghising; an importer, and Mr. Bharat Khanal; a fruit wholesaler/supplier in Kathmandu).

During the Nepalese citrus production season, temperatures in Tibet ranges from -1°C (average night temperature) to 15°C (average daily high temperature). These minimum temperatures could lead to citrus fruit damage if the non-insulated trucks are left parked for prolonged periods. Transport should be arranged to avoid overnight parking, or insulation should be added to truck sidewalls.

The location of a cold treatment facility is critical in terms of its sustainability and secondary utility for crops other than citrus. The site must also have continual electrical power supply. With Nepal Electricity Authority (NEA) now able to supply power without load shedding, this should not be a problem in any location across Nepal.

A potential site for a cold treatment facility is in Dhading in the Galchhi area (Fig. 63). This is a major vegetable producing area, with potential for the cool store to serve both industries. Vegetables such as cauliflowers, cabbage, radish, carrot, and peas could be stored during the peak season to supply into shoulder seasons, i.e., over the window of February-August, achieving higher prices for producers. Usage for the citrus season would involve the months October to February.

An alternative is to place a relocatable cold treatment facility in the production areas of Syangja and Sindhuli for the duration of the citrus season. Another alternative is to place a transportable treatment facility at the border, with seasonal relocation of the facility to vegetable production areas.

If the treatment facility is at the border, in areas free of the fruit fly, boxed fruit could be moved from refrigerated containers to transport trucks in the open place. However, if the treatment facility is in an area known to the harbor fruit fly, the fruit will need to be in fruit fly proof netted boxes or pellets, allowing for safe transport from the treatment facility to the border (Fig. 64).

Figure 64. An example of a fruit flies netted pallet from Profresh[37] and labelled carton ends from Syangja (2015) providing information on variety and source.

Fruits should be transported in cardboard cartons to allow for the labeling required under the Nepal-Tibet agreement (Fig. 64). An AusAID Public Sector Linkage Project (PSLP) implemented through the Micro-enterprise Development Program (MEDEP) sponsored the local production of such cartons in 2015 (PSLP, 2012-2016). The production of such cartons was undertaken in Pokhara by Goshali Print Pack Pvt. Ltd.

Recent years the province and local governments also supporting growers and traders through flagship Prime Minister's Agriculture Modernization Project by suppling carton packs for packing for domestic transportation.

Nepalese phytosanitary arrangements

Officers assigned by the Ministry of Agriculture and Livestock Development (MOALD), Plant Quarantine and Pesticide Management Center (PQPMC) and Department of Agriculture (DOA) are responsible for the implementation of the phytosanitary conditions of the Nepal-China agreement. Therefore, PQMC should be in regular and direct communication with the Chinese phytosanitary counterpart to confirm a clear understanding of required arrangements. The National Plant Protection Organization (NPPO) should also have regular contact with its counterpart in China.

Nepalese government-certified phytosanitary officers will need to be available to inspect and sign off on documentation at the treatment facility. This could involve the inspection of two containers of product and temperature records every second day, i.e., a very part-time role.

[37] https://www.profreshsystems.com/pallet-wrapping-systems provides details on pallet wrapping systems.

MOALD/ PQPMC should establish the cost of this service and decide if this cost will be borne by the Government or by exporters. If the latter, a charge per container should be set, to allow for exporters to factor this cost in when estimating the viability of the trade.

Site visits of proposed production areas, packhouses, transport, and treatment facility design by the Chinese phytosanitary group should be set before each citrus season.

Preparatory documentation

The following documentation is required in support of a visit by a Chinese phytosanitary group:

- List of proposed registered infrastructures (orchards, packhouses, storage facility, cold treatment facility, transport vehicles)
- Standard Operating Procedures (SOP) for grower registration, packhouse registration, farm and packhouse inspection
- Surveillance report and integrated pest management documentation
- Training and certification of PQPMC officers to issue a phytosanitary certificate
- Phytosanitary certificate issue

Standard Operating Procedures (SOP)

SOP for Packhouse registration and grower registration by packhouse:

A Packhouse must demonstrate the following processes are in place to be accredited for export:

(a) Maintenance of a list of growers supplying the product, with name, phone contacts, geolocation (latitude/longitude).

(b) Provision of training provided to these growers on orchard health and hygiene (e.g., training manual).

(c) A system at Packhouse for visual inspection of all fruit and all fruit surfaces, e.g., rolling of fruit along with a table, with the removal of all defect fruit, augmented by inspection aids (posters with images of fruit with various disorders).

(d) A system for training of grading staff.

(e) Evidence that staff can recognize diseases and pests.

(f) Maintenance of shed hygiene: removal of waste fruit, separation of graded export quality fruit from other fruit.

(g) Labelling of the export product with grower and Packhouse details (as in Fig. 4).

(h) Procedure to notify PQPMC of intent to ship when accredited shed has product ready.

Responsibility allocation

A Nepal to Tibet citrus value chain would contain the following main actors: (i) growers; (ii) packhouse/co-operative; (iii) transport company; (iv) trader; (iv) government agencies involve in pest inspection and certification; (v) cool room suppliers/maintainers and others associated with the supply of citrus production, promotion, and marketing accessories. A summary of the citrus value chain actors is presented below (Fig. 65). Packhouse/co-operative would assist small growers with management tasks.

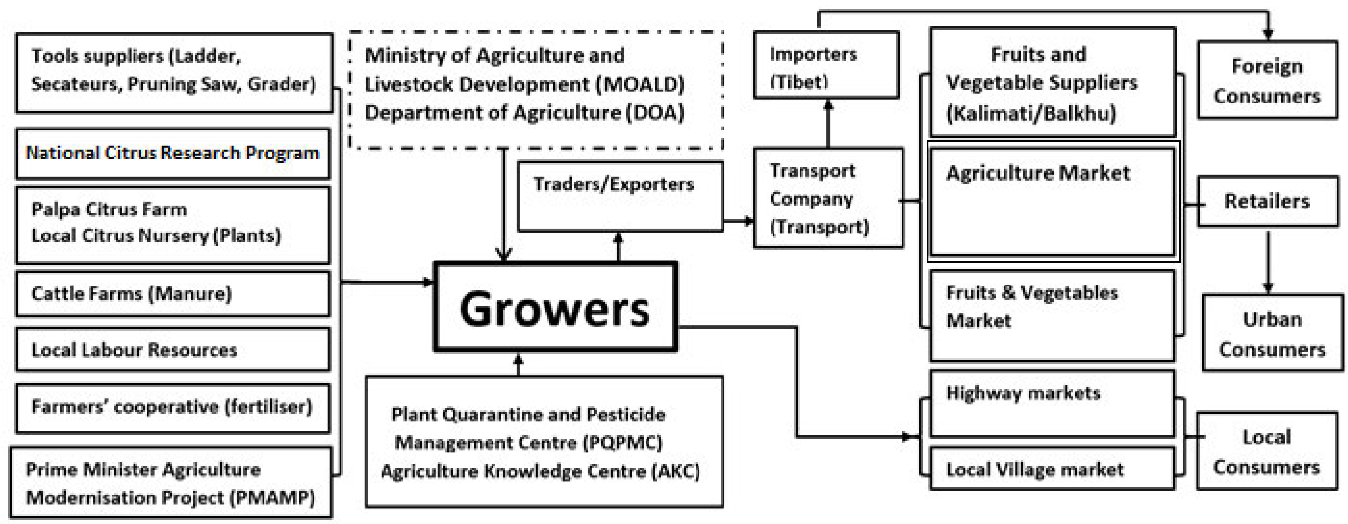

Figure 65. Value Chain actors in Nepalese Citrus value chain including a potential chain of citrus export to Tibet (Source: Own sketch based on (Ahmad et al., 2018))

Growers

- Orchard registration with packhouse/cooperative
- Documented integrated pest management with packhouse/cooperative support
- Implementation of integrated pest management

  Export quality fruit production

Packhouses/cooperatives

- Assist growers
- Registration for export
- Documentation (packhouse & orchards supplying fruit)

- Packaging and labeling requirements
- Truck/Container loading

Government of Nepal, Ministry of Agriculture and Livestock Development Plant Quarantine and Pesticide Management Center /, Department of Agriculture

- Communication with China phytosanitary office,
- Support area-wide pest management plans,
- Orchard inspection and Packages of Practices verification.

In-season requirements

- Cold treatment consignment sample inspection and phytosanitary certification,

Cost-benefit analysis

Most critically, financial analysis of cost of production, transport, and export marketing from Nepal to Tibet is important, to support (or discourage) private investment. This will also help to account for specific costs of production, transport, storage, treatment, handling, export taxes and other unknowns. A tentative estimate of the cost-benefit analysis for a per kg of mandarin orange showed that it is highly beneficial to export mandarin in Tibet (Table 15). An average Nepal market sale per kg of citrus fruits is around NPR 56, which sets an extra income of around NPR 150 per kg of fruits if exported to Tibet at current market price in Tibet (12 RMB/kg). The estimated net benefit from exporting citrus by deducting cost, transport, treatment, packaging, phytosanitary inspection, and export tax is NPR ~ 156/kg. This is an overwhelming price and benefit for small-holder growers and Nepalese traders if proposed trade of citrus is implemented timely and effectively to improve the livelihood status of the people living in mid-hill region.

Table 15. Cost-benefit analysis of proposed citrus trade.

Particulars	Cost (NPR/kg)	Remarks
The current cost of production	9.0	Subedi et al. (2008) reported NPR 4 for the cost; with adjustment for inflation
Loading for extra work and disease control 20%	1.8	
Packhouse costs including cartons	8.5	Syangja carton cost around NPR 80 for 10 kg size
Transport	6.0	Including Tibet transport cost
Cold treatment	1.0	assumption based on other calculations

Phytosanitary inspection	0.2	Government could subsidies, otherwise minimum cost for growers
Total Cost	26.5	
Proposed sale price	210.0	Current value[38]
Gross Profit	183.5	
Taxes	27.5	Assuming 15% taxes
Net Profit	~156.0	

Conclusions

Citrus production has provided a cash flow to the mid-hill farmers of Nepal. There is potential to improve returns through export of product to Tibet, given proximity of this market relative to production areas in China and based on the foundation of the phytosanitary agreement between China and Nepal allowing such export.

The potential market is described in terms of price and volume. A potential supply chain is described in terms of actors and pathways, including production areas, transport corridors and procedures for disease pest surveillances, management, cold treatment disinfestation, and other phytosanitary protocols. Key requirements for such a value chain include (i) development of packhouses with management skills to support grower groups achieve pest management and related documentation, to implement sorting procedures and cold treatment procedures, (ii) development of transport options, ideally involving back-loading of trucks delivering goods into Nepal from Tibet, and (iii) development of a phytosanitary certification service by MoALD. To catalyse investment into development of this value chain: (i) a system of recording citrus prices in Tibet is required, perhaps collected through the Nepalese consulate in Tibet; (ii) the proposed pest management and certification procedures should be communicated to and agreed upon by the Chinese authorities.

The estimation of cost-benefit analysis of citrus trade from Nepal to Tibet revealed that it is highly beneficial to export citrus from Nepal to Tibet (China). The per kg of citrus is nearly four times higher in Tibet (NPR 210) as compared to current farm gate price (NPR 56/kg) in Nepal. By accounting for all the transport, treatment, storage, handling, inspection and export tax, it is possible to get an extra NPR 150 per kg of fruit in the current trade scenario. This is an

[38] https://www.numbeo.com/cost-of-living/country_result.jsp?country=China includes price of oranges around 12 RMB per kg, conversion rates applied.

overwhelming price benefitting small-holder growers and traders if proposed trade of citrus is implemented timely and effectively.

Despite high export potentials and benefits, currently no citrus is exported from Nepal to China. A small quantity of citrus is exported to India, but this export is problematic as India produces citrus in the same period of the year as Nepal. Moreover, Indian market does not entertain a large quantity of export due to lack of the official export channel with distinct protocols in place compared to China which has specific protocol and clear description in place.

A recommendation is therefore made to capitalize export opportunities to Tibet (China) by developing Syangja district as mandarin production site and Sindhuli district as sweet orange production site with establishment of cold disinfestation treatment facilities in a feasible distance (Dhading or Kathmandu) and transport into Tibet through the border crossings at Rasuwagadhi or Tatopani. Use of cold disinfestation protocols agreed to by China in phytosanitary agreements with Egypt is recommended. Further advice should be taken from these agreements that China did with other countries for the design and operation of appropriate cold treatment or cold chain facilities. For increasing the volume of export, other prospective neighboring districts in Nepal such as Baglung, Parbat, Myagdi, Ramechhap can also be promoted as citrus production sites and protocols of production, packing and transportation can be agreed upon in subsequent negotiations.

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9.0 Conclusions

By definition, a value chain seeks to increase the value of a product at each step in the chain. Although the scale and market niche differed for each of the citrus chains considered, all strive to target and defend an evolving target market. Within the constraints of resources, multiple case studies allow greater insights into the overall operation of value chains. The three small scale Australian case studies captured different with each addressing a different market segment, and also captured change over time. The two large scale value chains faced similar issues but varied in their emphasis on domestic and export markets. The two Nepalese case study areas varied in production scale and potentials, e.g., the small producers above 1500 m elevation have potential for greening disease-free production of nursery stock and fruit free of fruit fly. The characterisation of the Australian value chains also informed the critical case study of the Nepal to Tibet export trade, in aspects from pest control to transport and export protocols.

Small scale Byfield area production

Citrus production in the Byfield area began a century ago, enabled by the higher rainfall and the proximity of the Rockhampton market. Growers adopted new production techniques and took advantage of improved transport options to access metropolitan market, with a 'golden era' for traditional production occurring in the late 1970s-early 1990s. The importance of market pricing and timing is illustrated by the reported sharp rise in prices and profitability following the exit of other small growers in the 1980s, but before the entry of the large growers of Central Burnett and Emerald. The development of citrus production based on irrigation schemes affording greater security of water supply and larger areas of cheaper undercut the Byfield producers. The remaining Byfield areas producers attempted to target niche local markets, such as local IGA stores with an 'heirloom' local variety, and biodynamic production. However, the producers lacked the scale to provide resilience to catastrophic events, such as cyclone and drought.

As recovery from major weather events was identified as a major constraint to the small scale Byfield area citrus producers, an evaluation or relevant insurance products was undertaken. Classic yield insurance products are not available, given the small scale and lack of documentation for insurers to estimate risk. However, weather index products are becoming available which could be appropriate to mitigate risk.

Large scale Wallaville area production

The large-scale producers of Wallaville have developed sufficient scale to self-insure and to play into export markets, being able to deal with the extra complexity of the export process. Their major concerns include labour supply, disease and pest management, documentation of practices, harvest load and harvest timing estimation. The labour supply issue has been accentuated by the COVID-19 pandemic. Harvest load and harvest timing estimation are critical to harvest resourcing, including labour supply, and marketing/postharvest decisions.

A concern was expressed by these large-scale producers that the level of innovation in the industry has dropped off, with the citrus industry judged to be "at least 10 years behind when compared to the apple industry". A range of technology innovations are relevant to the address the identified constraints, such as automated insect monitoring (e.g., RapidAim, https://rapidaim.io/), machine vision based fruit load estimation (Anderson et al., 2021), portable non-invasive tools for estimation of fruit quality and harvest maturity Walsh et al. (2020) and the development of farm decision support tools that maintain documentation (e.g., targeting tree crop production: TieUp Farming (https://www.tieupfarming.com/) and Farmable (www.farmable.com)

Optimum harvest timing currently relies on cutting and juicing of fruit for measurement of soluble solids content (SSC), making this process cumbersome. A technology for portable, rapid, non-invasive estimation of SSC of fruit on tree was evaluated. The prediction statistics for a test set were relatively poor (R^2 of 0.66, RMSEP of 1.16 %SSC, bias of -0.42 %SSC), such that the current technology cannot be recommended for use by the value chain.

Nepalese production

The Nepalese citrus industry was characterised by a very short production window, causing over-supply of the local market and low prices. The low profitability of the value chain limits investment into improved production and postharvest practices, such as increase of landholding size, adoption of a range of early to late-ripening varieties, use of grafted stock, use of nets and hail/frost protection, use of irrigation, and use of refrigerated storage or transport.

There is potential to improve returns to Nepalese citrus value chains through the export of citrus to Tibet. This potential is based on the proximity of this market relative to production areas in China, the foundation of the recently enacted phytosanitary agreement between China and Nepal allowing such export, and a recently established government system established to support grower groups capable of exporting produce. Recommendations for such an export trade were made, based on the experiences gained of the Australian export-oriented value chains. This included establishment of cold disinfestation treatment facilities and a cold disinfestation protocol for negotiation with China, based on a review of phytosanitary agreements made by China with other countries. These recommendations were taken by National Preparatory Working Group formed under the Ministry of Agriculture and Livestock Development (MoALD) in support for drafting policies about citrus export to Tibet.

Summary

All the value chains considered in this thesis were evolving, with lessons to be carried between the different chains. In particular, a number of practices and arrangements from the Australian value chains hold value for the Nepali value chain and the potential trade into Tibet. For example, the Byfield area producers operated at a similar scale to Nepali producers, yet operated in a vastly different way, using far less human labour, and paying much more attention to niche marketing arrangements.

In ten years, in 2031, it is anticipated that: (i) small scale citrus production will still occur in the Byfield region, focussed to niche local grown' markets; (ii) the large scale, export focussed Wallaville producers will have adopted technology that directly and indirectly reduces dependence on human labour, from automated sprayers and harvesters to technologies for fruit load estimation; and (iii) the Nepalese citrus industry will expand production with improved grafted varieties and adopt new sorting machines establishing packhouses and export citrus fruits.

In terms of techniques, the Qualtrics survey tool was useful to gather information from the Government officers in Nepal with acute utilisation of time and resources they have these days and considering they are not keen in giving interviews. NVivo analytics could be useful if it was used in a comprehensive way but for the current research, it was helpful to save a lot of time transcribing interviews (using NVivo transcription feature) and categorise information into certain groups (codes or value chain features).

The major limitation of the thesis work lies in the extent of the 'value chain walk' in the Australian value chains, in particular of the large retailer customers, and of the export process. Further work verifying grower claims of retail customer interest in biodynamic produce (Mason farm) or Emperor mandarin (Lucht farm) could also have been undertaken. Also, the process of export and a characterisation of markets could have been undertaken for the large (Wallaville) farms.

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Appendices

Appendix A: Information sheet

Improving Citrus Value Chains in Nepal, addressing key constraints in comparison with Australian and Nepalese examples

Project Overview

The main purpose of the study is to characterise the various citrus value chains in Australia and Nepal while identifying constraints they are facing. It is envisaged that improvements to those value chains will be identified within this project.

Research aim

b. To characterise and suggest improvements for three citrus value chains by identifying key constraints.

Research objectives

c. To undertake descriptive case studies of three different citrus value chains (Australian large-scale conventional value chain, Australian small-scale value chain; and typical Nepalese value chain), with identification of critical constraints and advantages in each chain
d. To evaluate suggested solutions to a limiting factor of each chain

Research questions

1. What are key constraints to these citrus value chains?
2. What solutions can be proposed for these constrains?
3. What aspects of Australian citrus value chains are adaptable to Nepalese citrus value chains?

The main significance of the project lies in developing a sustainable value chain model where both small-scale and large-scale citrus industries can adapt and implement for their effective and better performance.

Participation Procedure

You are invited to participate in an interview which consists of:

A series of questions about the history, development, motivation, past and present scenarios of your citrus value chain and industry, methods, and methodologies you use for efficiency or general management, production, pest management, harvest, package, and market citrus fruits.

Completion of the interview will take around 60 minutes.

Benefits and Risks

Participation in this project may not have significant benefit, but it will contribute towards the development and improvement of the citrus value chains which will support future management and role allocation for the actors involved in the citrus value chains.

The implication of potential technologies may benefit the small-scale, organic and large-scale citrus industry to learn, adapt and take positives in their value chain operations. The agriculture management system as well as the future farming system will significantly benefit from this project.

There is no anticipated risk to you greater than that of inconvenience for the time taken to complete the interview and discussion. We do not anticipate that participation in this research will cause you any undue discomfort beyond that experienced in normal day to day living.

Confidentiality / Anonymity

The project will not collect any identifying information; your responses will be de-identified as soon as you have verified the accuracy of our transcribed interview. There may be a risk of inadvertent identification, after publication of the findings, if fellow citrus growers are able to identify events, or processes that are described. The researchers will endeavour to minimise this inadvertent identification.

Data will be securely stored for five years after the publication date of the last paper/document based upon the data in accordance with the CQUniversity Code of Conduct for Research.

The data will be securely stored in accordance with CQUniversity policy. It is anticipated that the data may be disposed on the later part of the storage time mentioned above.

Outcome

The results of this research will be disseminated primarily in the form of a master's degree thesis and in the form of journal articles and conferences. The findings of the proposed research will contribute to new knowledge for developing the citrus industry; and, it will also provide an effective precision agriculture tool to assist management make harvest or market decisions.

Consent

Your consent to participate in this project will be obtained through your acceptance/agreement to the written consent form signed before the interview.

Right to Withdraw

Your participation in this research is voluntary. You may withdraw at any time prior to initiating the interview simply by sharing with the researcher. We believe the scenario will not arise as the expected questions and topics will be shared prior to the interview for preparation. The interview will only be initiated after the respondent confirms participation.

Feedback

You may request to receive a copy of the findings of this research by indicating this on the consent form.

Questions/ Further Information

If you have any questions about this project, please contact the Chief Investigator Mr. Dipendra Aryal d.aryal@cqu.edu.au or the research team of Prof. Kerry Walsh k.walsh@cqu.edu.au and Dr. Phul Subedi p.subedi@cqu.edu.au .

Please contact Central Queensland University's Division of Research (Tel: 07 4923 2603; E-mail: ethics@cqu.edu.au; Mailing address: Building 32, CQUniversity, Rockhampton QLD 4702) should there be any concerns about the nature and/or conduct of this research project.

This project has been approved by the CQUniversity Human Research Ethics Committee, approval number 0000022287.

Appendix B: Consent-Recruitment text

Hi! I am Dipendra Aryal; a permanent resident of Nepal and currently a Research Higher Degree Masters student at Central Queensland University, Rockhampton, Australia. I am here to study the Citrus value chain as I hope to improve the citrus industry of Nepal. I would like to assure you that the information you provide will be kept in confident and stored on password protected servers at CQUniversity. The anonymity and confidentiality will be maintained, and only de-identified data will be used in proposed publications. For our study, I am here with a series questions related to citrus production and marketing relative aspects. It is anticipated that the interview may take up to an hour to complete and with your permission I will be (audio) recording the conversation. Would you be interested and available to participate? If yes, you would be contributing to the future development of the citrus sub-sector of your area and Nepal/Australia as well. The information you provide will be assembled and analysed to draw conclusions for necessary improvement in technologies and methods of farming and marketing for the Australian and Nepalese citrus value chains.

Appendix C: Semi-Structured Interview Topics

Target Respondents:

a. Input Suppliers – Nursery, fertiliser, chemicals, cold room providers
b. Growers
c. Co-operatives
d. Traders – Middlemen, Agents
e. Packhouse operators
f. Transporters
g. Wholesalers
h. Retailers
i. Marketers/exporters
j. Research Institutions – Government, Institutions, Universities

Topics list:

1. Introduction (everyone)
    - details of the person, business history & experiences
    - income and expenditure/investment
2. Production / Packages of Practices (growers)
    - land ownership – lease/contract, plant quality, cultivars/varieties
    - organic farming history and motivation
    - fertilization, irrigation methods and frequency, fertigation, labour supply, training pruning, weed control
    - manure/compost management for the organic operation
    - decision making on the harvest, tools used, practices making a difference in - production, quality, any idea on per-unit costs
    - forward sale and system of forward sales
3. Pests & diseases (growers/input suppliers)
    - pests, diseases, economic or quarantine, damage on quantity/quality/price/demand
    - technology for prevention or control – economically feasible or not, pre- or post-harvest treatment, any idea about alternatives, any thoughts on residue hazard, the

effect on beneficial organisms, application time after a first sign or severe infestation on crops
- type of pesticides, frequency of use, who applies it, any attempts made to minimize costs, equipment used for the application, the magnitude of damage on crops, any recorded disorders

4. Pre-harvest treatments (growers/packhouse operators)
   - physical treatment, why is it done, who does it and when
   - impacts on quantity/quality/storage/shelf life/ market value
   - chemical treatments done or not, recommended treatments if any, aware/unaware of any treatments
   - identify any which favours post-harvest quality
   - problems affecting production, processing, post-harvest, and marketing
5. Costs for production and marketing (everyone)
   - Capital – land/drainage/vehicles/irrigation/farm equipment or machines/ processing facility/cold rooms/packhouses/ others
   - Operating/maintenance – vehicle management, water supply, tools replacement or repair, others
   - Production costs – planting/material/fertilization/irrigation/pest & disease control/ weed control/mulch/training pruning/harvesting/in-field transport/labour/other
   - Post-harvest and marketing cost cleaning/sorting/grading/waxing/ packaging/ cooling/storage/ branding/loading/unloading/transport – packhouse/market
6. Crop harvest (growers/traders/research institution)
   - Who harvests the crop, why this operation is important, use of harvest tools, the harvest time of day, what conditions, preferred temperature/rainfall/humidity?
   - Harvest time (maturity stage) for local, domestic and export markets
   - Methods impacts – quantity, quality, value; any idea about the volume unsuitable for market
   - Causes behind the unsuitability - size, weather, pest, disease, the nutrient in the soil, sun, harvest, others;
   - Percentage suitable for the market - approximate

- How are fruits selected for harvest? Production age – yield ratio; optimum harvest parameters (Brix, colour, texture, taste)
- Any idea on maturity indices? What criteria looked after by pickers? Sensitivity to mechanical damage during harvest taken into consideration. Dehydration issues recorded or not?
- Other problems (if any)?

7. Sizing and grading (growers/packhouse operators/marketers)
    - Where are the points of operation? Who does it? When is it done? Why is it done?
    - Labour involved record, machine used, market demand on size and grade
    - Any criteria on shape, size, weight, maturity, colour, pest, disease, physical injury, mechanical injury, cleanliness, and others
    - Any degreening and washing/waxing facilities?
    - Are any standards used? For example, Grade A, B, C / 1, 2, 3 / Export, Local, Juice
    - Is the approximate percentage of fruits moving into separate categories/grades?
    - Problems influencing post-harvest losses (if any)?
8. Cooling (packhouse operators/exporters)
    - Direct cooling or pre-cool?
    - Method of cooling- cool room/hydro/icing/forced air/air conditioning; how long is it done? how long after harvest? Who does it? What temperature range is used?
    - Once cooled, is it removed before the final market? Cost per kg for cooling? Any problems raised by cooling which affect post-cooling life or market?
9. Storage (packhouse operators/exporters)
    - On-farm/rural collection point/packhouse/retail/wholesale/agro-industry/supermarket/ other
    - Type, purpose – await shipping, await better market/ maintain quality/ assemble larger volumes
    - Any storage facility equipment in use? At what degree of maturity/ripeness is the best storage stage?

- Change in quality recorded or not? Is Air & RH control done or not? Stored alone or with other products? Cost of storage? Problems affecting post-harvest loss (if any).

10. Packaging (packhouse operators)
    - Why is it done? Who does it? Where is it done? When is it done? How long does it take?
    - Material used for packing. Why is it used? What size packing is preferred? Mechanical strength during handling/transport/stacking/storage; availability of packing materials assured or not?
    - Domestic/export requirements? Cost per packing or per kilogram? Cushioning by soft materials done or not? Why is it done or not done? Reuse them or not? If not packaged; why not? Problems impacting on post-harvest loss (if any).
11. Transport (transporters/marketers/exporters)
    - How many times – where to where? Methods of transport? How much and how the stacking of produce is done? Damage / Bruise in the fruits recorded? Any idea to minimize that?
    - Cost – labour/packing/vehicle/containers/others? Duration of transport? The distance of travel from field to packing house and to destination market?
    - Who owns the product during transport? Risk of damage born by producer or wholesaler/trader? Problems encouraging post-harvest loss (if any).
12. Marketing intermediaries (traders/wholesalers/retailers/institutional buyers/processers/brokers)
    - Percentage load for each value chain actors? Price determination controlled by grower or marketer? Is the quality problem faced during the operation? Volume problem based on demand and supply?
    - Do you have a specific trader/wholesaler/consumer group for organic citrus, or they just go in a general pathway?
    - What tricks are used for making a higher return? Adding leaves to give fresh looks/placing the best fruit on top? Any problems within the chain?
13. Market information (growers/traders/marketers/exporters)

- Any price information source? Farmgate price? Wholesale price? Retail price? Export price and market?
- Seasonal price index? The window of marketing? Fluctuations in price and volume demand? Lowest / Highest prices in the season?
- Consumer demand/excess supply/imports/exports/regulations/substitutes/other
- Highest prices – public/supermarket/agro-industry/exports/institutions/government buyers/others
- How about the organic market status in the country and outside?

14. Consumer demand (traders/marketers/exporters)
    - Domestic market %? Export volume percentage? Consumers group – regular/temporary/occasional
    - Any preferred parameter - cultivar? Size? Colour? Flavour? Texture? Maturity degree? Package type? Unit per package?
    - Acceptance of blemishes or minor external damage? Quality or price in the priority of consumers? Sensitivity in price fluctuation?
    - Is organic produce higher in demand among the consumers?
15. Export (exporters)
    - Export variety, cultivar/size/weight/colour/flavour/acid: brix ratio/ texture/ maturity degree/ packaging/ pest control requirements/ chemical residue limit/ grades or standards/ religious or cultural characteristics
    - Trade barriers in importing country. Few years trend on import/export
    - Limitation – infrastructure/technology/assistance/funds/other; transport via sea/air; insufficient volume/delay in payment/trade barriers/others
    - Competition- quality/supply/price/methods/research & development
16. Losses (growers/packhouse operators/marketers)
    - pre-harvest – frost/natural disasters/hailstorm/rain/wind/pests/disorders
    - harvest- tools/skills/tree canopy conditions/tree health
    - transport – geography/container/tools
    - grading/packaging – heaping/bulking/size/squeezing/machine wearing/bruising
    - storage- unseen injuries/bruising/unloading or shifting

- shipping- road/transport used/distance/time of storage
- market- unloading/retailers taste preference/others

17. Prices (respective value chain actors)
    - farm gate, trader, broker, wholesaler, retailer, consumer
    - is the organic status providing more benefits compared to other conventionally produced fruits?
18. Areas of potential improvements throughout the value chain? If you have any suggestions, please share (everyone)

Appendix D: Nepal-China Citrus Export Protocol (2019)

Protocol of Phytosanitary Requirements for the Export of Citrus Fruit From Nepal to China
between
Ministry of Agriculture and Livestock Development of the Government of Nepal
and
General Administration of Customs of the People's Republic of China

For the purpose of safe exports of Nepali citrus fruits to China and on the basis of the pest risk analysis, the Ministry of Agriculture and Livestock Development of the Government of Nepal (hereinafter referred to as MoALD) and the General Administration of Customs of the People's Republic of China (hereinafter referred to as GACC), have exchanged views and reached a consensus as follows:

Article 1

Nepali citrus fruits exported to China, including sweet orange (*Citrus sinensis*), mandarin orange (*Citrus reticulata*) and lemon (*Citrus limon*) (hereinafter referred to as citrus) must comply with the relevant phytosanitary laws and regulations of China and satisfy the phytosanitary requirements as stipulated in this Protocol.

The citrus fruits exported to China should be limited in Xizang Autonomous Region for consumption and use.

Article 2

Citrus shall be free of any quarantine pests concerned by China which are specified in the Appendix.

If any other pests are newly detected in citrus growing areas that have not been assessed by GACC, MoALD shall inform GACC as soon as possible, in order to determine if they are quarantine pests and adopt proper quarantine measures if required.

Article 3

The citrus orchards and packinghouses (including cold treatment facilities) shall be registered officially by MoALD, and jointly approved by GACC and MoALD. Before each export season, MoALD shall provide GACC with a list of citrus orchards and packinghouses.

Article 4

The citrus orchards shall be monitored and found free of the following quarantine diseases. If any of these pests are detected, the relevant orchards will be banned from exporting citrus to China for the season.

1.*Candidatus Liberibacter asiaticus* Jagoueix

2. *Xathomonas campestris pv. citri* (Hasse)

For the following quarantine pests of concern to China, citrus fruits shall come from the orchards that conduct cold treatment before export according the international standards or the standard that both sides agreed. Upon request by MoALD, GACC will provide technical assistance for the establishment of cold treatment facilities and shall support capacity enhancement activities for the concerned MoALD officials and farmers.

1. *Bactrocera correcta* (Bezzi)
2. *Bactrocera cucurbitae* Coquillett
3. *Bactrocera dorsalis* (Hendel)
4. *Bactrocera tsuneonis* (Miyake)
5. *Bactrocera zonata* (Saunders)

Article 5

Under the supervision of MoALD, the citrus orchards and packinghouses shall undertake effective monitoring, precaution and Integrated Pest Management (IPM) to avoid and control the occurrences of quarantine pests of concern to Chinese side; and ensure that orchards and packinghouses maintain the phytosanitary conditions.

Upon request by GACC, MoALD shall provide GACC with relevant procedure and results of the above-mentioned pest monitoring, precaution and IPM programs.

Article 6

The processing, packing, storage, and transportation of citrus shall be conducted under the quarantine supervision of MoALD. Before the packing, citrus shall be culled and sorted, those with the color or surface are abnormal shall be removed, to ensure that citrus are free of insects, mites, rotten fruits as well as twigs, leaves, roots and soil.

The citrus processed (selected for packing) shall be stored separately in the chamber to avoid re-infestation. The packaging material shall not be of raw plant material, and for citrus shall be clean, sanitary, unused.

Every citrus packaging carton shall have markings in English indicating the place of origin, the name or registration numbers of orchards and packinghouses. The cartons must be marked with Nepali, Chinese and English characters "For Export to the People's Republic of China".

Article 7

MoALD will sample no less than 2% of fruits in a consignment for export quarantine inspection. In cases where live quarantine pests of concern to China are detected, the whole consignment shall not be exported to China.On completion of quarantine inspection, MoALD shall issue a Phytosanitary Certificate, with the following declaration:

"The consignment is in compliance with Protocol of Phytosanitary Requirements for the Export of citrus fruit from Nepal to China and is free of any quarantine pest concern to China". The Certificate shall indicate in English the producing area, the orchard and the packinghouse. The Phytosanitary Certificate of shipments having undergone cold treatment before export must indicate the cold treatment temperature and duration, together with the facility name or code.

MoALD shall supply GACC with a template of the Phytosanitary

Certificate in advance of trade, for confirmation and keeping record.

Article 8

When citrus arrives at entry port, China Customs (the port branch of GACC) will examine relevant certificates and labels, and conduct a quarantine inspection. For items having undergone cold treatment before export, the cold treatment results with attached MoALD's sign-offs, as well as fruit temperature sensor record table, must also be delivered.

In cases where citrus comes from unapproved orchards or packinghouses, the shipment shall not be allowed entry.

Any shipment that is determined as the cold treatment is invalid shall undergo a cold treatment at the destination port (such as in the container itself), or be returned or destroyed.

In cases where any quarantine pest or other non-compliances is found, the citrus shipment shall be re-exported, destroyed or quarantine treated (only limited to cases where pests can be exterminated effectively).Accordingly, GACC may suspend the importation of citrus from relevant orchards and/or packinghouses or even suspend the whole program until both parties conduct investigations to find out the causes and take relevant corrective measures.

If such situation arises GACC will facilitate to MoALD for technical support from the People's Republic of China to comply with the quarantine requirements of China.

Article 9

After signing of this Protocol, if necessary and agreement is reached by both sides, GACC will send two quarantine inspectors to Nepal to conduct on-site investigation, audit and inspection of the citrus growing areas, orchards, packinghouses, to examine pest monitoring and control.

Article 10

GACC shall conduct further risk assessment according to the pest occurrences and interceptions information. In consultation with MoALD, the quarantine pest list and relevant quarantine measures shall be adjusted.

Article 11

In order to ensure the efficient performance, all operations and activities described in this Protocol could be reviewed and evaluated. This protocol may be revised by mutual agreement between the two countries.

The Protocol will come into effect from the date of signature. It has two-year validity.In the case that neither party requests revision nor termination within two months before its expiration date, the Protocol shall be extended automatically for every year.

This protocol is signed in Kathmandu on 13 October 2019 in duplicate in Nepali, Chinese and English languages, each side shall retain a copy of all texts. All texts shall be equally authentic and in case of divergence of interpretation, the English text shall prevail.

For the Ministry of Agriculture and Livestock Development of the Government of Nepal

For the General Administration of Customs of the People's Republic of China

Signature Redacted

Name: Yubak Dhoj G.C.

Designation: Secretary

Date: 2019/10/13

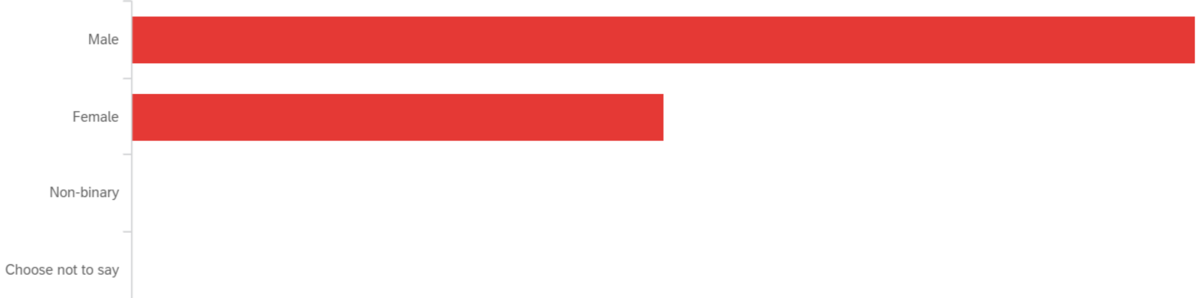
Name: Hou Yanqi

Designation: Ambassador

Date: 2019/10/13

Appendix E – Qualtrics Survey Summary

1. Male vs Female participants in the survey

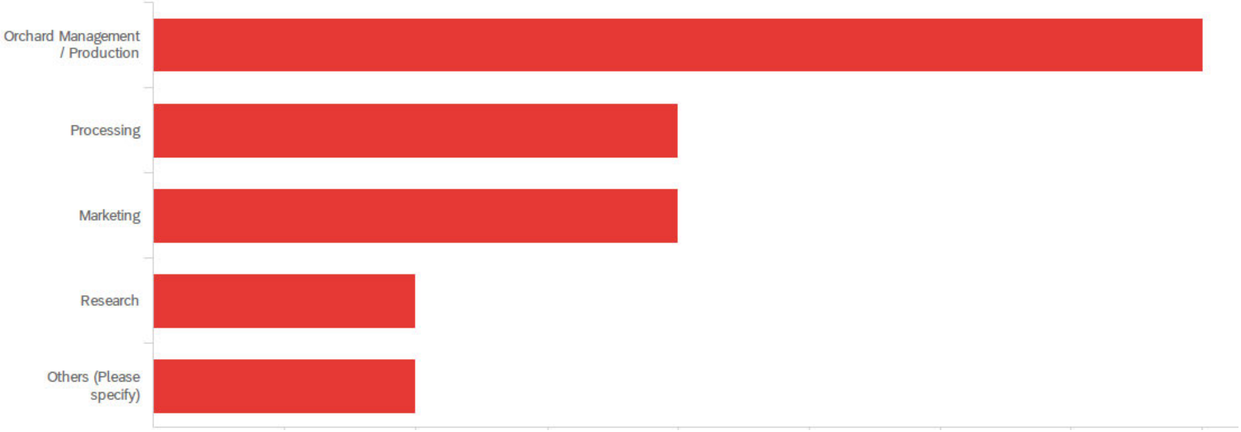


2. Education level of government officers who participated in the survey

3. Departments where the government officers currently work

4. Employment level of the survey participants

5. PMAMP Focus according to the respondents



6. PMAMP Priority as per the recorded responses

7. Number of farmers benefitted from PMAMP in different districts surveyed

8. Future focus on research and development of citrus industry as per the respondents

9. Machines in citrus industry of Nepal

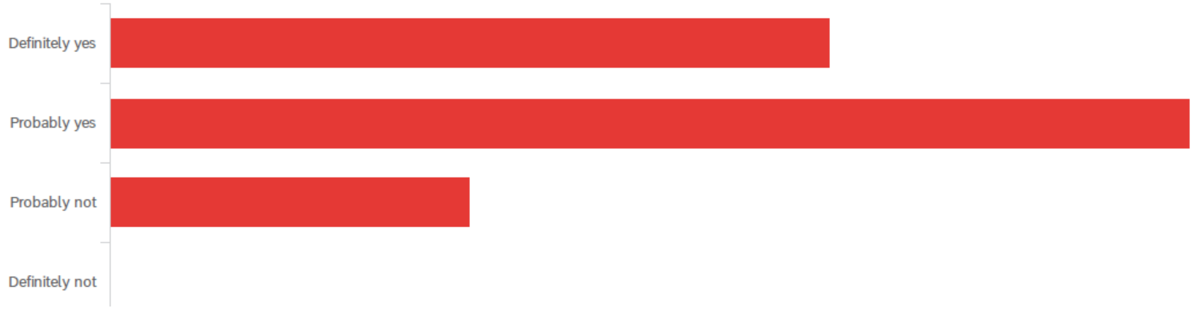
10. Improvement necessary in the citrus industry according to the survey participants

11. Support achieved from different stakeholders

12. Export value chain assessment by the participants

13. Number of growers expected to benefit directly in the beginning of citrus export

14. Cold treatment disinfestation knowledge status among the government officials



16. Export improvements required to achieve success according to the survey respondents

17. Sustainability of export as judged by the officials

Appendix F: How the CBH Mutual scheme operated—an example excerpt from Willis, Product Disclosure Statement—Cost of Production Cover by CBH Mutual Fund (Willis, 2011)

A farmer who is a member of CBH Mutual applies for the product by 30 April 2011 stating their intention to plant 10,000ha (4,000ha wheat and 6,000ha barley) in the shire of Perenjori for the 2011–12 season. An Offer of Cover is provided to the farmer which based on their historical yields, will use historical yield averages of 1.5 t/ha for wheat and 1.7 t/ha for barley. The farmer accepts the Offer of Cover and submits payment of the Contribution by 20 May 2011.

- The farmer nominates selected Cover to commence at 50 % of average yield.
- The Cover Price of $250 is used for the calculation of expected Value of Production.
- The Underwritten Value is $2,025,000: » 4000ha x 1.5t x $250 = $1,500,000 for wheat » 6000ha x 1.7t x $250 = $2,550,000 for barley – $4,050,000 expected revenue (total production) » $4,050,000 (total production) x 50 % of average yield = $2,025,000 (underwritten value).
- The product may payout when the Value of Production of wheat and barley falls below $2,025,000.
- The level of cover is: $202.50 / Ha » ($2,025,000 / 10,000ha).
- As a result of adverse seasonal conditions, total farm production harvested/yield is: » 2,200t wheat (4,000ha @ 0.55 t/ha) » 3000t barley (6,000ha @ 0.50 t/ha).
- Value of Production (under the Cover) is calculated as: $1,300,000 » 2,200t x $250/t (Cover Price) = $550,000 for wheat » 3,000t x $250/t (Cover Price) = $750,000 for barley – Value of Production: $550,000 + $750,000 = $1,300,000.
- Therefore, maximum payout is $725,000 (i.e., $2,025,000 – $1,300,000).

Source: Willis, Product Disclosure Statement—Cost of Production Cover by CBH Mutual Fund (Willis, 2011).

Appendix G: Insurance Product documentation provided by Carol O'Connor from Nutrien Ag on 13 August 2021)

Marsh Advantage in conjunction with Nutrien Ag Solutions® are offering a solution for Australian farmers to manage their production risk against the risk of lost income caused by weather events but covered differently to traditional crop insurance covers.

DESCRIPTION

An insurance product that offers coverage to compensate the insured for lost revenues and/or recoup costs due todamaged caused by adverse weather conditions (precipitation, cool temperatures, wind, soil moisture, hail etc.).

The premium is proportionate to probability of the pre-defined weather condition eventuating, according to a pre-defined weather data source; regardless of what your past farm yields have been.

Benefits of a Parametric Weather Product

- Quick, desktop claim settlement: upon eligibility of claim, claim payment made within 30 days
- Highly flexible and tailored structure in terms of risk period, location, sum insured, extent ofweather event to insure (e.g., decile 1 drought event)
- Insurance format with at least A rated counterparty, acceptable by most financiers and lenders
- Unlike peril-based covers there are no constraints placed on the farmers' managementpractices such as planting date, crop type planted, or starting soil moisture.

METRICS AVAILABLE:

1. **Deficit rainfall**

Nominate number of rain mm's, below which claim will be triggered for each mm missed

2. **Low temperature**

Nominate daily minimum temperature at the weather station for which frost is registered

3. **Excess rainfall**

Nominate number of rain mms above which claim will be triggered for each mm exceeded

4. **High temperature**

Nominate daily maximum temperature at the weather station

5. **Others, please specify hail, soil moisture**

INFORMATION REQUIRED

If you would like a quote, please complete the below information, and return to your local Nutrien Ag Solutions broker:

Busines Name:	
Contact Name:	**Phone Number:**
Email:	
Farm Name:	
Farm Address:	
GPS Co-Ordinates (to 2 decimal places):	
Farm Size (Ha):	
Nominated Sum Insured (e.g., $1,000,000):	
Nominated product:	
Risk period (Date range for cover, minimum of 1 month):	

Allow 2-4 months before start date
Nominated weather threshold, nominated rainfall or nominated decile (1-4)

Data Source (please tick)	BOM Station (if selected please list)	CHIRPS* Data (rainfall products only)

*CHIRPS (Climate Hazards Group InfraRed Precipitation sponsored by NASA NOAA project) produce daily remote satellite-based rainfall reading at ~5km x 5km resolution. This can be used in a location absent any quality BOM data. Any remote satellite-based readings are expected to have less than perfect correlation to ground station data.

pre-filled example (for rainfall)

Busines Name: Joe Farmer	
Contact Name: Joe	**Phone Number:** 0400 000 000
Email: joe.farmer@outlook.com	
Farm Name: Joe's Farm	
Farm Address: 123 Lane, Town/Suburb	
GPS Co-Ordinates (to 2 decimal places): -15.89, 657.01	
Farm Size (Ha):	100
Nominated Sum Insured (e.g., $1,000,000): $1,000,000	
Nominated product:	Deficit rain
Risk period (Date range for cover, minimum of 1 month): 1 August to 30 September 2020 Allow 2-4 months before start date	
Nominated weather threshold,	Please provide options of 50mm or decile 1 event.

nominated rainfall or nominated decile (1-4)		
Data Source (please tick)	BOM Station (if selected please list) CHIRPS* Data (rainfall products only)Yes, please use BOM station #xxxxx and (NAME)	

Frequently Asked Questions:

WHAT IS WEATHER INSURANCE?

Weather insurance allows clients to take out insurance to protect their revenues or profits based on a pre-agreed threshold of weather activity.

HOW DOES THIS DIFFER FROM PERILS-BASED INSURANCES?

(MULTI-PERIL OR SINGLE-PERIL CROP COVER)

Unlike traditional crop insurance products, the trigger for claims payment is an adverse weather event, resulting in damage to your items or crop. These adverse weather events could be tailored accordingly to address the following risks:

Deficit rain ☐ **drought**

Low temperature ☐ **frost**

Excess rainfall ☐ **flood**

High temperature ☐ **extreme heat**

WHAT ELSE CAN I INSURE?

With these products you can insure your financial loss because of a whole range of different events, additionalto rain and/or temperature you can include hail, wind speed, soil moisture, all of which can have a huge effecton a grower but need to be independently measured.

IS THIS JUST FOR CEREAL CROPS?

No, this type of cover could be for any type of crop, broad acre, horticulture, viticulture. It could also include temperature for things like loss of milk production or heat in intensive farming (feedlots cattle sheep or poultry).

CAN I USE MY OWN WEATHER STATION?

It is not possible at this stage with most insurers as most are only accepting BOM data and satellite data e.g., CHIRPS. There is inherently a basis risk by using these alternative sources compared to your own. It is critical for you to study any potential differences between your own site versus the BOM data. We strongly believe over a period of month or season, the correlation is often very strong but the two data sources may be consistently different.

WHEN SHOULD I START CONSIDERING HAVING COVER IN PLACE?

We strongly recommend considering cover 2-4 months prior to requested risk period. As most risk-takers relyon a blend of in-house proprietary weather modelling and BOM outlooks which are typically released 3 monthsin advance. Thus, this is for your benefit and avoid any disappointments to have adequate lead-up time to start of risk period and keep the insured event fortuitous (not predictable).

HOW WILL CLAIM BE PAID?

The claim will be a digital payout upon verification of data, i.e., as and when the BOM data is updated, they arematched to the policy, losses are confirmed, and any eligible claims will be processed and paid.

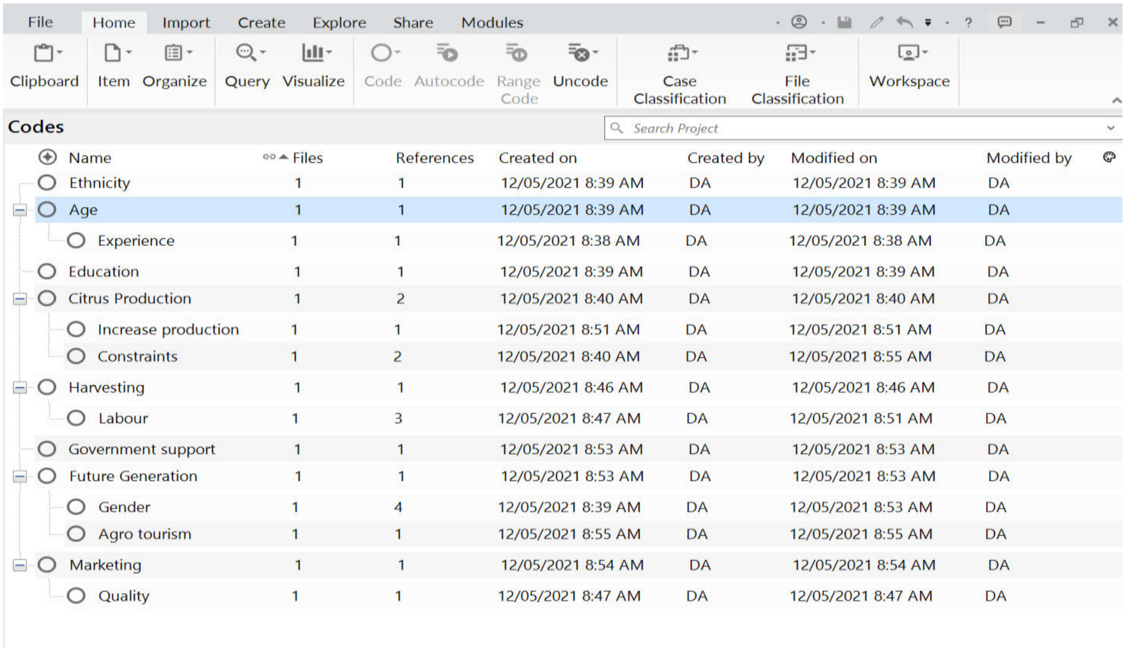
Appendix H: List of interviewees and dialogue participants and their roles.

NAME	*ORGANISATION*	*ROLE*	*LOCATION*
Small-scale Australian citrus value chains			
Peter Richter Kay Richter	‘By Citrus’	Co-owners	Byfield, Queensland
Ken Mason	‘Woodvale Park’	Owner	Adelaide Park, Queensland
		Farm stall consumers	Yeppoon market 19/02/2022
Darren Lucht	Lucht Citrus Farm	Owner	Byfield, Queensland
		Farm stall citrus consumers	Rockhampton market 13/02/2022
Bill Dargel	Fitzroy Nurseries	Co-owner, Manager	Rockhampton
	Amcor / Opal Packaging	Packaging supply, cartons	Rocklea, Rockhampton
Peter Podolinski	‘Fresh State’ Biodynamics Australia	Owner, Manager	Melbourne, Victoria
Wendy	Rocky's Own Transport	Transportation	Rockhampton
Barry Brookes	CQ Pineapple Grower	Supplying Pineapples to Woolworths	Yeppoon, Queensland
Kerry Battersby	Queensland Farmers Federation	Insurance product development	Brisbane, Queensland
Large scale Australian value chains			
Peter Leach	DAF, Queensland	Market Access Team Leader	Brisbane, Australia

Noel Ainsworth	DAF, Queensland	Principal Supply Chain Horticulturist	Brisbane, Queensland
Paul Cox	Abbotsleigh Citrus	Packhouse manager	Wallaville, Queensland
Roberto Marques	DAF, Queensland Agri-Science Queensland	Research Horticulturist	Queensland, Australia
Sohail Mazhar	DAF, Queensland	Horticulturist (Supply Chain Innovation & Market Access)	Cairns, Australia
Will Thompson	Spencer Ranch	Farm Manager	Wallaville, Queensland
Bed P Khatiwada	Spencer Ranch	Quality Assurance Officer	Brisbane, Australia
Nepalese citrus value chains			
Bodhraj Aryal	Syangja Citrus Grower Group Prime Minister Agriculture Modernisation Project (PMAMP)	Citrus grower Chairperson	Syangja, Nepal
Bharat Khanal	Khanal Fruit and Vegetable Suppliers	Wholesaler, Trader	Kalimati, Kathmandu, Nepal
Buddha Ghising	Tibet Export and Import	Trader (Importer/Exporter)	Kathmandu, Nepal
Phani Narayan Aryal	Syangja Citrus Grower Group	Citrus grower	Syangja, Nepal
Pitambar Aryal	Syangja Citrus Grower Group	Citrus grower	Syangja, Nepal
Punya Rijal	Syangja Citrus Grower Group	Citrus grower	Syangja, Nepal
Jagat Bahadur Khatri	Parbat Citrus Grower Group	Citrus grower	Parbat, Nepal

	Prime Minister Agriculture Modernisation Project (PMAMP)	Committee Member	
Shivalal Aryal	Syangja Citrus Grower Group	Citrus grower	Syangja, Nepal
Keshav Dhakal	Syangja Citrus Grower Group	Citrus grower	Syangja, Nepal
Yam Garbuja	Parbat Citrus Grower Group	Citrus grower	Parbat, Nepal
Tej Bahadur Khatri	Parbat Citrus Grower Group	Citrus grower	Parbat, Nepal
Tek Bahadur Rana	Syangja Citrus Grower Group	Citrus grower	Syangja, Nepal
Toya Narayan Rijal	Syangja Citrus Grower Group	Citrus grower	Syangja, Nepal
Maya Tiwari	Syangja Citrus Grower Group	Citrus grower, labour	Syangja, Nepal
Bharat Poudel	Syangja Citrus Grower Group	Citrus grower	Syangja, Nepal
Mekh Bahadur Khatri	Parbat Citrus Grower Group	Citrus grower	Parbat, Nepal
Nar Bahadur KC	Parbat Citrus Grower Group	Citrus grower	Parbat, Nepal
Panu P Paudel	Bhatbhateni Supermarkets	Manager	Kathmandu, Nepal

Appendix I: List of NVivo codes used to categorise information under specific topics (value chain features) and to help analyse the interview transcripts from different years (2013, 2015, and 2020)



Codes

Name	Files	References	Created on	Created by	Modified on	Modified by
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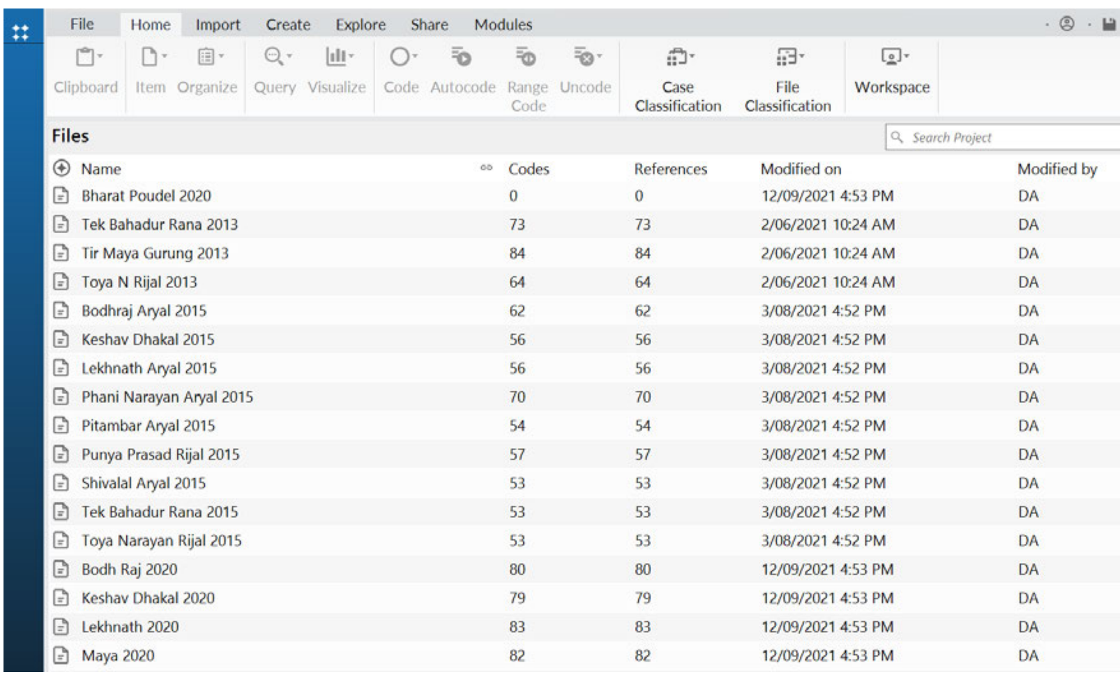
Age	1	1	12/05/2021 8:39 AM	DA	12/05/2021 8:39 AM	DA
Experience	1	1	12/05/2021 8:38 AM	DA	12/05/2021 8:38 AM	DA
Education	1	1	12/05/2021 8:39 AM	DA	12/05/2021 8:39 AM	DA
Citrus Production	1	2	12/05/2021 8:40 AM	DA	12/05/2021 8:40 AM	DA
Increase production	1	1	12/05/2021 8:51 AM	DA	12/05/2021 8:51 AM	DA
Constraints	1	2	12/05/2021 8:40 AM	DA	12/05/2021 8:55 AM	DA
Harvesting	1	1	12/05/2021 8:46 AM	DA	12/05/2021 8:46 AM	DA
Labour	1	3	12/05/2021 8:47 AM	DA	12/05/2021 8:51 AM	DA
Government support	1	1	12/05/2021 8:53 AM	DA	12/05/2021 8:53 AM	DA
Future Generation	1	1	12/05/2021 8:53 AM	DA	12/05/2021 8:53 AM	DA
Gender	1	4	12/05/2021 8:39 AM	DA	12/05/2021 8:53 AM	DA
Agro tourism	1	1	12/05/2021 8:55 AM	DA	12/05/2021 8:55 AM	DA
Marketing	1	1	12/05/2021 8:54 AM	DA	12/05/2021 8:54 AM	DA
Quality	1	1	12/05/2021 8:47 AM	DA	12/05/2021 8:47 AM	DA



Files

Name	Codes	References	Modified on	Modified by
Bharat Poudel 2020	0	0	12/09/2021 4:53 PM	DA
Tek Bahadur Rana 2013	73	73	2/06/2021 10:24 AM	DA
Tir Maya Gurung 2013	84	84	2/06/2021 10:24 AM	DA
Toya N Rijal 2013	64	64	2/06/2021 10:24 AM	DA
Bodhraj Aryal 2015	62	62	3/08/2021 4:52 PM	DA
Keshav Dhakal 2015	56	56	3/08/2021 4:52 PM	DA
Lekhnath Aryal 2015	56	56	3/08/2021 4:52 PM	DA
Phani Narayan Aryal 2015	70	70	3/08/2021 4:52 PM	DA
Pitambar Aryal 2015	54	54	3/08/2021 4:52 PM	DA
Punya Prasad Rijal 2015	57	57	3/08/2021 4:52 PM	DA
Shivalal Aryal 2015	53	53	3/08/2021 4:52 PM	DA
Tek Bahadur Rana 2015	53	53	3/08/2021 4:52 PM	DA
Toya Narayan Rijal 2015	53	53	3/08/2021 4:52 PM	DA
Bodh Raj 2020	80	80	12/09/2021 4:53 PM	DA
Keshav Dhakal 2020	79	79	12/09/2021 4:53 PM	DA
Lekhnath 2020	83	83	12/09/2021 4:53 PM	DA
Maya 2020	82	82	12/09/2021 4:53 PM	DA