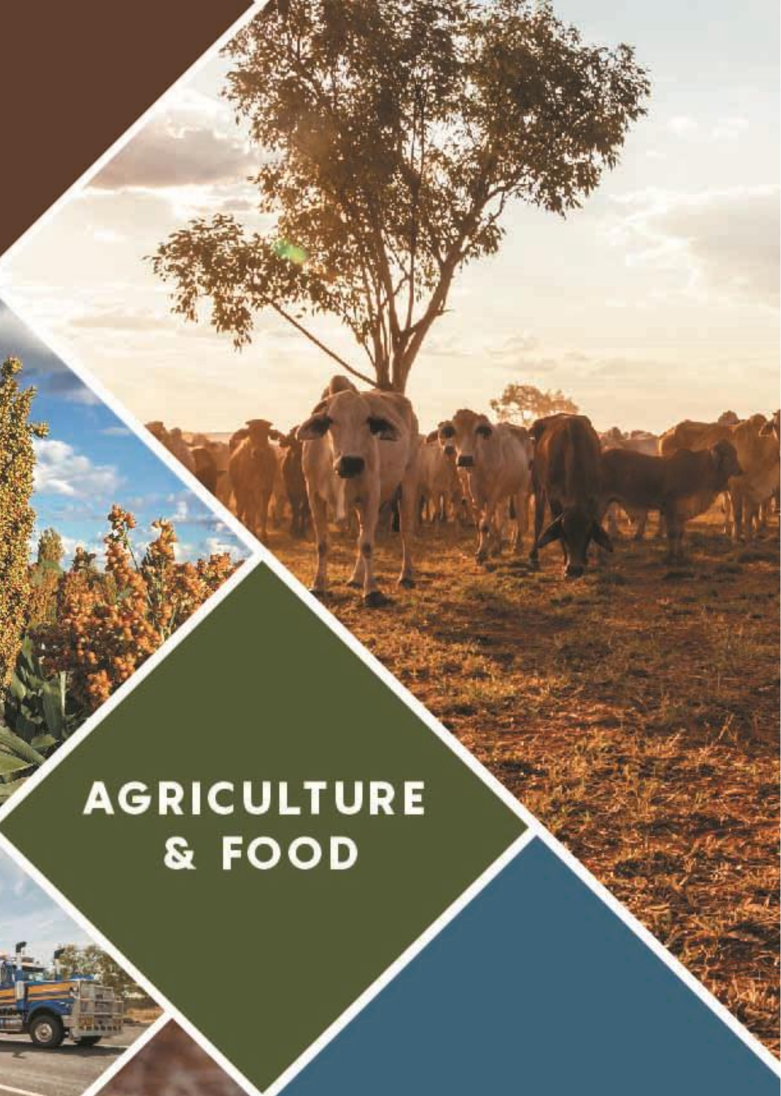

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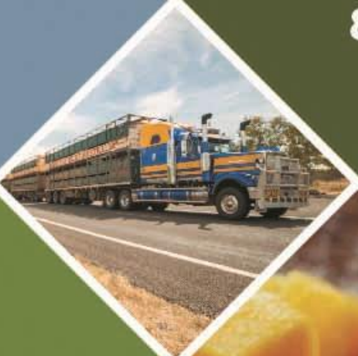

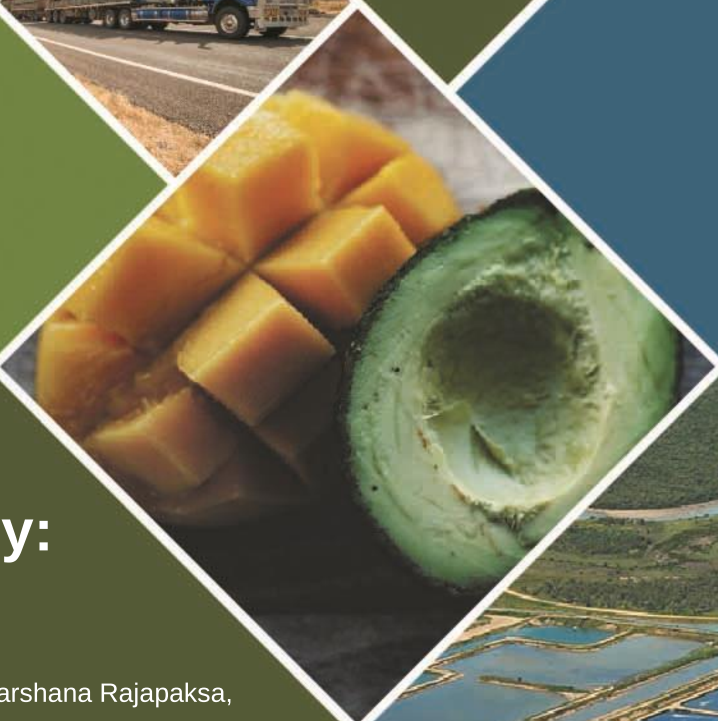

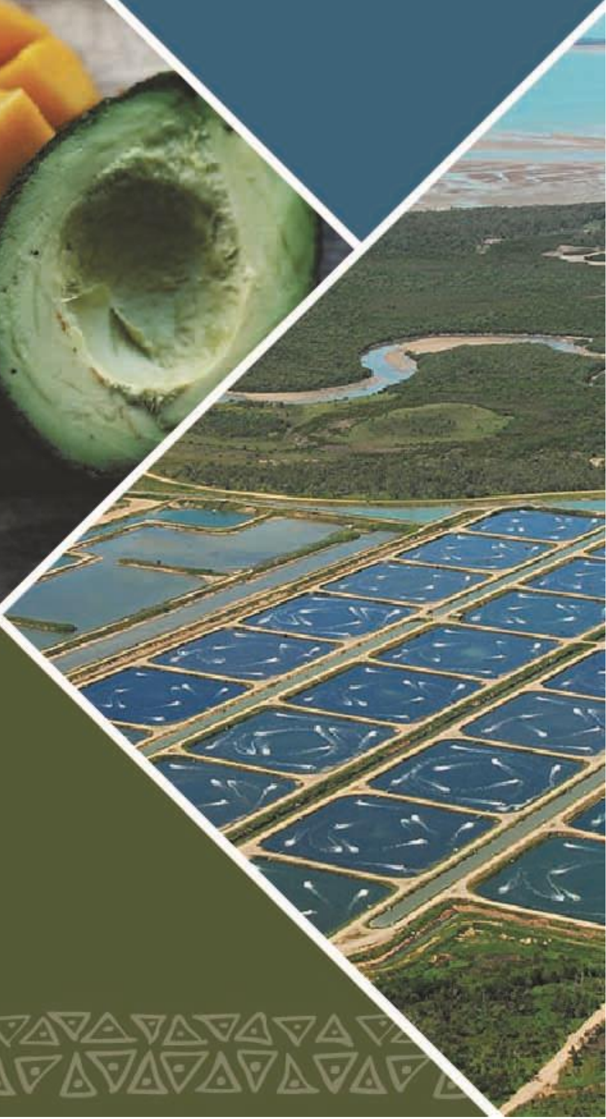

Central Queensland Agricultural Supply Chain Baseline Study: Final Report

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CRCNA

DEVELOPING NORTHERN AUSTRALIA

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Peer Review Statement

The CRCNA recognises the value of knowledge exchange and the importance of objective peer review. It is committed to encouraging and supporting its research teams in this regard.

The author(s) confirm(s) that this document has been reviewed and approved by the project's steering committee and by its program leader. These reviewers evaluated its:

- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2018),

and provided constructive feedback which was considered and addressed by the author(s).

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List of Acronyms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABC	Australian Broadcasting Corporation
ABS	Australian Bureau of Statistics
BSC	Banana Shire Council
CHDC	Central Highlands Development Corporation
CHRC	Central Highlands Regional Council
CQ	Central Queensland
CQU	Central Queensland University (also known as CQUniversity Australia)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAF	Queensland Department of Agriculture and Fisheries
DFAT	Australian Department of Foreign Affairs and Trade
DFTA	The Department of Foreign Affairs and Trade
DSDIP	Queensland Department of State Development, Infrastructure and Planning
FAO	Food and Agricultural Organisation
FNQ	Far North Queensland
GPC	Gladstone Ports Corporation
GRC	Gladstone Regional Council
HPP	High Pressure Processing
HVPAC	High value perishable agricultural commodity(ies)
LGA(s)	Local Government Area(s)
MIW	Mackay, Isaac and Whitsunday
MLA	Meat and Livestock Australia
NQ	Northern Queensland
QLD	Queensland
RDACWQ	Regional Development Australia Central and Western Queensland
RDAFCW	Regional Development Australia Fitzroy and Central West
RRC	Rockhampton Regional Council
SWOT	Strengths, Weaknesses, Opportunities, and Threats (strategic management technique used to identify these four components of an organisation)
TEUs	Twenty-foot Equivalent Units (a measure of volume in units of twenty-foot-long containers)
TIQ	Trade and Investment Queensland

Central Queensland Agricultural Supply Chains Baseline Study

Key highlights

- Development and validation of agricultural supply chain baseline framework and a mapping tool, which can be tailored for different commodities.

- Identification of five commercially important commodities (i.e., beef, cotton, wheat, sorghum and chickpeas) at the central Queensland (CQ) regional level and two niche commodities (i.e., mandarin and table grapes) with significant economic value at the local government level.

- Collection, collation and ground truthing of production and export data for selected agricultural commodities, and generation of a commodity-based agricultural supply chain mapping tool.

- Identification of the current and potential future export destinations for the selected agricultural commodities.

- Scoping of future opportunities to digitize and commercialise the Agricultural Supply Chain Mapping Tool.

Executive Summary

A. Overview

Export of agricultural commodities from the Central Queensland (CQ) region offers significant growth prospects due to existing multi-sectoral developments, the potential for market diversification, and ability for product value-adding. However, the functioning of export supply chains within the CQ region is yet to be examined in terms of supply and market size, labour markets, land and water availability, external economies and diseconomies. Undertaking a structured analysis of key products, supply chain features, and the structure and processes of markets, offers an important first step in realising the full potential of the region's agricultural profile through well-coordinated and integrated supply chains.

The purpose of this project was to develop a baseline framework for agricultural supply chain characterisation at regional level as well as to develop a supply chain mapping tool, which can be used to build a database of commodity specific agricultural supply chain. This mapping tool would help identify commercially viable produce for local and export markets. In this report, we (1) review the literature to develop a baseline framework and mapping tool for describing agricultural supply chains, (2) validate and refine the framework and mapping tool to achieve greater reliability and comprehensiveness, (3) identify limitations in agricultural datasets in Australian and other contexts which, if resolved, could enable more effective supply chain mapping, (4) discuss data/information about key products and their supply chains in CQ, and (5) use the tool to map the supply chains of seven case study agricultural commodities in CQ.

B. Methodology

An applied methodology was employed to scope the project, consisting of both literature review and stakeholder consultation. After project scoping, a mixture of methodological approaches was employed, including literature review, primary and secondary data collection, data analyses and framework validation. Two processes were used in parallel as follows:

(1) The agricultural supply chain framework and mapping tool involved a literature review augmented by expert review (using a survey and workshop). The literature review was completed using a dual deductive – inductive approach to consider the diverse features and characteristics of agricultural supply chains. This provided a strong basis for developing a baseline framework and mapping tool for agricultural supply chain characterisation. An expert review was then used to validate the baseline framework and mapping tool. In the first round of the expert review, a survey was released to a diverse stakeholder group. The second round of expert review was facilitated by a hybrid mode round-table workshop where stakeholders directly shared their perspectives about the framework and mapping tool. Survey data were analysed using descriptive statistics and workshop data were analysed using thematic analysis.

(2) The agricultural datasets for case export commodities were created through a process of desktop review, selection of secondary data and stakeholder interviews. A desktop review was adopted to investigate data collection processes in related studies and to identify potential data gaps relating to production volume and value for the agriculture industry. This literature review served two purposes: (a) to summarise and synthesise existing agricultural data collection practices and (b) to identify the use of new technologies and methods for improving data accuracy. Secondary data from reliable online/industry sources were selected and cross-checked. These data were then used to compile profiling information about five key agricultural products in CQ, and to map the supply chains of those five commodities. Interviews with stakeholders were conducted to collect additional quantitative and in-depth qualitative data related to supply chain features. Those data were explored using thematic analysis and then mainly used to map supply chains of the selected five commodities.

C. Research activities

(1) Development of a baseline framework and mapping tool

Following a deductive and inductive literature review approach, the research team examined studies related to agricultural supply chains to develop a four-dimensional supply chain framework. This framework explores common characteristics of agricultural supply chains in terms of product, infrastructure, process, and factors. A mapping tool designed to collect information and characterise agricultural supply chains was also built as an expanded form of the framework.

(2) Validation of the framework and mapping tool

The framework and the mapping tool were slightly modified and validated through a stakeholder survey and stakeholder workshop. The refined version of mapping tool was then applied to process the data relating to five case study agricultural commodities in CQ.

(3) Review of data collection and correction methods

In parallel with the first two steps, the research team reviewed common collection and correction methods for agricultural datasets, and then presented information about key products and their supply chains in Central Queensland. These data were reported according to their usefulness in supply chain mapping exercises. A priority ranking model was developed to identify major agricultural commodities of the CQ region, and the top five commodities were used to trial the supply chain mapping tool.

(4) Supply chain maps of selected agricultural commodities

In the last stage of the research project, supply chains of five selected agricultural commodities (beef, wheat, chickpeas, sorghum and cotton) in the CQ region were mapped, using the refined mapping tool together with the trial (primary and secondary) data sets. Two other localised commodities, mandarin and table grapes, were also included based on the feedback from regional stakeholders and project partners. A brief overview was provided for other commercial commodities and emerging crops in the region. The mapping of selected commodities suggested that supply chains of different agricultural commodities are not identical.

D. Regional agricultural profile

In 2020-21, the gross value of agricultural production (GVP) of the CQ region was approximately $1,430 million, and this figure has increased by 21% in two years, thus demonstrating the increased agricultural activities and ongoing potential of the region. By 2023, the GVP of the CQ region was estimated at $1,734 million (excluding fisheries and forestry), representing approximately 10% of Queensland's GVP. The four major categories contributing to the region's agricultural GVP are livestock (66%), broadacre crops (24%), horticulture (9%) and livestock products (1%). Aside from the livestock and livestock products industries, about 30 other agricultural commodities are produced in Central Queensland. Based on production value, production volume and production area, the five primary agricultural commodities of CQ are currently beef, wheat, chickpeas, sorghum and cotton. All these are currently being exported to a variety of world markets. Based on the feedback from regional stakeholders, the research team also identified two other commodities, mandarin and table grapes, which have high export potential but are not well reflected in Australian Bureau of Statistics' (ABS) datasets. Ground-truthing with stakeholders revealed that volume data for citrus production in CQ was underreported, due to confidentiality issues related to regional citrus producers.

E. Key theoretical and empirical findings

E.1 Supply chain framework and mapping tool

Agricultural supply chains have been extensively studied and several agricultural supply chain frameworks for specific commodities have been proposed in the research literature. This project involved an extensive literature review on supply chain frameworks and considered theoretical accounts to develop an agricultural supply chain baseline framework and mapping tool, tailored for CQ. The literature considered included Chhetri et al.'s (2022) model, Keast's (2016) relationship forms; Romsdal et al.'s (2011) framework and Schrobback et al.'s (2020) description matrix. Based on these theoretical accounts, a baseline framework for agricultural supply chains was developed, comprising four domain areas, namely product, infrastructure, processes, and factors (see Figure ES.1). Each component consists of different dimensions, which collectively outline all the known aspects/features of an agricultural supply chain. This framework was then expanded into a supply chain mapping tool by populating the domains and dimensions with regionally specific datasets. The baseline framework and mapping tool were then validated using a stakeholder survey and stakeholder workshop.

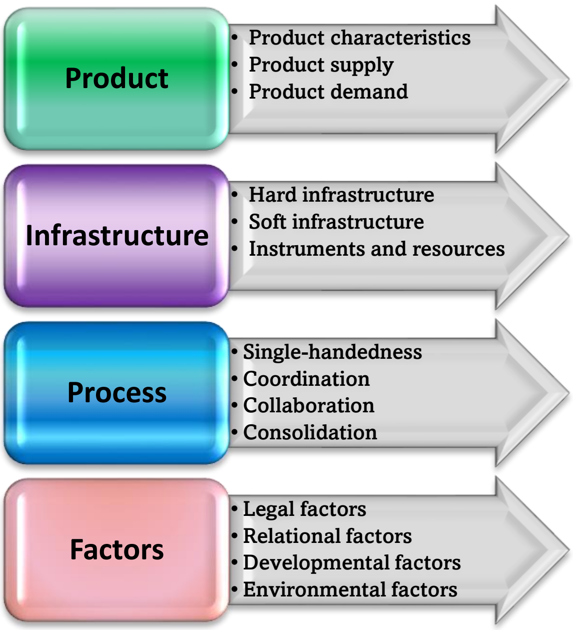


Figure ES.1: The four domains of an agricultural supply chain, together with their dimensions

E.2 Supply chain maps for selected agricultural commodities

Five of the key agricultural commodities of CQ were identified based on a priority ranking reflecting product value and volume. Two fruits were also selected based on feedback from project partners and local producers. Supply chain maps for these seven commodities were prepared based on data collected from local producers and industry bodies. This results in mapping of the dominant commodities into one of four groups: beef, grains, cotton and fruits.

Beef

Product: The gross value of cattle and calf disposal in Queensland was estimated at A$5.9 billion in 2020-21 which represents about 44% of cattle industry value in Australia. CQ, known as the "Beef Capital of Australia", accounts for about 18% of Queensland production. According to the AgTrend data developed by the Department of Agriculture and Fisheries (DAF), a 7% increase in GVP is predicted for CQ cattle and calf disposal by 2023.

There was a slightly increasing trend in Queensland's export earnings over the last 10 years (Figure ES.2), however specific information about beef export from the CQ region, was not available from open data sources. In CQ, supply uncertainty is generally very low given that the region holds a major proportion of Queensland's live cattle. Nevertheless, extreme weather conditions (including drought) could affect the region's beef supply chain, as has been experienced in recent years. The region has some value-added products, although there appeared to be few innovations reported in relation to the products.

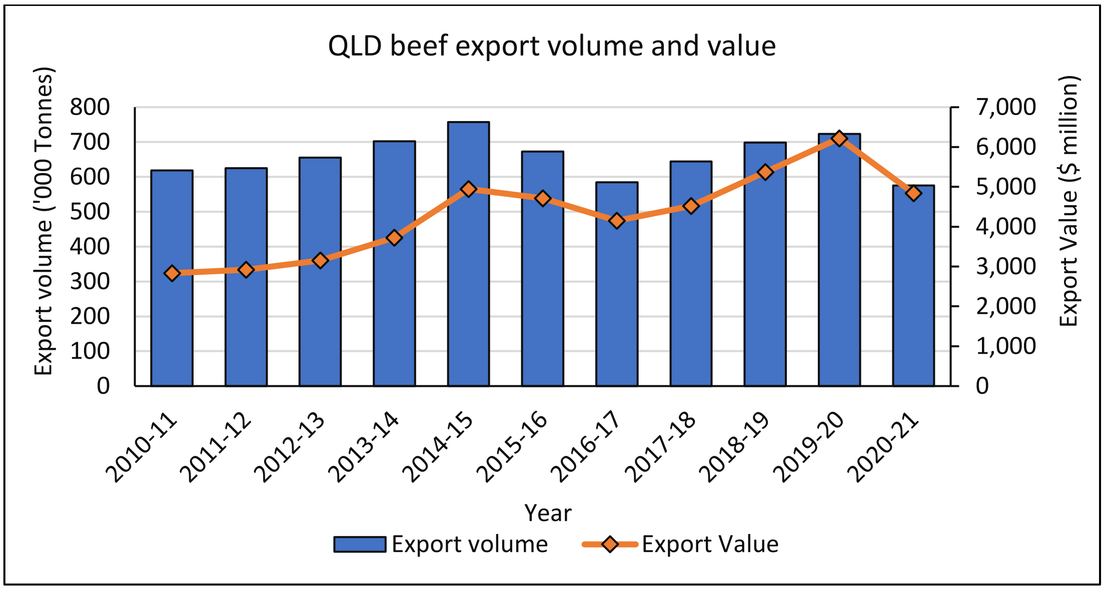


Figure ES.2: Trends in QLD beef export volume and value

The top five export destinations for Queensland-grown beef are Japan, the Republic of Korea, the USA, China and Indonesia. In recent years, because of some political issues and Australia's current herd rebuild, beef export volume to China has declined significantly. By comparison, beef export volume to Vietnam doubled in 2020-21 compared with the previous year, which makes Vietnam a potential alternative export destination. Another alternative export destination for QLD beef could be the United Arab Emirates, as it features high demand, yet QLD currently holds only a small fraction of the market.

Infrastructure: The supply chain structure of beef is complex, featuring multiple entities including feedlot, saleyard and selling agents who are each involved in different stages of the supply chain. The general format of the supply chain is vertical; however, a form of network often occurs as the live products are moved back and forth between different entities within the supply chain. In the CQ region, a well-developed meat processing industry exists with three large abattoirs. Most farms are family-owned, and the processing industry is equipped with a permanent labour force.

Processes: Most farms are involved in the backgrounding or stocker and finishing stage, with some collaboration with input providers. The producers have different options regarding sending their product to the next stage. However, once processed (or sent to the processing facility), producers lack control over the product. After the processing stage, processors therefore hold the market power.

Factors: The beef export industry is very mature and export protocols for major destinations are well established. Meat & Livestock Australia (MLA), the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), and the Department of Agriculture and Fisheries (DAF) in Queensland each provide the necessary technical support to cattle farmers and related industries. A significant amount of research work on the beef industry is undertaken each year by regional universities, supported by funding from Government bodies and MLA.

Grains and legumes (wheat, sorghum and chickpeas)

Product: The gross value of selected grains and legumes in Queensland was estimated at A$ 1.02 billion in 2020-21, which accounted for about 9.5% of the Australian market. The GVP of the selected three commodities for CQ was about A$ 119 million. According to AgTrend data, it is estimated that the total GVP of these commodities will increase 43% in the next two years for CQ region (DAF, 2021). Wheat production figures for QLD and CQ are relatively stable regardless of the drought in recent years. Sorghum production has featured a declining trend over recent years (see figure ES.3). Chickpea production datasets were missing for several years in ABS reporting, although ABARES provided some time-series data about chickpea production in QLD. Notably, the recent AgTrend of QLD report regarding the GVP of chickpea production over the last 15 years appears conflicted with the existing legume production data available in ABS. The Queensland Government Statistician's Office's (QGSO) datasets about the value and volume of chickpea export (including re-export) also does not match with ABARES data for recent years.

Wheat, sorghum and chickpea commodities are often handled as bulk products in their supply chain. Harvested products are stored in silos and dispatched to different markets, mainly South and Southeast Asian countries. The Middle East could represent an alternative export market in the event of export supply chain disruption in other countries. Value-adding industries for the selected three products are not prominent in CQ region. The key export supply chain challenges for these grains and legumes are export market prices and market instability. Many small local producers supply their products to local feedlots and are not interested in exporting their products. Also, there is a paucity of value adding activities and facilities in CQ region. Finally, the delivery lead time is high for these commodities because of the shortage of trucks for transporting, combined with the distance to ports for export.

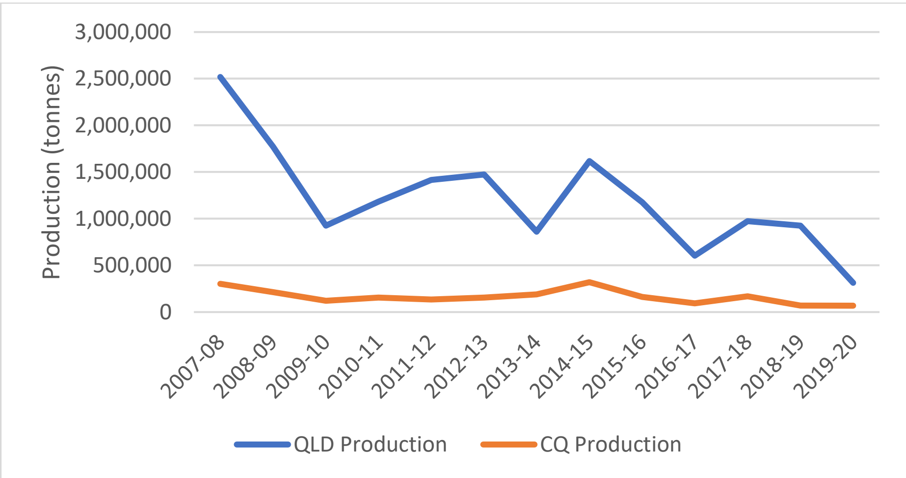


Figure ES.3: Queensland and Central Queensland sorghum production

Infrastructure: The supply chain structure of these selected grains and legumes are very simple, consisting of about 4 to 5 entities. Producers are in coordination with the input providers and distributors to supply the products in the market. Storage facilities are moderately established in the CQ region. On-farm storage is available in most locations while the larger silos are operated by GrainCorp. In the Central Highlands, an inland port was developed to agglomerate regional grain production and to distribute the products to different markets. Transport and logistics services are moderately available however transport costs are quite high, which impacts the gross margin for producers. Ground-truthing with stakeholders highlighted that labour force is a challenge for this region. The use of internet-based technologies for these commodities appears minimal, possibly resulting from poor internet reception on-farm.

Process: GrainCorp is a key player in the wheat and grain supply chain, with processing, storing, handling and marketing capabilities. Producers can market their products through GrainCorp or through other channels. Pulse Australia is the leading industry body which oversees the chickpea and mung bean industries and provides support to producers. Strong coordination exists amongst producers and industry bodies to make these commodities ready for domestic or export markets. However, most businesses for these commodities operate singlehandedly. The Gladstone port in the CQ region has grain loading facilities and some of CQ grains are exported through this infrastructure. Other grain exporting ports close to CQ are those are Brisbane and Mackay. The export market is heavily regulated, and producers need to go through export agents or GrainCorp to reach export markets.

Factors: GRDC, DAF, ABARE and universities are involved in research to improve the efficiency of wheat and sorghum production. The Queensland government has invested in expanding the rail network which may help to improve transportation facilities. GRDC, DAF and the New South Wales Department of Primary Industries have also been involved in promising programs for chickpea breeding and high-yielding varieties. Sorghum is a good alternative to incorporate into farming systems in Central Queensland as whilst it needs some technical know-how, farmers in the region already have the necessary skills. However, extreme weather can affect the grain and pulse yields.

Cotton

Product: Cotton is grown mainly in northern New South Wales and the Southern Queensland regions. However, Emerald, Theodore, and Biloela in Central Queensland also produce substantial quantities of cotton. More than 95% of Australian-grown cotton is exported as cotton lint (after the ginning process). The top three destinations for QLD cotton are Vietnam, China and Bangladesh. These three countries have exhibited steady growth in cotton import in the last few years (Figure ES.4). However, QLD currently supplies less than 2% of the huge demand for cotton in these three countries. The other major cotton exporting countries are the USA, Brazil and India. Cotton is exported through the Brisbane port, and this incurs high transportation costs. Cotton seeds, a by-product of cotton industry, also have some economic value as stockfeed and are currently exported to Japan, South Korea and China.

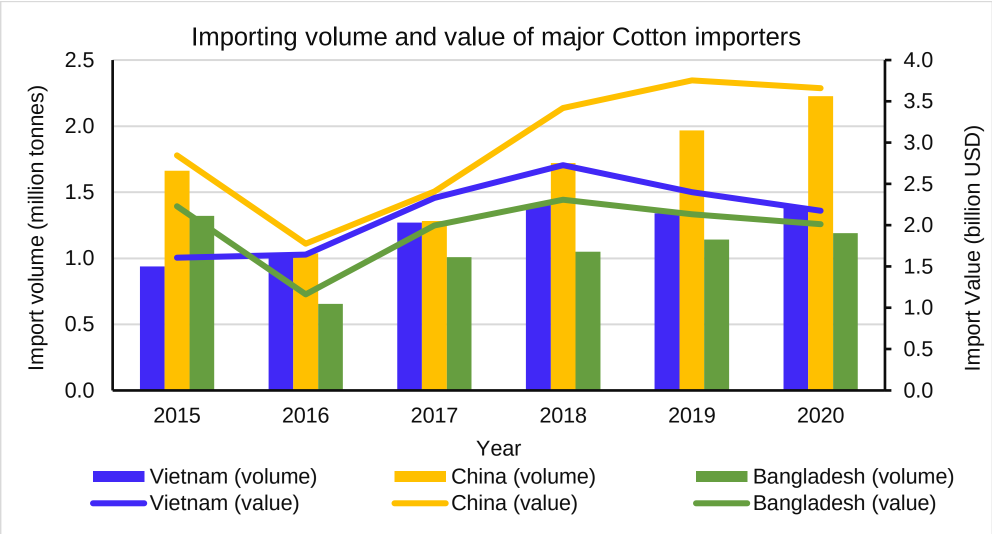


Figure ES.4: Volume and value statistics for the world's major cotton importers

Multiple varieties of cotton are produced in Australia, with four predominating in the CQ region. The CQ region has a consistent supply of cotton. Before ginning, the raw cotton is stored on the production field, hence post-harvest storage is not an issue for this commodity. Cotton lint goes straight to the fibre industries of the importing countries; hence, consumer segmentation does not exist.

Infrastructure: In the Central Queensland region, cotton is mainly grown in Biloela and Emerald and the production approaches using technologies in those regions have been consistently applied over time. While cotton is not a heavy product, the low bulk density means it needs substantial space for both storage and transportation.

The CQ region has three cotton gins (two in Emerald and one in Biloela) which are convenient when transporting raw cotton to gins from the field. Australia does not have weaving mills to conduct further processing and most of the cotton goes to the export market. Transporting cotton to Brisbane as the major exporting port is both time and cost intensive. The labour force is moderately available in the CQ region, although labour shortages have been challenging for the industry during the COVID-19 pandemic.

Process: Most of the cotton produced in CQ goes to the export market in form of bales after processing at cotton gins. Producers can also export their products through export agents after ginning. The producers' business structure is mostly single-handed. However, producers need to coordinate with the cotton gins for processing. The transportation from farm to gin is relatively simple as production areas are concentrated near existing gins. The Cotton Australia Board is the leading industry body and the Cotton Grower Associations in different regions often work under the Cotton Australia platform. Cotton growers and the cotton industry bodies are closely linked; however, no contractual collaboration exists among the cotton growers.

Factors: Cotton cultivation has been criticized due to its high demand for water, but Australia has achieved the highest efficiency of water use in the world, and the crop can therefore be grown with minimum water requirement. Continuous research on improving water efficiency is an advantage to continue the cotton cultivation in the Central Queensland region. The cotton industry has strong relations with the beef industry because of the use of cotton seed as stockfeed.

Fruits (mandarin and table grapes)

Product: Mandarin and table grapes are mainly produced in the Emerald region of CQ. Both are perishable and require temperature-controlled storage and supply chains. Both fruits are handled as boxed products. A major portion of CQ mandarins goes to export markets, particularly China, Thailand, and the Philippines. The current trend in Mandarin export from QLD is presented in Figure ES.5.

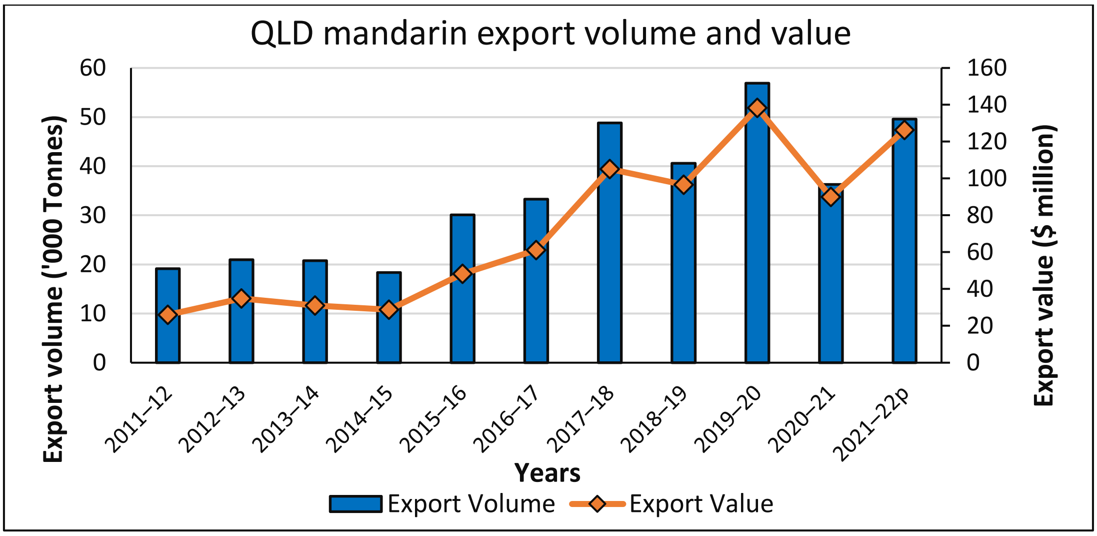


Figure ES.5: Trends in QLD mandarin export volume and value

Most table grapes produced in CQ go to the domestic market. However, QLD grapes also have market access to China, Japan and Indonesia. Several mandarin and table grape varieties are produced in the CQ region. The cultivated areas and production volume of mandarin in the CQ region have been significantly understated in the ABS datasets due to the data confidentiality policy applied by large mandarin production companies which are accountable for almost all regional production. The QLD AgTrend Spatial map suggests that in 2021-22 over 1,000 hectares of land were used in the Emerald region for citrus production. The recent economic profile of Central Highland Development Corporation (CHDC) indicates that the GVP of locally produced mandarin is about AUD$54 million. The report also indicates that GVP of table grapes in the Central Highland region is about AUD$25 million. The supply of both commodities to the domestic and international markets is relatively stable.

The primary processing of both products is managed on-farm. However, further processing is required to access the export market. The opportunity for upscaling the production volume of table grapes is limited as producers are small to medium scale farmers and the producers have more interest on other crops. Mandarin production, however, could be increased via further plantation areas as well as innovation with high yield varieties.

Infrastructure: The supply chain structures for both commodities are streamlined with 4 to 5 entities including producer, processor, merchant, wholesaler, and retailer. Producers are heavily dependent on input providers and merchants/agents for distribution. Temperature-controlled trucks are used for transportation and this service is moderately available in this region. Small- and medium- scale grape producers are involved in freight consolidation efforts to transport their products to the same merchants. The labour force is often a challenge for the grape industry in the CQ region. Labourers are only required during the narrow window of the harvest season and often it is difficult to hire casual workers for such short periods.

Process: Most tasks associated with supplying these two commodities are handled by producers in coordination with other supply chain entities and collaboration with industry bodies. Some forms of freight consolidation exist in the grapes supply chain. However, no contractual collaboration exists among producers and other supply chain actors.

Factors: Standard quality regulations need to be fulfilled for exporting these products. Producers often maintain a close relationship with industries bodies including Growcom, the Table Grapes Association and Hort Innovation. Extreme weather events have a severe impact on production yields and product quality.

E.3. Ground truthing regional production data

Reliable agricultural production data are vital for understanding supply and demand gaps relating to different agricultural commodities as well as planning for production shortages or surpluses. However, agricultural data published by governments or government-affiliated authorities may contain inaccuracies that can mislead end-users.

Production and export related statistics for the selected commodities were collected primarily from government websites such as ABS, ABARES, QGSO and QDAF. MLA also has rich datasets, and these were included for the beef sector. Although most data are accurate for the selected commodities, some inconsistencies were detected between values reported on different websites. The other concern is the breakdown of data, particularly regionally specific time series data (e.g., fortnight, monthly data), which are not available in most cases.

To validate and complement the data about the five commodities as collected from online resources, the research team undertook a ground-truthing exercise with producers and industry bodies. The key organisations targeted for ground truthing were:

- Beef: Meat and Livestock Australia (MLA), Central Queensland Livestock Exchange (CQLX), JBS (initials of the founder, José Batista Sobrinho), Teys, Rockhampton Regional Council (RRC), AgForce
- Cotton: Cotton Australia board, Central Highlands Cotton Growers' and Irrigators Association, Emerald Gin
- Chickpeas: Pulse Australia, GrainCorp, CQ Inland Port
- Wheat and Sorghum: GrainCorp, GRDC, Australian Wheat Board, CQ Inland port
- Mandarin and grape: CHDC, 2PH

The research team also considered secondary data from the ABS, ABARES, QGSO and AgTrend QLD. These data were collated and presented to the relevant stakeholders for validation and identification of data gaps. Despite extensive efforts to obtain feedback, the ground-truthing exercise was fully completed only for the beef and cotton commodities. Nevertheless, this report also presents secondary data to help demonstrate the variation in the existing agricultural production data.

Table ES.1: Comparing ABS and AgTrend data for selected agricultural commodities in QLD: An example

GVP of selected commodities (million AUD)															
	Cattle and calf disposal*			Wheat			Chickpeas			Sorghum			Cotton		
Year	ABS	AgTrend	Variation agreement**	ABS	AgTrend	Variation agreement	ABS	AgTrend	Variation agreement**	ABS	AgTrend	Variation agreement	ABS	AgTrend	Variation agreement**
2021	5901.8	5,901.80	1.00	519.4	470.1	0.91	151	143	0.95	355.7	321.3	0.90	540.2	524.1	0.97
2020	6546.9	6,546.90	1.00	163.3	246	1.51	122.3	133	1.09	121.6	101	0.83	75.4	102	1.35
2019	5802.6	5,802.60	1.00	178.9	179	1.00	n.a.	136	n.a.	319.3	319	1.00	278.6	279	1.00
2018	5472.6	5,472.60	1.00	246.2	246	1.00	n.a.	377	n.a.	302.4	302	1.00	881.8	882	1.00
2017	5,731.20	5,731.20	1.00	361.4	361	1.00	n.a.	744	n.a.	139.4	139	1.00	621.8	622	1.00
2016	5,860.60	5,860.60	1.00	383.6	384	1.00	291.1	471	1.62	312	312	1.00	465.8	466	1.00
2015	5,076.00	5,076.00	1.00	328.6	329	1.00	n.a.	117	n.a.	485.8	486	1.00	383.2	383	1.00
2014	3,890.10	3,890.00	1.00	339.2	339	1.00	n.a.	118	n.a.	261.2	261	1.00	697.7	698	1.00
2013	3,460.80	3,247.00	0.94	511.5	511.5	1.00	n.a.	175	n.a.	360.4	360	1.00	677.1	677.1	1.00
2012	3,450.10	3,450.10	1.00	413	413	1.00	103.2	57.2	0.55	278.5	278	1.00	981	981	1.00
2011	3,418.00	3,418.00	1.00	378.4	302	0.80	55.5	49	0.88	251.7	320	1.27	776.1	660	0.85
2010	3,174.30	3,229.00	1.02	301.1	265	0.88	n.a.	60	n.a.	171.9	155	0.90	301.1	355	1.18
2009	3,365.60	3,365.60	1.00	535.6	535.6	1.00	56.6	50	0.88	355.7	355.7	1.00	325.2	325.2	1.00
2008	3314.7	3,314.70	1.00	353.4	353.4	1.00	n.a.	50	n.a.	637.2	637.2	1.00	79.2	79.2	1.00

*The cattle and calves disposal includes live cattle data.

Source: AgTrend, https://www.daf.qld.gov.au/strategic-direction/datafarm/qld-agtrends

** A variation agreement value of 1 indicates perfect agreement between the ABS and AgTrend dataset. Cells shaded in green indicate where AgTrend data exceeded ABS data. Cells shaded in red indicated where ABS data exceeded AgTrend data. N.a: data not available.

It was noted that ABS, QGSO and ABARES reported production data in terms of both volume and value; whereas QDAF produced AgTrend data based on the present GVP data for different agricultural commodities at the state level. Table ES.1 indicates the data variation at the state level, when comparing ABS and AgTrend data. The data variations between ABS and AgTrend worsen during 2020 and 2021, which could be because of the new data estimation techniques adopted by ABS in these two years.

It was observed that except chickpeas, most of the data were in good agreement apart from two periods (2010/11 and 2020/21). It is not clear why data were different during these periods. The chickpea production data were missing for several years as they were combined with the total pulse production (includes chickpeas, mung bean, soybean etc). AgTrend has the pulse production data for all years, however, some issues were evident in those data. For instance, according to AgTrend, the GVP of chickpeas for QLD in 2017 was 744 million AUD. The same GVP was also mentioned in ABS but for the total pulse crop.

Beef: The data set for beef was prepared using information from ABS and MLA. ABS reported the number of herds in QLD, as well as specifically in CQ, on their data portal. MLA reported a wide range of data on beef and beef export, however regional level data were missing. Also, inconsistencies exist in the data about Australian beef prices in the international market. For instance, according to ABS trade data, the average price of Australian beef in the world market was AUD 9.22/kg but the international market price was lower than this price. In addition, regional level data of beef production and processing were not available. Through the ground truthing exercise (using stakeholder interviews) the research team identified that the existing data provided by ABS and MLA are consistent with the field level data. The stakeholders indicated that whilst some errors may exist, these were expected to be mild errors only (lower than 5%). For beef, average price is not the ideal figure on which to base research and/or decision-making purposes because high price variation exists among different cuts of beef. The regional level production data are available in ABS. However, the export data for CQ was not found during the ground truthing process.

Wheat: Most of the data regarding production, export and price of wheat were collected from the ABS website. From 2017-18 onwards there was a consistent decline in wheat production in QLD. Historically, CQ produced about 14% of QLD wheat. However, in 2019-20 this number jumped to over 36%. This production percentage hike could be authentic, as suggested by local producers, because of the low production wheat in other regions due to the severe drought in QLD. The research team also attempted initial contact and interviews with GrainCorp, Inland Port, and GRDC to check the production and price data, but this was not successful.

Chickpeas: Chickpea data were collected from the ABS database and ABARES websites. At the regional level, the production data were missing for several years as chickpea production data had been merged with other pulse production categories, rather than being reported separately. Australia is the largest chickpea exporter in the world, and in 2019-20, Australia exported about 370,234 tonnes of chickpeas, including the re-exported volume. Of note, the collated datasets demonstrate that the chickpea export volume for QLD was significantly higher than the production volume in the state. This could result from data skewing due to chickpea production in NSW which was exported and re-exported through the QLD ports. However, this assumption could not be verified in the absence of interview participants from the pulse industry.

Sorghum: Sorghum data were collected from the ABS database and ABARES (2022) websites. On average, CQ produced about 14% of QLD's sorghum crop. Sorghum export from QLD has increased in recent years but specific regional-level data about export volume and value for CQ were not available. China, Japan, Papua New Guinea, New Zealand and Taiwan are the major export destinations for QLD sorghum. Representatives from GrainCorp were approached for interview by the research team multiple times, but unfortunately were not available to participate.

Cotton: Most of the data regarding production, export and price of cotton were collected from the ABS website, although this was also supplemented with recent year trend data from local cotton gins. These data align well with the ABS data at QLD level but appear to be mismatched at the CQ level. The export quantity of cotton from QLD was higher compared to the production volume. As with chickpea, this could reflect the export activity of NSW product through the QLD ports system.

F. Contributions

(1) Theoretical contribution

The value-add of this work is to provide a comprehensive understanding of agricultural supply chains as well as build a theoretical tool (the framework) of appeal to researchers. Meanwhile, a practical tool (the mapping table) is useful for supply chain stakeholders and those who are concerned with issues related to supply chains in the agriculture sector. The baseline framework, which is comprised of the four domain areas (product, infrastructure, process and factors of/in agricultural supply chains), can be used as a theoretical lens for future research on agricultural supply chains in Australia and international contexts. The framework has also been used as a skeleton for building a mapping tool for collecting information and characterising agricultural supply chains, which provides a basis for further supply chain analysis and evaluation. The discussion on methods of data collection and correction for the geographic area of concern may contribute to building potential instruments for improvement of agricultural data.

(2) Practical contributions

2.1 Agricultural commodities mapping tool

The mapping tool allows a variety of end-users, including producers, investors, and government bodies, to systematically describe and explore agricultural supply chains in different dimensions and components. In turn, this comprehensive information about commercially viable commodities can be used to build a digital database of systematic information about agricultural supply chains, with the ability to exemplify different products in different contexts. This kind of information literacy and functionality could lead to the more rapid, and context-specific, development of horizontally connected and/or vertically integrated supply chain networks and markets. Here, supply chain actors can identify and monitor supply chain structures, operation, and performance to inform decision-making and solution-seeking, for long-term benefits.

2.2 Data evaluation

The review of data collection, estimation and correction methods may be applied to manage data about different commodities in different agricultural regions in Australia. Given the contribution of the agriculture sector to Australia's national economy, improved agricultural data would be significant for effective data use among producers, marketers, distributors, retailers and/or policy makers.

2.3 Output beneficiaries

The supply chain mapping tool will preserve information on the entire supply chain once all the relevant information is collected and deposited on the mapping tool. All the supply chain entities and the relevant industry and government bodies will be the beneficiaries of this integrated information. Figure ES.6 illustrates the direct beneficiaries of the supply chain mapping tool and the most important pieces of information for them. The producers know most of the product characteristics already and will therefore benefit especially from the information regarding demand, infrastructure and legal factors associated with the export supply chain. The wholesalers and distributors will benefit from knowing the supply and demand quantities and the instruments & resources available to move the products along the supply chain. For an exporter, it is critically important to know and act upon all components of the products as well as the instruments & resources. These stakeholders also would be interested in collaboration among the supply chain actors. On the other hand, an importer would be interested in the product characteristics, product supply, instruments & resources and any form of consolidation. Both importers and exporters should know about the legal factors relevant to the export supply chain. An investor, either domestic or foreign, would be interested in all aspects of the supply chain before investing and the mapping tool will provide that.

2.4 Scrutiny of agricultural production data for the CQ region:

This study adopted a ground-truthing approach to identify the variation between published production data and actual production data. It was found that there are some variations in the publicly available data in the different web portals (e.g., ABS, AgTrend. ABARES, MLA etc.). Beef data are found to be very accurate, while cotton production data for the CQ region differ by about 20% from the actual figure. Knowing accurate production data is vital in investment decision-making as well as for future planning to develop an efficient export supply chain. The methodology used to investigate data variation could be employed for other commodities.

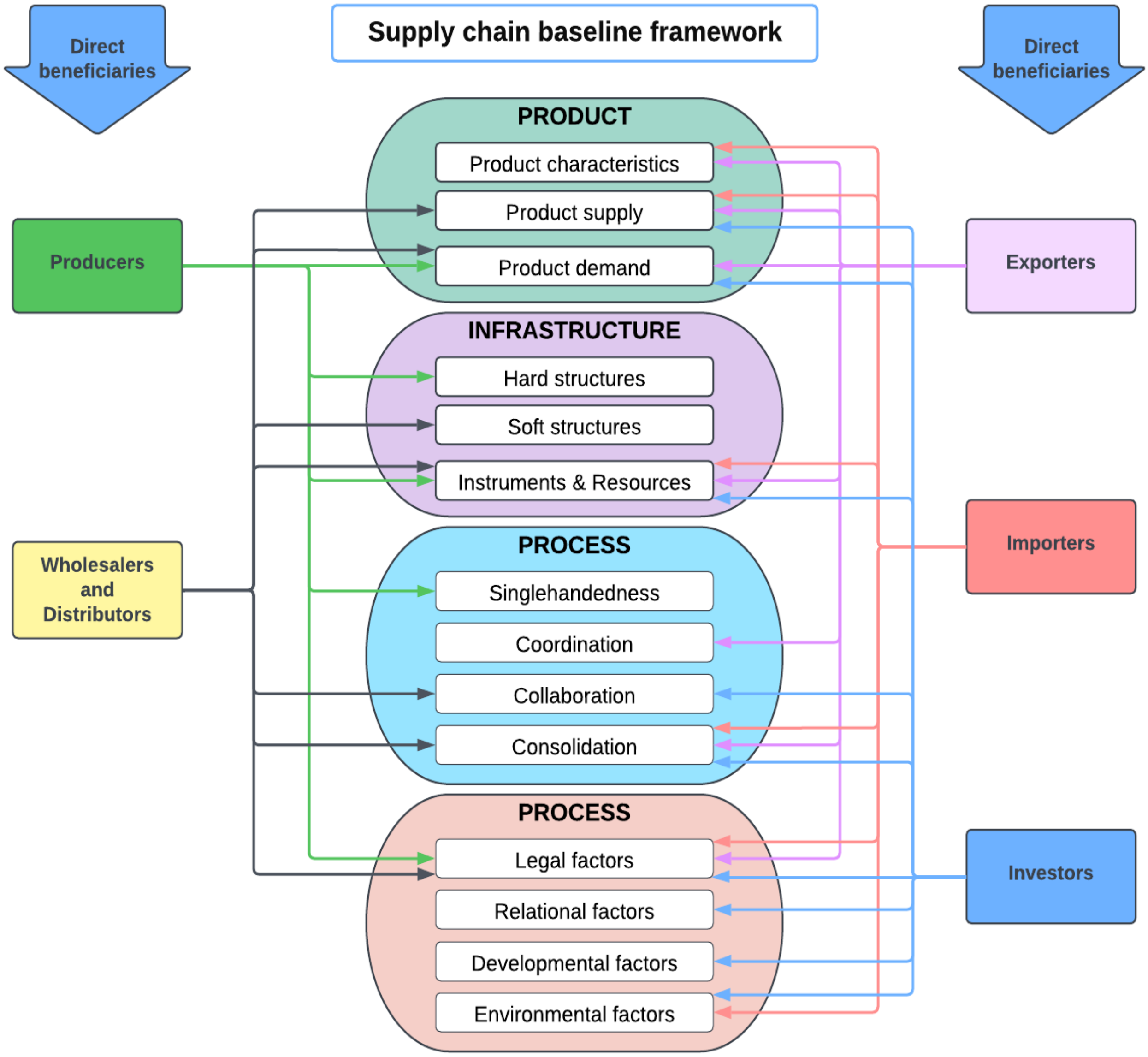


Figure ES.6: Direct beneficiaries of the supply chain baseline framework and mapping tool

G. Translation of research findings

A knowledge-to-action framework (Figure ES.7, given below) was suggested to form connections between knowledge producers and knowledge implementers.

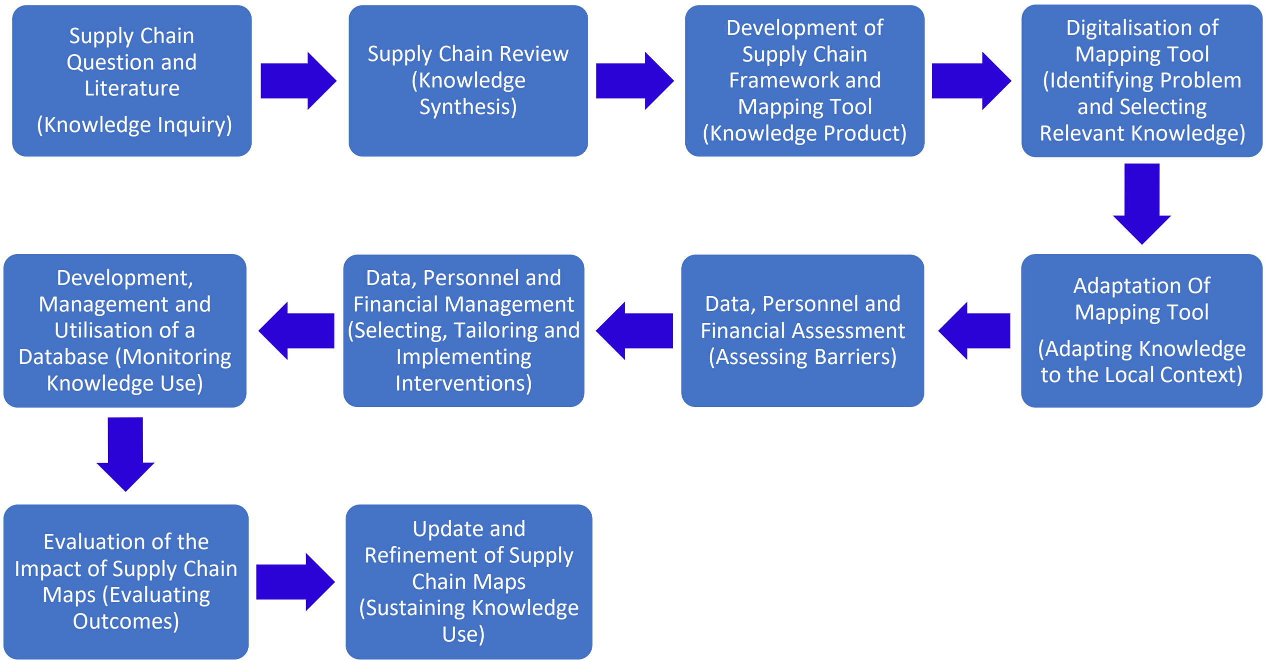


Figure ES.7: Translation pathway of the supply chain baseline framework and mapping tool (Source: Based on Graham et al. 2006)

The agricultural supply chain mapping tool will allow general end-users to systematically collect relevant data/information to describe and explore selected agricultural supply chains in detail. Digitalization of the tool by developing an app would offer greater functionality and user-friendliness. This app would be useful for all those who are involved and interested in agricultural supply chain characterisation not only in Central Queensland but also in the other global agricultural contexts. Subject to adaptation. However, there may be possible risks associated with supply chain mapping, such as issues related to inaccurate data, missing important data, or difficulties in (regularly) updating new data/information and changes in the supply chains. These risks should be properly managed for effective use of the mapping tool, as we have demonstrated in discussing the translation approach. Some recommendations and future research include:

- Digitalization of the mapping tool by developing an App or other appropriate software. The commercialization of the mapping could also be possible.
- Identify the custodian of the mapping tool and develop the management system for the mapping tool.
- Inform the supply chain actors on how to utilize the tool for enhancing the efficiency of the supply chain.
- Utilise the mapping tool to build up collaboration amongst supply chain actors.
- Conduct regular updating of the mapping tool data to inform the producers and other supply chain actors about new opportunities and barriers to market their products.
- There is a need to develop an agricultural supply chain data repository.

1 Introduction

1.2 Background of the project

Central Queensland (CQ) is a major economic region within northern Australia, which contributed approximately 43 billion dollars to the Queensland state's economy during the years 2019-2020 (Australian Bureau of Statistics (ABS), 2020; REMPLAN, 2021). CQ presents as a diverse agricultural region that produces beef, sugar, cotton, grains, fish (aquaculture), and a range of horticultural commodities. Agriculture in CQ contributes about 11 percent of the gross value of the state agricultural produce (Australian Bureau of Agricultural and Resource Economics (ABARES), 2020) and 25 percent of the state's total exports (TIQ, 2018). The CQ region exports about 80 percent of its agricultural products to Asian countries (Department of Foreign Affairs and Trade (DFAT), 2018).

Despite the CQ region's strong capacity for providing a higher volume of diverse agricultural produces, the potential for market diversification, value-added product development and exporting agricultural commodities from CQ is yet to be examined in terms of its supply chain efficiency, supply and market size, labour markets, land and water availability, external economies, and diseconomies. An in-depth understanding of the key products, supply chain features, structure and processes would be the first step in planning for a well-coordinated and integrated supply chain in the CQ region. Some local and regional studies have focused on agricultural production, stakeholder collaboration, consumer demand and market systems; characterisation of agricultural produces; mapping supply chain features; structure and processes, supply chain network and added value; demand in domestic and international markets; and factors affecting the structure of supply chains (ACIL Allen 2019; Akbar et al., 2019; Central Highlands Development Corporation (CHDC), 2018, 2021; CQG Consulting, 2018; Regional Development Australia Fitzroy and Central West Inc (RDAFCW), 2018; Rockhampton Regional Council (RRC), 2018). This study, as a complement of past studies, fills the research gap of defining features, structure, and processes of agricultural supply chains. It also develops a supply chain framework and a mapping tool, which can be used to build a database of precise volume and value of agricultural produces across a broader CQ region, that is important to identify commercially viable key produces of horizontally coordinated and vertically integrated supply chains in various markets (i.e., domestic retail, domestic value-added, international – niche, premium, and general markets etc.).

As mentioned, past research on agriculture in the region has focussed on agricultural production, stakeholder collaboration, preliminary market information, and supply chain analysis. However, those studies have not provided a generic framework and/or a mapping tool that can be used to describe and capture common dimensions, features and characteristics of agricultural supply chains in a specific region (such as CQ). Without clear and systematic information about supply chains, stakeholders may find it difficult to make decisions about when it is appropriate to reorganise or redesign their supply chain's activities and/or structures. However, tracking information about and taking an overview of supply chains has become increasingly more complicated, given that supply and delivery systems are commonly global in nature, and more firms use outsourcing as a strategy (Gardner & Cooper, 2003) to save costs and achieve flexibility. For that reason, there is a need to develop a unified baseline framework for agricultural supply chain description which will appeal to supply chain researchers, and a mapping tool, which will be applicable for supply chain end-users to examine common dimensions, features and characteristics of supply chains. The framework contributes to addressing the research gap in relation to characterising agricultural supply chains from a holistic perspective. The mapping tool will be practical to collect real information about particular supply chains or build a database of supply chains of different commercially viable large scale agricultural commodities in a certain region. Such information is significant for having a systematic overview of, classifying, and comparing the supply chains, that can assist supply chain stakeholders, industry managers, and government agencies in assessing commercially viable produces, with respect to present and future capacities of supply chains in the region. An understanding of such information would be the first step in planning for well-coordinated and integrated supply chains for diverse markets.

The agricultural supply chain mapping tool and the present projects' findings also significantly contribute to the RRC's "Making Water Work" initiatives, the Livingstone Council's (LSC) value chain project (High pressure processing (HPP) Centre building), and the Gladstone Ports Corporation (GPC) container port development, as well as other local and state government planning for future logistics and transport development. There will be strong links to the CHDC's managed "Food and Fibre Plus" project which has ambitions to address shortcomings in current database development across a broader CQ region. Currently, GPC is developing containerisation facilities up to 1.5 million twenty-foot equivalent unit

(TEUs), and this study would help understand the CQ's potential agricultural export volume that can be transported through this facility.

1.2 Project scoping

Project scoping is part of a project's initial planning phase, which is to define the boundaries of what needs to be included and excluded in a proposed project. Project scoping can provide preliminary information and baseline for building the project's timeline, resources, budget, risk analysis, and quality management (Dumont et al., 1997; Khan, 2006). Project scoping, which includes a scope baseline and planning, is also important to track changes during the process of conducting the project. The scope baseline and planning can be outlined by analysing stakeholder requirements, relevant documents, and previous research (Mahlangu, 2020). In the present research, we conducted a scoping study drawing on a literature review and consultation with the project's partners. The scoping study aims to identify opportunities and challenges associated with the CQ's agricultural supply chains, that require attention for further research. It also identifies priorities of each local government area for supply chain development in the future. This information is important for selecting and analysing data about case export commodities in the region in the next stages, as some of these commodity data are applied to the mapping tool which we develop in this project.

1.2.1 Regional profile of CQ

- Central Queensland has a total land area of 117,588.0 km^2 and consists of six regional and shire council.
- Estimated population of CQ is 231,104 persons as of 30 June 2021 with a growth percentage of 0.5%.
- Agriculture industry contributes about 5% of employment in CQ.
- Agriculture in CQ contributes about 11% and 25% of the state's gross agricultural economic output and total exports, respectively.
- Estimated GVP of CQ region for 2023 is $1,734 million (excluding fisheries and forestry), representing approximately 10% of Queensland's GVP.

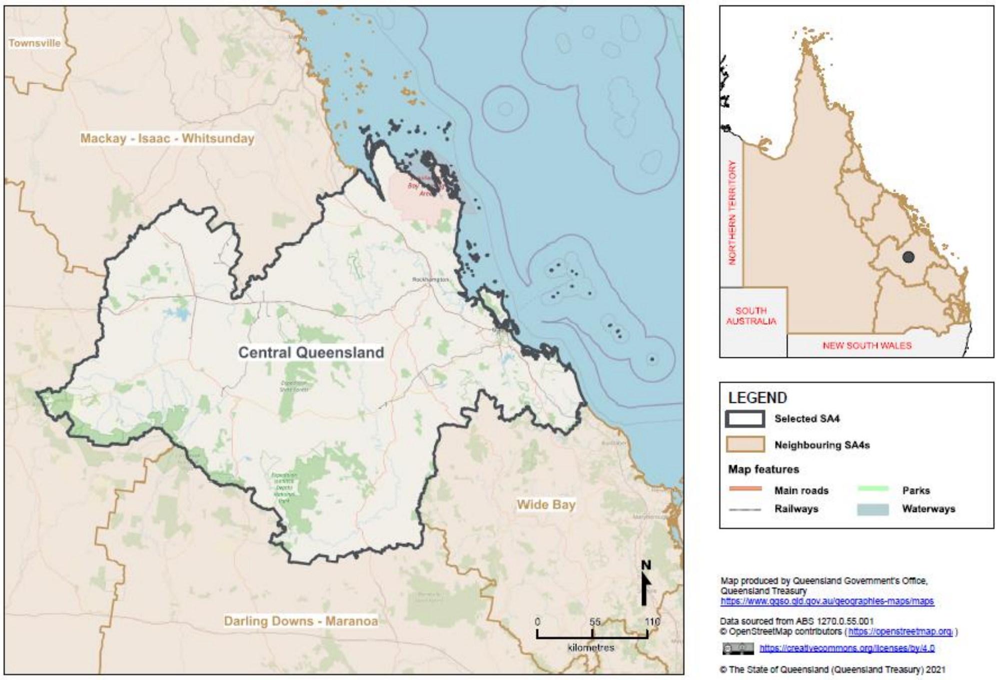


Figure 1: Map of central Queensland

Source: Queensland Treasury (2021)

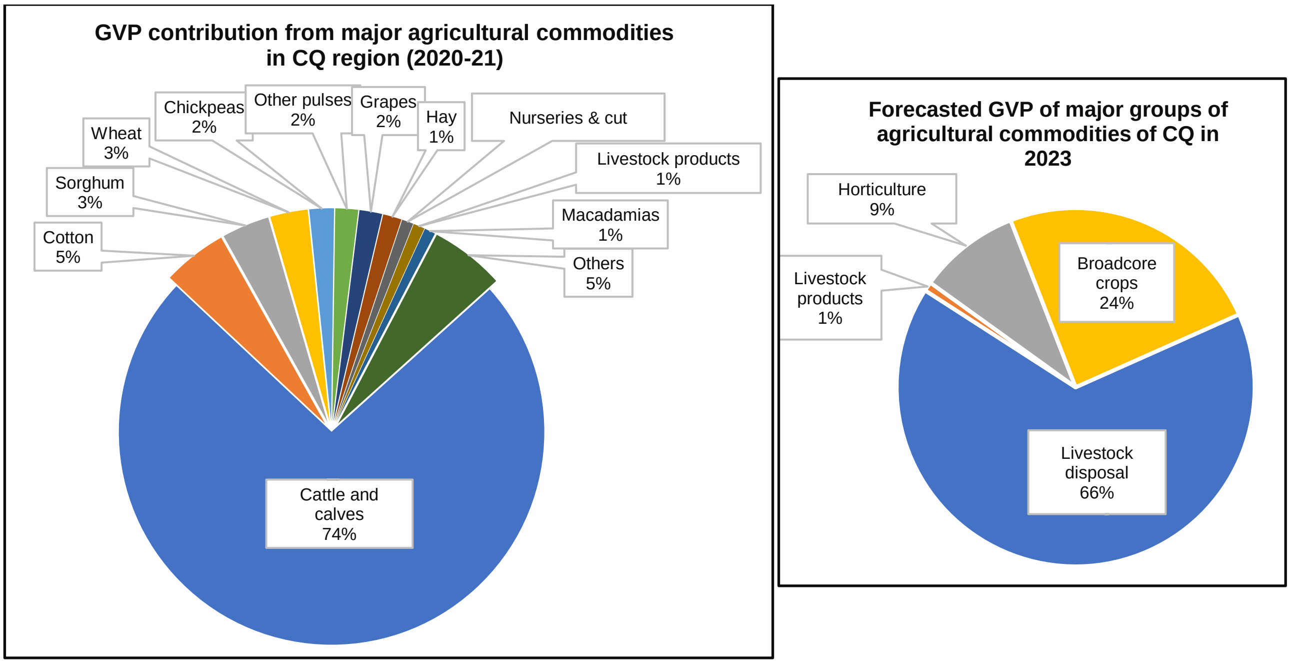


Figure 2: Gross value of agricultural production (GVP) share by the agricultural commodities and groups of commodities in the CQ region.

1.2.2 Agricultural supply chain baseline studies in Queensland

Several studies have been recently undertaken to identify a baseline for visualising various agricultural supply chains in different regions in Queensland. The available reports can be classified for three main regions of Queensland namely: Far North Queensland (FNQ), Northern Queensland (NQ) and Mackay, Isaac and Whitsunday region (MIW). A summary of these reports is provided in Table 1.

By comparing these reports, it was evident that three areas of agricultural export supply chains can be identified for further development. These include:

- Collaboration
- Logistics and infrastructure
- Export readiness and market access

Table 1: A summary of agricultural supply chain baseline studies in three Queensland regions

Key study components	**FNQ Study (KPMG, 2020)**	**NQ Study (KPMG, 2019)**	**MIW Study (ACIL Allen, 2020 and AEC, 2022)**	**Common components**
Focus	Export supply chain development for agricultural produces	Analysis of both production and export supply chains	Value and volume of agricultural produces targeting agricultural supply chains	Export supply chains for agricultural produces
Methodology	• Approach: Explorative and mixed methods • Data: Secondary data (mostly from	• Approach: Explorative and cross-sectional approach • Data: Secondary data (mostly from ABS &	• Approach: Explorative & cross-sectional approach	• Explorative study • ABS data

	ABS), and some primary information (i.e., stakeholders' consultation) • Methods: Descriptive analysis	online), and some primary information (i.e., stakeholders' consultation) • Methods: Descriptive and qualitative analysis, CBA analysis	• Data: Secondary data (mostly from ABS/ACIL Allen), and some primary information (i.e., stakeholders' consultation) • Methods: Descriptive and SWOT	• Stakeholder consultation • Descriptive and qualitative analysis
Product	High value - Horticulture, seafood & beef	High value- Horticulture, seafood & beef, and broadacre crops	Sugarcane, horticulture, seafood, beef, and broadacre crops	Horticulture, beef, and seafood
Market	Export and qualitative assessment of export markets	Priority export markets	• In the first report no clear identification of market. • In the second report export destination of all agricultural commodities has been identified. Potential new markets have also been investigated in this report. • A gross margin analysis tool is presented and used for the agricultural commodities.	Priority export markets
Supply chain	Gap analysis (what and how) for five areas: production, logistics, processing, distribution, and export	Mapping of land capability, suitability, production priority; and method analysis of gaps and constraints in existing supply chains and markets, and value-adding analysis	Production diversity and opportunity	• Production related issues
Recommended theme areas for development **(Short to long term)**	• Collaboration initiatives • Export readiness • Advocacy priorities • Infrastructure development • Implementation roadmap • Short to long term	• Trade and market access • Production • Supply chain and logistics • Collaboration and innovation • Short to medium term	• Collaboration • Future market and supply chain study • Developing aquaculture enterprises. • Developing local value adding industries.	• Collaboration • Logistics and infrastructure • Export/future market

1.2.3 Regional agricultural supply chain baseline components: Stakeholder opinions

Initial consultation with the project's partners focused on five basic themes, i.e., i) opportunities within the local government areas for sustainable agricultural supply chains, ii) challenges within the local government areas for sustainable agricultural supply chains, iii) relevant stakeholders in the region and agricultural industries, iv) local knowledge and reports, and v) local priority issues. The outcomes from the face-to-face consultations with the project's partners are listed in Table 2.

Table 2: Key components identified for CQ regional agricultural supply chains, based on stakeholder consultation

Agenda	Project partners	Identified key components	Component/s applicable across the LGAs
Opportunities (production and supply chain)	RRC	• Primary agricultural commodity is Beef, which has a well-developed supply chain. Two abattoirs in this region underpin the strength of the beef supply chain. • Strong transport network for the beef supply chain through Brisbane • Rockhampton airport has a potential to become an export hub for this region. • There exist opportunities for some perishable commodities (e.g., mango, lychee) and nuts (e.g., macadamia) to increase their export market share • Food manufacturing opportunities • Aquaculture production in Rockhampton region • Aquaculture education and training • Rookwood wire and water security • Soil improvement and carbon capturing opportunities	Beef, horticulture, and grain Value adding industries Water availability Road, rail and marine transport networks
	GRC & GPC	• Value adding opportunities/ circular use • Better utilisation of the port for grain export • Transport cost reduction. • Consolidation in distribution and shipping. • H2 plant for renewable energy in agricultural and industry sectors • Use of freight 'top-up' with agricultural commodities while serving anchor customers of key mineral commodities	
	LSC	• Bovine genetics and high-quality beef production • Growing niche products including seaweed, and pharmaceutical trees (tea tree) etc. • Aggregate stock of resources for expanding the Tourism Events Portfolio • Value added industry such as high-pressure processing (HPP) centres for pineapple and other perishable fruits. • Local exporters network • Forestry in LSC and carbon capturing opportunities	
	CHDC	• Citrus, cotton, and beef • Agri-tourism • Value adding opportunities • Supply chain infrastructure: Inland port • Grading of chickpea: High grade chickpeas could increase revenue • Cotton grading and multi-purpose by-products (seed as animal feed, hay, compost etc)	

	BSC	• Opportunities to increase the processing capacity • On-farm processing (needs approval from the council and environmental licence from the federal government) • Availability of industrial land (land from the 3rd stage development was sold recently) • Diverse agricultural commodities (Beef, Grain, Wheat, Sorghum, Cotton, Herb (including processing) Mung bean, honey (cottage industry)) • Teys: Beef processing • Road connectivity and rail connection to GPC. • Water security: Future project for pipeline from Dawson River. • Potential water allocation from Rookwood Wier • Post mining land use: May be use as a solar farm or waste disposal site • Growth of renewable energy including wind farms	
Challenges (production and supply chain)	RRC	• During the wet season, some cattle stations could be disconnected due to poor road infrastructure • Cold storage facilities • Increased freight charges	Consistency of production & seasonal variability High freight cost Limited logistic facilities Limited value added or processing industries near the growing places Underutilisation of Gladstone Port and Inland Port Lack of skilled labour force
	GRC & GPC	• Seasonality of different commodities and production location • Logistics in the catchment area including inland rail to gladstone port • Utilisation of containerised ports • Convertible freight tasks (due to different freight types for different commodities)	
	LSC	• Effects on and disruption of the supply chain due to the pandemic SARS-COVID-19 • Consistency of supply • Economy of scale • Damage of products during transportation • Each grower has their own network, but the combined effort is not there	
	CHDC	• Beef road: High freight cost • Rail network: Overshadowed by the mine rail • Lack of processing facilities • Lack of human resources • Port does not have grain storage facilities • Input cost of cropping: Cost of fertilizer and chemicals.	
	BSC	• Lack of skilled workforce • Over reliance on traditional marketing • Marketing: Educating local producers about alternative markets • Damage rail connection (Grain crop is lobbing to state to fix the rail line) • Grain loading facilities at GPC are suitable for rail but not for road truck. • Lack of mung bean processing facilities. • Grade A agriculture land could be used by solar plant/renewable energy plants.	
Relevant stakeholders (individuals	RRC	• Sunwater • Abattoirs, and Gracemere saleyards	Primary Industry bodies
	GRC & GPC	• Fortescue Future Industries	

and organisations)	LSC	• Geoffrey Kerr, Principal Trade and Investment & Trade Adviser, TIQ.	Value added industries Growers Water authorities Supply chain and economics practitioners Transport and logistics companies
	CHDC	• GrainCorp, Inland Port, • Cotton and irrigator groups • Glencore: Grain transport • Julianne Hill, GRDC • CQ smart Cropping DAF, Alicia Dunbar • Costa Group: Mandarin • Paul Macintosh: Grain • Nigel Burnett, Chair of Cotton Australia Board. • ACIL Allen	
	BSC	• Australian Mung Bean Association	
Local knowledge and reports	RRC	• Detailed business case: Lower Fitzroy River infrastructure project Rookwood Weir Landholder Support and Grants Program). Consultancy reports for landholders in the Lower Fitzroy region (farm based) and business cases developed for macadamia, mango, mandarin and pulses. • Industry development team focused on Agriculture and Water growth • Rockhampton Region Economic Health Check 2021 • ProfileID statistics platforms including Economy • Cattle reports	Classified and published reports and data ABARES and ABS data
	GRC & GPC	• CSIRO report: Wide Bay Burnett to Gladstone: Transport Analytics • Gladstone Region Wellbeing: 2021 Baseline Report • Commonwealth Department of Social Services Report: Stronger Places, Stronger People Model	
	LSC	• Livingstone Economic health check • Livingstone: Short Term Economic Forecast	
	CHDC	• Economic profile of CHDC • Stage 1 report: Food and Fibre • ACIL Allen Data (based on ABS data)	
	BSC	• ABS Data	
Local Priority issues	RRC	• Utilisation of Rockwood Weir's water for growing high value crops • Export processing hub • Food manufacturing opportunities	High value crops Export processing Hub Water security Supply chain mapping Skilled manpower
	GRC & GPC	• Identification of different commodities with volume and seasonality	
	LSC	• The need to assess the impact of natural disasters across the region and/or their impact on a given industry supply chain • Mapping and assessing the capabilities, connections, opportunities, waste streams, under-utilized assets, growth impediments, skills shortages within supply chains, value chains or networks.	
	CHDC	• Water availability • Agri-tech • Inland port	
	BSC	• Securing water for agriculture • Solar powered irrigation pump	

The scoping, thus, provided directions for conducting and delivering the project's activities and focus for outputs. This acted as a key communication tool between the project's funding agency, the research team, and end-users of the research outcomes (i.e., local governments and ports).

Based on the literature and consultation findings, as previously discussed, the research team acknowledges that there is a variety of studies on agricultural production, forecasting and market analysis at various scales, and that there are also studies on similar issues in the Queensland region. However, few studies develop and provide a unified and structural baseline framework and/or mapping tool for agricultural supply chain characterisation, which can be consistently applied to collect data about agricultural supply chains of different commodities in the region. This is important as these data can be considered as open and transparent information, which can be used to improve production and distribution, supply chain operation, market analysis, and sector management at a more macro level. The present project, as an applied study, contributes to fill the research gap, and provides a mapping tool which can be applied in not only the CQ region, but also in other parts of Australia and the world. The project draws on available published and unpublished research and data, anecdotal information, and stakeholder engagement, to address its aims and objectives.

As a result of the scoping, we have outlined the present project's major phases, objectives and key research activities, as presented in the subsequent section.

1.3 Project aim and objectives

The aim of this project is to develop a baseline framework and mapping tool for agricultural supply chain characterisation as well as identifying, describing and analysing commercially available agricultural commodities in the CQ region.

The project objectives and key research activities have been given Table 3.

Table 3: Outline of the project's objectives and key research activities

Objectives	Task description	Data sources
Objective 1: To develop a structured baseline framework and a mapping tool for agricultural supply chain characterisation through an extensive review of existing literature.	1. Development of an agricultural supply chain baseline framework and mapping tool	Secondary literature review
	2. Project partner and stakeholder discussions on the baseline framework and mapping tool	Primary data: Consultation
Objective 2: To validate and test the framework and mapping tool through stakeholder engagement and direct liaison with stakeholders across the landscape	1. Validating and building consensus on the proposed baseline framework and mapping tool	Primary data: Stakeholder survey and workshop discussion
	2. Testing the mapping tool using selected commodities	Secondary data Primary data: Stakeholder interview and consultation
Objective 3: To identify agricultural markets including examination of high value and commercially viable large scale agricultural commodities for both domestic and export markets	1. Identifying commercially viable agricultural commodities in CQ based on volume and value	Secondary data: ABS, ABARES, DFAT
	2. Identifying data gaps in existing secondary sources and data correction (i.e., ground truthing) by i) comparing locally available data and ii) consulting relevant stakeholders	Primary (stakeholder interview and consultation, workshop discussion) and secondary data
	3. Identifying potential demand for the agricultural commodities in domestic and export markets	Secondary data
	4. Identifying current export market access and possible future markets	Secondary literature review and consultation with relevant stakeholders (primary data)
Objective 4: To explore factors affecting current supply chain structures and processes that lead to meet the future export demand	1. Identifying the availability of resources including land, labour, and water to support supply chains of the selected commodities	Secondary data
	2. Identifying logistics and transportation capabilities of the region for the selected commodities	Secondary data

	3. Identifying existing value chains for the selected commodities	Secondary and primary data (stakeholder consultation and interview)
	4. Identifying horizontal collaboration in the existing supply chains for the selected commodities	Secondary and primary data (stakeholder consultation and interview)
	5. Identifying vertical integration in the existing supply chains for the selected commodities.	Secondary and primary data (stakeholder consultation and interview)

1.4 Organisation of the report

The report is organised as follows: after the introduction, a detailed description of the project's methodology, including methods for review, data collection and validation, and data analysis, is provided. This is followed by a literature review where discussions on agricultural supply chains and their characteristics, and on agricultural data for export commodities are presented. The results and findings, where an agricultural supply chain baseline framework and mapping tool, validation and refinement of the framework and mapping tool; product, supply chain, and market data analysis; as well as presentation of supply chain maps for five agricultural commodities, are then discussed. Finally, a summary of findings, discussion on contributions, recommendations for translation of research findings, and conclusion together with foreshadowing of future research, is provided.

2 Methodology

Details of the project methodological approaches are given below. We have received ethics approval from the CQUniversity's Human Ethics Committee (CQU HREC23342) for the present project's research activities and data collection.

2.1 Project scoping and tasks

An applied methodology was employed for scoping the project, where literature review and stakeholder consultation were used. The literature review was conducted to recognise past studies on agricultural supply chain baseline in the Queensland region, and to outline major phases, objectives, and research activities required for the current project (see Table 3). The outline of research activities was also used as a guide for consultation with the project partners.

The consultation steps involved speaking with the project partners to collect information about agricultural supply chains in the region and to identify relevant stakeholders who can participate in the project. Organisation partners for this project are Rockhampton Regional Council (RRC), Gladstone Regional Council (GRC), Gladstone Port corporation (GPC), Banana Shire Council (BSC), Central Highlands Development Corporation (CHDC) and Livingstone Shire Council (LSC). The research team requested semi-structured, face-to-face consultations with one representative from each of these organisation partners. All consultations were held between November to December 2021. Data were collected by taking notes and through follow-up email correspondence.

The findings of the consultation revealed opportunities and challenges for sustainable agricultural supply chains in the CQ region. Local priorities for the LGAs of the CQ region were also identified through the consultation process. The initial consultation with the project's partners allowed the research team to identify relevant stakeholders for further consultation and feedback. The scoping, hence, set a pathway for collecting data and streamlining research activities in the next stages of the project (Table 4).

Table 4: The phases of project activities

Project Activities	
Phase 1	Stakeholder consultation: Scoping the project
Phase 2	Literature review: Developing Agricultural Supply Chain framework and mapping tool, data collection and correction methods, and major export commodities of CQ.
Phase 3	Stakeholder workshops: Development & testing the mapping tool
Phase 4	Stakeholders interview: Ground truthing of production and export data for selected commodities.
Phase 5	Final report: Key findings, contributions and translation pathway
Phase 6	Stakeholder forums: Stakeholder perceptions about the usability and governance of the mapping tool
Phase 7	Publish final report: Independent review and publishing final report

2.2 Research design

After scoping the project, we used a mixture of methodological approaches for literature review, primary and secondary data collection, data analysis, and framework validation. An overview of the research design, which highlights the methods applied in this study can be seen in Figure 3:

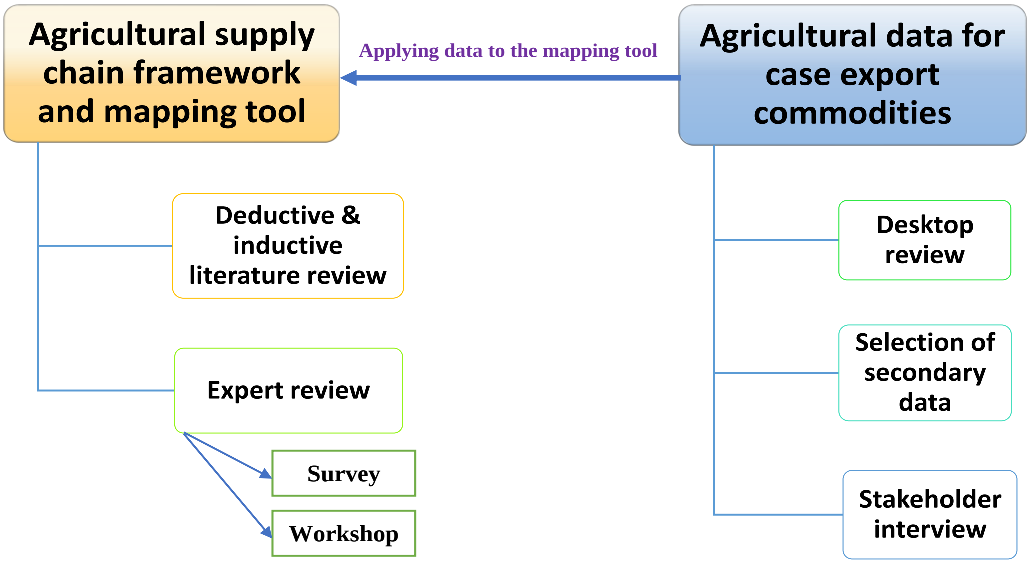


Figure 3: Overview of the project's methodological approach

2.3 Methods for development and validation of an agricultural supply chain baseline framework and mapping tool

2.3.1 Deductive and inductive literature review

2.3.1.1 Approach

We drew on a dual deductive – inductive approach in conducting a literature review on diverse features and characteristics of agricultural supply chains, which is a strong basis for developing a baseline framework and mapping tool for agricultural supply chain characterisation.

Deductive literature review is a method which uses one or more than one theoretical foundation as a guide to develop related dimensions, features, or items (Tanwar & Prasad, 2017). An inductive literature review begins broadly with an area of study, uses specific ideas from the literature to make broad generalisations and allows the theory to emerge from these ideas (Hall et al., 2022; Hong & Coogle, 2016). In developing a framework and mapping tool in this project we utilise both the deductive and inductive reviews. The dual approach enables us to conduct a literature review where our creative selection and analysis of variables, patterns and themes, systematic development of clusters, and rigorous structure maintenance, are to a certain extent balanced (Durach et al., 2021).

The proposed framework and mapping tool were expected to consist of several layers of components, dimensions and features about multiple characteristics of agricultural supply chains. The first layer, which is associated with major components, was proposed with reference to selective supply chain/agriculture/relationship models, frameworks and mapping tools. The second layer involves general dimensions, which are structural of these components, was determined from both the existing models, frameworks, and mapping tools, and literature review on agricultural supply chains. The third layer, which includes diverse features associated with the general dimensions, was identified by extensively examining the literature about supply chain and agriculture. Thus, in this project, we characterise agricultural supply chains as a multi-aspect complexity formed by interrelated components, dimensions, and features.

2.3.1.2 Procedure

The literature review for building a framework and mapping tool went through two different review phases, where the two methods were combined and applied in a systematic manner.

Phase 1: Initial literature review was conducted to identify existing models, frameworks or mapping tools related to agriculture and supply chains as well as major components and dimensions of agricultural supply chains. The literature was searched using Google Scholar Search Engine, which provides a wide coverage of scholarly work.

We used multiple keywords such as “supply chain”, “agriculture”, “agricultural”, “agricultural supply chain”, “supply chain characteristics”, “characteristics of (agricultural) supply chains”, “dimensions of (agricultural) supply chains”, “framework”, “supply chain framework”, “mapping”, “mapping (agricultural) supply chains”, “supply chain map”, and so on (all with double quotation marks). We combined them in different ways in our search attempts to maximise the search results. The Endnote software was used to save and manage the references found.

Our search results suggested that there were not many studies which provide a complete framework or mapping tool for agricultural supply chain characterisation. At least 20 studies which discuss a framework/model were selected and examined in detailed. Considering the purpose of the present project, we considered four publications for our framework and mapping tool development, i.e., Chhetri et al.’s (2022) model, Keast’s (2016) relationship forms; Romsdal et al.’s (2011) framework; and Schrobback et al.’s (2020) description matrix.

Based on the four theoretical accounts, we proposed a simplified framework of agricultural supply chains which consists of four domains, namely PRODUCT, INFRASTRUCTURE, PROCESS, and FACTORS (see Figure 4). This simplified framework was then used as a deductive guide for literature search and an analytical framework for literature examination in the next phase. Some initial dimensions (sub-categories) associated with these four domains were also identified during this phase. The theoretical review results, which are the basis of the deductive review procedure, are presented in Section 3.1.3.

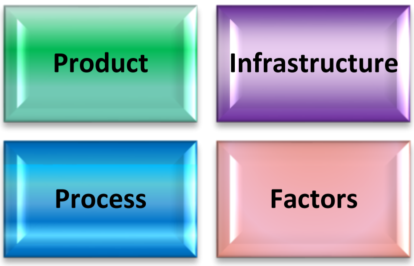


Figure 4: Four domains of an agricultural supply chain baseline study

Phase 2: In the second phase, the review of literature was conducted to synthesise existing knowledge about diverse characteristics of agricultural supply chains. Arksey and O’Malley (2005) outline a framework for a scoping literature review, in which they highlight a five-stage review procedure (see Figure 4). We followed these five stages with some minor adaptions so they would suit our review purpose.

The first stage identified the research question. We sought to understand ‘*what is known in the literature about common characteristics of agricultural supply chains in terms of product, infrastructure, process, and factors?’*

The second stage was identifying relevant studies. The literature was searched extensively using Google Scholar Search Engine, which provides a wide coverage of scholarly work, and other search engines in several databases such as Scopus, Web of Science, ProQuest and EBSCOhost.

We used multiple keywords related to items associated with the four domains of product, infrastructure, process, and factors. The search keywords were taken from components/items listed in selected theoretical account papers, as well as from our knowledge about agricultural supply chains and their characteristics. As shown in

Table 4, keyword snowballing technique was also applied as we screened documents from the initial searches and found other terms related to different characteristics and features of agricultural supply chains. To maximise the search results, we did not filter them in terms of publication time or context. The documents selected were limited to English only. We used the Endnote software to manage themes associated with the references found. The last search date was 22 March 2022.

Table 4: Selective examples of keywords used in searching the literature.

Keyword 1	Keyword 2 (additional)	Keyword 3 (Always included)
"food type", "perishability", "seasonality", "bulkiness", "product life cycle", "product variety", "supply uncertainty", "demand variety", "delivery lead time", "farm gate to", "traceability", etc. "contract", "communication", "information sharing", "power distribution", "business culture", etc.	"agricultural", "agrifood", "agri-business", "aquaculture" "horticultural", "food", etc.	"Supply chain"

The third stage was study selection. Due to the use of dozens of key words in our literature search, that resulted in thousands of documents found, as well as some difficulties in the searching process such as the variance of terminologies used to describe the same issues in different studies (such as the case of "agricultural supply chain" discussed in the previous section) although a *Boolean* search strategy was sometimes applied, our search results seemed to show the breath rather than the depth (Arksey & O'Malley, 2005). For that reason, we screened and examined the documents to compare and select the most relevant studies or discussions which could be used to illustrate the supply chain characteristics. Finally, nearly 150 studies were used to illustrate our discussions in the literature review.

The fourth stage was charting the data. After selecting the most relevant studies for inclusion in the review, we sorted and charted the materials in a systematic manner, which is in line with our intended discussions. We extracted and sorted the materials referring to the four components of product, infrastructure, process, and factors (level 1), which were used as an analytical framework. Papers which describe different supply chain features (level 3) were then allocated to different sub-categories associated with supply chain dimensions (level 2). The sub-categories included in this study are presented in Figure 5.

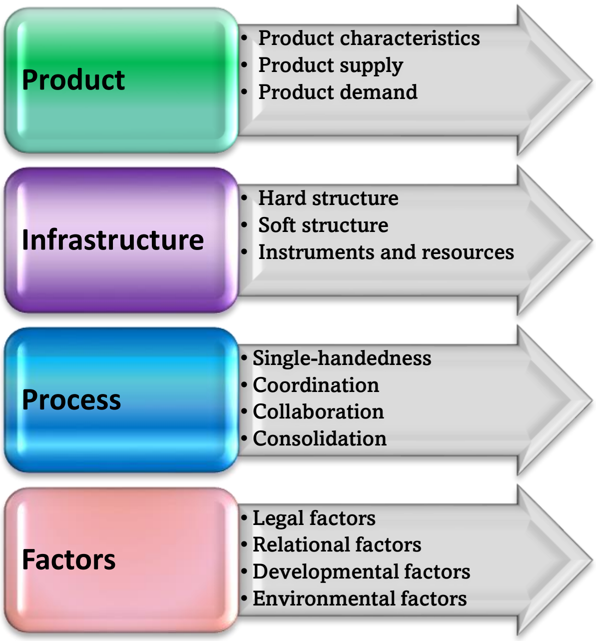


Figure 5: The four domains of an agricultural supply chain, together with their dimensions

The last stage is collating, summarising and reporting the results: The writing based on the charted materials was organised thematically, that helps highlight our discussions featuring each characteristic of agricultural supply chains. This report presents a systematic account of existing literature related to agricultural supply chains. As such, we tried to provide evidence from the literature relevant to our presentation and discussions. The review results are presented in Section 3.1.3.

2.3.2 Expert review

2.3.2.1 Expert review as a content validation approach

Expert review (or expert validation) is one of the most common methods which are used to validate the content of a particular framework, model, or instrument and its relevance, applicability, and representativeness (Haynes et al., 1995). Expert review is where a group of experts inspect and evaluate a given framework in terms of its overall structure, components, individual items, and useability (Hyrkäs et al., 2003; Richey, 2005), and put forward suggestions for modifying or refining if necessary (Wu & Lee, 2016). This validation stage is of critical importance, as it can provide informed opinions, assessment, and judgement by qualified experts (Ghadiminia, 2021). In order to obtain reliable review results, according to Podvezko (2008), it is necessary to invite from 6 to 9 experts to join the review panel. In studies by Babatunde et al. (2016) and Eadie (2009), the size of the expert review panel ranges from 5 to 10.

Expert opinion collection methods can be quantitative and qualitative in nature (Hyrkäs et al., 2003). In validating the framework and mapping tool in the present project, both quantitative and qualitative expert review method (survey and workshop discussion) were used. This allowed us to gain richer insights into the views of the experts on the models developed.

The quantitative and qualitative expert review in this project focused on the following issues:
- The level of importance and necessity of features and dimensions in the proposed framework and mapping tool.
- The need to include additional features to have a more comprehensive framework and mapping tool.
- The applicability of the mapping tool.

2.3.2.2 Quantitative expert review: Survey questionnaire

An online survey was developed to quantitatively collected experts' opinions about the importance and necessity of features included in the framework and mapping tool for agricultural supply chain characterisation. The survey questionnaire was designed using Qualtrics, a high-quality online survey tool. The questionnaire was developed based on components, dimensions and features in the framework and mapping tool (see Appendix 2). Most of the questions regarding the supply chain features were designed using a five-point Likert scale, ranging from "not at all important" to "extremely important".

In the first round of the present project's expert review, we sent a survey (survey link and workshop invitation), via email, to a group of around 35 people of diverse expertise, background and work experience related to supply chains in the agriculture sector in Central Queensland. Initial results of the survey were shared with experts participating in the workshop (discussed below). A total of 13 survey responses (12 online and 1 paper-based) were received (among which there are two responses with some incomplete answers), representing a response rate of 30 percent approximately. Information about the survey respondents' work background is presented in Figure 6.

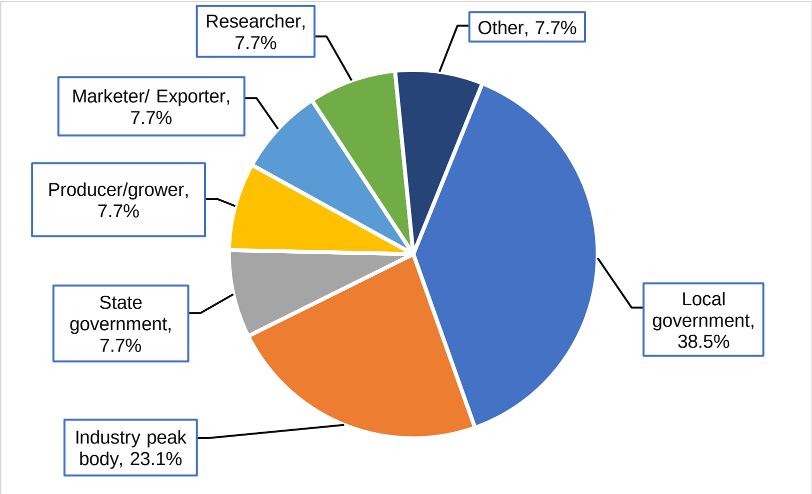


Figure 6: Profile of experts participating in the survey

2.3.2.3 Qualitative expert review: Workshop discussion

The research team organised a workshop to collect qualitative feedback from the experts. We invited a cross-section of experts with expertise, background and work experience, using two approaches: a "representative" approach that identified people from different sectors (such as state government, industry peak body, or researcher), and an "interest" approach that identified people who would be most affected, such as producers. This structured way of approaching workshop participants enabled a discussion of experts across different sectors and interests and the convergence of these throughout the review process (Akbar et al., 2020).

The expert workshop was designed in a hybrid mode (face-to-face and Zoom) around 3 weeks after the survey invitation. A total of 15 experts (excluding members of the present project's research team) attended the workshop, including 11 coming to the face-to-face session and 4 joining online. A summary of the information about the workshop participants is presented in Figure 7:

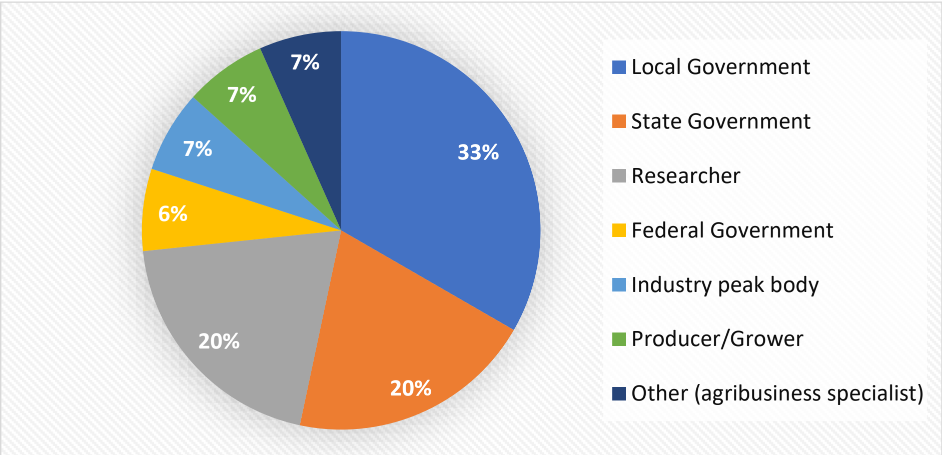


Figure 7: Experts participating in the workshop

The workshop was designed to discuss features in the proposed framework and mapping tool, supply chains of two case commodities, and some issues about collecting agricultural data of some commodities in the region. The experts spent a lot of time on discussing the supply chain features, which helped the research team to refine the supply chain mapping tool.

2.3.3 Analysis of survey and workshop data

2.3.3.1. Quantitative data analysis

Data analysis was carried out to understand the experts' views and feedback on the framework/mapping tool in a systematic manner. The main data collected include survey responses and workshop discussion records. Survey responses were analysed quantitatively using simple descriptive statistics.

2.3.3.2. Qualitative data analysis

Workshop discussion records were transcribed verbatim. Qualitative data were analysed using thematic analysis to develop themes inductively and systematically in examining the experts' views on components, dimensions and features of the framework and mapping tool.

Finally, we triangulated by clustering and examining data about the same issue from both the survey and workshop, that enabled us to confirm or make decision on each feature of the framework and mapping tool. The experts' survey responses and feedback in the workshop were used to double-check and refine the framework and mapping tool. The refined framework and mapping tool were noted as the refined versions which were then used to characterise supply chains of some case export commodities in central Queensland.

2.4 Methods for evaluation and collection of agricultural data for export commodities

2.4.1 Desktop review (desk study)

Desktop review, or desk study, is a review method which is often used to collect information about and carry out a preliminary assessment of one or more research issues based on existing materials. The present study adopted a desktop review to investigate data collection processes in related studies and identify potential gaps in their data about production volume and value for the agriculture industry. This literature review serves two purposes: (1) to summarise and synthesise the existing practice of agricultural data collection and (2) to identify the use of new technologies and methods for improving the accuracy of agricultural data. In this review, we considered both academic journals and publicly published reports, which are available online. Google Scholar and the general Google search engines were used to identify relevant and recent studies because both search engines provide a wide coverage of both peer-reviewed and grey literature compared to other search engines or databases. For the purpose of the present review, we considered articles and reports published in the last 10 years only. The literature screening process, which was undertaken manually, included two stages: The first stage is abstract screening, and the second stage is full-text screening. The search framework is presented in Table 6.

Table 5: Literature review strategy: Search framework

Search tools	Google Scholar and Google search engines
What	Agricultural data, production volume data, value data, and yield data.
For whom	Agriculture producers, Government and National statistics agencies.
Search keywords	Agricultural data, ABS data, accuracy of data, data gap, data correction, agricultural survey
Institutions	Australian Bureau of Statistics (ABS), Australian Government Departments, Food and Agriculture Organization of the United Nations (FAO), Asian Development Bank (ADB),
Temporal attributes	Recent 10 years

2.4.2 Selection of secondary data

- Secondary data were collected from ABS, ABARES, QGSO, MLA, QDAF, FAO, US Department of Agriculture, and foreign agricultural services.
- The base data set was ABS data, and all the other data sources were utilized to complement the ABS data and to cross-check the existing data.
- Some data were also collected from the project partners and were utilized to develop baseline data sets.
- Relevant data about selected case study agricultural commodities were also collected from peak industry bodies.

2.4.3 Stakeholder interviews

The research team organised stakeholder interviews to develop a better understanding on agricultural supply chain. Based on the secondary data, five commodities with high economic values were selected. The key purpose of the interviews was to develop a supply chain map for these commodities. In building the interview protocol, we considered the refined mapping tool and identified the sources of data for each supply chain components. Four main sources of data were identified to describe the multiple supply chain features (as presented in the mapping tool). The data sources include Literature review, Secondary data, Primary data from the producers, and Primary data from relevant industries and experts. The assignment of data sources is presented in Table 6. For some feature data could be collected from multiple sources, however, we selected the most reliable data sources for each entry in Table 7 to avoid any conflicts in the data reporting.

Table 6: Data collection framework to populate entry fields of five supply chain maps

Data source: A: Literature review B: Secondary data
C: Primary data from the producers D: Primary data from relevant industry and experts

		Code	Feature	Data sources
Product	Product characteristics	P1	Product category	A
		P2	Food type	A
		P3	Perishability and shelf life	A
		P4	Seasonality	A
		P5	Bulkiness	A
		P6	Product life cycle	A
		P7	Product innovativeness	A
		P8	Product variety	C
	Product supply	P9	Farmgate-to-shipping time	A
		P10	Type of product processing	A
		P11	Supply availability	B
		P12	Product value	B
		P13	Supply uncertainty	C
		P14	Stock ability	C
		P15	Value adding	C
		P16	Delivery lead time	C
	Product demand	P17	Market type and distance	A
		P18	Access to market	A
		P19	Consumer segmentation	A
Infrastructure	Hard structure	I1	Number of entities	C
		I2	Type of networks	D
	Soft structure	I3	Level of dependency	C
	Instruments & Resources	I4	Facilities	A
		I5	Technology	C
		I6	Labour force	C
		I7	Transport	D

Process	Singlehandedness	Ps1	Single-handed production and business	C
	Coordination	Ps2	Communication and information sharing	A
		Ps3	Power distribution	D
	Collaboration	Ps4	Shared strategies and interests	D
		Ps5	Business culture	D
		Ps6	Trust and commitment	D
	Consolidation	Ps7	Brand consolidation	C
		Ps8	Freight consolidation	C
Factors	Legal factors	F1	Government policies, regulations and support	A
	Relational factors	F2	Relationship with industries	C
		F3	Relationship with investors	D
	Developmental factors	F4	Research and development	A
	Environmental factors	F5	Natural or human-induced risks	A

In the next stage, we developed two sets of interview protocol for each commodity to cover all the components of the mapping tools. The interview protocol for the industry bodies and experts consists of both open-ended and structural questions with more emphasis on production and export data. The interview protocol for producers, includes semi structured questions, and is more concentrated on supply chain structure and related issues. A purposive sampling method was chosen and the sample size for the interviews was 30. Since the interviews would not focus on very in-depth discussions, the research team opted to interview 3 persons from the producers' side and 3 from the industry peak bodies for each commodity. The interviews were conducted from September to October 2022.

2.4.4 Analysis of interview data

A mixed methodology was adopted to analyse interview data. Data was categorised under the themes developed from workshop data and based on the mapping tool structure. A thematic analysis was undertaken to select relevant data to fill in the five agricultural supply chain maps. A predictive model was employed to analyse the quantitative data collected through the interviews. Information which was confirmed by many of the stakeholders in their interview discussions were collated to finalize data for each feature in the supply chain maps. The data collection was interrupted due to the harvest season of different crops and the excessive rains during the early summer of 2022. The research team interviewed 27 stakeholders including producers, processors, and industry and government representatives. In addition to stakeholders who have knowledge about the five key commodities, mandarin and grape producers were also interviewed. Key outcomes of the interview analysis were used to build case-study supply chain maps for five selected commodities and for identification of data gaps in production and export data about these commodities.

2.5 Stakeholder forum

Two stakeholder forum was organised to disseminate the research findings and to identify the way forward. First workshop was held at Emerald in February 2023 and the second one was organised at Rockhampton in March 2023. In the first forum, 16 relevant stakeholders participated, while in the second workshop about 10 participants attended. The key discussion themes of the stakeholder forum were 1) usability of the Agriculture Supply Chain (ASC) Mapping Tool, 2) Implementation of the ASC Mapping Tool, and 3) Development & management of the ASC Mapping Tool. The participants' discussions on these three themes were recorded and analysed later using narrative analysis to identify the way forward.

3 Literature Review

3.1 Agricultural supply chains

3.1.1 Defining agricultural supply chains

In consumer societies, the term supply chain has become common even for those who are external to activities in the sector. A supply chain involves a set of practices to deliver the continuous flow of goods through various stages from raw materials to final produce, and from production to consumption, as well as bi-directional information circulation during these stages (Monczka et al., 2002). For Chandrasekaran and Raghuram (2014), a supply chain comprises of two main elements: (1) the physical element – strategic partnering, and (2) the information element – data sharing. Supply chain quality can be evaluated by examining the process in which entities participating in the chain work jointly to enhance their product quality and service performance to satisfy customer satisfaction (Siddh et al., 2017). Thus, a supply chain can be seen as a value-chain network in which functional chain members commit to working together towards optimising their profit through a competitive production and distribution channel (Chandrasekaran & Raghuram, 2014).

Supply chains in the agriculture sector are distinct from other supply chains, such as in manufacturing industries. As agriculture involves diverse farming, animal husbandry, and aquamarine-related activities (Chandrasekaran & Raghuram, 2014; Routroy & Behera, 2017; Schrobback et al. 2020), significant variation exists with respect to the concepts characterising agricultural supply chains. Specifically, agricultural supply chains can be referred to as agri-food supply chains, food supply chains, agriculture value chains, post-harvest supply chains, fruit supply chains, agri-business supply chains, perishable produce supply chains, fresh produce supply chains, aquaculture supply chains, or horticultural supply chains, and others (Routroy & Behera, 2017). Agricultural supply chains, which include all activities required to bring the food product to consumers, are highly complex due to special characteristics/conditions of their product, such as variability, perishability, short shelf-life, strict safety requirement or demand uncertainty, that makes the management of such supply chains typical and difficult (Schrobback et al., 2020; Siddh et al., 2017).

Although scholars and practitioners in the field provide various and different definitions which emphasise on different dimensions of agricultural supply chains to suit their research purpose, an agricultural supply chain, generally, can be described as a sequence of “farm-to-fork” activities including farming, production, processing, testing, packaging, warehousing, transportation, distribution, and marketing (Tsolakis et al., 2014). These activities often involve multiple processes, operations, and entities, which aim to procure or converse the raw/freshly harvested food to a produce which can be provided to consumers (Chandrasekaran & Raghuram, 2014; Dani, 2015). An agricultural supply chain, however, may not be fully characterised if the definition of description is limited only to operational activities such as production, transportation, or distribution. Rather, this should also be augmented by a description of structure, relationship, and management, as these are also to capturing a holistic picture of the full complexities of agricultural supply chains.

3.1.2 Frameworks and mapping tools for characterising agricultural supply chains

Research which explores the link between supply chain characteristics and the competitiveness of the chain in the market has suggested that different product, manufacturing and/or market characteristics exert different structural and operational pressures and requirements on agricultural supply chains in terms of efficiency, flexibility and responsiveness (Romsdal et al., 2011, p.2). In developing a framework and mapping tool for agricultural supply chain characterisation, therefore, it is important to take a multidisciplinary and multi-theoretic approach by involving multiple features related to product, production and marketing, structure, management and other issues, thereby holistically capturing productive, structural, relational, operative, and externally influenced aspects of supply chain complexity (Chhetri et al., 2022; Romsdal et al., 2011).

There is an impressive number of studies focussed on describing various features of agricultural supply chains. However, very few of them provide a generic framework or mapping tool that can be used to characterise and interpret agricultural supply chains and their common attributes. The few existing frameworks, models or mapping tools which capture (agricultural) supply chain characteristics, furthermore, provide limited guidelines on supply chain relationships and external elements that influence supply chains. In an attempt to understand and learn from what is known in the literature, below we provide a brief discussion of selected supply chain frameworks or mapping tools which are relevant to the present study. Particularly, these include:

- Chhetri et al.'s (2022) model for theorising the link between product demand, product design, and supply chain complexity,

- Keast's (2016) continuum of interorganisational relationships. It is necessary to note here that although Keast's (2016) model does not directly relate to supply chains, this model provides a systematic look at different relationships (e.g., coordination, collaboration, consolidation) which are often discussed as different types of "collective actions" by internal and external supply chain entities in various supply chain studies (e.g., Kanda & Deshmukh, 2008; dos Santos & Guarnieri, 2020).

- Romsdal et al.'s (2011) framework for characterisation of fresh food supply chains, and

- Schrobback et al.'s (2020) supply chain description matrix.

As we observe, these supply chain description frameworks or mapping tools explicitly or implicitly consist of components or items related to four main themes, namely supply chain product, supply chain infrastructure, supply chain process, and factors that influence supply chain.

Supply chain product is perhaps the first and most important theme included or featured in most supply chain description models and maps. Chhetri et al. (2022), for example, emphasise the role of product in forming relational arrangements in supply chains, and highlight the relationships between product demand, product design, and supply chain relational complexity. They insist that characteristics of product demand (such as demand volatility, product variety, or product life cycle), as well as of product design (such as product structure complexity or product innovativeness) have a significant impact on supply chain complexity. Romsdal et al. (2011) and Schrobback et al. (2020) also include product characteristics (including items such as product perishability and shelf life, product complexity, product variety, food category, seasonality or product life circle) as the major component of their supply chain framework/matrix. In addition to product characteristics, Romsdal et al. (2011) recommend two other description categories, being market characteristics (such as delivery lead time or demand uncertainty) and manufacturing system characteristics (such as supply uncertainty, make-to-order lead time, or technology), which can be seen as comparable to Chhetri et al.'s (2022) product demand and product design, respectively.

Another important theme for describing supply chains is infrastructure, which refers to networks, instruments and resources available in a supply chain. This theme is not explicitly discussed, but randomly included as sub-categories or items in the above frameworks/matrixes. Romsdal et al. (2011), for example, mention technology under the "manufacturing system characteristics" category, noting that this is about machines, equipment and devices involved in product manufacturing. Schrobback et al. (2020) provides more aspects related to this theme, such as supply chain structure (changes of hands), relationships (types of collaboration) or capacity (which includes several sub-items such as level of technology adoption/need for advanced technology structure, availability of infrastructure or availability of resources, and so on).

Supply chain process, which is about relationship forms among entities in the supply chain, are also discussed in these frameworks/models, although to varying degrees. Keast's (2016) continuum of interorganisational relationships, for instance, especially focuses on such processes and this is relevant in describing not only supply chain relationships, but also interorganisational relationships in general. The author suggests five main relationship forms, including competition, cooperation, coordination, collaboration and consolidation (the 'five Cs'), and highlights the close grouping of cooperation, coordination and collaboration (the 'three Cs) as playing a central role in this relational continuum. These three interorganisational relationship forms are widely mentioned in supply chain research (e.g., Bhattacharya & Fayezi, 2021; Soshko et al., 2007). Supply chain process is also the key component of Chhetri et al.'s (2022) model, which aims to explore supply chain (relational) complexity in relation to product demand and product design. They propose three constructs that can be used to measure this complexity, namely coordination, collaboration, and configuration. Supply chain relationships are also included in Schrobback et al.'s (2020) supply chain matrix, although it is not presented as a major description category.

In addition to the key components characterising supply chains previously discussed, Schrobback et al. (2020) posit that there are external factors that may influence supply chains' structure, process and performance. These factors can be related to government regulation and investment, market access, economic situation or natural risks. For them, these factors can sometimes facilitate or constrain supply chain practices and activities.

The above frameworks/matrixes are useful for researchers to describe various supply chain features. However, none can be used as a specific tool to capture a complete picture of supply chains in general or agricultural supply chains in particular. This is because although these supply chain description frameworks or mapping tools, explicitly or implicitly, include different components or items related to the four main themes, namely supply chain product, supply chain infrastructure, supply chain process, or factors that influence supply chain, none of them have clearly comprised of all these themes as parts of their model.

Referring to the four frameworks/matrixes previously discussed and drawing on a review of literature, we have developed an innovative framework for describing agricultural supply chains which are made up of four main components: product, infrastructure, process, and factors (see Figure 3). Specific features under the components have been adapted so the framework can be used in the context of central Queensland's agriculture sector, yet they are general enough to be applied to theorise agricultural supply chains in various parts of the world. This framework was then expanded as a mapping tool for general end-users to characterise and understand agricultural supply chains in their own context. The literature is discussed in the subsequent section.

3.1.3 Describing agricultural supply chains: A review of literature

3.1.3.1 Product

Product, or the product which the supply chain produces and distributes, is essential to characterise and differentiate supply chains, especially in the agriculture sector where organisation of supply chains is highly complex due to special characteristics and conditions of the product. Our review supports the well-established view in research that characteristics of a supply chain need to align with the chain's product features, as this is important for effective supply chain practices. For that reason, our discussion on this category is extensive compared with the discussions on infrastructure, process and factors (in the coming sections). Under the PRODUCT category, we focus on three main issues, namely product characteristics, product supply, and product demand.

Product characteristics

Product characteristics include various features related to the product itself, such as food type, product category, perishability, seasonality or bulkiness.

Food type (e.g., horticulture, grain, animal protein, dairy, aquaculture product, non-food agriculture product) is a key feature which determines the whole supply chain construction, process and behaviours. As different food types have their own attributes, each type may present natural issues that are addressed by the operators constituting that supply chain (Battacchi et al., 2020). For example, food type is a deciding factor in supply chains' processing, storage, quality guarantee, or transportation period (Weber & Matthews, 2008; Zhang et al., 2013). Asche et al. (2018), for instance, compared supply chains for chicken and salmon, and found that in processing the products, it often takes an average of 1.5 hour for chilling, bleeding and washing salmon, while chicken can be processed immediately after killing. This makes the product processing in these supply chains differentiated.

In addition to food type, ***product category*** (e.g., processed, lightly processed, unprocessed) is also important in deciding the way a supply chain works. Depending on the category it belongs to, food may be kept fresh, shelf stable, refrigerated, frozen, dried, packaged and so on. Often, processed products require a more complex supply chain (Baron & Dimitri, 2019) as they must go through several processing stages. Product category is also related to consumption, and consumers' views and buying behaviours. This is evidenced in Ajisola et al.'s (2021) study on consumers' preference of fresh fruit and processed fruit, in which the authors suggest implications in relation to consumers' views about cost of purchase, nutritional content, health, convenience for fresh citrus and processed citrus fruits.

Perishability is another characteristic that contributes to the complexity of an agricultural supply chain. While some agricultural products (e.g., grains and oilseeds) are storable, many of them often have a relatively short shelf life, and so their supply chain is often under pressure of ensuring the product quality and on-time delivery to consumers (Hobbs, 2021; Sjah & Zainuri, 2020). The perishable nature of these products is hence the major constraint of their supply chain. For example, milk must be sold daily, and fruit/vegetable products must be collected at the appropriate stage of ripeness (Hobbs, 2021). During the handling process, these products can then be impacted by numerous microbial, chemical and physiological factors that can deteriorate their freshness (Routroy & Behera, 2017). Many perishable products, in addition, require a temperature-controlled (chilled, frozen or ambient) supply chain which is to maintain their quality in the whole chain process from harvest to consumption (Aung & Chang, 2014).

A unique feature of agricultural products compared with other products is their ***seasonality***, which is the availability of the products in certain season periods and weather conditions (Bloemhof & van der Vorst, 2015). There is often an oversupply of the products in the harvest season and under-supply during other times of the year (Aung, 2006). Due to seasonal variation, the products need to be imported from other countries if year-round supply is to be maintained. This has an impact on the products' price in the market, and consequently, on the chain operation, value added and turnover. An example of price change in different seasons comes from Minten et al.'s (2020) study on food value chains for a few products, in which the authors find that there was a significant price seasonality, with the highest price was before the new harvest started, which then decreased immediately after the main harvest.

In addition, many fresh products are bulky, and their ***bulkiness*** makes the handling, transporting, market reach and delivering processes difficult (Montealegre et al., 2007; Gokarn & Kuthambalayan, 2017; Roy, 2015), and this sets conditions for their supply chain operation. Akuriba et al. (2021), for example, believe that the bulkiness of products such as cassava, sugar cane, or oranges may decide the mode of transportation in sending them to the market. Makuya et. al. (2017), in a study on logistic services for the watermelon value chain in Tanzania, comment that due to watermelon's bulkiness, there were often challenges in relation to logistics. They indicate that handling this kind of fruit required very special care, that was too costly for farmers and traders, and this led to the loss of product value before it reached the market.

Product supply

Product supply is related to the process of handling, designing and preparing the final product, so it is ready to be supplied to consumers, as well as to the value/cost created through that process. Product supply includes issues such as: type of product processing, make-to-order lead time, product life circle, product variety, product innovativeness, product value, value creation, supply uncertainty, stock ability, or delivery lead time.

The first factor that can decide the supply capacity of a supply chain is the ***type of product processing*** which the chain operates. Type of product processing is about the specific features of the supply chain related to the temperature control needed to maintain food quality and safety (Meneghetti & Monti, 2015). As such, there can be chilled, cold, frozen, or mixed-processing types of supply chains. Agricultural products, which are often perishable, are very sensitive to temperature, humidity, and light conditions (Aung & Chang, 2014), and thus they need to be stored at the specified temperature in a special environment through the production to consumption stages (Vodenicharova, 2020). These conditions are hence important to not only provide high-quality products to consumers, but also reduce food waste and spoilage (Aung & Chang, 2014).

Farm-gate-to-shipping time is another factor that determines a chain's supply capacity. As agricultural products are often highly perishable and have short shelf life, it is necessary to ensure a reasonable farm-gate-to-shipping time so the products can be delivered to consumers in a timely manner without compromising the product quality. Goetz et al. (2008) comment that the quality of fresh produce such as fruits vary, as it depends on the time of picking, or the time required to move the produce from the farm gate to the ship. An example related to the issue of farm-gate-to-shipping time comes from Fries et al.'s (2013) study on Logistics Chain Analysis for cocoa and nutmeg in Grenada, which explores these relationships and transitions by taking a comprehensive snapshot of product movement from the farm gate to the port of destination. The author's analysis suggests that where there were logistics inefficiencies, from the farm gate to the port of exit, the logistics expenses, travel times and uncertainty would often increase. Farm-gate-to-shipping time, in addition, often depends on multiple internal and external factors, such as road networks. Poor quality of rural roads during the rainy season, for instance, may increase shipping times and costs, especially for time-sensitive products such as agricultural food. Time delays, especially from the farm gate to the consolidation centre can cause product losses, and thus, affect the whole supply chain (Guasch, 2022). Guasch (2022), in examining sources and incidence cost related to beef exports from Nicaragua to the USA, indicate that poor-quality roads in rural areas significantly reduces driving speeds, and this increased shipping time, that might lead to cattle injuries, deaths, and weight loss.

Type of product processing and make-to-order lead time can affect the supply chain's ***product life cycle***—the complete lifespan of a product through different chain stages, from raw materials until final disposal, including the benefits and costs related to this circle (Islam & Cullen, 2021; Nelson, 2015). In the agriculture sector, a very short life cycle is often applied to most products. A product which has a shorter life cycle would need more rapid changes in its supply chain design, so the product can meet different demands in the market (Chhetri et al., 2022). Short or long product life cycle is, in addition, related to the supply chain's environmental management as part of its design, production, distribution, use and reuse of the product (Zsidisin & Siferd, 2001) and thus, can determine the supply chain structure. An example of this comes from Hagelaar and Van der Vorst's (2001) study on environmental supply chain management and life cycle assessment in relation to food products. The authors discuss that understanding the type of supply chain structure is important to ensure the implementation of the life cycle assessment in line with the supply chain's environmental strategy. In other words, if a supply chain wants to apply a life cycle assessment for better environmental management, it needs to build a suitable structure for effective implementation of this strategy.

Product variety is the number of different product forms which a supply chain offers to consumers (Pine, 1993). Variety may be related to product colours or "models" in the current line or across different generations of the product (Brun & Pero, 2012). In the fresh produce sector, product variety can be related to features such as new format and packaging, different standards, longer shelf life or improved technological foods (Hingley & Sodano, 2009). Product variety, hence, decides the way a supply chain operates. For Gadde and Amani, (2016), expanded product variety makes the supply chain's production and processing more complex in terms of both quality and quantity. Nouira et al. (2022), in a study on olive oil variety, for instance, suggest that different from the premium variety, the conventional product variety is often associated with a more local supply chain. Also, a mix of premium and conventional varieties (instead of only one variety) would require a more local supply chain. In addition, a supply chain offers a variety of product forms often because it wants to compete with other firms in the market. This, however, may be a barrier to gaining profit and seeking potential entry to a new market, as in the case of Korean soju discussed in Hong and Chung's (2015) study. In addition, it can be noted here that ***product innovativeness*** is an important feature that can contribute to the chain's capacity to provide a variety of their product. Product innovativeness is the application of a new attribute in a product to make it more attractive to consumers, more competitive in the market, and more profitable to the chain. Research has suggested that consumers' acceptance of product innovations is important for supply chains' innovativeness. In a study on the addition of nutmeg essential oil to intensify the aroma for cookies that use durian seeds, Mahyiddin, et al. (2022), for example, suggest that as consumers accepted this product innovation well, the production of this innovative product can be continued in the chain.

Another supply feature that influences the operation of supply chains is ***product value***. Product value is often interpreted as both the nutritional and economic value of the product (Machum, 2019), although this value can also be related to the safety, environmental or ethics credence of the product. Product value can influence consumers' purchasing behaviours, and in turn, the chain's profit and its relationship with consumers. As there have been increasing concerns about food quality and safety, organic food labels have become more popular in the market (Delibas, 2021). Organic products, although they are often more expensive, are seen as having higher value compared with non-organic ones. Aleksejeva et al.'s (2021) study on organic food production, for example, shows that consumers preferred short food supply chains where they could buy local organic products. Similar findings come from Delibas's (2021) study on a short food supply chain in Romania, in which the author find that consumers appreciated high value organic food, and their trust in the product value was formed through their long-term relationship with the producer. Product innovativeness and product value, in addition, play an important role in enhancing the supply chain's ***value adding*** — economically adding value to a product by processing it as desired by customers (Coltrain et al., 2000). Value creation or value adding is the core purpose of the chain construction and operation and the main objective of its business activities (Sadovska et al., 2020; Vargo et al., 2008).

Supply chains may not always be able to act on their own in terms of supply, as there are sometimes various factors that influence their activities and cause their ***supply uncertainty***. This uncertainty can be related to materials/product availability, product amount, or in-time delivery (van der Vorst 2000). As agricultural production depends on weather, environmental or other uncontrollable factors, the supply of a product can fluctuate significantly (Thongrattana & Perera, 2014), and cause price sensitivity (Nakandala & Lau, 2019). Sometimes supply uncertainty can be because of government policy changes, as in the case of rice production in Thailand discussed in Yao's (1997) study. Supply uncertainty often has a negative impact on supply chains' key activities, as this prevents the regular practice and the maturity of chain processes, the application of established technologies, as well as opportunities for long-term contracts (Nakandala & Lau, 2019). A factor that may be related to supply uncertainty is the chain's ***stock ability*** or the capacity to stock their product. For Obike et al. (2017), stock capacity can significantly affect farm revenue. They suggest that farmers with small-scale poultry production who have limited stock ability may have risks in managing their business.

In addition to make-to-order lead time, ***delivery lead time***—the duration between the time customers place their order to the time they receive the product—is also an important measure of supply chains' service quality, as it has significant effects on consumers' satisfaction and the chain's profit (Hua et al., 2010). Good lead time, hence, can enhance the product competitiveness in the market. Pieter van Donk (2000), in a study on customer-driven manufacturing in the food processing industry, indicates that many consumers preferred shorter delivery time. Delivery lead time is even more important for fresh agricultural products, and this requires agricultural supply chains to properly organise their delivery system so that it is more responsive to retailers and consumers (Chan et al., 2020). Depending on their business objectives, however, supply chains must be balanced in decisions between shorter delivery lead time—that leads to increase in logistics costs and profit reductions; and longer delivery lead time—that leads to consumers' dissatisfaction and their refusal to keep buying the product (Hua et al., 2010).

Product demand

As most supply chains are, perhaps, demand-driven, understanding of consumers' demand in relation to the product can help design optimal supply chains to enhance its effectiveness (Chhetri et al., 2022). Common factors related to product demand, that influence supply chain activities, can be market type, market distance, access to market, demand uncertainty and consumer segmentation.

Market type refers to local, international, domestic or export markets, as well as market segmentation, which is about dividing the market into submarkets based on similar consumer demand. Supply chains which mainly serve consumers in the local market often have production and business strategies which are different from chains which target the international market. For Kagira et al. (2012), local and international markets have different characteristics that can cause different challenges. Challenges in local markets are often low consumption and lack of value addition, while challenges in international markets can be related to price fluctuation, product standards, and difficulties in working with trade partners (Kagira et al. 2012). Variability in relation to product quality and standards, however, can also be found in local market. An example of this comes from Zúñiga-Arias et al.'s (2009) study on managing quality heterogeneity in Costa Rica's mango supply chain. The authors indicate several differences in the supply chain's product handling, selection and management practices. They also highlight that the organisation of the mango supply chain was much more complex for the local market (compared with the export market), where there were several different outlets and intermediaries.

In addition to market type, ***market distance*** is another demand factor that can affect supply chains' operation and structure. Sagareishvili (2021), in discussing the role of maritime logistics and supply chains in exporting Georgian agricultural products, demonstrates that although Georgia wants to target the EU and China, there is a long distance between Georgia and these markets. In order to reach these market, Georgian supply chains need to develop a complete and effective transport and logistics system to achieve sustainable export of their agricultural products, which often have short shelf life. In another study on tomato producers in Ethiopia conducted by Kassaw et al. (2019), the authors suggest that market distance was related to producers' outlet choice decisions. As producers had to transport their tomato products to urban markets if they wanted to sell it to wholesalers, they preferred selling tomatoes to collectors and consumer channels who could come to collect their products at the farmgate (Kassaw et al., 2019), and this had changed the tomato supply chain's structure.

Supply chains, in addition, often face issues in seeking to gain ***access to market***, that sometimes confronts the smooth flow of their product (Yilma & Ensermu, 2020). Supply chains' issues related to market access can be in both local and international markets. Nupueng et al. (2022), in a study on the Thai palm-oil supply chain, for instance, indicate that most Thai palm oil could only be sold in the domestic market because it could not compete with other countries which provided lower price for this product. In the fresh produce sector, sometimes producers have little direct market access. Usually, cooperatives have better access to the market than individual producers (Huang & Liang, 2018). However, producers' difficulties in access to market can be a motivation for them to involve in contractual business. This is evidenced in Mounirou's (2020) study on contract participation in the agriculture sector, in which the author suggests that producers who had difficulties in accessing the market were more inclined to sign a contract than those who could sell their product easily, as producers are also rational economic agents who seek to increase their business profit.

Another factor that influences supply chains' operation in responding to consumers' demand is ***demand uncertainty***— the instability of and difficulties in predicting consumer preferences and expectations of the product (Sheng et al., 2013). High demand uncertainty can be a risk to supply chains (Thongrattana & Perera, 2014). Low demand uncertainty allows supply chains to design a highly responsive system to meet consumers' needs, as in the case of Barilla pasta supply chain discussed in Chopra and Meindl's (2013) study. Mounter et al. (2016) suggest that a low-cost value chain can best fit if demand uncertainty is low; but a responsive value chain is better if demand uncertainty is high. In addition, demand uncertainty may be related to ***consumer segmentations***, which are related to consumer group division based on their demographic and socio-economic characteristics. For example, consumers who have knowledge about product value and safety may prefer organic products, as indicated by Bal and Gulse (2013) in their study on consumer characteristics and organic milk consumption.

3.1.3.2. Infrastructure

Infrastructure is the structures and services which facilitate the connection among various chain activities and business processes and allow firm linkages and resource sharing (Rajagopal et al., 2009), that are necessary for a supply chain to run smoothly. Infrastructure can be described as the "backbone" that makes up the supply chain itself, as without suitable infrastructure, supply chains cannot work properly. Under the INFRASTRUCTURE category, we focus on three main issues, namely hard structure, soft structure, and instruments and resources.

Hard structure

Hard structure includes physical components and elements of a supply chain which interact with one another, and each of the component/element has its own function and responsibilities in the chain (Kim et al., 2014). A supply chain's hard structure is often formed with different entities and various types of networks.

Number of entities participating in a supply chain is a factor related to the chain's degree of complexity and intensity. The more entities the chain have, the more complex and intense it is (Matopoulos et al., 2007; Yee & Oh, 2013). Many products required an extended supply chain with multiple entities involved, that results in numerous interactions, exchanges and issues arising (Matopoulos et al., 2007). Basically, supply chains in the agriculture sector often include the following entities linked from "farm-to-fork" (see Hernandez et al., 2021; Matopoulos et al., 2007):

- Producers or farmers who directly produce/grow the product.
- Processors or manufacturers those who process and manufacture the product.
- Distributors including wholesalers and retailers who market and sell the product.
- Consumers or buyers who buy and consume the product.

There are however often other entities whose work is important to maintain the supply chain's smooth operation, including input suppliers, pack-houses, transporters, or exporters/importers. There are sometimes external entities such as governments, industries or universities, to varying degrees, have influence on the supply chain (see also Hernandez et al., 2021; Matopoulos et al., 2007; Thompson et al., 2005). The number of entities however varies in different types of chain. In short supply chains, for example, this number should be as small as possible.

These entities come together to form different ***types of networks***, that is, the ways the supply chain organises. In the present report, we focus on two most common networks: vertical and horizontal. Vertical network is formed through a kind of continuum partnerships along an upstream-downstream linear (Lyons et al., 2012). Farmers, processors, distributors and consumers, for example, are in a vertical network in the supply chain. Horizontal network, by contrast, is the relationship between entities providing the same or similar service to allow ease of work in the supply chain (Lyons et al., 2012; Naesens et al., 2009). For Akbar et al. (2021), in the agricultural sector, vertical supply chain networks may include farmers, farm input service providers, processors, wholesalers, retailers, exporters and consumers, while horizontal networks are often formed by the connection between farmers, growers and growers' associations who may be involved collectively in the supply chain.

Soft structure

Soft structure, which can be seen as a kind of "relationship structure" (Yang et al., 2004), and is "looser" and can be adjusted more quickly (Ismael, 2011). Soft infrastructure plays an important role in ensuring the integration between entities in the network. For Hyz and Karamanis (2016), "soft structure" is more about relationships and networks which are different from a formal organizational structure. Relationship structure can be partly described by considering the ***level of dependency*** (dependence, independence, interdependence, mutual dependence, etc.) in business relationships among the entities. Silva et al. (2021), suggest that the type and structure of organisation can have impact on power distribution in the chain and the relationship between buyers and suppliers in terms of mutual dependency.

Dependency can be described as a link or a tie between a firm or entity in relation to another (Lambert et al., 1998). There are different types of dependency among supply chain entities in relation to technology, time, market information, knowledge about each other, social bonds and economical as well as judicial ties (Svensson, 2004). The level of dependency in chain entities' relationships can define the performance of the supply chain. For O'Keeffe (1998), close relationships may cause a loss of independence, and it is significant for chain entities to move from independence to interdependence (rather than independence to dependence). O'Keeffe provides an example about the Strawberry Wholesalers, a small group of strawberry growers in Western Australia and their challenges in developing a closer relationship with export agents. One of the challenges was how to establish a level of interdependence in working with the agents rather than depending too much on them. It was suggested by the agents that customer confidentiality, communication and feedback were key to achieve this interdependency (O'Keeffe, 1998).

Soft structure, in addition, can turn into a more sophisticated complexion when it is no longer simply part of a supply chain's infrastructure, but reflects different natures of relationship and connection process of the chain, such as single-handedness, coordination, collaboration or consolidation. These are discussed separately in the subsequent section (the "process" category).

Instruments and resources

Instruments and resources are equipment, devices, or tools that are necessary for a supply chain to conduct various tasks and organise various activities to achieve their business aim. Important instruments or resources most supply chains often need are transport, technology, and labour force.

Transport (such as road, rail, air…) is one of the key instruments of a supply chain because for any kind of product, the accessibility to transport is a prerequisite for the chain's business activities to be successful (Ljungberg, 2006). As food and agri-products are often perishable and have short shelf life, it is essential for supply chains in this sector to have access to reliable and effective transport systems and ensure the quality of their product during transportation. Transportation of some products must be very fast due to the product specific characteristics. Research has suggested that producers who have access to transport can sell more products, reach more business partners, and gain more profit. Kassaw et al. (2019), in a study on market outlet choice decision of tomato producers, for example, indicate that farmers who owned transport facilities had more opportunities to supply their product to urban centres, choose wholesalers outlets, and directly sell the product with a better price. For the authors, access to transport facilities helped the farmers in terms of reducing the market distance constraints. A similar example of the role of transport in facilitating market access comes from Louw and Jordaan's (2016) study on smallholder fresh produce farmers in South Africa. Louw and Jordaan demonstrate that it is essential for producers to have the transportation capacity, and that not having access to transport would prevent their access to formalised markets. Their findings reveal that retailers were rarely able or willing to collect products at the farm gate, but instead wanted the product to be brought to the distribution centre, and that some retailers even required refrigerated transport to ensure the product quality in the cold chain (Louw & Jordaan, 2016).

Technology is another valuable resource that can contribute to facilitating supply chains' activities, enhancing product quality, value and variety, and improving the efficiency of supplying perishable foods. In today's rapidly developing technological and digital world, the use of modern technologies in various supply chain stages and procedures has become much more common. Saryatmo and Sukhotu (2021) suggest that digital supply chains often have more advantages than other chains in terms of quality, productivity, and cost reduction. Technology can also help reduce and utilise food loss for new purposes (Kör et al., 2021). In a study on an apple supply chain in north China, for example, Jiang et al. (2021) demonstrate that the adoption of technology is significant for improving the sustainability of the apple supply chain. It is revealed in their findings that the technology helped increase the apple chain's economic benefit by 63 percent and decrease the nitrogen footprint by approximately 68 percent (Jiang et al., 2021).

Depending on the production scale, ***labour force**,* including labour size, seasonality of labour and employment structures, can be a critical factor deciding an agricultural supply chain's production capacity. Labour force is, hence, part of the traditional variables internal to supply chains' production unit (Grando et al., 2020). Labour size in agriculture is often characterised by diverse activities and product seasonality (Mavridis et al., 2012). The size of labour force, in addition, has direct influence on turnover rates (Gasson, 1974). Families with small-scale production who usually depend on self-employed or unpaid labour supplied by family members, for example, may face a lack of labour in harvest seasons. The large labour size they have, the more likely they can get higher yield of the product, as evidenced in Hashmiu et al.'s (2022) study on cocoa farming in the Forest-Savannah transition zone of Ghana.

3.1.3.3 Process

Process refers to different models or forms of relationship and connection in the same or different supply chains, which are a platform for entities to participate in and work together to accomplish specific business objectives. Supply chain process is associated with a series of actions needed to deliver the connection outcomes (Keast, 2016). Chain relationships may vary, depending on the low-high level of connection among the entities, which manifest in various forms such as single-handedness, coordination, collaboration or consolidation. We now examine these connection forms under the PROCESS category. Similar to what we have discussed in the sections about product and infrastructure, each issue in this category (i.e., single-handedness, coordination, collaboration or consolidation) is associated with several factors or features which can be described as manifestations or illustrations of the connection form. We, however, acknowledge that as the line between different supply chain processes/connection forms may be blurred or unclear, the factors and features associated with one chain process (e.g., coordination) can also be found in another process (e.g., collaboration). It is, however, important to note that these factors or features are often at different levels or degrees in different chain connection processes. Detailed of the connection forms are discussed below.

Single-handedness

Single-handedness means doing something by one's own effort, without assistance from others. It is when an independent supply chain entity make decision or directly takes part in all or most of their production, distribution and/or trade activities without the involvement of other entities. Those who manage their business single-handedly do not have collaboration with other people, and their business is run based on trust and casual connections. Single-handedness is often found in short food supply chains, where producers undertake all production works, and/or directly sell their product to consumers. Even when they have participation by someone in their production or sales process, there should be no more than one middleman (Dragoi & Grubor, 2021). It is observed that single-handed production and single-handed business are common in agricultural supply chains.

Single-handed production is often similar to traditional farming practice, where producers need numerous skills and this can be seen as one of the constraints of doing things single-handedly (Rucabado-Palomar & Cuéllar-Padilla, 2020). They can play the role of not only a farmer, but also an agricultural chemist, a biologist, a harvester, or a processor (and then a transportation worker, a distributor, and a salesman in their later single-handed business process) (McWilliams, 1941). Simple micro farming or family farming can also be a form of single-handed production. The fact that these forms of single-handed production are still common in today's mass agricultural production is perhaps related to (1) local needs or (2) local product value. For Rucabado-Palomar and Cuéllar-Padilla, (2020), the idea of "local" may carry the meaning of a distinctive value and quality associated with a traditional production process in the geographical region. ***Single-handed business*** is also part of this short supply chain process. Producers, when entering into the market and have direct contact with their consumers, have to take the role of distributor, marketer, and salesman, that requires additional technical, psychosocial, financial, and communication knowledge and skills (Rucabado-Palomar & Cuéllar-Padilla, 2020). The place of their sale can be their home/yard, roadside, home delivery, local markets, food festivals, web stores, social media, or guest tables (Szerb et al. 2018). Some farmers who are not able or don't have the means to reach a large number of consumers have to connect with other people in the community in order to transfer their messages to potential consumers (Singh et al., 2014).

Coordination

Coordination refers to interactions among different chain entities to allocate functions, adjust and align business goals, and work together to accomplish joint and individual tasks (Gulati et al., 2012). Some manifestations of effective coordination are reasonable/effective contracting, communication, informational sharing, and power distribution.

Contracting is an important means for constructing coordination mechanism in supply chains, that can help decrease channel conflicts and maximise the chain's profit (Song & He, 2018). There can be contract farming, wholesale contracts, buy-back contracts, cost-sharing contracts, or revenue-sharing contracts, and so on. Yu et al. (2019), in a study on coordination mechanism for contract farming supply chains, for instance, indicate that contract farming is a mechanism of price protection, which is often used to protect farmers' profit and interests. Under this contract, the farmer undertakes the production process under the guidance of the company with which they have signed the contract (Yu et al., 2019). Cost-sharing contracts are also useful in terms of improving supply chains' profit. An example of this comes from Tan et al.'s (2020) study in which the authors suggest that cost-sharing contracts could help motivate the supply chain members to improve the greenness level of their agricultural product, thereby enhancing their profitability under certain conditions.

As ***communication*** often aims at mutual adjustment, it can be seen as another essential mechanism of coordination (Weigand et al., 2003). Coordination in supply chains is characterised by effective communication (Handayati et al., 2015), as chain partners need to exchange information to coordinate their activities (Batt & Le, 2011). In agricultural supply chains where there are many different entities of diverse backgrounds and characteristics, flexible and proper communication is critical (Dania et al., 2018). Ballou et al. (2000) emphasise that if there is unequal distribution of benefits in a supply chain, communication is a significant means that can support the desired outcome of the chain's coordination. Communication is beneficial not only for those who directly participate in the supply chain, but also for consumers in relation to the product they purchase. An example of this can be found in Santeramo et al.'s (2021) study on innovative communication in agri-food supply chains in which the authors suggest that effective communication is very important for informing consumers on food risks.

Information sharing—the extent to which various forms of information is communicated to supply chain partners (Monczka et al., 1998)—is another manifestation of coordination. It is believed that to achieve a high degree of cooperation, supply chain participants should voluntarily share information about their operation, inventories, joint plans and business strategies. Information sharing enables supply chain partners to work together as in a single entity, where they can exchange and access up-to-date data along the chain, that contribute to elimination of misunderstandings and distortion risks, smooth and cost-effective supply chain processes, and optimum coordination performance (Dania et al., 2018; Ding et al., 2014). The more complex the product is, the more information sharing is required among chain partners (Lusiantoro et al., 2018). Information sharing is hence critical for managing the quality of perishable products in agricultural supply chains (Salin, 1998).

As supply chain management involves alignment of actions, ***power distribution*** is also one of the key elements of chain coordination in addition to communication and information sharing. Research often suggests that imbalanced of power distribution may hinder the smooth and effective supply chain processes and have negative effects on the level of trust among chain partners (Falkowski, 2015; Ye et al., 2020). Hingley (2005), in discussing the UK agri-food supply networks, however, believes that chain members' acceptance of power imbalance is critical for building successful business relationships. It is, hence, important for supply chain partners to understand that there may be different types of power, which have different effects on relationships in the chain. Belaya and Hanf (2012), in their study on managing Russian agri-food supply chain networks with power, for example, propose and test a theoretical model of the effects of different types of power on supply chain coordination, in order to find out what role power often plays in management of supply chain networks, and suggest strategies for effective use of mix of power mechanisms. Their findings suggest that among different types of power for improving coordination, "expert power" was ranked the highest, and that this power type should be prioritised in building chain coordination relationships.

Collaboration

Collaboration is a higher-level form of supply chain relationships according to Keast's (2016) 5Cs model. As such, collaboration can also involve contracting, communication, information sharing and effective power distribution, but at a higher level compared with the coordination form. Collaboration, in addition, requires some other values, which need to be inherent among chain members to enhance supply chain co-creation (Dania et al., 2018), including shared strategies and interests; shared business culture; and trust and commitment.

Collaboration in supply chains should aim to build the chains as a "community of ***shared strategies and interests***", that is important for generating collaborative advantages (Han et al., 2020). At this relationship level, there need to be more efforts to orient chain partners to the same direction and align their strategies and interests for the balance of risks and benefits, as well as the overall success of the supply chain (Dania et al., 2018; Meng, 2012). Different supply chain collaborations may have different strategies and interests. In the agriculture sector, collaboration towards building a "green" or "sustainable" supply chain is a popular trend in recent years. Kasim et al. (2021), in a study on promoting sustainable palm oil in a supply chain, for instance, discuss the way a food company dealt with challenges in their promotion of sustainable palm oil as a core business strategy. The study's findings, which draw on a strategy-as-practice approach, highlight that effective collaboration is needed in formulating and implementing a sustainability strategy for a controversial commodity such as palm oil. Another interesting example of sustainability as a shared collaboration strategy in food supply chains comes from Steele and Feyerherm's (2014) study on Loblaw's seafood supply chain collaboratively working towards the shared goal of improving ocean health. As discussed in the study, Loblaw was originally a Canadian grocery company which was interested in seafood, and then realised the need for change in facing the risk of diminishing fish stock and declining ocean health. In responding to this risk, Loblaw leveraged their existing relationships, adopted a shared goal of sustainability for positive change, implemented their sustainable seafood project through a collaborative process, and improved their externally oriented collaboration capacity to accomplish a more encompassing collective objective (Steele & Feyerherm, 2014).

Shared strategies and interests can sometimes only be achieved when the supply chain has a ***shared business culture***. For Tian and Sheng (2017), shared business culture refers to the values that are understood, approved and voluntarily complied with by all chain members in all their business activities. Flexible collaboration, for instance, can facilitate collegiality and contribute to a "no-blame" culture within the network. Suppression of individualism and promotion of mutual understandings are essential for achieving collaborative benefits (Dania et al., 2018). Inclusiveness where all voices and discourses are brought into the chain discussion would help its members to understand the diverse nature of value, identify points of overlap, and take responsibility for their actions in the network (Soundararajan et al., 2019). Supply chains' business culture is, in addition, influenced by the culture of the society where it is located or with which it is connected. Felzensztein and Gimmon (2007), in a study on Chile's salmon farming industry, for example, indicate that as Chile's business culture is often individualistic, companies may not like to cooperate in joint projects, nor share information about their customers. By contrast, supply chains' business culture in China is often described as being influenced by the Chinese Confucianist society's relational ("guanxi") culture, which is often more hierarchical than in the Western societies. For Lu et al. (2018), guanxi networks are important for maintaining a good relationship between managers and staff in supply chains, generate trust between players, and increase the flow of capital. Therefore, a lack of knowledge and understanding of these cultural norms may be a barrier for foreign supply chains to work with their partners in China (Yi et al., 2021).

In addition, ***trust and commitment*** are among essential collaboration behavioural factors in supply chain relationships. Trust is related to a chain member's eagerness to rely on other members as they believe that these members will act for common benefits rather than for one's self-interests (Dania et al., 2018). In supply chain collaboration, trust helps ensure effective risk management, stability, open up opportunities and encourage more initiatives in business partnerships (Laeequddin et al., 2009; Nyaga et al., 2010; Qu &Yang, 2015). Commitment, in addition, positively affects stability in supply chain collaboration (Dania et al., 2018), and contributes to building trust among chain members. This is evidenced in Živković et al.'s (2021) study on organizational commitment in a food supply chain, in which the authors indicate that long-term affective commitment with the organisation is crucial for employees to remain in the organisation. Regarding trust, Sun et al. (2021) suggest that trust perception has a positive impact on the relationship quality of the agricultural supply chain. Level of trust in supply chains, however, may vary, depending on the length of the collaboration among chain partners (Gajdić. et al., 2021).

Consolidation

Consolidation is a unique form of supply chain connection, which refers to the act or process of joining things together into one to achieve one or some business purposes in supply chains. Supply chain consolidation can occur at several dimensions (Soshko et al., 2007). Among which, brand consolidation and freight consolidation seem to be common.

Brand consolidation is carried out when "weaker" or smaller brands are brought together with or reformatted under the umbrella of a "stronger" or bigger brand (Coumau et. al, 2012). This is found, for instance, in Ferreira et al.'s (2021) study on the Brazilian Southeast wine sector, in which the authors indicate that in order to survive and compete with competitive-cost international brands, these wineries may need to consolidate their brands and this strategy may be feasible over time. Another example of brand consolidation comes from Baldacchino's (2010) discussion on beer manufacturing on the Pacific islands in which the author describes various cases in which the product names are synonymous with the place, and comments that this may be seen as a market signal or trademark of the place's indigenous history and culture, that can bring long-term benefits to the product in terms of visibility, reputation, international recognition and support of brand expansion. As local beers also exercised this brand consolidation, they could connect easily with both the domestic market and visiting tourists, while still maintaining their authenticity and uniqueness.

Freight consolidation (or shipment consolidation), on the other hand, is the process of combining the transportation of multiple products. For Nguyen et al. (2014), consolidation allows shippers of perishable products to take advantage of economies of scale and save transportation costs. Hu et al. (2018), in discussing freight consolidation for perishable goods, also suggest that freight consolidation can be a solution to the question of how much volume of products before releasing a shipment, and that leverages economies of scale in transportation costs. This process can take place in inventory, vehicles, or terminals. Findings in studies by Nguyen et al. (2013, 2014) and Hu et al. (2018) show that consolidation by many suppliers could yield a large amount of annual savings depending on the number of consolidation participants.

3.1.3.4 Factors

In addition to factors associated with the supply chain itself, there are various external **factors** that can have a positive or negative influence on chain operation and management. These can include legal, relational, developmental and environmental factors.

Legal factors

Legal factors are related to ***government policies and regulations*** or ***government support***. Government policies and regulations can either facilitate or constrain supply chain activities. In a study examining regulatory restrictions across U.S. protein supply chains, for instance, Staples et al. (2021) demonstrated that the number of federal and state regulatory restrictions are sometimes overlapping and cumbersome, that had affected the beef, pork, sheep, goat, poultry, and seafood industries. In another study on key processes along the supply chain, Zimon et al. (2020) indicate that the implementation of the requirements of the ISO 22000 standard in food supply chains could contribute to increasing food quality and minimising food waste. Governments, in addition, may sometimes provide financial support to some food products, and that influences the supply chain operation at some certain times. Yu et al.'s (2021) study on investment decisions in food supply chains with government subsidy, for example, analyses different payment methods used for government subsidies to encourage food processors to invest in better food safety efforts. Their results suggests that the demand-based payment did not always benefit the supply chain members, although this might help increase the market share of products.

Relational factors

Relational factors are about the relationship between the supply chain and their potential ***investors*** or ***external industries***. Investors' decisions of whether to invest or not and their engagement in a supply chain as shareholders can have a positive influence or put pressure on the chain (Damert et al., 2020). In a report on the issue of sustainable cocoa, for instance, Visser (2017) suggests that investors could play an important role in encouraging cocoa and chocolate companies to enter the level playing field to mature in their critical mass and institutionalisation phase and motivating them to enter the playing field to address the legislation and other issues. Other industries such as banking may also be a factor that influences supply chain activities—especially in terms of finance. Cadot and Ugaglia (2018), in examining the link between debt and price in relation to the lifecycle of Bordeaux wine cooperatives, for instance, demonstrate that the relationship between banks and cooperatives was critical in the lifecycle of the cooperatives.

Developmental factors

Developmental factors are about ***research and development*** in relation to supply chains. Supply chains' internal research and collaborative research and development with external entities such as technical service providers, engineering firms, universities or research institutes can help explore and develop new ideas for product and service improvement in the chain (Lyons et al., 2012). Supply-chain partnerships, hence, can involve not only downstream alliances (with other industries), but also upstream alliances (with research institutes or universities). Oelze et al. (2016), in discussing sustainable development in supply chain management, for instance, indicate that in Germany, the development of responsible supply chain management was facilitated when supply chains worked with universities, where academic staff were experts in designing and implementing policies for sustainable supply chain management and development in practice. Universities can also provide professional development courses for supply chain members, as in the case of chain professionals and universities in Australia described in Sohal's (2013) study. In addition to individual supply chain's research efforts, there are larger-scale research and development platforms and forums. An example of this is the EU Platform on Food Losses and Food Waste or the World Bank's workshop on reducing food loss in Africa in 2011 where there were representatives of supply chain and research institutions (Despoudi, 2021).

Environmental factors

Environmental factors are related to ***natural or human-induced risks*** to supply chains. Environmental issues such as weather conditions can contribute to shaping food supply chains' geography, especially under the impact of the global warming on climatic regions, seasonality, and conditions for crops (Accorsi et al. 2022). Climate change may have implications for the whole supply chain process, including production, storage, transportation, retail, and consumption (Godde et al., 2021). Haverkort and Verhagen (2008), in a discussion on climate change and its repercussions for a potato supply chain, for instance, indicate multiple climate effects on potato crop yield, potato quality, and potato diseases and pests. In addition to environmental issues, supply chains sometimes face unexpected risks such as the COVID-19 pandemic. In the last two years, there are many studies on the impact of the pandemic on agricultural supply chains in particular. Mangano et al. ‘s (2022) stakeholder survey, for instance, indicate that the pandemic could cause disruption, ripple effects, food insecurity, and socio-economic conflicts in perishable food supply chains. The COVID-19 was also responsible for price increase, reduced profits, or food waste and shortage in studies by Wannaprasert and Choenkwan (2021), Wunderlich (2021) and Zhang et al. (2021).

In conclusion, the above literature review on characteristics of agricultural supply chain serves as a strong basis for our development of a baseline framework and mapping tool for agricultural supply chain characterisation. The proposed framework and mapping tool are introduced in Sections 4.1.1.1 and 4.1.1.2.

In the subsequent sections, we discuss some literature on agricultural data for export commodities in general and in Australia in particular, which is considered as a theoretical overview of common methods used for collection, correction, monitor, estimation and/or selection of agricultural data in general and data about export commodities. This can be considered as a basis for collecting and analysing data for selected export commodities in the next stages. Some of the data about case commodities were used to test the refined mapping tool we have developed (see Section 4.4 for details of this testing process).

3.2 Agricultural data for export commodities

Reliable agriculture production data are vital for understanding the supply and demand gap of different agricultural commodities as well as planning for surplus produces. Among the Australian states and territories, Queensland has the largest area of agricultural land. There are currently about 40,000 firms operating in agricultural activities in Queensland (Agriculture, Water and the Environment (AWE), 2021). In 2021-2022, the estimated gross value of agricultural production in the region is $20.66 billion (Department of Agriculture and Fisheries (DAF, 2021), which is about 25 percent of the total gross value of agricultural production in Australia (AWE, 2022). Given the contribution of the agriculture sector to the national economy, it is important to gather accurate agricultural data for domestic and exports markets’ supply chains as well as for long long-term land use and resource planning.

Agriculture statistics are useful for the agriculture sector in terms of transport and logistics industries, as well as for marketers, distributors and retailers. Agricultural data collection frameworks, thus, need to be designed with relevant information, including farm input and output, trade indices, land use, and government levies. Agricultural data collection can involve designing and validating a questionnaire, conducting farm surveys, checking the quality of data, categorising data, and publishing them for end-users. In general, the sample size of agricultural surveys should be large enough to minimise possible sampling errors. Despite all efforts, agricultural data published by governments or government-affiliated authorities may still contain some inaccuracy or errors. As data published by governments are often used for research and policy development, flaws in the data may mislead researchers and their research outputs.

The accuracy of the agricultural value and production data is a major issue in most countries in the world. The European Commission (EC), for example, suggests that the current methodological structure of agricultural statistics is not presented in an efficient way and does not offer a great deal for the future use of these data (EC, 2016). The National Agricultural Statistics Service of the United States reports that agricultural survey response rates are declining day by day, and that affects the quality of data regarding crop production, yield, and cash rents (National Academies of Sciences, Engineering, and Medicine (NASEM), 2017). The Asian Development Bank (ADB) also identifies discrepancies in agricultural data sources for some countries. The key factors that contribute to these data discrepancies include differences in coverage, nonresponse, and the timing of data collection; as well as data processing errors (ABD, 2016). The Food and Agricultural Organisation (FAO) has also taken different initiatives to improve agricultural statistics, such as building a strategic plan for collecting and managing agricultural statistics for 40 developing countries (FAO, 2021). More recently, FAO, the World Bank, and the International Fund for Agricultural Development (IFAD), in collaboration, initiated a program named ‘50x2030’ to solve the problem of the agricultural data gap in 50 Asian, African and South American countries by the year 2030 (FAO, 2022).

The Australian Bureau of Statistics (ABS) is a national statistical agency and custodian of official data in Australia. ABS' agricultural production data are often collected through surveys sent to the agriculture producers. The aggregated survey response-based data are used for estimation of the population and then published on ABS' websites. Though the sample sizes are often very large, published data sometimes contain sampling variability because of non-response participants (ABS, 2021). In reporting this sampling variability, ABS states that the relative standard error (RES) calculated for most of the published estimates is less than 10 percent. However, for some commodities, the reported RES is very high. For example, the estimate for oats in Queensland's grain production contains 30.5 percent RSE (ABS, 2021). Given the variability and inconsistency in the national data published, it is imperative to investigate the current practice and initiatives necessary for minimising the agriculture data gap in the Australian context. Drawing on a review of the literature on agriculture studies by different organisations including ABS, ADB and FAO, the present study investigates the existing agricultural data collection and correction methods, that are useful for effective use of agriculture data for supply chain mapping.

3.2.1 Agricultural data collection, correction, and monitoring process

3.2.1.1 Common agricultural data collection and estimation methods

Different methods have been developed to estimate agricultural production in various countries of the world. These methods encompass different techniques for collecting data from the farm level to the national level. Some of these methods are popular in developing countries because they require less cost and technology involved. Whereas the use of high-tech equipment and the internet of things (IoT) in collecting agricultural production data is preferred in developed countries as they are less labour-intensive.

The most popular production and yield data collection technique is the **crop cuts** method. In using this method, several small subplots are considered. The production and yield data for the subplots are measured after harvesting, and the calculated data are applied to the entire field to estimate the total production. It is suggested in the literature that in order to get a better estimate, at least 1 m^2 size subplots should be considered, and the size of the subplots needs to be even bigger for land with variable yield performance.

Farmer's survey is another common technique to directly collect data. Face-to-face interviews or computer-assisted surveys are also used to collect production and yield data. The data collection process can occur before or after harvesting. The data quality often depends heavily on farmers' estimation of the production. The unit used for reporting data is often one of the sources of errors that are often found in this method, as producers may not recall their production amount in the prescribed units when answering the survey (generally in kg or tonne), but in the form of a local unit (e.g., box, tray or sack). Underestimation or overestimation of the production amount by producers is another source of errors that often occurs while using this method.

Grain weight data (average) are sometimes used to estimate production and yield data. However, this method may not be suitable for all types of agricultural commodities.

Sampling for harvest unit is another data collection method with a few samples of the total harvest being weighed and used to calculate the total production. Sometimes agronomists or experts can assess the yield of a certain crop by visual inspection (eye assessment).

Expert assessment is a method that depends on assessors and their capability to assess different crops in different environments.

Crop modelling is a relatively new approach to estimate production and yield data. Environmental and climate data are also considered while estimating the production and yield using this method. To cross-check the production data, **administrative data or financial data** can also be used. An example of such a technique is using insurance data, although this technique is very cost-effective. However, the accuracy of such estimation often depends on the quality of both sets of data.

Another modelling-based approach is **the allometric method** which involves the plant's morphological characteristics.

In recent years, the usage of new technologies has allowed national statistical agencies to estimate production data more accurately. **Remote sensing techniques** are one of the data collection methods which use spectral reflectance of green plants to estimate crop yields. Spectral reflectance data can be captured from satellite images which are then used with a set of vegetation indices to estimate crop yields for a piece of land. The resolution of satellite images or the pixel size of images plays a key role in accurate estimation. Multiple crops producing fields could be a source of potential flaws in applying this method if the satellite images are not captured during different crop tenures. A comparison of the data collection and estimation methods discussed in this section is summarised in Table 8.

Table 7: Methods in common use for estimation of crop yield

Categories of data collection	**Method**	**Description**	**Scale**	**Pros and cons**
Survey and survey-based estimation	Crop cut	• Commonly used and standard method. • Total yield per unit area is calculated based on the measured yield in one or more subplots. • Per unit area yield is used to calculate the total production.	Field or farm level, and sometimes landscape level	• Time and labour intensive. • Tendency to overestimate
	Farmers' estimate	• Data are collected through a farmer survey	Farm to landscape. Commonly used at national and regional level.	• Cost effective and time efficient. • Fairly accurate estimation. • Outcomes are subjective and sometimes supervision is required. • Farmers can deliberately overestimate or underestimate
	Crop yield estimation by using grain weight	• Using the grain weight (e.g. 1000 grain weight) for estimation • Number of ear heads/pods and grain per ear head in the sample area is counted • Using a standard formula to calculate the total production	Plot level, farm level.	• Possibility of counting errors. • Labour intensive • Not suitable for horticulture production.
	Sampling harvest unit	• Only a few samples out of the total harvest are weighed • Total production is estimated based on sample results	Farm to landscape	• Cost-effective • Crops must be harvested all at once from the sample area.
	Whole plot harvest	• Harvesting the entire field to determine the crop yield	Plot level, farm level, case study	• Almost bias/error-free • Cost intensive, labour intensive • Not suitable for landscape level.
	Expert assessment	• Experts / field agronomists estimate the crop production by visually assessing the crop condition before harvesting.	From farm to landscape level	• The outcomes are subjective and depend on the skill of the expert. • Moderately cost-effective

Modelling approaches	Crop modelling	• Estimating average biological yields in the conditions of smallholder farmers. • Environmental conditions are taken into account.	Landscape	• Cost effective • Parameters need to be carefully calibrated to achieve more accurate results.
	Purchasers'/ insurance record	• Estimating the crop production based on monetary records.	Field scale	• Cost-effective but less accurate. • Suitable for cash crops with only no household consumption
	Allometric models	• Mathematical modelling of plant morphology and crop yield.	Field scale	• Cost effective and accurate. • Suitable for few crops only
Technology based approach	Remote sensing	• Using modern technologies including GPS and satellite images to estimate the crop production. • Considered as the future of agricultural data collection.	Landscape	• Cost-effective and accurate. • Need very high-resolution satellite images to estimate production correctly. • Possibility of errors in cases where different crops have the same signature (in satellite images)

Sources: Sapkota et al., 2016, Sahajpal et al., 2020, Carletto et al., 2015, Liu et al., 2020, Muller et al., 2017

3.2.1.2 Common agricultural data correction and monitoring methods

Collection of accurate agricultural production data and monitoring these data are vital to ensure food security on a national and global scale. Precise and up-to-date information will help control the price volatility in the market (Fritz et al., 2019). The remote sensing technique previously discussed has been widely adopted by different countries to collect higher quality data. With better (high-resolution and pixel) satellite images, crop production estimation with remote sensing data becomes more accurate. To examine the data collection process and streamline information flows, different agricultural monitoring systems can be deployed on the regional, national, and global scale. Fritz et al. (2019), in their study on global agricultural monitoring systems and current gaps, describe and draw a comparison between different agricultural monitoring systems. For instance, they indicate that FAO has organised such monitoring systems on a global scale through the **Global information and early warning system (GIEWS)** in collaboration with government- and non-government organisations. This system uses the Normalised Differences Vegetation Index (NDVI) to process remote sensing data. The system can be used to investigate the effect of climate changes (drought, water stress) on crop production (Rojas, 2015). The Monitoring Agriculture with Remote Sensing (**MARS) crop yield forecasting system**, in addition, has been used to provide information about the status of crop production and forecast crop yield in the European Union (EU) and neighbouring countries (Fritz et al., 2019, Lopez-Lozano et al., 2015). This system uses the remote sensing technology along with the crop model simulation and weather data to report production and yield forecasting data. Another crop production monitoring system, namely **CropWatch**, which is led by the Chinese Academy of Science, has been used to produce crop production and crop condition data at global, regional, and national levels (including China). National-level data from the CropWatch cover 31 countries that produce over 80 percent of the world's rice, maize, soybean and wheat (Wu et al., 2015). The **US Department of Agriculture-Foreign Agriculture service (USDA-FAS)** has also provided remote sensing and meteorological data-based global and national crop production estimates. This data accuracy monitoring tests has provided market intelligence for all major commodities of all foreign countries.

3.2.2 Agricultural data collection, estimation, and correction process in Australia

ABS has been responsible for providing agricultural statistics for Australia for more than a century and contributed to the country's development of agricultural policies, initiation of research in relation to the agriculture sector, allocation of funding, and development of the market structure. However, the Australian agricultural statistical system has been criticised for its lack of a robust and modernised statistical system to provide accurate and high-quality data (Hodgesand and Lehmann, 2016, McRobert et al., 2019). The National Agricultural Statistics Review (NASR) is an initiative by ABS and ABARES, which was established to review the agricultural statistical system based on feedback from stakeholders and end-users of agricultural statistics. Based on the review of NASR, the Australian Government set a road map for improving the national agricultural statistical system (DAWR, 2017), including four main streams: Consolidation of collection, alternative data sources and collection methods, future collection methods and data sources, and stakeholder engagement. ABS has already implemented the strategy of consolidation of collection for their Big Data platform encompassing administrative data with agricultural production data. Table 9 summarises traditional and new data collection techniques adopted by ABS and a data collection process applied by FAO.

Table 8: Australian agricultural data collection approaches by different organisations

Organisation	**Methods**	**Reference**
FAO agricultural statistics	a) Data were collected primarily through surveys and from national publications/databases. In addition, information was collected through correspondence with governments and consultation with regional officers and field experts. b) Selection of data through analysis and scrutiny with cross-reference checking if required. c) Filling-in gaps when necessary. d) Processing and storage of the data selected. e) Dissemination of the data through yearbooks, census reports, bulletins and other publications.	FAO, 2015
ABS agricultural production data	a) Paper-based and online surveys were sent to selected agricultural businesses. b) Quality checking of the survey responses. Follow-up contact was made, or imputation technique was used to resolve missing data. c) Data were then aggregated. Aggregated estimates were compared against a range of other information sources (other ABS surveys, administrative data, industry estimates and expectations etc.) d) Adjustments were also made in the estimation process to account for any new agricultural businesses registered in the ABSBR which would be in scope of the survey but were not identified when the initial survey population frame was created. e) The estimates were based on information obtained from agricultural businesses which responded to the survey. The data were subject to sampling variability and sampling error.	ABS, 2021

ABS new methodology Grain production and value: experimental analysis using administrative data	a) A co-design method that maximised the use of existing administrative data. b) A significant existing administrative data source, which was taken from the levy payer data generated during the sale of agricultural commodities. These levies were collected by the Department of Agriculture, Water and the Environment (DAWE). c) The new methodology considered the suitability of levy payer data as an important component in producing national and state level statistics for a selection of high value broadacre crops, specifically: wheat, oats, barley, sorghum and canola. d) The Levy Payer Register collected detailed information about levies paid on broadacre crops from individual producers. This information includes: • Quantity of commodity sold by levy payers • Amount paid to the levy payers for the sale of the commodity • Business address of each levy payer • Using the existing levy payer data to produce a range of agricultural statistics has the potential to produce more timely statistics with greater regional detail. e) This analysis compared levy payer data with ABS data at State and National levels. f) Further work would be required to compare levy payer data with survey-based data over additional time periods and for smaller regions to determine its full utility.	ABS, 2021a

The new methodology adopted by ABS used administrative data, which is common in other developed countries and some developing countries. It was mentioned in the previous section that most developed countries and some organisations have used remote sensing data in the form of satellite images to monitor global and national crop production and yield data. Recently, ABS took the initiative to use satellite data from the Digital Earth Australia (DEA) to develop a national map on crops and land cover (ABS, 2020). The process involves the following steps (ABS, 2020)

1. ABS shares de-identified agricultural data with Geoscience Australia
2. These data were compared with satellite data stored within DEA
3. Machine-learning methods were developed to distinguish between different crops or land covers
4. The Geoscience Australia used these data to create regularly updated national-coverage maps of crops and land cover
5. The maps were made available to users for farming, policy decisions and official statistics.

In 2021, ABS released experimental statistics on sugarcane for 2020 by using remote sensing data (ABS, 2021b). The experimental data were compared with the official sugarcane statistics of previous results. As reported, the data produced using the new methodology closely align with traditional production statistics. However, for some sugarcane-producing regions such as Cairns and Townville, the variation in the estimated data was still high. Adoption of remote sensing data for the entire agricultural data set in ABS would require more time as this involves changing the data file extension and data collection and management procedure.

Using data correction methods is often time-consuming and requires multistage data collection over time. ABS has adopted two basic techniques for data correction and both of them are currently applied on a trial basis. The first approach is using a big data platform to correct agricultural data. “Big data” is generally defined by its three basic characteristics, namely Volume, Velocity and Variety (Daas & Puts, 2014). The big data platform can be used for detecting and treatment of anomalies in survey data, imputation of missing data, and ensuring the consistency of survey data (Tam and Clarke, 2015). ABS recently has undertaken an Administrative Data Initiative which will progressively replace the agricultural survey content with alternative data sources from big data platforms. The alternative data sources include:

- Agriculture levy data
- Precision agriculture systems
- Satellite data
- Industry data

In a regional context, Central Highland Development Cooperation (CHDC) also adopted a similar approach by collecting industry data as well as data from key stakeholders in the agriculture industry to generate comprehensive production data on a regional scale (CHDC, personal communication, 2022).

The second approach adopted by ABS is using remote sensing satellite data to correct agricultural census data. This method is also based on the big data platform but is sometimes considered as a standalone approach due to the involvement of advanced technologies (as earlier described). Innovative technologies adopted in the agricultural statistical system can generate more accurate and timely data with greater regional details. This can help facilitate policy decision making at both the micro (farm level) and macro (state/federal) level. Some recommendations for improving the agricultural statistical system from the roadmap have already been implemented by ABS (DAWR, 2017).

3.2.3 Export commodity selection techniques

The Australian Bureau of Statistics has recorded over 100 agricultural commodities in their data bank. The importance and significance of the commodities may vary over different regions. Analysing all commodities to check their suitability in the export supply chain is time consuming and not worthwhile as some commodities often generate very small revenue at the farm gate. Traditionally, the volume and value of commodities are used for ranking their significance and priority in a region. Marinoni et al. (2012) suggested a scientific way to prioritise commodities in the Australian context. They developed a method to rank the priority of the commodities, which depends on two variables, the land used for each commodity and the value of that commodity. Following in their footsteps, we have developed a function that can be used to rank the priority of commodities in a region. In this ranking function, the production volume is seen as the third independent variable. In the formula (presented below), the area represents the total area used for the commodity, the value represents the local value or the farmgate total value of the commodity, and the volume represents the production volume of the commodity. All the data were collected from the ABS 2019-2020 commodity data set for the Central Queensland region (SA4 region). The priority ranking formula is given by

$$I_{C_x} = \frac{A_{C_x,y} + V_{C_x,y} + Vol_{C_x,y}}{3},$$

with $$A_{C_x,y} = \frac{Area\ (ha)\ dedicated\ to\ commodity\ x\ in\ year\ y}{Total\ area\ (ha)\ dedicated\ to\ all\ recorded\ commodities\ in\ year\ y}$$

$$V_{C_x,y} = \frac{Total\ value\ (\$)\ generated\ by\ commodity\ x\ in\ year\ y}{Total\ value\ (\$)\ generated\ by\ all\ commodities\ in\ year\ y}$$

and $$Vol_{C_x,y} = \frac{Volume\ (t)\ of\ commodity\ x\ produced\ in\ year\ y}{Volume\ (t)\ of\ commodities\ produced\ in\ year\ y}$$

where, C_x represents the commodity x, the year for the importance index is y, $A_{C_x,y}$ is the relative area used for the specific commodity, $V_{C_x,y}$ is the relative local value of the commodity C_x, and $Vol_{C_x,y}$ is the relative production volume of the commodity C_x.

This approach for prioritising commodities is useful for selecting priority commodities in a region, as some commodities can be produced in a small area but have high value, and in some other cases, the production volume of the commodities is high, but their value is not that high. The value and volume of agricultural commodities in central Queensland in 2019-2020 are listed in Appendix 1. The data indicate that livestock was the primary agricultural commodity in central Queensland in this period, which generates about 80 percent of the total gross value. Livestock commodities can be categorised into native pasture, open grazing and sown pasture. It is hence difficult to do commodity priority ranking for livestock (e.g., beef cattle, dairy cattle, sheep etc.) using the current method. Considering livestock and livestock product as the primary commodities in the region, we include only **crops** and **horticulture** as major commodity features in our priority commodity analysis. The analysed data are presented in Table 10. The production volume data are missing for some categories in the ABS data set. In such cases, we adopted the formula proposed by Marinoni et al. (2012) which is given by $I_{C_x} = \frac{A_{C_x,y} + V_{C_x,y}}{2}$.

Table 9: Priority ranking for agriculture commodities in central Queensland (2019-20)

Commodity description	**Local value ($)**	**Area (ha)**	**Volume (t)**	**Ranking measure (%)**
Total crops	284,274,811	219,462	466,794	
Broadacre crops - Cereal crops - **Wheat** for grain	54,309,179	75,306	151,774	28.64
Broadacre crops - Non-cereal crops - Pulses and legumes - **Chickpeas**	51,138,521	40,784	70,826	17.25
Broadacre crops - Cereal crops - **Sorghum** for grain	24,396,444	40,680	68,543	13.93
Hay - Total	22,011,817	18,360	84,931	11.43
Broadacre crops - Non-cereal crops - **Cotton** lint (irrigated and non-irrigated)	47,286,206	9,791	20,036	8.46
Broadacre crops - Non-cereal crops - Pulses and legumes - Other pulses (b)	18,881,083	15,094	16,902	5.71
Broadacre crops - Cereal crops - Maize for grain	8,877,565	6,660	19,348	3.43
Fruit and nuts - Grapes - Total	21,020,587	982	5,692	3.02
Broadacre crops - Cereal crops - Barley for grain	3,942,858	4,033	11,537	1.90
Fruit and nuts - Plantation fruit - Pineapples	6,626,409	823	9,751	1.60
Fruit and nuts - Nuts - Macadamias	9,229,165	550	1,502	1.27
Broadacre crops - Cereal crops - Oats for grain	1,540,743	4,700	4,047	1.18
Vegetables - All other vegetables n.e.c.	5,926,085	116		1.07
Nurseries, cut flowers or cultivated turf - Total	3,592,490	119		0.66
Fruit and nuts - Orchard fruit - All other orchard fruit n.e.c.	2,933,015	67		0.53
Fruit and nuts - Orchard fruit - Mangoes	1,525,289	111	764	0.25
Broadacre crops - Cereal crops - All other cereals for grain or seed (a)	270,386	486	750	0.16
Broadacre crops - All other crops n.e.c.	114,745	553		0.15
Broadacre crops - Non-cereal crops - Oilseeds - Other oilseeds	102,737	199	129	0.05
Fruit and nuts - Other fruit - All other fruit n.e.c.	113,425	9		0.02

Fruit and nuts - Orchard fruit - Avocados	121,952	15	36	0.02
Fruit and nuts - Orchard fruit - Oranges	101,856	4	74	0.02
Vegetables - Melons	46,471	4	57	0.01
Vegetables - Pumpkins	7,521	2	11	0.00
Vegetables - Tomatoes	8,269	1	4	0.00
Fruit and nuts - Plantation fruit - Bananas	193	8	0.1	0.00
Vegetables - Sweet corn	5,580	1	4	0.00
Vegetables - Cauliflowers	3,096	0.2	4	0.00
Vegetables - Mushrooms	790	0.0	0.1	0.00

**n.e.c.: not elsewhere classified*

The ranking analysis indicates that the leading crop and horticulture commodities are wheat, chickpeas and sorghum. The next priority category is hay which is significant only for the domestic market. The next commodity on the list is cotton. Recent statistics suggest that Australia exported about 99 percent of its cotton (Queensland cotton, 2022). The export value and volume of these commodities for Queensland are listed in Table 11. As specific trade and export data were not available for central Queensland, we used the data for Queensland to demonstrate the importance of key commodities of central Queensland in particular.

Table 10: Export value and volume of major crop and horticulture commodities in Queensland

Commodities	Year	Sum of Value ($AUD)	Sum of Gross weight (KG)
Wheat	2019-2020	10,611,905	20,476,520
	2020-2021	387,046,899	1,088,411,940
Chickpeas	2019-2020	230,401,468	275,760,077
	2020-2021	313,587,326	434,916,687
Cereals, unmilled (excl. wheat, rice, barley and maize)	2019-2020	33,729,492	68,871,448
	2020-2021	182,319,592	488,443,856
Cotton, not manufactured into yarn or fabric	2016–2017	851,369,756	360,123,276
	2017–2018	222,564,234	90,356,295

Source: Queensland Government 2022

As such, we have presented an overview of agricultural data collection, monitoring and correction methods available worldwide and in Australia. We have then suggested an appropriate method of data collection, monitoring and correction for the area of concern, and provided some data about selecting export commodities in the Queensland region. The literature review and discussion suggest that there is a scope for improvement in the data collection, monitoring and correction methods used in Australia, particularly for the central Queensland region.

In the coming section, we describe results and findings in relation to our development and validation of a framework and mapping tool for agricultural supply chain characterisation, major product, supply chain and market analysis in reference to the mapping tool, as well as presentation of data about five case communities using the mapping tool.

4 Results and Findings

4.1 Agricultural supply chain framework and mapping tool

4.1.1 Development of an agricultural supply chain framework and mapping tool

4.1.1.1 Framing agricultural supply chain complexity: A baseline framework

Our deductive and inductive literature review in Section 3.1.3 foregrounds the four major domains, namely product, infrastructure, process, and factors, associated with various dimensions and features of agricultural supply chains. as previously proposed. It is a structured state of inter-relation and inter-connectedness of agricultural supply chain features, where a change in one feature can affect the functioning of others (Chhetri et al., 2022).

This framework provides a theoretical model for describing, analysing and evaluating agricultural supply chains for any commodity. It also provides a basis on which to build a mapping tool for general end-users, which enable them to collect information about, characterise, compare, and evaluate agricultural supply chains as well as identify issues and opportunities in relation to the chains and their networks (Schrobback et al., 2020). The framework, in general, comprises of four fundamental components, namely product, infrastructure, process, and factors. In addition, the three bi-directional arrows (see appendix 3) which connect the product, infrastructure and process components imply that product, infrastructure and process mutually influence one another. The three uni-directional arrows which connect the factors component with the three other components of the framework suggest that factors can influence them, but supply chains themselves do not often have much influence on these factors.

4.1.1.2. Mapping agricultural supply chain characteristics: A tool for end-users

As aforementioned, the agricultural supply chain baseline framework serves as a theoretical basis for building a mapping tool for agricultural supply chain characterisation. For Norwood and Peel (2021), and Gardner and Cooper (2003), supply chain maps are useful for several reasons, as they can:

- Provide supply chain end-users (such as stakeholders, leaders, members, decision-makers, industry groups, or other entities) with an overview of their inter-organisation and better understand their own business.
- Help chain stakeholders, leaders and members to learn more about the standard mode of operation in modern supply chains, identify ways to make their chain more flexible, monitor supply chain strategies, enhance communication for generating profitable ideas and achieving their business goals, and contemplate realignment, modification or redesignation of their chain if necessary.
- Contribute to facilitating supply chains' strategic planning process, easing distribution of information, clarifying channel dynamics, and elaborating common perspectives.
- Provide a basis for both simplistic and sophisticated supply chain evaluation and analysis.

The mapping tool which we have developed is, hence, an extended version of the baseline framework previously discussed. The mapping tool will be practical and applicable for supply chain stakeholders and other entities in several ways. The tool, that integrates main elements of agricultural supply chains, is presented in a table form, that is believed to be convenient for end-users to follow. In addition to three columns in which three levels of supply chain components, dimensions and features are presented, another column in which explanations of each feature is also included. These explanations are expected to help readers to understand exactly what kind of information/data they should refer to when examining each supply chain feature.

The mapping tool, which is developed in reference to the literature review, is labelled as "Mapping tool for agricultural supply chain characterisation (DRAFT version)" (see Appendix 4).

In addition, given that the framework and mapping tool are developed mainly based on the literature, they need to be tested and validated using primary and secondary data. In the next section of the report, we present stakeholders' feedback and comments to modify, refine and polish the framework and the mapping tool. The mapping tool was then applied to initially describe some agricultural supply chains of case products in the central Queensland region, using trial data sets, to recommend early lessons for decision-makers.

4.1.2 Validation of the framework and mapping tool: Experts' perspectives

As previously discussed, the expert validation mainly investigated the framework and mapping tool in terms of content, that is, supply chain dimensions and features embedded in the design. In the sections below, we discuss the experts' quantitative and qualitative feedback (taken from the survey results and workshop discussion), which are considered as important suggestions to make decisions on whether we should retain or modify some items in the proposed models towards a more comprehensive framework and mapping tool.

In discussing the survey data, we refer to Voutilainen and Liukkonen's (1995 – in Hyrkäs et al., 2003) suggestion on determinations of content validity that if 80 percent of respondents confirm that an item is important or necessary, it can be retained in the proposed model. When the total number of respondents who thought that a supply chain feature was "slightly important" or "not at all important" is more than 20 percent, we would pay some attention to that feature, considering whether we should modify or provide more explanations about it or not. Workshop discussion is also an important validation source in this process. When two or more than two workshop participants had the same or similar ideas about a particular supply chain feature, we would take it into more careful examination, although suggestions by a single expert were also attached importance. Where there were survey and workshop data of the same topic, triangulation strategy was also applied.

We present the experts' views in six main thematic sections, namely product characteristics, product supply, product demand, infrastructure, process, and factors, in reference to the framework's components/dimensions and the survey's questions. In addition, we include a section about usefulness and form of the mapping tool, considering a few experts' suggestions in the workshop. The survey data are presented in a table form and the tables are followed by extracts of the same topic taken from the workshop discussion. In line with the discussions of the analysis and findings, a summary box of suggested changes or modifications in the framework/mapping tool is also included as a conclusion of each theme or sub-theme section. Finally, an amendment matrix for the framework and mapping tool is provided towards the end of this section.

4.1.2.1 The PRODUCT component

Product characteristics

The survey question related to this supply chain dimension is "How important is it to include ………………(the below items) in the mapping tool as a feature in the PRODUCT domain of agricultural supply chains (the items are related to product characteristics)?"

The experts provided their opinions about the importance of "product characteristics" features in the framework and mapping tool (see Table 12). Among the five features shown in the table, "perishability" was rated of highest importance, considering the responses very important and extremely important. The answers for the "food type" and "product category" features are slightly mixed. However, no one thought that these features were "not at all important", hence there would be no change in relation to them. The experts' discussion on the salient role of the "product category" feature in the workshop (see below) was also brought into consideration in making this "no change" decision.

Table 11: The importance of "product characteristics" features in the framework and mapping tool

#	Question	Not at all important (%)	Slightly important (%)	Moderately important (%)	Very important (%)	Extremely important (%)
1	Food type	0.00	15.38	15.38	46.15	23.08
2	Product category	0.00	7.69	23.08	61.54	7.69
3	Perishability	0.00	0.00	15.38	46.15	38.46
4	Seasonality	0.00	0.00	30.77	46.15	23.08
5	Bulkiness	0.00	0.00	23.08	61.54	15.38

The workshop discussion

The experts participating in the workshop had different suggestions on the "product characteristics" features, especially on the "product category" and "perishability" features. Regarding "product category", a local government representative believed that this feature was more important than "food type", as it could determine all food criteria (and consequently, how the supply chain worked). As this representative commented:

> The product category, probably says, more than the food type because there'll be various food type or different food types that all forms of the same product category. That will be the product category, which then determined all rest.

In a similar vein, a specialist suggested that "product category" was a critical feature which decides how the product was managed in the supply chain. They said:

> The product category runs around to my way of thinking, it's all about processing. It is processing. The processing thing there's a whole business or industry around that. We send to Chinese market where you're [inaudible]. So I think product category is critical based around how you manage the product.

In addition, the specialist emphasised the significant role of the "perishability" feature in the supply chain by mentioning the issue of freshness and food damage. This view contributes to confirming the importance of this feature, which was highest rated by the survey respondents, among the five features related to product characteristics. As the specialist stated:

> I am not sure about the freshness. You can Chill it and keep it for weeks. Yeah, you don't chill. It's gone. So, your perishability in fact has got variables in it and can damage your ability with if it's procedure. So, the perishability got the standard point.

In line with the discussion on the "perishability" feature, a researcher suggested that the term "shelf life" might be a good option instead of "perishability". The researcher said "They use shelf life. Is that bad to quantify the indicator compared with perishability?". In considering this suggestion, we reviewed the literature about the two features, and found that "the two terms were often used together in several studies, as they are about the same issue which is often observed in agricultural production (e.g., Nardi et al., 2020; Romsdal et al., 2011; Vandeplas & Minten, 2015). For that reason, we decided to replace the term "perishability" with "perishability and shelf life" and provide additional explanations about this feature in the framework and mapping tool.

Product supply

The survey question related to this supply chain dimension is "How important is it to include ………………(the below items) in the mapping tool as a feature in the PRODUCT domain of agricultural supply chains (the items are related to product supply)?"

Table 12: The importance of “product supply” features in the framework and mapping tool

#	Question	Not at all important (%)	Slightly important (%)	Moderately important (%)	Very important (%)	Extremely important (%)
1	Type of product processing	0.00	7.69	23.08	53.85	15.38
2	Farmgate-to-shipping time	0.00	7.69	7.69	53.85	30.77
3	Product life cycle	0.00	0.00	23.08	30.77	46.15
4	Product variety	0.00	0.00	46.15	30.77	23.08
5	Product innovativeness	0.00	7.69	38.46	38.46	15.38
6	Product value	0.00	15.38	23.08	23.08	38.46
7	Value adding	0.00	15.38	23.08	46.15	15.38
8	Supply uncertainty	0.00	15.38	15.38	30.77	38.46
9	Stock ability	0.00	15.38	23.08	23.08	38.46
10	Delivery lead time	0.00	7.69	15.38	30.77	46.15

It can be seen from Table 13 that most of the survey respondents (more than 80 percent) were relatively consistent in agreeing that all the 10 features associated with the product supply dimensions were “extremely important”, “very important” or “moderately important”, although the levels of importance rated for each feature varied. Specifically, “product life cycle” and “delivery lead time” and "farmgate to shipping time” were rated the highest, with over 75 percent of the expert believing that they were “extremely important” or “very important”. Also, no one thought that the 10 features were “not at all important”. This is one of the significant bases for our consideration of retaining all the 10 features in the framework and mapping tool, as initially designed.

The workshop discussion

The experts who participated in the workshop also discussed the importance or necessity of including the 10 features associated with the product supply dimension. A state government representative, for example, suggested that in considering the value of an export product, the volume which we could export was what matters: “So, if you've got something that's exported a long way away and it's slight value that will equates to risk, because that's what we call the volume here”. We agree with this view and have decided to make the feature “supply uncertainty” clearer by naming it “supply volume and uncertainty”.

The experts were particularly interested in “product life cycle” and “farmgate-to-shipping time”. They, for example, asked for more explanation or clarification of the term “product life cycle” in the framework and mapping tool. A state government representative said: “I'm trying to clarify what part of life cycle we are talking about”. Likewise, a specialist commented:

> “What part of the life cycle, the year-round life or the seasonal things. Think of macadamia, they have [inaudible]. They had a consistent market demand stream decide who will [inaudible], you know, we can live. You make them all year round. The biggest family was exiting in The Growers and your cash flow projections to actually manages to having a long flood. So, the product life cycle has changed from when the seasonal flow to into an all-around side, some of them tassel, last, couple years that they're doing the same thing”

In response to the experts' comments on the "product life cycle" feature, we have considered providing more details in the explanation column of the mapping tool, where we added a note about products which have "year-round life" and "seasonal life" in describing what it means by product life cycle.

A local government representative, in addition, suggested that instead of "farmgate-to-shipping time", a feature called farmgate-to-consumer may be better, as "farmgate-to-shipping" and ""farmgate-to-consumer" should go together. The representative said:

> "So that farm gate to shipping time. It's really farm gate to consumer. First different products would be different. So it's a six-week window. You don't make a highwall sunshine. So the shorter that is from farm gate to consumer for lychees, there is a huge bearing as opposed to chill and frozen beef. So, product life cycle on the farm gate to not necessarily shipping. Farmgate to consumer because that will be then targeted to by over 20 steps in the middle. So I think these two things need to go together because they're interrelated"

We have brought this comment related to farmgate-to-shipping time into consideration in analysing the data and refining the framework/mapping tool. We agree with the local government representative that "farmgate-to-shipping" and "farmgate-to-consumer" are interrelated. However, "farmgate-to-consumer time", if included in the framework/mapping tool, will overlap another feature, namely "delivery lead time", which is about the duration between the time customers place their order to the time they receive the product. For that reason, we have decided to retain the "farmgate-to-shipping time" and "delivery lead time" features. We may consider placing the two features together under one category called "lead time" in designing a digital mapping tool for building a database of agricultural supply chains in our future research.

In designing the second layer of the framework and mapping tool we sometimes found it difficult to make decision on which features of the supply chain should be associated with which dimensions. For example, we were wondering if the features "product life cycle", "product variety", and "product innovativeness" should belong to the "product characteristics" or "product supply" category. We sought comments from the workshop participants in this regard. In answering this question, the expert generally agreed that it might be better to put "product life cycle", "product variety", and "product innovativeness" in the "product characteristics" category. A state government representative, for example, said: "If you are having some question about product lifecycle, product varieties, and product innovativeness, what I suggest is that they are falling less in the supply category". Similarly, a local government representative suggested that the three features "should go to the product characteristics". In line with such discussion, a researcher had concerns about whether "product variety" should be seen as a product characteristic. As the researcher said:

> I've got a feeling that product variety more of like a label rather than directly addressed them specific character of the product. But if it's sometimes, you want to use one label to simplify several different arrivals and putting them all together like this variety of lychee they flower and produce early. They are very sweet, but they are less shelf life. You can use one variable to substitute all these three, but that basically it's just one label to not really directly address.

The researcher might question about whether different types and forms of a product should be seen as different product varieties, or they were just different labels. The researcher, however, did not reject the idea of moving them to this category. In bringing this comment into consideration, we would suggest that not only "product variety", but some other features such as "product category" or "food type" can also be related to the issue of label, although different product categories and food types may create different kinds of supply chains. In bringing the experts' suggestions into consideration, we have decided to move "product life cycle", "product variety", and "product innovativeness" to the product characteristics category.

Product demand

The survey question related to this supply chain dimension is "How important is it to include ………………(the below items) in the mapping tool as a feature in the PRODUCT domain of agricultural supply chains (the items are related to product demand)?"

Table 13: The importance of “product demand” features in the framework and mapping tool

#	Question	Not at all important (%)	Slightly important (%)	Moderately important (%)	Very important (%)	Extremely important (%)
1	Market type	0.00	15.38	7.69	46.15	30.77
2	Market distance	0.00	15.38	0.00	53.85	30.77
3	Access to market	0.00	7.69	0.00	38.46	53.85
4	Demand uncertainty	0.00	0.00	30.77	30.77	38.46
5	Consumer segmentation	0.00	7.69	53.85	23.08	15.38

The respondents shared their observation about the importance of features related to product demand. As shown in Table 14, all the features associated with the product demand dimension were rated highly by the majority of respondents, with more than 80 percent in total believing that the features were “extremely important”, “very important” or “moderately important”. The highest rated features include “access to market” and “market distance”, with over 85 percent of the experts agreeing that the two features, were either “extremely important” or “very important”. Significantly, no one suggested that the five features in this category were “not at all important”. Therefore, in making decision on whether we should make changes in this category, we also referred to the experts’ ideas and suggestions in the workshop, that are discussed below.

The workshop discussion

In discussing features associated with the product demand dimension, the experts focused on clarification of the terms related to the issues of market, consumer and demand. Regarding market, a state government representative suggested that domestic or export market which supply chains can or want to access is often related to the distance the chains need to consider in order to reach the market. For the representative, therefore, the features “market type” and “market distance” should go together. We agree with this idea, and in considering the suggestion, we have combined the two features into one, namely “market type and distance” in our refined framework and mapping tool. As the representative commented:

> Market type, which is export domestic, low value, high value. We combine that with market distance, as another factor, it all adds up to a level of market complexity. So, if you've got something that's exported a long way away and its slight value that will equates to risk, because that's what we call the volume here. Yeah, I could almost see myself rolling, those two factors together. I'm having five or six different variables rather than by giving me a score on complexity.

Regarding the feature “consumer segmentation”, we have decided that we would include and provide more explanation about the psychographic factors in studying consumers’ characteristics and their needs, in referring to a local government representative’s comment: “The consumer segmentation, are you thinking demographic or psychographic. And how you are going to do that?”. Arguably, adding the psychographic factor to this feature is important to understand consumers’ demands and needs, which were also brought into the discussion by the experts.

As mentioned, the workshop participants brought the feature “demand uncertainty” into focus. They questioned the clarity of this term, and indicated that demand uncertainty, if any, was linked to consumer segmentation. They explained that if we did not know clearly about consumers, we might not understand their demands. “I guess consumer segmentation because it all comes back to that demand element” - a state government officer, for instance, stated. In a similar vein, a specialist said:

> I understand the demand uncertainty is because of consumer segmentation […] you worry about the demand uncertainty if you don't know about the consumers. Don't know your consumers where it's going […]. if you don't have some idea of consumer segmentation and the market you are access to, you're not going to pay the farm on. The demand uncertainty is relevant.

In line with such discussion, an industry peak body representative suggested that the "demand uncertainty" feature might not bring much value or information to supply chains, and that this might be related to risk rather than uncertainty:

> You don't have the history where there's a demand uncertainty, you're talking about things that have happened. But you knew that was going to happen with our policy decisions. But if you've got a nice strong example of what a demand uncertainty looks like then I'd say it's perhaps not a category that has a lot, we've obviously responded to it. We've all probably come with a different approach of what it means. That's the risk not the uncertainty.

Many experts participating in the workshop were consistent in agreeing that the issue of demand uncertainty was either unclear or not very important. We, hence, carefully considered their views and suggestions, and have decided to remove this feature from the framework and mapping tool. We acknowledge that this feature was rated highly by the survey respondents. We, however, believe the psychographic factor in relation to consumers' demands and needs, which has been added to the explanation of the "consumer segmentation" feature, would help shed light on their demand uncertainty, if any. As we indicated in our literature review, consumers' demographic and/or psychographic characteristics could provide us important information to forecast their demands (c.f., Bal and Gulse, 2013; Hamzaoui-Essoussi & Zahaf, 2012). Our recent research on Chinese consumers' perception and willingness to pay for imported Australian fruits and vegetables (Rahman et al., 2020) also provide evidence to this argument.

General survey question: "Do you think the above items are sufficient to describe major features related to supply chain PRODUCT?"

All the survey respondents all thought that the features mentioned in the previous three questions were sufficient to describe major features of supply chain product and did not suggest any new item. For that reason, no new feature had been added to the PRODUCT component in the framework/mapping tool.

General workshop discussion question: "Do you think we missed any features here?" (same for all three dimensions "product characteristics", "product supply", and "product demand").

The workshop participants did not discuss this question.A summary of changes in the PRODUCT component of the framework/mapping tool in light of the experts' feedback and suggestion is provided in Box 1.

Box 1: Major changes in the PRODUCT component in response to the experts' feedback

- Modify the name of the item "perishability", and instead, use the name "perishability and shelf life", and provide more explanation of the term.
- Modify the name of the item "supply uncertainty", and instead, use the name "supply volume and uncertainty", and provide more explanation of the term.
- Edit and provide a clearer explanation of the "product life cycle" item.
- Move the three items "product life cycle", "product variety", and "product innovativeness" from the "product supply" category to the "product characteristics" category.
- Edit and provide a clearer explanation of the "consumer segmentation" item.
- Combine the items "market type" and "market distance" into one.
- Remove the item "demand uncertainty" from the "product demand" category.

4.1.2.2 The INFRASTRUCTURE component

The survey question related to this supply chain component is "How important is it to include ……………… (the below items) in the mapping tool as a feature in the INFRASTRUCTURE domain of agricultural supply chains?"

Table 15 shows the experts' opinions about the level of importance of six features associated with the infrastructure component. We can see that a vast majority of the survey respondents were consistent in suggesting that features related to instruments and resources, including "transport", "labour force", and "technology" were the most critical in an agricultural supply chain's infrastructure. Specifically, all three of these features were believed to be "extremely important" or "very important" by approximately 92 percent of the respondents. If referring to the survey results in this table only, we would retain all the six infrastructure features.

Table 14: The importance of "infrastructure" features in the framework and mapping tool

#	Question	Not at all important (%)	Slightly important (%)	Moderately important (%)	Very important (%)	Extremely important (%)
1	Number of entities	0.00	7.69	38.46	38.46	15.38
2	Type of networks	0.00	7.69	23.08	53.85	15.38
3	Level of dependency	0.00	7.69	23.08	30.77	38.46
4	Transport	0.00	7.69	0.00	30.77	61.54
5	Technology	0.00	7.69	0.00	53.85	38.46
6	Labour force	0.00	7.69	0.00	46.15	46.15

The workshop discussion

In the workshop, the experts expressed their views about different infrastructure features, especially the "transport" one. A state government representative, for example, believed that it was crucial to include the "road condition" issue in explaining how transport affects supply chain activities. The representative said: "We need heavy vehicle corridor opened up. So we can access the port to send your container for export". Along the same line, another state government stated that road conditions could have an impact on the load and transporting time. As the representative commented:

> Guess, my question is about transport and supply chain. One of the things that we need to know is, it is a, if we're talking road as an example, is it a main transport corridor, is it not? You know, where you can take over the triples, it may not be rated for that. So we have limitations with our roads as to what kind of vehicles. We can travel with what kind of loads at what times. So, do we need to put on somewhere in there? Those limit the limiting factors or anything like that, around transport?

In considering the above ideas, we have decided to add the issue of road conditions to the explanation of the transport feature.

The experts, in addition, mentioned another infrastructure feature called processing availability, which was not included in the drafted framework/mapping tool. A researcher, for instance, suggested that processing facilities was needed to produce particular products for exporting. Likewise, a specialist provided examples about how important processing facilities are:

> Mandarin and mangoes are not viable because the processing is too far away. The processing is too far away from the edge and mung beans. Mung beans are on the edge of it, instead of a person with over think they put up and all the props and nothing else. But processing is the component, whether [inaudible] Freights taking away the profitability. For the Bundaberg last 15 years, we went fine ground with a modest powerhouse of small crops, macadamia nut and avocado and it's processing.

We have brought the experts' suggestions about processing availability into consideration. We decided to include a new feature called "facilities" in the instruments-and-resources category. Facilities involve processing, storage and other facilities (storage facilities was suggested by some survey respondents, see the discussion below).

The survey respondents also answered the general question about the sufficiency of features for describing supply chain infrastructure included. In answering the question about whether the items presented in the proposed supply chain framework and mapping tool are sufficient to capture major Infrastructure features of agricultural supply chains, nearly 77 percent of survey respondents chose "yes". Among the 23 percent of those who chose "no", one wrote a general question that "is additional infrastructure needed", and two suggested adding the "storage" feature. Their comments are as follows:

> - Cold storage at the agricultural district level (a survey respondent)
>
> - Only a consideration - do we need to think about pulling apart the freight task into the different types of transport - trucking, shipping and air freight. Also do we need to think about storage options as well. Cold storage, grain storage etc. (another survey respondent).

As previously discussed, we have considered these suggestions and included the idea of storage in the new feature called "facilities".

As "facilities" is a new feature in the refined framework and mapping tool, some literature evidence related to this theme is needed to confirm the importance and necessity of the feature. Facilities, which refer to equipment, machines, power, buildings, and services and so on are needed for supply chains production, package, transportation, and distribution processes to operate. Processing facilities, for instance, are often indispensable in supply chains of processed or highly perishable products. Insufficient processing facilities may cause significant food loss, or limited operation capacity (Gardas et al., 2018). Ge et al. (2022), for example, suggest that lack of access to processing facilities may limit the expansion potential of the chain's production. Gardas et al. (2018), in a study on critical causal factors for post-harvest losses in the fruit and vegetables supply chains in India, indicate that the unavailability of power supply can make processing very costly, and this may seriously affect the production. Other studies on agricultural supply chains during the COVID-19 also highlight that when processing facilities closed due to workforce outbreaks of COVID-19, daily processing volumes of beef, pork and other products in many countries decreased (e.g., Hobbs, 2021). In addition, sufficient and suitable storage facilities are especially important for storing agricultural products which are highly perishable or have short shelf life. For Gardas et al. (2019), inadequate facilities may cause products to perish in the open air and at shipping locations, and proper storage facilities can help farmers preserve and hold their product until the prices of the commodity become stabilised. Another example of the importance of storage facilities comes from Balaji and Arshinder's (2016) study on causes of food wastage in perishable food supply chains in India. The authors comment that India has faced the problem of lacking cold storage facilities, and that food wastage from post harvesting to consumers could be minimised if they have sufficient cold storage facilities.

A summary of changes in the INFRASTRUCTURE component of the framework/mapping tool in light of the experts' feedback and suggestion is provided in Box 2.

Box 2: Major changes in the INFRASTRUCTURE component in response to the experts' feedback

- Edit and provide a clearer explanation of the "transport" item, include the issue of "road conditions" in the explanation.

- Add a new item named "facilities", which includes processing facilities and storage facilities.

4.1.2.3 The PROCESS component

The survey question related to this supply chain component is "How important is it to include ……………… (the below items) in the mapping tool as a feature in the PROCESS domain of agricultural supply chains?"

The survey respondents shared their views about the importance of 11 different features associated with the PROCESS component of the framework/mapping tool. It is indicated in Table 16 that the features "trust and commitment", "communication", and "information sharing" were the three highest rated, with around 41.7 percent of the experts believing that the three features were "extremely important" (this number is the same for the three features). Other features, including "freight consolidation", "shared strategies and interests", "brand consolidation", and "shared business culture" were also rated highly although the levels of importance of the features were quite varied. In addition, we suggest that special attention needs to be paid to two features "contracting" and "single-handed business", as they were believed to be "slightly important" or "not at all important" by more than 30 percent of the respondents (in total).

Table 15: The importance of "process" features in the framework and mapping tool

#	Question	Not at all important (%)	Slightly important (%)	Moderately important (%)	Very important (%)	Extremely important (%)
1	Single-handed production	0.00%	25.00%	8.33%	58.33%	8.33%
2	Single-handed business	8.33%	25.00%	8.33%	50.00%	8.33%
3	Contracting	16.67%	16.67%	16.67%	33.33%	16.67%
4	Communication	0.00%	0.00%	25.00%	33.33%	41.67%
5	Information sharing	0.00%	0.00%	25.00%	33.33%	41.67%
6	Power distribution	0.00%	8.33%	33.33%	33.33%	25.00%
7	Shared strategies and interests	8.33%	0.00%	25.00%	41.67%	25.00%
8	Shared business culture	0.00%	16.67%	25.00%	50.00%	8.33%
9	Trust and commitment	0.00%	16.67%	0.00%	41.67%	41.67%
10	Brand consolidation	0.00%	8.33%	33.33%	41.67%	16.67%
11	Freight consolidation	0.00%	0.00%	18.18%	54.55%	27.27%

The workshop discussion

The workshop participants discussed different features associated with the Process component of the framework/mapping tool. They exchanged views on the relationship between "communication" and "information sharing", and the meaning of "power distribution". A local government representative, for instance, believed that it would be better if "communication" and "information sharing" are combined as they are interrelated. For the representative, perhaps, when members in a supply chain share information, they are communicating with one another. "Question would be why separate categories for communication and information sharing, if you share information, you're communicating" – the representative said. We appreciate this argument about the relationship between the two features, and have decided to combine them into one, namely "communication and information sharing".

The experts also suggested clarification of the term "power distribution". A specialist, for instance, said:

> Power distribution, having balanced imbalanced, don't really understand the wording. Why sharing magic power with enemies. Lines and these lines and routes. I'm going to get some little car. So we must be powerful somewhere, but thanks for division. They go to the get along and monopoly comes along with the contractor or transport company grows.

In responding to the specialist's question, a state government officer said: "we are we talking here about the difference between grower power versus buyer power". In line with such discussion, a local government representative commented that power was actually the power to control price in the market:

> Are we trying to capture concept of controlling the market or in the, in the supply chain rather than actual power? How's that? How's the price controlled by any one player in that chain.

The experts were then consistent in agreeing that power in supply chains was often related to price control. The specialist concluded: "Everyone would give price control a break. Ask industry and various other ones". In light of the experts' feedback, we have decided to include price control in the explanation of the "power distribution" feature in the mapping tool.

During the discussion, we also asked for their suggestions on the importance of "single-handed business" and "contracting" in agricultural supply chains, as they are the two features which were rated the lowest among the 11 Process features by the survey respondents. Regarding "single-handed business", the specialist stated:

> I would say single-handed production and business. They are the same time. Runs and annoy, streamline business to that involved with outside external cross, and by default, they restrict themselves, but they are the same to me.

The specialist's observation of singlehandedness in supply chains is considerable, as singlehandedness is where an independent supply chain entity directly takes part in all or most their production, distribution and/or trade activities without or with very limited involvement of other entities, and with no long-term plans or collaboration with other people. If there are single entities responsible for the whole supply chain process, from production to business, the term "single-handed production and business" is perhaps more reasonable to describe their activities. For that reason, we have combined the two features "single-handed production" and "single-handed business" into one, namely "single-handed production and business" in the refined version of the framework and mapping tool. This also contributes to addressing the issue related to "single-handed business" which was low rated by many survey respondents, as previously discussed.

Regarding "contracting", the experts participating in the workshop had mixed views about whether this is an essential feature of agricultural supply chains. A state government officer, for example, believed that contracts were not important. They commented:

> Contracting. Does it, doesn't it matter who does the work now? Just as long as the work gets done. Suppose it comes into a labour issue. Yeah, if you can't get contractors. But again, it's from a tool perspective. What does it add by?

An industry peak body representative, however, stated that contracting could create dependency among chain entities, and thus it was necessary to have contracts to ensure safety. As they said:

> I actually want to keep the contracting in. Well, it's a huge dependency. You think you were the grains harvester; this is an example. If that falls over, you lost. Yeah.

Due to the workshop participants' mixed views on "contracting", their opinions might not be seen as strong evidence for the necessity of this feature in supply chains. Given that this feature was rated quite low by the survey respondents, we have decided to remove it from the framework and mapping tool.

In answering the question about whether the items presented in the proposed supply chain and mapping tool are sufficient to capture major Process features of agricultural supply chains, nearly 92 percent of the survey respondents chose “yes”. We have considered providing more explanation of the “power distribution” feature, where we include the idea of “price control” in the mapping tool.

A summary of changes in the PROCESS component of the framework/mapping tool in light of the experts’ feedback and suggestion is provided in Box 3.

Box 3: Major changes in the PROCESS component in response to the experts’ feedback

- Combine the items “single-handed production” and “single-handed business” and replace them with “single handed production and business”.

- Combine “communication” and “information sharing” and replace them with “communication and information sharing”.

- Edit and provide a clearer explanation of the “power distribution” item, include the issue of “price control” in the explanation

- Remove the feature “contracting” from the framework and mapping tool.

4.1.2.4 The FACTORS component

The survey question related to this supply chain component is “How important is it to include ……………… (the below items) in the mapping tool as a feature in the FACTORS domain of agricultural supply chains?”

The experts provided their opinions about the importance of 6 features associated with the Factors component in answering the survey questions. As shown in Table 17, the item “government policies and regulations” was rated very highly (either extremely important or very important) by all the respondents. Government policies and regulations are critically important for supply chain activities in general, as they play the role of an umbrella legal framework or environment, that guides, and can either facilitate or constrain, supply chain activities. Most of the other features were also rated highly by the participants.

Table 16: The importance of “factors” features in the framework and mapping tool

#	Question	Not at all important (%)	Slightly important (%)	Moderately important (%)	Very important (%)	Extremely important (%)
1	Government policies and regulations	0.00	0.00	0.00	41.67	58.33
2	Government support	0.00	0.00	16.67	58.33	25.00
3	Relationship with investors	0.00	8.33	25.00	33.33	33.33
4	Relationship with external industries	0.00	8.33	16.67	50.00	25.00
5	Research and development	0.00	16.67	16.67	41.67	25.00
6	Natural or human-induced risks	0.00	0.00	16.67	58.33	25.00

The workshop discussion

The experts also brought some features associated with the Factors component into their discussion in the workshop. For instance, a producer emphasised the role of “research and development” in supply chains. “I want to put more yellow on the, on the research, on the R&D thing. That is just so important” – the producer said.

Another topic of focus related to the Factors component was about the two features “government policies and regulations” and “government support”. The participants, in general, agreed on the critical role of governments in supply chain activities. They, however, suggested that the two features were actually interrelated to or part of one another.” A state government representative, for example, stated:

> I was kind of going again a definition between government support and the government policy and [inaudible] regulation. I think it's my gut feeling is that might be a little bit interrelated in. What's the government policy and regulatory position might be rolled together.

In a similar vein, the specialist seemed to support the state government representative’s above comment in suggesting that “support” was in fact a “bonus” from governments. The specialist said:

> You have support for export and unknown freight cost. One is support, one is you respect that. Support will be the element and I won’t leave that […]. The change of government and once again impeding different sectors of the environment for a lot of other reasons, but mostly the support part of it I think that is a bonus.

In considering the experts’ opinions, we agree that “government policies and regulations” and “government support” were interrelated, as they both come from governments. We have combined the two features into one, namely “government policies, regulations and support” in the refined framework and mapping tool.

In answering the question about whether the items presented in the drafted supply chain and mapping tool are sufficient to capture major Factors features of agricultural supply chains, more than 83.3 percent of the survey respondents chose “yes”. Around 16.7 percent (2 person) chose “no”, and each provided a note as follows:

- Support during natural disaster

- Relationships with existing industries

As previously discussed, we already have the features “government policies, regulations and support” which can cover the idea of “support during natural disaster”. In considering the second comment on “relationships with existing industries”, we have decided to replace the feature “relationships with external industries” with “relationships with industries” so the term can cover a broader range of industries.

A summary of changes in the FACTORS component of the framework/mapping tool in light of the experts’ feedback and suggestion is provided in Box 4.

Box 4: Major changes in the FACTORS component in response to the experts’ feedback

- Combine the items “government policies and regulations” and “government support”, and replace them with “government policies, regulations, and support”.

- Rename the feature “(relationships with) external industries” and replace it with “(relationships with) industries”.

4.1.2.5 Usefulness and form of the mapping tool

The workshop participants, in addition, had comments on whether the mapping tool is useful for characterising, providing information about, and comparing supply chains of the same or different agricultural products. A federal government representative, for example, commented:

> I was thinking about the form and how this is going to be used and be useful asking this question above. If the input price is increasing, somebody wants to know which supply chain is a more efficient business and they'll start using this supply chain mapping. That sort of nimble in sensitivity.

During the workshop, the experts also provided suggestions on the form of the mapping tool. They believed that multiple layers of the mapping tool would help users to add more details about a particular feature when entering data/information related to the feature. A researcher, for instance, gave examples related to features in the Product component:

> Possibly, you do something I like are hierarchy characterisation. So you have one layer which is the basic characteristics, like the markets distance freighting speed like water, air or surface. And then you have another layer on which can combine a few of those characteristics putting together as some of the layer 1, but people just enter the bottom one, but when the summarize, another layer looks on easy […].
>
> Basically, just a typing the more complicated upper level 1 for the, you are have a specific formulation determining by Factor may be c and d and that can give us simplified. Let's simplify the value of [inaudible] you that for label, like conditional access to the market or not. If that's yes. And then calculate market distance and then they calculate finding out into the market time.

In line with the discussion on layers in the form of mapping tool, a state government representative said:

> I like the idea of adding a transport layer in there, as well. Because you market is somewhere it's better to send there by air than by along the road. whereas, if you require what the actual transport types is that will come.

We appreciate the experts' feedback and have decided that these suggestions would be brought into consideration when we designed a digital mapping tool for building a database of agricultural supply chains in our future research.

4.1.3 Framework and mapping tool refinement

On the basis of the feedback received from the experts in their survey responses and workshop discussion, we have modified and refined the framework and mapping tool with thoughtful consideration. An amendment matrix which provides an overview of the modifications and changes in the framework and/or mapping tool is presented in Table 18.

The refined versions of the framework and mapping tool are presented in figure 8 and Table 19, which are labelled as "Agricultural supply chain baseline framework (REFINED version)" and "Mapping tool for agricultural supply chain characterisation (REFINED version)".

In the next section, we present some secondary data about several agricultural products and their supply chains in the region, referring to the four main components of the framework and mapping tool, namely product, infrastructure, process, and factors (where possible). This provides readers with an overview about major agricultural commodities in the region and some characteristics of the supply chain for each of the commodities.

Table 17: Amendment matrix for the framework and mapping tool

Item (in the draft version)	Position (in the drafted version)	Change						Item (in the refined version)	Position (in the refined version)	Change applied to the framework (figure 8)	Change applied to the mapping tool (Table 19)
		Moving	Naming	Explaining	Combining	Adding	Removing				
perishability	Product Characteristics category		√	√				perishability and shelf life	Product Characteristics category	√	√
product life cycle	Product Supply category	√		√				product life cycle	Product Characteristics category	√	√
product variety	Product Supply category	√						product variety	Product Characteristics category	√	√
product innovativeness	Product Supply category	√						product innovativeness	Product Characteristics category	√	√
supply uncertainty	Product Supply category		√	√				supply volume and uncertainty	Product Supply category	√	√
consumer segmentation	Product Demand category			√				consumer segmentation	Product Demand category		√
market type	Product Demand category				√			market type and distance	Product Demand category	√	√
market distance	Product Demand category				√			market type and distance	Product Demand category	√	√
demand uncertainty	Product Demand category						√	NA	NA	√	√
transport	Infrastructure category			√				transport	Infrastructure category		√
NA	Infrastructure category					√		facilities	Infrastructure category	√	√
single-handed production	Process category				√			single-handed production and business	Process category	√	√

single-handed business	Process category				√			single-handed production and business	Process category	√	√
communication	Process category				√			communication and information sharing	Process category	√	√
information sharing	Process category				√			communication and information sharing	Process category	√	√
power distribution	Process category			√				power distribution	Process category		√
contracting	Process category						√	NA	NA	√	√
government policies and regulations	Factors category				√			government policies, regulations and support	Factors category	√	√
government support	Factors category				√			government policies, regulations and support	Factors category	√	√
relationships with) external industries	Factors category		√					“(relationships with) industries	Factors category	√	√

Figure 8: Agricultural supply chain baseline framework (REFINED version)

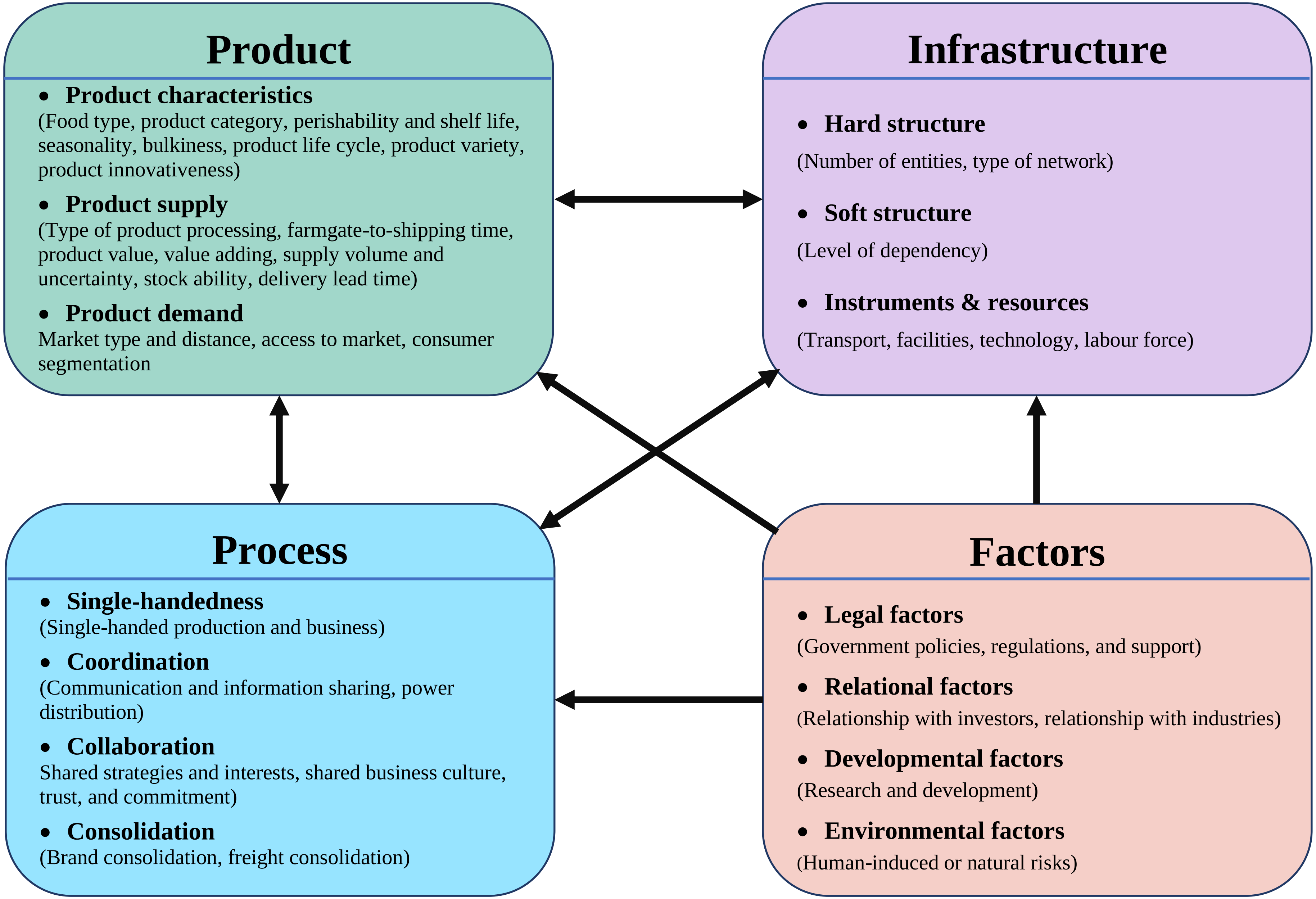


Table 18: Mapping tool for agricultural supply chain characterisation (REFINED version)

Supply chain name and location:

………

Date: ……………………………………………………………………………………………………

		Feature	Explanation	Data entry and sources of data
Product	Product characteristics	**Food type**	Type of food the supply chain provides (horticulture, grain, animal protein, dairy, aquaculture product, *non-food* agriculture product…)	
		Product category	Product category on which the supply chain is based (processed, lightly processed, fresh…)	
		Perishability and shelf life	Level of perishability the product has (low/high perishable…), and the length of time the product can be kept before it is too old to be sold (number of hours, days, or weeks…)	
		Seasonality	Availability of the product in certain seasons (spring, summer, autumn, winter, rainy, dry season…)	
		Bulkiness	Level of bulkiness the product has (bulky, non-bulky…)	
		Product life cycle	Complete lifespan of a product, from raw materials until final disposal (seasonal, year-round, short, average or long-life cycle…)	
		Product variety	Number of different product forms which a supply chain offers to consumers (one, two, three…) [please specify].	
		Product innovativeness	Application of a new attribute in a product to make it more attractive to consumers (new preservation technology, new package...)	
	Product supply	**Type of product processing**	Specific features of the supply chain related to the handling and temperature control (chilled, cold, frozen, normal room temperature, handle, cattle handle, or mixed-processing types…)	
		Farmgate-to-shipping time	Average time needed for transporting the product, from farm-gate to processing centre and from processing centre to ship/aeroplane (number of days…)	
		Product value	Nutritional/economic value, and safety/environmental/ethics credence of the product (high/low nutritional/economic value, high/low economic value, high/low safety/environmental/ethics credence …)	
		Value adding	Value added to a product by processing it as desired by customers ($/unit…)	
		Supply volume and uncertainty	Supply uncertainty (high, low…) related to materials/product availability, product amount, or in-time delivery.	
		Stock ability	Capacity to stock the product (high, low, flexible…)	
		Delivery lead time	Duration between the time (individual and/or firm) customers place their order to the time they receive their product (number of hours, days, weeks, months…)	

	Product demand	**Market type and distance**	Type(s) of market and market segmentations the supply chain has access to (local, international, domestic, export, low/high-value market…) Spatial distance between producers and consumers of the product (number of kms from production location…)	
		Access to market	Supply chain's market accessibility (yes, no, high, low, which markets…)	
		Consumer segmentation	Consumer segmentations based on demographic, socio-economic, and psychographic characteristics which the supply chain targets (domestic, overseas, high-income, highly educated, female, young, preference…)	
Infrastructure	Hard structure	**Number of entities**	Number of individuals, firms, companies and other entities participating in the supply chain, including both upstream and downstream entities (three, four, five….) [please specify].	
		Type of networks	Way of organising the supply chain (vertical, horizontal, hybrid…) [please specify]	
	Soft structure	**Level of dependency**	Level of dependency between entities in the supply chain (high, low, mixed…)	
	Instruments & Resources	**Transport**	Types of transport needed (e.g., road, rail, air…); accessibility or availability of transport (yes, no, high, low…); and road conditions (good, bad, average, mixed…)	
		Facilities	Availability of processing facilities and storage facilities (yes, no, sufficient, insufficient…) [please specify].	
		Technology	Availability of or capacity to apply new farm/non-farm technologies in production, harvest, distribution and/or transportation (yes, no, high, low…)	
		Labour force	Supply chain's size of labour force (small, average, large, flexible…); seasonality of labour (production/harvest time, holiday time…); and employment structures (permanent labour, casual labour…)	

Process	Singlehandedness	**Single-handed production and business**	All production, transport, distribution, marketing and sale processes/activities undertaken by an independent entity, with no long-term collaboration with others (yes, no…) [please specify if yes].	
	Coordination	**Communication and information sharing**	Communication among entities in the supply chain (open, limited, flexible, effective, ineffective…); level of information sharing among entities in the supply chain (high, low, effective, ineffective…)	
		Power distribution	Way of sharing and managing power among entities in the supply chain (balanced, imbalanced…); who often control price in the market (producer, wholesaler, retailer…)	
	Collaboration	**Shared strategies and interests**	Business strategies and interests shared and approved by all entities in the supply chain (yes, no…) [please specify if yes].	
		Shared business culture	Values understood, approved, and voluntarily complied with by all members in the supply chain (yes, no…) [please specify if yes].	
		Trust and commitment	Level of trust and commitment among entities in the supply chain (high, low…)	
	Consolidation	**Brand consolidation**	Act of bringing smaller brands together under the umbrella of a “stronger” or bigger brand (yes, no…) [please specify if yes].	
		Freight consolidation	Combination of the transportation of multiple products to save costs (yes, no…) [please specify if yes].	

Factors	**Legal factors**	**Government policies, regulations and support**	Government policies and regulations that facilitate or constrain supply chain activities (yes, no…) [please specify if yes]; government support to some food products or supply chain activities (yes, no…) [please specify if yes].	
	Relational factors	**Relationship with investors**	Involvement of one or more than one investor in the supply chain (yes, no…) [please specify if yes].	
		Relationship with industries	Entities from other sectors which have influence on the supply chain activities (yes, no…) [please specify if yes].	
	Developmental factors	**Research and development**	Supply chain's internal research or collaborative research with technical service providers, engineering firms, universities or research institutions (yes, no…) [please specify if yes].	
	Environmental factors	**Natural or human-induced risks**	Weather conditions, disasters, diseases, or epidemics that influence the supply chain activities (yes, no…) [please specify if yes].	

4.2 Major products and supply chain analysis in Central Queensland

4.2.1 Beef

Product: Over the past two decades, global beef consumption has increased at an average of 1% per annum (MLA, 2021). Particularly, economic development in developing Asia creates demand for more meat. In the global market, beef is traded as beef and veal and live cattle, and Australia is a key exporter of these products. Beef and veal are perishable and need special requirements for storing and transporting (cold storage). As an important protein-rich food, beef can be available throughout the year. However, severe drought and biosecurity issues are the main threats to beef production in Australia.

ABS reports the number of herds in the agricultural production statistics. It is difficult to identify the volume of beef produced from these numbers. However, ABARES and MLA report the beef production in their data sets for national and state level. The annual beef production in QLD since 2000 is presented in the Figure 9 with a five-year forecast indicated as blue columns. In 2019-20, QLD produced about 1.15 million tonnes of beef. However, the production of beef declined in the following two year because of the rebuilding strategy for number of herds. Despite low production in 2021-22, it is forecasted the production is forecasted to increase in the coming years and will reach to 1.1 million tonnes by 2026-27.

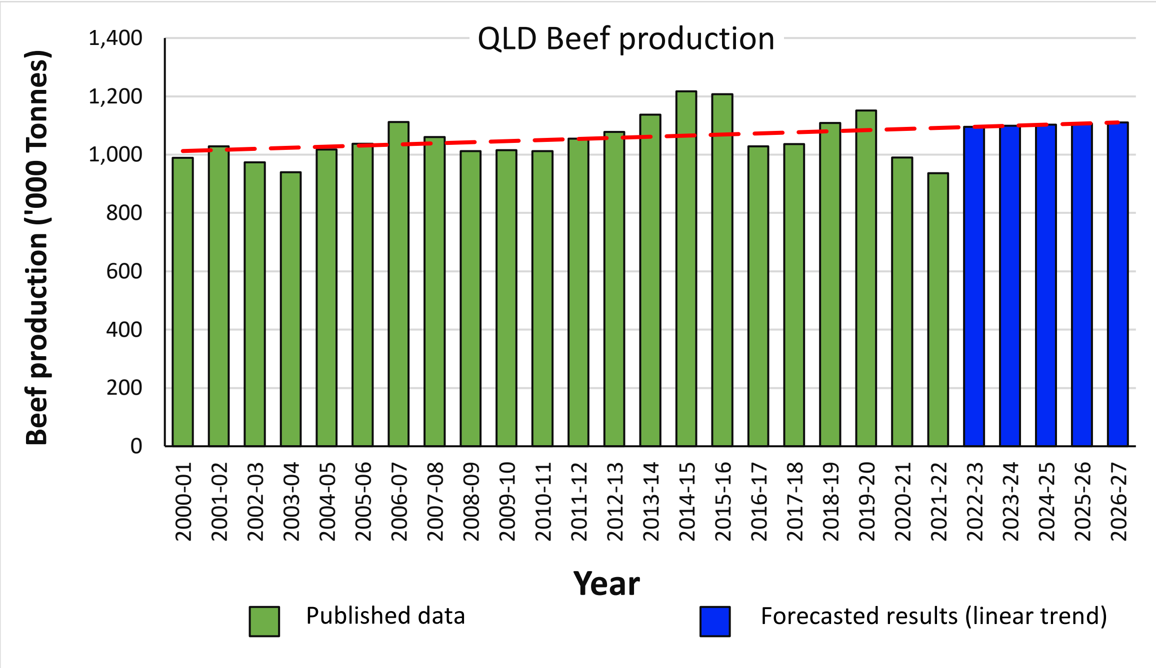


Figure 9: QLD beef production volume and forecasting

Beef is one of the most important agricultural products in Australia and particularly in the State of Queensland in terms of production and export value. The gross value of cattle and calf production is estimated at A$15.1 billion, and in 2018-19 produced approximately 2.4 million tonnes of carcass weight (cwt) (MLA, 2020). Of the total Australian production, 47% of beef is produced in the State of Queensland and particularly from the Central Queensland region – called the “Beef Capital of Australia” (17% of total Queensland production). Queensland has shown a slightly increased trend in volume of trade and export earnings (Figure 10), exporting about 575 thousand tonnes in 2020/21 and earning million A$4841.

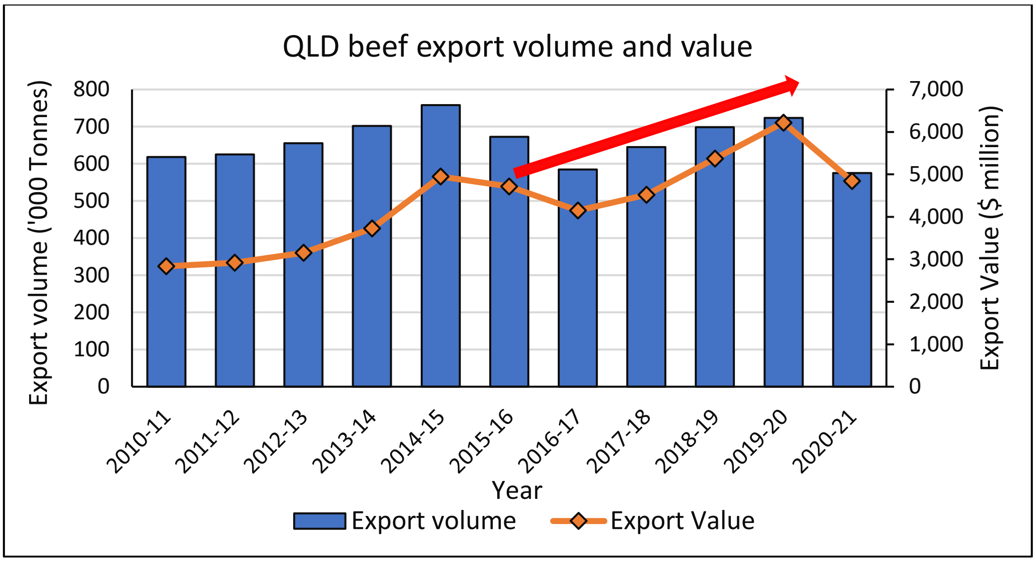


Figure 10: QLD beef export volume and value

Australian per capita beef consumption is higher than other OECD countries and was 23.4 kg in 2020. Nevertheless, of total beef production in Australia, 24% is consumed locally whereas 76% is exported to different countries. A large portion of the Australian beef and veal is exported to Japan, Republic of Korea and the USA whereas live cattle are to Indonesia and Vietnam. US is the major competitor for these export markets. Japan's beef consumption volume, in 2021, was about 1.4 million tonnes and about 35% of that demand was met by domestic products. Australia supplied about 28% of that demand in 2021. In 2020-21 Republic of Korea imported about 464,000 tonnes of beef which is 5% higher from the previous year. The demand trend for beef in the Republic of Korea is steadily increasing. In both these cases there are opportunities for future growth in export market share and QLD and in particular CQ has the capacity to fulfil extra demand for beef in these two markets. On top of that CQ and QLD has the additional advantages of location proximity. The demand for beef in the other export markets are predicted to increase in the future, expanding the opportunity for high-quality Australian beef. Figure 11 indicates the beef export volume from QLD to the top five export destinations.

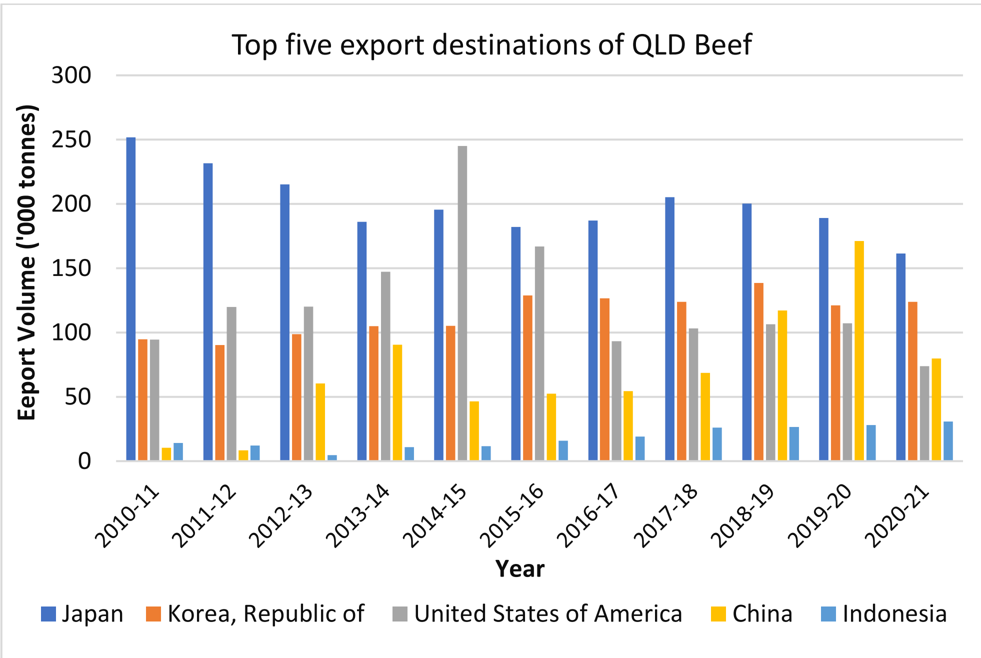


Figure 11: QLD beef export destinations

Infrastructure: Central Queensland region is predominantly an agricultural area, in which 27% of businesses in the region are related to agriculture, forestry, and fishing (Queensland Treasury, 2021). Natural capital and man-made infrastructures have played an important role in flourishing the agriculture sector. In most of the regions in Central Queensland, the population has been increasing (ABS, 2022) and most of the agricultural farms are family-owned and managed with family labour. For cattle farming, the traditional cattle management knowledge and experience that blend with new technologies, make the farming more labour efficient. The region also has enough grasslands to expand the industry. Most of the farms are medium to large-scale, achieving economies of scale. Farmers can sell cattle at auctions or use slaughterhouses to produce their own-branded meat. Since cattle farming does not require any specific time to process, farmers can keep cattle in paddocks till achieving a good farmgate price, and hence, the price of beef is quite constant.

Beef is a bulk product that needs considerable specialised storage facilities as well as an efficient transport network, especially for the export market. The Central Queensland region has some infrastructure facilities for the beef industry. There are three major beef processing facilities located in this Central Queensland region, two in Rockhampton and one in Biloela. The road network, as well as the railroad network, is well established to transport live cattle to processing centres and to the port. Gladstone port is close to the "Beef Capital of Australia". In the years 2020/2021 Brisbane port exported 0.59 million tonnes (0.75 million tonnes in 2019/2020) of beef to different destinations.

Process: Cattle farming can be divided into the cow/calf, backgrounding or stocker, and finishing stage (Farm Credit, n.d.). Farmers can select either one of the stages or a combination of a few or all stages depending on their land quality, other facilities, and management skills. Cattle farming is mostly a family business and in the production stage, the decision-making power depends on them. However, farmers need to collaborate with supplement feed suppliers, other farm machinery/ equipment suppliers, veterinary surgeons, breeders, and transporters. Farmers often hold a considerable bargaining power as the product is not perishable till they are slaughtered. Once the cattle are ready to be sold, farmers need to find transporters and as the Central Queensland region is specialised in cattle farming, facilities are available on different scales for cattle transportation. Processing centres and packages are prepared for all quality maintenance thereafter.

Factors: Meat & Livestock Australia (MLA), ABARES, and Department of Agriculture and Fisheries (DAF) in Queensland provides necessary technical support to cattle farmers and related industries. The State government, as well as the Federal government, have invested in research and development work for breeding, developing technologies, and controlling biosecurity threatens, to the beef industry. Universities (i.e. Central Queensland University) are involved in researching different aspects of cattle farming and supply chain management. Several certifications for Australian beef are available for the producers which help them to send their product to specific markets.

Despite all strengths and opportunities, there are threats in the industry. Natural disasters and global climate change are negatively influencing cattle farming. Basically, cattle farming occurs with grass feeding and grain feeding, but the quality maintenance of grass-feeding is challenging without feeding supplements in long drought periods. Nearly half of the emissions from the Australian agriculture sector come from cattle farming. The beef industry has a close relationship with the grain industry, the latter to supply fodder.

4.2.2 Wheat

Product: Australia is a leading country that produces and exports clean, dry, and food-safe wheat. Australia produces only 3% of the world's production (33 million tonnes in 2020, ABARES, 2022) but occupies 10% of the global wheat export market. About 65%-75% of wheat production is exported annually and the rest is for domestic consumption. Wheat quality management, such as low moisture content, cleanliness, and flour yield, along the supply chain of wheat, is important to meet the demands of end-users. Wheat is mainly produced in Western Australia and South Australia, but the production in Australia has highly fluctuated. Wheat is an annual crop, with one season per year in southern and western Australia as a summer crop. Most of the leading producers finish their harvest by October of the year whereas the Australian harvest starts in October and runs till March (spring and summer) of the next year (Figure 12), and this is an advantage in the global market. However, the end product of wheat is not perishable and can be stored to assist market stability. Bread, noodles, and other sweet products produced using wheat and wheat-based foods are staples for many nations. Wheat in CQ is a winter crop, shown in March and harvested in September to November.

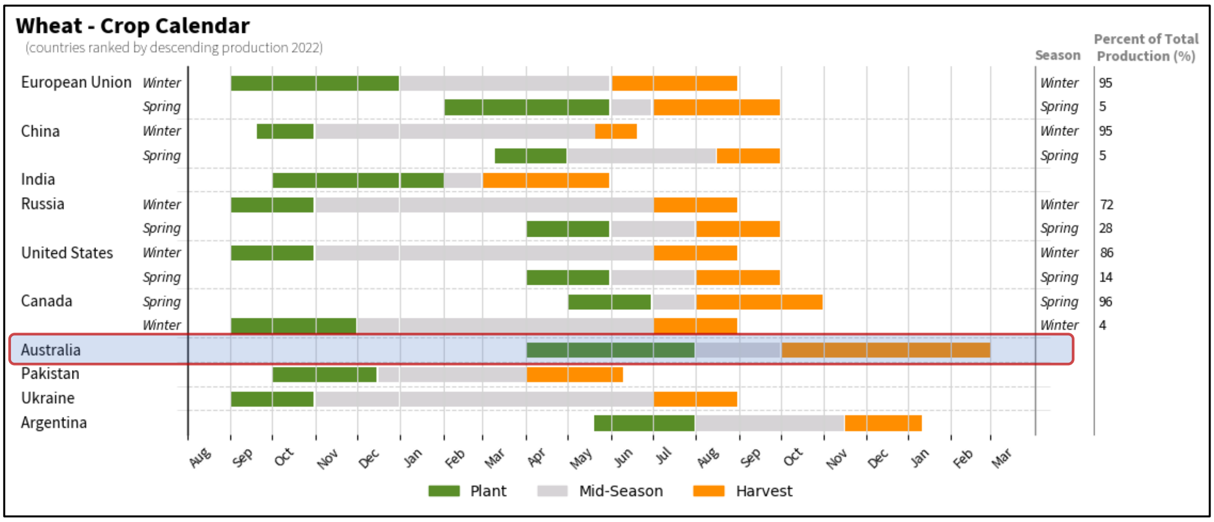


Figure 12: Seasonality of wheat production

Source: https://ipad.fas.usda.gov/cropexplorer/Default.aspx

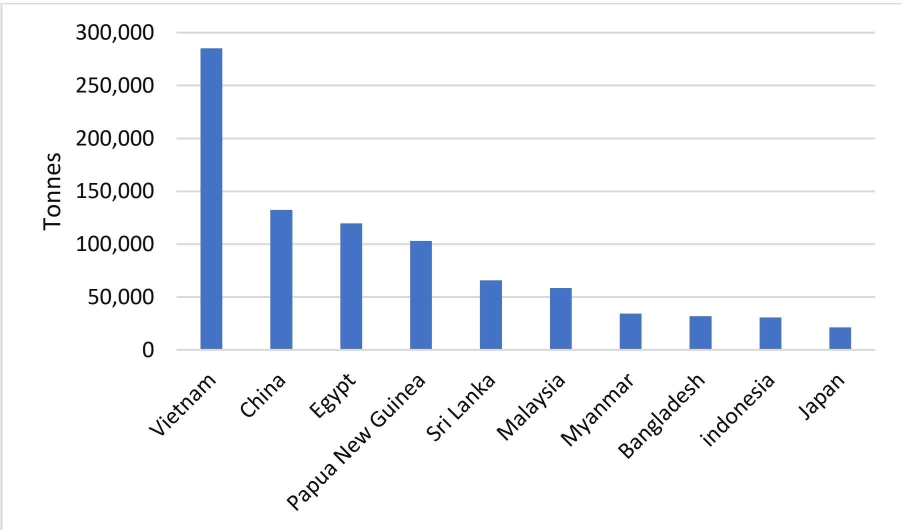
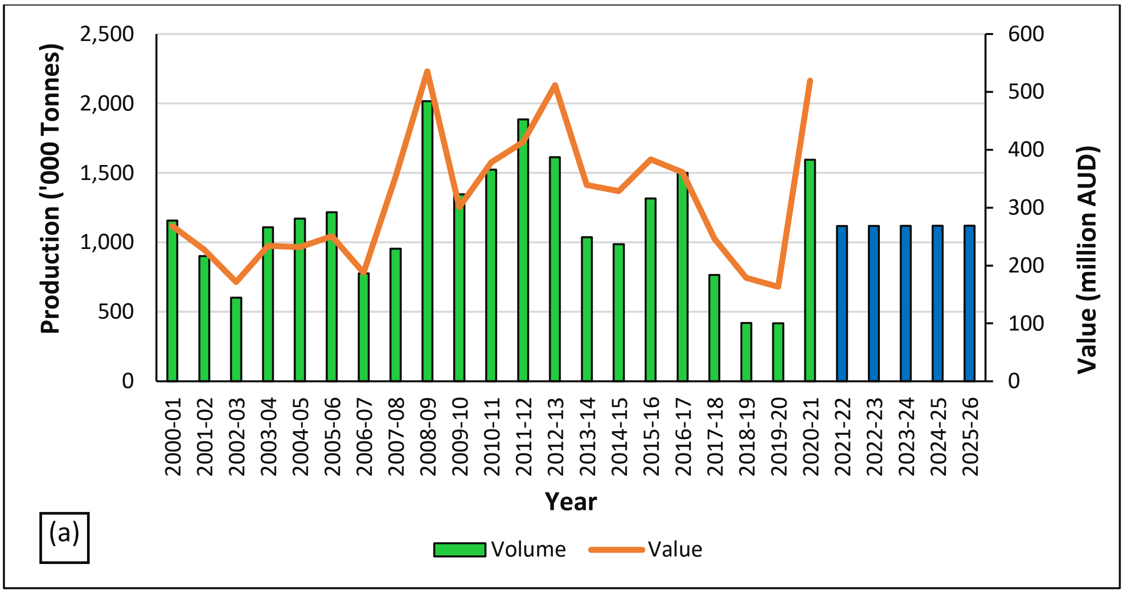


Figure 13: Major wheat export destinations from QLD in year 2020-21

Queensland exports wheat to mainly Vietnam, China, Egypt, and Papua New Guinea (see Figure 13). The projected population and per-capita income increases in those countries may indicates more demand for food, and there is a potential for market access. The demand for wheat and other grains has been predicted to increase by 2030, particularly in the Asian region due to increase in economic growth and population growth (AEGIC, n.d.). In 2021 Australia exported about 1.3 billion worth wheats to Indonesia where the share for QLD is very small (about 10 million). This is a potential market where QLD as well as CQ could send their products. Queensland wheat production fluctuates considerably (Figure 14 (a)) and 418,500 tonnes were produced in 2019/20. However, the QLD wheat production bounced back in 2020/21 and reached to 1.59 million tonnes. The trend of recent years production indicates that wheat production will reach 1.2 million tonnes by 2026/27. This prediction is heavily affected due to the sharp production fall in year 2018 to 2020. A similar trend in wheat production in CQ can be observed in Figure 14 (b). Despite the low production in the recent years, it is predicted that the CQ wheat production volume will reach to 200,000 tonnes by the year 2026/27. In figure 14 (a) and (b), the blue columns represent the forecasted wheat production in QLD and CQ. The research team employed a trend analysis to forecast the production.



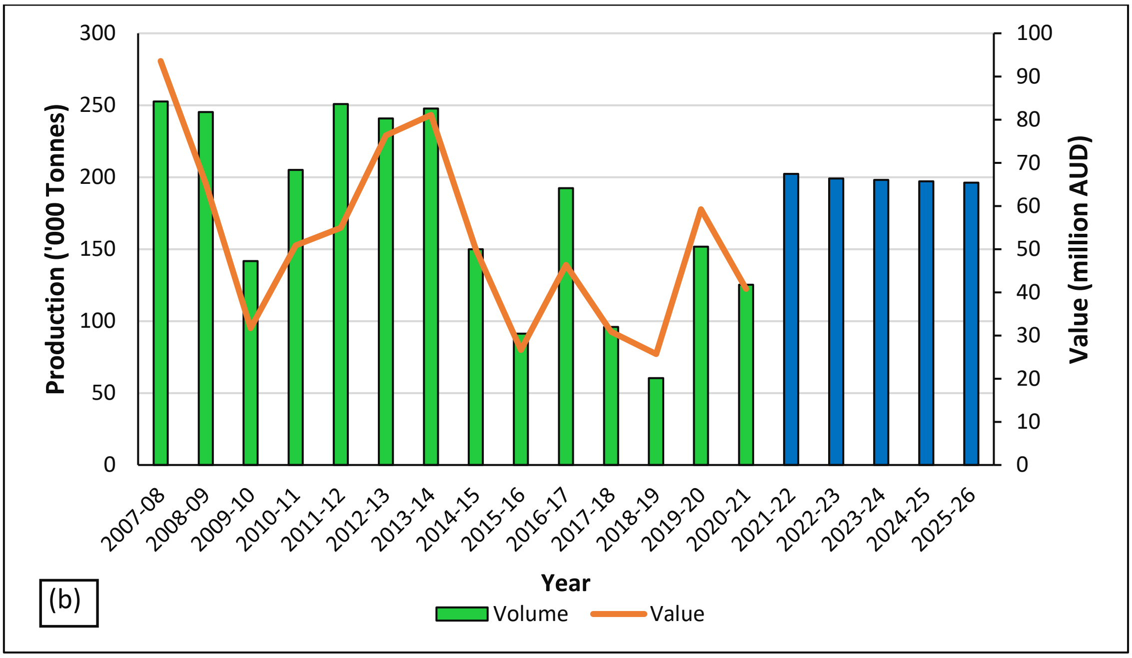


Figure 14: Wheat production and value in (a) Queensland and (b) Central Queensland region

Queensland holds about 5% share of the total Australian wheat exports and there is huge opportunity of growth in this sector. Of the Queensland wheat production, around 36% (2019-2020) produce come from the Central Queensland region. The central Queensland's estimated wheat production volume in 2020/21 is 125,218 tonnes (A$ 40.80 million). However, during the consultation with the local producers it is revealed that most of the CQ produced wheat goes to the local feedlots. Streamlining the export supply chain and better price would lead the local producers to export their products. In 2020/21, Gladstone and Mackay's ports, which are close to CQ region, have handled 22,078 and 14,000 tonnes (A$ 7.21 and A$ 5.08 million) respectively (Queensland Government (2022b).

Infrastructure: The diversity of landscapes in the Central Queensland region provides suitable soil conditions in some areas to grow wheat. Fitzroy river basin and other water sources are available to irrigate the crop. Typically, bulk handlers have sufficient storage facilities to handle grains, and farmers also have their own in-farm storage facilities. Moreover, major ports have storage facilities to handle grain production in Queensland. As a predominantly agricultural area in the

Central Queensland region, there are well-established and qualified transportation companies which can assist in maintaining supply chain activities.

Wheat is also considered a non-perishable bulky product that has quite a long self-life. In order to properly store the harvest, storage technologies have been developed (GRDC, 2012). Other than ground transport facilities, the proximity to an international seaport is also important to access the export market. Port of Gladstone is Queensland's largest multi-commodity port. The road network and railroad network are well established in several parts of Central Queensland; that is important for expanding export facilities.

Process: The wheat supply chain comprises growers, mills and feed operators, pre-production business (fertilizer, agronomic services), bulk handlers, and trading companies. Most wheat farms are owner-occupied in Australia, and the business decisions are made by the owners. GrainCorp is a key player in the wheat and grain supply chain with their processing, storing handling and marketing capabilities. Producers can market their products through the GrainCorp or through other channels. Gladstone port in CQ region has the grain loading facilities and some of CQ produced wheats are exported through the Gladstone port. The other wheat exporting ports near to CQ are Brisbane and Mackay. GrainCorp has their operation at Gladstone port and GrainCorp has coordination with the producers. Generally, wheat producers have the grading facilities and send the lower graded wheat to the feedlots.

Factors: GRDC, DAF, ABARE, and universities are involved in research to improve the efficiency of wheat production. Central Queensland University within the Central Queensland region has the capacity to research many aspects of wheat production. The Queensland government has invested in expanding the rail network which may help improve the transportation facilities. Particularly, from Biloela to Gladstone, the railroad will be developed to facilitate connecting port facilities. However, unpredictable weather events, such as cyclones and drought, are major constraint to consistent production within the region.

4.2.3 Chickpeas

Product: Chickpea is an important crop in New South Wales and Queensland and Queensland produces nearly half of the Australian chickpeas. There are two types of chickpeas: Desi and Kabuli. Chickpea is an annual crop and in Australia, the harvest is generally from October to December (Figure 15). Chickpea is a bulky product that requires suitable storage and transportation facilities. Since chickpeas are not perishable, they can be stored to stabilise the market prices.

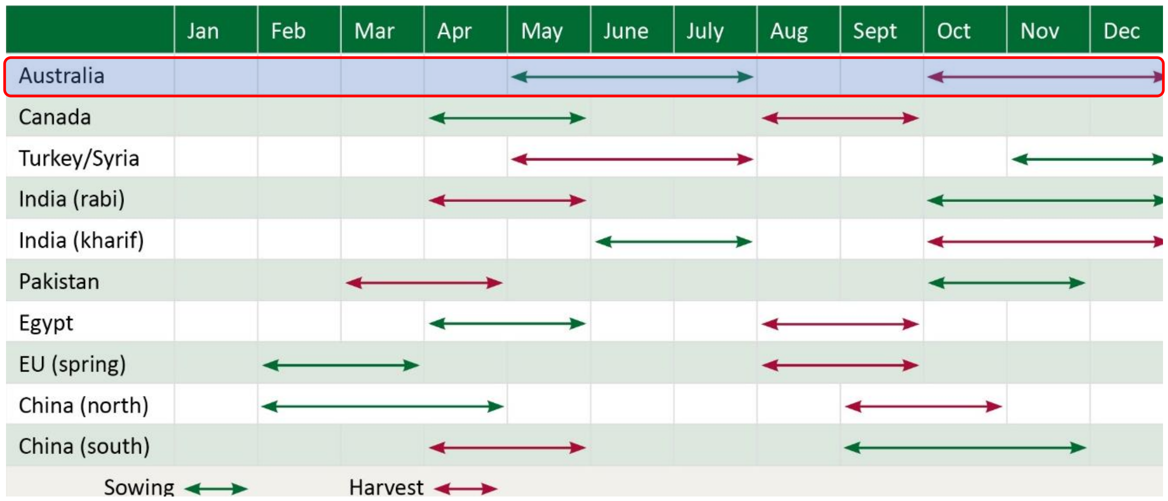


Figure 15: Global chickpeas production calendar

Source: https://www.pulseaus.com.au/growing-pulses/bmp/chickpea/northern-guide

In 2021 QLD produced about 250,000 tonnes of chickpeas which is a sharp decline from the 1.15 million tonnes production in 2017 (Figure 16). This decline is because of trade restriction applied by the largest export market India. However, the trend indicates that the QLD chickpeas production will reach about 325 thousand tonnes by 2025/26. The chickpea production data for CQ were not published for every year by ABS. In 2020/21, CQ produced about 44,272 tonnes of chickpeas which is about 17.6% QLD production and worth about 26.7 million AUD. It is expected that in the coming years CQ chickpeas production will follow the similar increasing trend as for QLD.

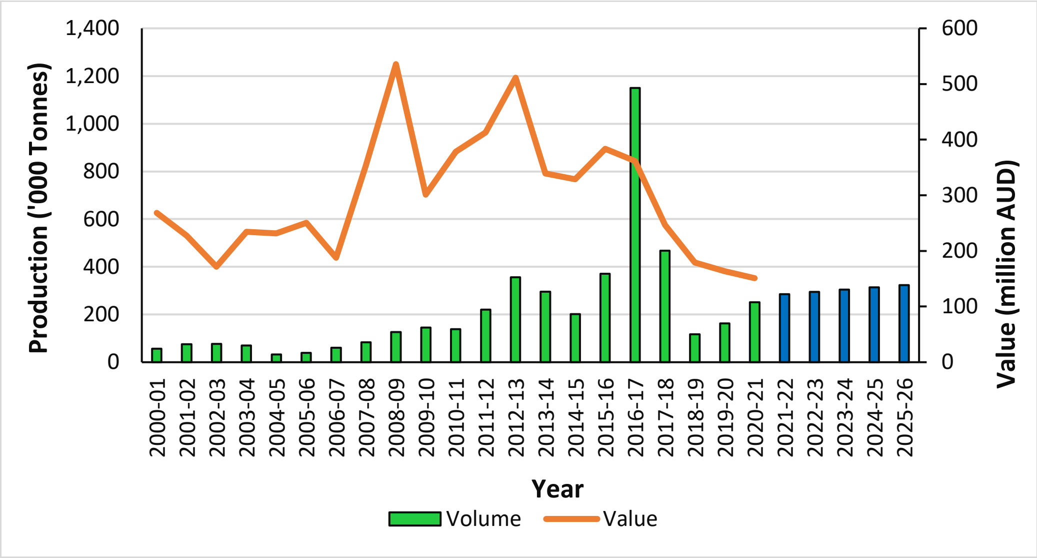


Figure 16: Chickpea production and value in Queensland region with forecasted production up to 2025/26

About 80% of QLD production is exported mainly to Bangladesh, Pakistan, UAE, Nepal, UK, and Canada (Figure 17). In past Australia exported large volumes of chickpeas to India, this is now reduced because of trade barriers imposed by Indian Government. However, the Chickpeas export market in Bangladesh and Pakistan showed promise in recent years with 54% and 70% growth in last three years (2018-2021) respectively. In 2021 Australia exported about 360 million USD worth of chickpeas only to these two countries. Because of increasing demand, there is potential for Australian chickpeas to supply middle east countries including UAE and Saudi Arabia.

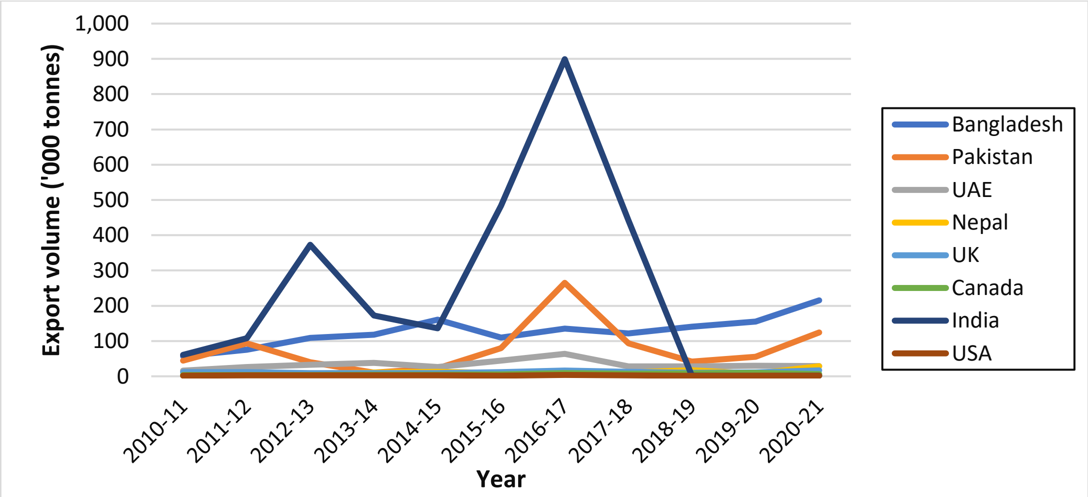


Figure 17: Chickpeas exports from QLD

The data collected through the stakeholder interviews indicates that the local chickpea producers in CQ are not interested with the chickpeas export because of relatively low price in export markets. However current political conflict in Russia and Ukraine may lead to a price hike for this commodity.

Infrastructure: Natural, as well as physical infrastructure in the Central Queensland region, is suitable to further expand the chickpea production. There are suitable lands, particularly Biloela, available with irrigation options for production. The existing road networks can facilitate transporting the product to storage locations and to reach to the seaport, Gladstone.

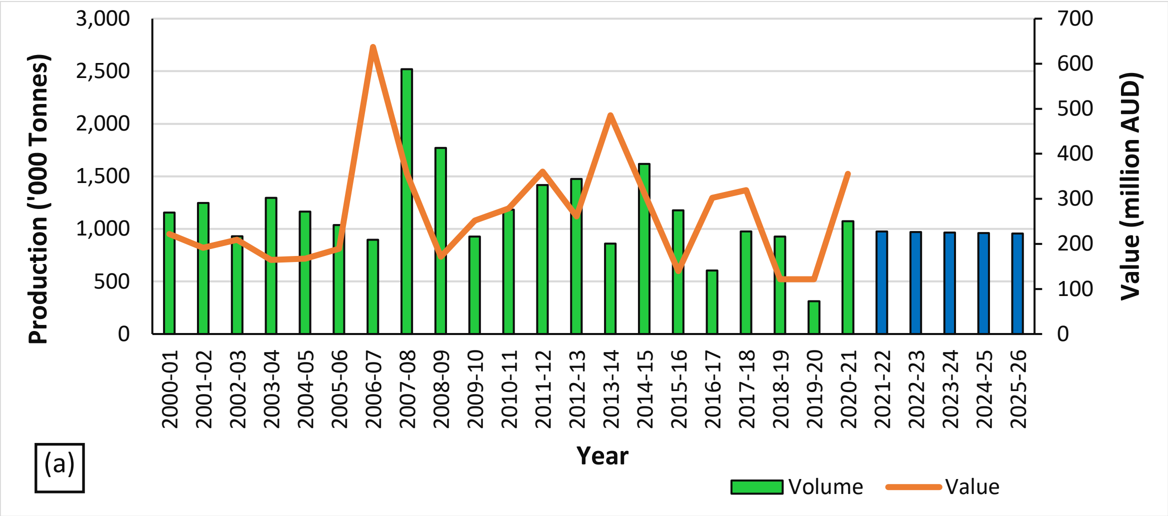
Process: The irregular shape of chickpeas makes them very prone to mechanical damage during handling. The coat of chickpeas can also crack due to the change in air moisture. In the extreme case, the level of cracked and damaged grain can be up to 50%. The standard export threshold is 6% defective chickpeas. However, Desi chickpeas are ultimately processed into dahl by removing the seed coat. After grading, the chickpea can be de-husked by a machine that can shell & separate chickpeas automatically. Chickpea shells can be further processed for animal feed.

Chickpeas can be handled several times before delivery to receiving points, and it is important to use an efficient handling technique to minimise damage. Chickpeas might need to be stored for medium to long-term storage (6–12 months), and quality can deteriorate. Insects are not considered a major problem in stored chickpeas; however, the storage container needs to be checked for any infestation before storage. Pulse Australia is the leading industry body that oversees chickpeas and mung bean and provides support to the producers. There is a strong coordination among the producers and Pulse Australia to make the product ready for the export market. Most of the businesses for this commodity are operated singlehandedly.

Factors: Chickpea production, as well as prices, are expected to be increased, and this can be seen as an advantage to attract investment in the Central Queensland region. The increasing demand in India and other South Asian countries can be tapped by expanding chickpea production in the region. Moreover, the Gladstone port’s trade in multiple goods with many Asian destinations can contribute to assuring the transport network. GRDC, DAF and New South Wales Department of Primary industries are involved in chickpeas breeding programs to develop promising high-yielding varieties. In the Central Queensland region, Central Queensland University can help in researching different aspects of the supply chain, breeding, and developing agronomic practices to flourish the crop. The Queensland government has also invested in fulfilling the knowledge gap and expanding storage facilities for pulses.

4.2.4 Sorghum

Product: Globally, Australia is a small producer and accounts for only 2-3% of the world’s sorghum production. In the export market, however, Australia’s sorghum commands around 12-14%, which can be seen as a large portion of the world’s export production (GRDC, 2012). Close competitors in the world market are Argentina and USA. Sorghum can be cultivated in dry conditions and 99% of production comes from New South Wales and Queensland. Sorghum is the most important cereal crop in Queensland. This is mainly due to the development of new agronomic practices and breeding programmes implemented by GRDC and universities. However, the production highly fluctuates (Figure 18 (a), (b)) due to weather conditions. Despite the production fluctuations, in recent years, close to 14% of Queensland production comes from the Central Queensland region. In 2019/20 the sorghum production in QLD dropped down to 300,000 tonnes buy picked up next year and reached 1.07 million tonnes. The same trends were visible in the CQ sorghum production and in 2020/21 CQ produced about 156,000 tonnes of sorghum which was worth about 51.7 million AUD. Despite fluctuations, it is forecasted that the annual production in next five years in QLD will be closed to 1 million tonnes while that for CQ will be about 100,000 tonnes.



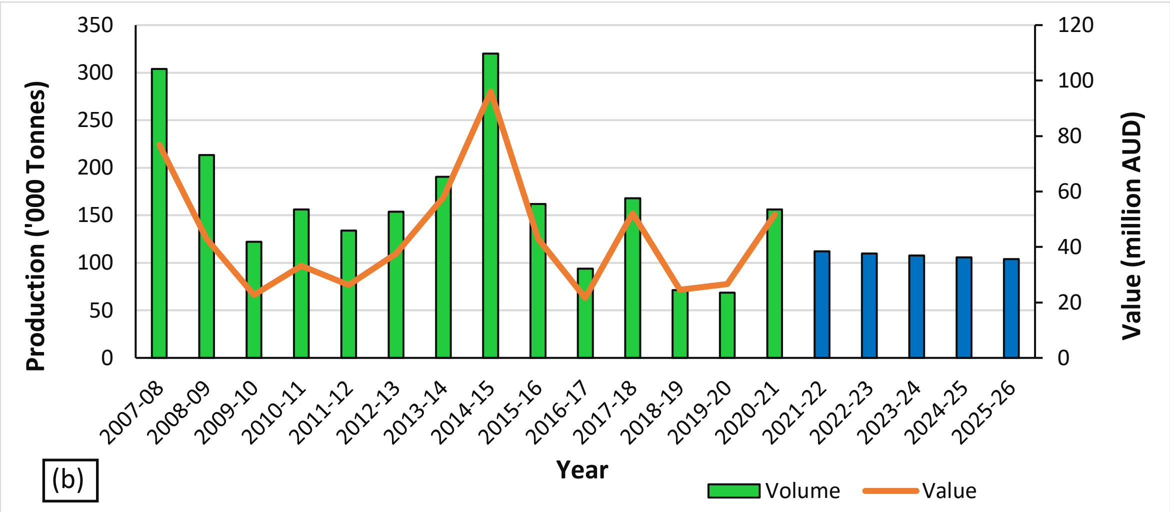


Figure 18: (a) Queensland and (b) Central Queensland sorghum production and value with five-year forecast (in blue columns)

Sorghum seeds are dry and non-perishable agricultural products which are used for human consumption, animal feed and ethanol. Sorghum in Australia are harvested from March to June (Figure 19), and farmgate prices, which decides the farm income, are highly variable (GRDC, 2012).

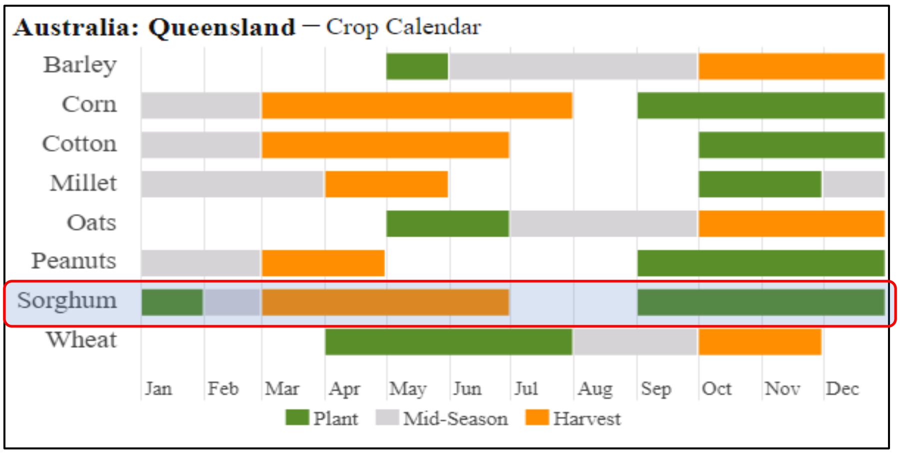


Figure 19: Crop calendar, Australia

Source: https://ipad.fas.usda.gov/rssiws/al/crop_calendar/as.aspx

Most of the sorghum is exported to China, Japan and Taiwan. In 2021, QLD exported 475,000 tonnes of sorghum in the form of bulk, bagged or for seed purpose and this volume is about 67% of Australia's sorghum export. In the same year QLD exported about 381,000 tonnes of sorghum to China, about 80% of QLD total sorghum export. It is projected that in 2021-22 QLD will export about 1.2 million tonnes of sorghum to China. CQ has a huge opportunity for growth in the export market with about 14% of QLD's sorghum production in this region. Australian sorghum export to China is observed to have grown by about 155% in the last three years. In 2020 China imported about 4.85 million tonnes of sorghum among which Australia only supplied about 11%. Two other major suppliers of sorghum to China are USA and Argentina. Overall demand for sorghum in China is increasing after lows in 2018 and 2019 as presented in Figure 20. Given the location proximity QLD and CQ have the opportunity to increase the export market share in China for sorghum.

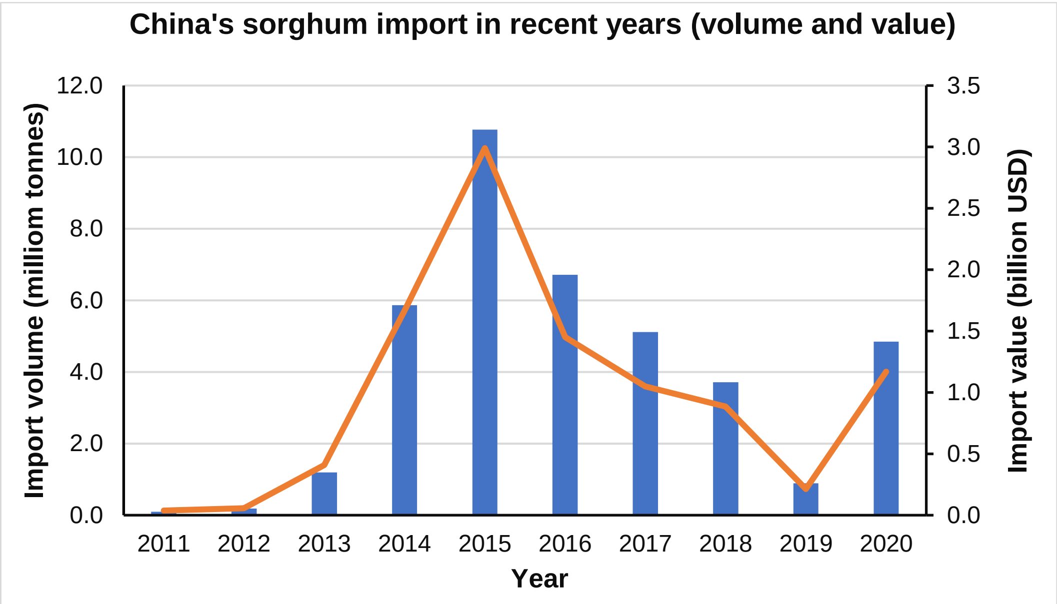


Figure 20: China's sorghum import

Infrastructure: Gladstone port is currently trading with many ports in the South Asian region, and this is an advantage in the export supply chain of sorghum. Basically, sorghum transport (ground transport) often uses trucks, as the established road network is a good transportation advantage.

Process: Similar to the wheat, the sorghum supply chain comprises pre-production business (fertilizer, agronomic services), growers, mills and feed operators, bulk handlers, and merchants or exporters. GrainCorp is one of the industry peak bodies and provides different support to the producers. Producers are handling their business singlehandedly and they have the option to sell their product to different market. The export market is heavily regulated, and producers need to go through export agent or GrainCorp to reach export markets. Grains can be stored on the farm or in private silos. In central highland an inland port is developed to agglomerate the grain production in this region and to distribute in different markets.

Factors: Sorghum is a good alternative to incorporate into the farming system in the Central Queensland region. It needs little technical know-how and farmers in the region already have the skills. Heat stress is identified as one of the limiting factors to expanding sorghum cultivation in Central Queensland and agronomic practices have been tested and introduced to overcome the problems.

4.2.5 Cotton

Product: Cotton is grown in more than 70 countries in the world leading in China, the USA, India, Pakistan, and Brazil. Australia is not a major cotton grower in the world, but Australia is among the top ten exporters in the world. Cotton is a summer crop that needs irrigation facilities. In Australia cotton is grown mainly in northern New South Wales and the Southern Queensland regions. However, Emerald, Theodore, and Biloela in Central Queensland produce substantial quantities of cotton (Keogh et al., 2010). In 2019/20 the QLD Cotton production dropped down to the lowest point in the last 20 years. In that year, QLD only produced about 30,000 tonnes of cotton among which about 65% was produced in CQ (see figure 21(a), (b)). During the ground truthing stage we checked these data and found that the low production was due to the severe drought in the southern QLD regions and CQ actually produced about 50% of QLD cotton. In 2020/21, cotton production increased, and QLD produced over 200,000 tonnes of cotton while CQ produced about 27,000 tonnes of cotton. Future trends in cotton production indicate that in the next five years QLD cotton production will increase up to 250,000 tonnes while CQ will reach 50,000 tonnes. Queensland cotton harvest is generally from March to July (Figure 22), and it is a bulky product with low bulk density.

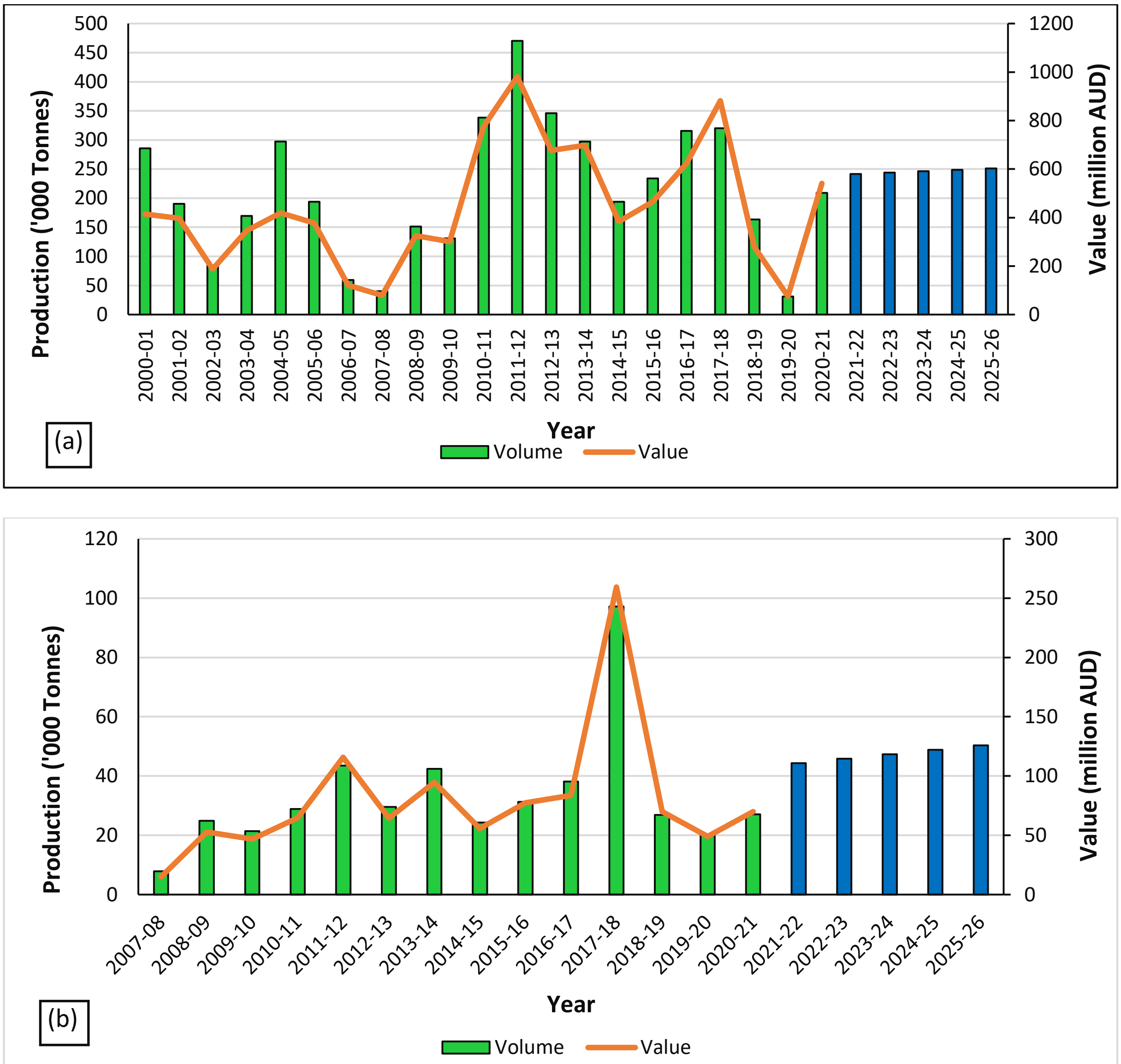


Figure 21: (a) Queensland and (b) Central Queensland cotton production with five-year forecast (in blue columns)

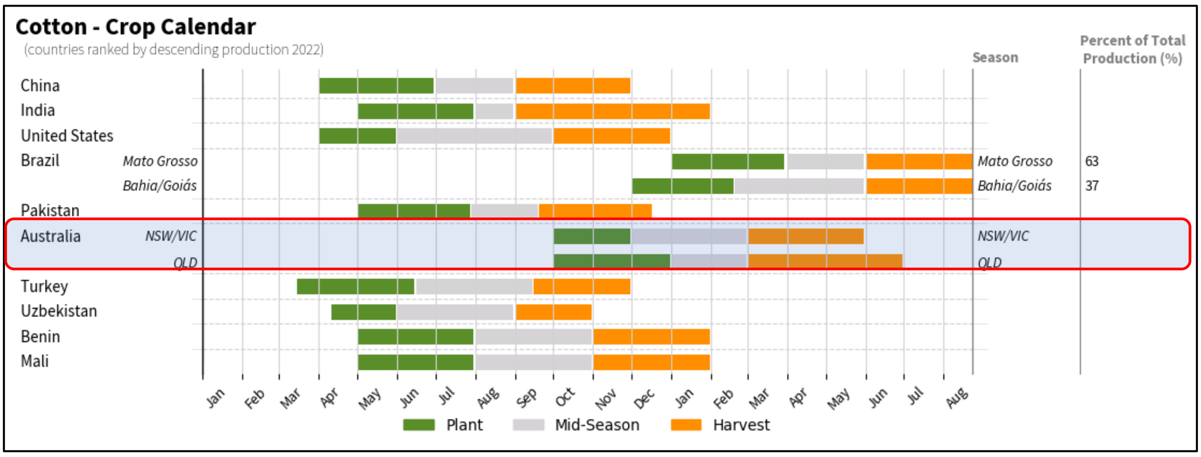


Figure 22: Global cotton production calendar

Source: https://ipad.fas.usda.gov/cropexplorer/Default.aspx

More than 95% of Australian-grown cotton is exported as cotton lint (after ginned), to many of the Asian countries. Top three destinations of QLD cotton are Vietnam, China and Bangladesh. These three countries have exhibited steady growth in cotton imports in the last few years (Figure 23). QLD supplied less than 2% of this huge demand for cotton in these three countries. The other major cotton exporting countries are USA, Brazil and India.

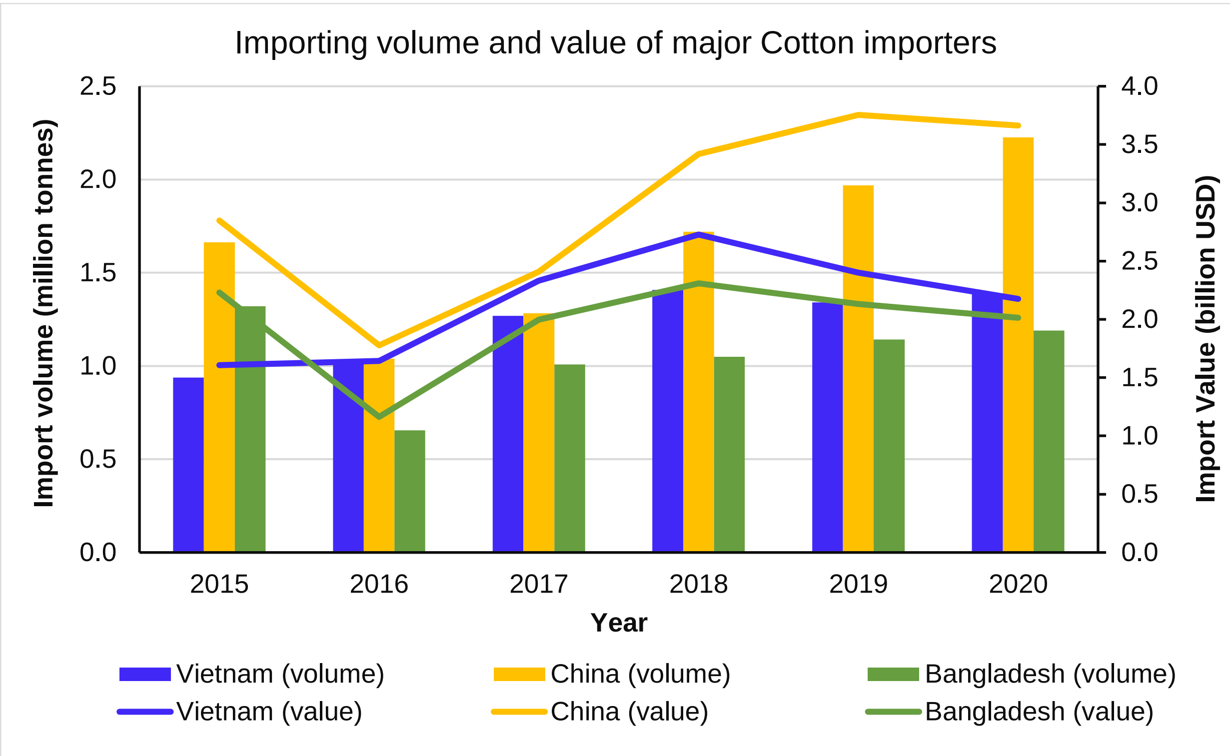


Figure 23: Statistics on major cotton importers

Infrastructure: In the Central Queensland region, cotton is mainly grown in Biloela, Theodore and Emerald and the technology is well known. Although it is not a heavy product, it needs a substantial space (low bulk density) for storage and transportation. This region has three cotton gins, two in Emerald and one in Biloela. However, Australia don't have weaving mill and most of the cotton goes to the export market. There is a potential to develop the fibre market by establishing weaving mills in QLD. The main cultivation area, Biloela, is close to the Gladstone port, and the projected railway line from Biloela to Gladstone can be seen a good advantage to further expand the cultivation.

Process: Most of the cotton produced in CQ goes to the export market in the form of bales. Cotton gins process the raw cotton and send it to the export market. Producers can also export their products through export agents after ginning. The producer's business structure is mostly single handedness. However, the producers need to coordinate with a Cotton gin for processing. The transportation from farm to gin is relatively simple as the production is concentrated near the existing gins. Cotton Australia is the leading industry body and Cotton grower associations in different regions work under the Cotton Australia umbrella. The growers and industry are closely linked; however, no contractual collaboration exists among the cotton growers.

Factors: Cotton cultivation was criticized due to its high-water demand, but Australia has achieved the highest efficiency in terms of water use in the world, and the crop can be continued with existing water availability. Continuous research on improving water efficiency is an advantage to continue the cultivation in the Central Queensland region.

4.2.6 Niche and other commodities

Vegetables & herbs: Australian total fresh vegetable exports in 2020/21 were A$264. As one of the main producing states, Queensland produced vegetables on 33,751 ha of land in 2018/19 (ABS, 2022.), and most of them are for domestic consumption. However, a substantial quantity of those perishable vegetables and herbs are exported to South-East Asian countries (Hort Innovation, 2023(a)). The Central Queensland region also produced several types of vegetables and herbs cultivating over 241 ha in 2018/19 and involving 17 businesses (ABS, 2022). The majority of Central Queensland production is destined for domestic consumption; however, some farmers have processed their products to export to different countries. In the winter season, the tropical and subtropical regions have the advantage to continue vegetable production and supply both domestic and export market channels.

Mandarin: Orange and mandarin are important horticultural crops that earn foreign exchange. In 2020/21 the value of total orange and mandarin exports were A$285.1 million and A$143.8 million, respectively (Hort Innovation, 2023(b)). Around 60% of Australian mandarin are produced in Queensland, and nearly 8.6% are from the Central Queensland region. Queensland has exported a A$89.62 million worth of mandarins in 2021. However, in recent reports from CHDC indicates that the values of mandarins produced in central highland is around 125 million AUD in 2019-20 and around 61 million AUD in 2020-21. During the field visit the research team identified that the CQ mandarin production data in ABS is heavily suppressed due to business confidentiality. Given the high value of these commodities the research team has prepared the supply chain mapping tool in consultation with local mandarin producers. The mapping tool is included in the next section. The three main varieties of mandarin that are grown in the region are Imperial, Murcott, and Afourer. Australia exports mandarin mainly to Asian countries, including China, Thailand, Japan, Philippines.

Mangoes: In 2020/21 Australia produced 51,528 tonnes and exported A$25 million of mangoes (Hort innovation, 2023(b)). Mangoes in Australia are commercially cultivated in tropical and subtropical regions – mainly in Queensland and Northern Territory. Australia exports mangoes to New Zealand, Singapore, Hong Kong, UAE, South Korea, and China (Hort Innovation, 2023 (b)). Queensland produces around 43% of total mango production in Australia (Hort Innovation, 2023 (b)). Queensland exported A$18.8 million of mangoes (3,384 tonnes) in 2020/21.

Two major mango growing regions, Bundaberg and Burdekin, are close to the Central Queensland region and there is a potential to expand mango cultivation within the region.

Lychee: Lychee is an evergreen perennial fruit tree that grows well in tropical and sub-tropical climates. In Australia, Queensland is the main growing state (99% of production), especially, Sunshine Coast, Bundaberg, Rockhampton, and Atherton, accounting for, 2283 tonnes worth A$32 million in 2020/21 (Hort Innovation, 2023 (b)). Only 18% of production was exported in 2020/21 earning A$6.9 million. Lychee is a seasonal product, and the harvest starts in October. North Queensland region has an advantage as the harvest first comes in this region compared to Southern Queensland and New South Wales. Over the last decade, lychee production shows a growing trend.

Table Grapes: Table grape are produced all over Australia, and Queensland contributes nearly 8% of Australia's total production. In 2020/21, Australia's total production of table grapes was 198,389 tonnes (worth A$632 million) and 120,775 tonnes were exported, earning A$4461 million. Australia exports table grapes to Asia, Europe, the Middle East, North America, and New Zealand. Close to Central Queensland Emerald and Mundubbera are the main growing regions, showing the potential to expand table grape cultivation in the Central Queensland region. Since the Gladstone port is trading with exporting counties, there is a good potential to export Central Queensland production. Considering the future potential of this commodity, the research team have collected data from the local producers to develop a mapping tool and included this in the next section.

4.2.7 Emerging crops

There is some potential to expand the agriculture sector in the Central Queensland region, especially in producing other emerging crops.

Macadamia: Macadamia is a perennial crop, and macadamia seeds are of commercial importance and supplied as kernel and in-shell form. Macadamia is used for domestic consumption as well as earning export income. The value of export in 2020/21 was A$276.1 million, and of them, A$166.3 million was earned from Queensland exports (Hort Innovation, 2023 (c)). Australia exports macadamia mainly to China, Vietnam, Japan, the USA, and South Korea. In Australia macadamia mainly grows in Queensland (57%), New South Wales (42%), and Western Australia (Hort Innovation, 2023 (c)). The global demand for raw and value-added macadamia products is increasing and steady throughout the year which is an advantage to investing in the Central Queensland region. Within Queensland there are currently 18,806 ha of macadamia cultivation, predominantly in the Southern part of Queensland but the cultivation is still expanding towards the Central Queensland region (Australian Macadamia Society, n.d.). North Queensland cultivation consists of 359 ha in Rockhampton, 23 ha in Livingstone, and 513 ha in the Gladstone area. Close to the central Queensland region, Bundaberg is the main cultivation area, which has around 12,447 ha of macadamia. Hence, macadamia can be considered as one of the important emerging crops in the Central Queensland region. However, the crop needs long-term investment to establish the supply chain such as, storage facilities, processing equipment, or processing centres.

Aquaculture: The aquaculture industry in Queensland has been increasing over the last decade and reached up to A$194 million in year 2020/21 (DAF, 2021a). The wild-caught fish export cannot be increased further as sustainable management of natural resources is important and hence the excess demand can be met through aquaculture. Prawn farming is the largest aquaculture sector in Queensland occupying 75% of total production, followed by barramundi. Close to the Central Queensland region, Mackay is the leading aquaculture-producing area. In 2020/21 Fitzroy region produced million A$7.1 worth of aquaculture (DAF, 2021a). The region needs to diversify agriculture, and aquaculture could be a good suggestion to expand. There is plenty of farmland in proximity to the seaport that provides easy access to transport. With projected population growth and family-based farming, the availability of labour is an advantage to expand the market. The unmet demand for many aquacultures such as Tropical rock lobsters in the Southeast Asia market can be seen as an advantage.

4.2.8 Gross margin of major and niche commodities

Gross margin is the difference between the gross income or revenue from selling the commodities by the producers and the variable costs of production. Therefore, this information is used to determine the profitability of the farming business or investment on farming based on the expenditures related to production, yield potential, and gross revenue per hectare ($/ha) bases (Hristova, Yates et al. 1993). Net farming profit and the gross margin are not same information as the net farming profit is obtained from subtracting the fixed or overhead costs from total gross margin of the farming business (Hristova, Yates et al. 1993).

Table 20 – Table 22 are showing an indication of gross margin of selected agricultural commodities in and around CQ region. The gross margin values shown in these tables derived through literature review and existing available estimation. In the Table 20, the gross margin values of chickpea, cotton (surface/syphon, and lateral/centre pivot), sorghum, and wheat commodities for the Central Highland (a cropping sub-region within CQ region) are presented for both the rainfed and the

irrigated cultivation processes. These data sets have been updated in June 2021 using available original data from 2020. The gross margin values for these commodities in rainfed cultivation condition are very low in comparison to those for irrigated cultivation processes. Though chickpea and sorghum yield positive gross margin as rainfed condition, both the cotton and wheat yield negative values for gross margin. Whereas the irrigated cultivation process for these commodities indicated higher yield of gross margin values for the enterprises due to higher production per hectare production facility. The irrigated cultivation process requires higher expenditures for fallow management, nutritional supply, irrigation, harvesting and post-harvest processing activities than those of the rainfed cultivation process. The selling price of the commodity can vary with the different cultivation processes, for instance, the selling price of lint produced from the rainfed cultivation process of cotton has been reported as lower than that of irrigated cultivation process (AgMarginsTM updated in 2021). Moreover, the expenses on planting, and other miscellaneous items for irrigation cultivation process of the cotton production are higher than the rainfed process.

Table 19: Gross Margin of Chickpea, Cotton, Sorghum, and Wheat for Central Highland Region (AgMargins^{TM} updated in 2021)

Regions & Year of Data Availability	Commodities	Gross Margin, ($/ha)	
		Rainfed	Irrigated
Central Highland (CH), 2020	Chickpea	$ 251.00	$ 2,194.00
CH, 2020	Cotton (Surface / Syphon)	-$ 553.00	$ 4,415.00
CH, 2020	Cotton (Lateral / Centre Pivot)	-$ 553.00	$ 4,527.00
CH, 2020	Sorghum	$ 209.00	$ 1,487.00
CH, 2020	Wheat	-$ 48.39	$ 1,280.70

Table 20: Gross Margin of Southern and Northern Region Beef (2017) (MLA 2017)

Regions & Year of Data Availability	Commodity	Gross Margin, ($/kg of LWt sold) (Note: LWt = liveweight)	
		Southern Beef	Northern Beef
Southern and Northern Beef Regions, 2017	Beef	$ 0.78	$ 0.66

Table 21: Gross Margin of Mandarin (CQ Region) and Table Grapes (NQ Region) (Agbiz 2022)

Region & Database Update Year	Commodity	Gross Margin, ($/case)	Gross Margin ($/ha)
Central Queensland (CQ), 2018	Mandarin	$ 8.57	$ 23,048.00
North Queensland (NQ), 2018	Table Grape	$ 23.51	$ 17,634.00

In Table 21, the gross margin for the northern and southern beef regions have been presented in terms of $/kg of LWt (liveweight) sold. The values were obtained from the demonstrated case studies presented with the cost of production (CoP) calculator proposed by the Meat and Livestock Australia (MLA) (MLA 2017). The trading and production processes of the beef cattle are highly diverse due to diverse demand from the export market, hence the producers have mix of different cattle within a production timeframe. It makes the process of determining gross margin for a certain production range highly intricate. The processes used in the calculator determined the overall cost of production and gross income against the total liveweight gain and total variable expenses within a trading year from raising different aged cattle in the farm. Therefore, though the two case studies considered different number and breeds of cattle samples the gross margin in terms of $/kg of LWt sold made it easy to compare the gross margin for the cattle production in northern and southern beef regions. Table 21 shows that the gross margin for the beef cattle enterprises in the southern beef region is $0.78/kg LWt, and that of northern beef region is $0.66/kg LWt. The case studies (MLA 2017) for these two regions showed that the cost of production ($/kg of LWt), and gross income ($/kg of LWt) are also lower in the northern beef region than the southern beef region. The variable cost of production was divided into direct expenses, overhead and labour expenses for this analysis. While comparing these costs in terms of per kg of liveweight gain, both the overhead cost and the labour expenses were very high in the southern beef producing region. The data were obtained from a 2017 study.

Table 22 shows the gross margin in terms of $/case, and $/ha for both the mandarin and table grapes grown in the Central Queensland and North Queensland regions, respectively (Agbiz 2022). The calculated gross margin values are reported based on the updated data in 2018. Due to unavailability of regional data for the gross margin analysis a comparative analysis of growing mandarin and table grapes in these regions could not be made. But the tool provided by the Agbiz (2022) can be useful to determine the gross margin values if the updated regional data are accessible for further analysis.

These commodities, i.e., chickpeas, wheat, cotton, sorghum, beef, mandarin, and table grapes, have been identified as key agricultural economic drivers for the Central Queensland (CQ) region of Australia. Though not all of these data are representing the actual and updated gross margin values based for this region, these can be considered as indicative. In addition, gross margin values can differ from one year to another year depending on input and other variable costs. So the end users should use these gross margin value with cautions.

4.3 Supply chain maps of selected agricultural commodities

In this section we present case-study supply chain maps of five key commodities. As mentioned earlier, that data for these mapping tools were collected from four main sources: primary data from the producers and industry bodies, literature review, secondary data. In addition, we have included two other supply chain maps for mandarin and grapes considering their production value and future potential.

Beef supply chain map

Name of the commodity and region: Beef, Central Queensland

Date: 30th September, 2022

		Feature	Data entry
Product	Product characteristics	Food type	Animal protein
		Product category	Processed and comes in different cuts
		Perishability and shelf life	Highly perishable. Shelf life is about 3 to 5 days if refrigerated (below 5⁰C). If it is kept in freezer (below 0⁰C) it can be consumed up to 12 months.
		Seasonality	Available all year round
		Bulkiness	Depending on the packaging it could be categorized as bulky or non-bulky
		Product life cycle	Depending on the age of the cattle
		Product variety	Multiple varieties, because of different types of cattle and meat from different parts of the cattle.
		Product innovativeness	A few innovations in the Central Queensland region
	Product supply	Type of product processing	Generally handled as chilled or frozen
		Farmgate-to-shipping time	Depending on the location of farm, it requires up to 1 day to supply cattle to the local abattoir. It would take another 1 day to transport processed beef from abattoir to the Brisbane port.
		Product value	Because of different cuts of beef, it is difficult to identify the average price. The gross margin for beef from norther regions is about AUD 0.66 per kg of liveweight.
		Value adding	Value added products include Wagyu beef and organic beef which have significantly higher price compared to regular beef.
		Supply volume and uncertainty	Supply uncertainty is low. However, it can be affected due to extreme weather conditions (drought, flood)
		Stock ability	High
		Delivery lead time	Delivery lead time is minimal as the meat processing industry is available in this region.

	Product demand	Market type and distance	Local producers send their cattle to the abattoir and then the processed beef is sent to different markets. For export markets, most of the products go through Brisbane port which is about 700 km away from the region
		Access to market	CQ beef has access to the international markets
		Consumer segmentation	There are consumers from different socio-economic backgrounds and the consumer segmentation is very diverse.
Infrastructure	Hard structure	Number of entities	Supply chain structure is very complex and more like a web of network as the actors are connected in different ways. Depending on the individual supply chain, the number of actors range from 5 to 8.
		Type of networks	The supply chain is organised vertically. However, no collaboration exists among the actors.
	Soft structure	Level of dependency	Producers are heavily dependent on input providers and meat processors/abattoirs. Producers are moderately dependent on feedlots but not very dependent on exporters, as meat processors are those who often deal with exporters.
	Instruments & Resources	Transport	Cold and chilled transportation are required for processed beef. However, trucks and road trains are required for transferring live cattle to slaughterhouses.
		Facilities	A well-developed processing industry exists in the region.
		Technology	Digital technologies and IoT exist in this region, which are moderately affordable. However, the internet connection is not strong in some parts of the region.
		Labour force	Most producers have their own family business and permanent employers working on farm. Labour force is not a big issue for the beef supply chain.
Process	Singlehandedness	Single-handed production and business	The majority of the tasks associated with supplying beef are handled by producers in coordination with other supply chain entities.
	Coordination	Communication and information sharing	Common among supply chain actors.
		Power distribution	Processors have the most power to control the market price. No visible power distribution exists within the supply chain.
	Collaboration	Shared strategies and interests	None exists among supply chain actors.
		Shared business culture	There is some extent of shared values among producers.
		Trust and commitment	There is trust and commitment among producers and processors in an informal way.
	Consolidation	Brand consolidation	Does not exist
		Freight consolidation	Dose not exist

Factors	**Legal factors**	**Government policies, regulations and support**	There are a lot of regulations and certifications in relation to production and classification.
	Relational factors	**Relationship with investors**	No external investors exist at the production level.
		Relationship with industries	There is a close relationship with industries which can provide fodder (grain, cotton seed etc.)
	Developmental factors	**Research and development**	Numerous research works are going on in the regional Universities and MLA.
	Environmental factors	**Natural or human-induced risks**	Extreme weather conditions often affect the supply chain.

Box 5: Opportunities and Challenges: Beef supply chain

Opportunities

- The development of Rookwood Weir will supply 72,000 ML of medium-priority water in the region for agriculture and urban use. This additional water availability would underpin the development of feedlot and cattle finishing and hence expansion of the beef industry.
- Proposed beef corridors of QLD will strengthen the road network and enhance the efficiency of the beef supply chain.
- Well-established export supply chain with opportunity for further expansion to increase market share in the existing market and explore new markets.
- Central Queensland University is one of the leading universities in Australia that is situated in this region and has a strong world standard capacity for research and development in cattle farming and supply chain management.

Challenges

- Key threats to the industry's development are natural disasters, biosecurity, and price volatility in the international markets.
- There is a lack of collaboration and coordination among the producers, particularly in sharing production and market information.
- Cattle farming is accountable for more than half of the greenhouse gas (GHG) emissions from the Australian agriculture sector, so the traditional method of cattle farming can further aggravate the GHG emissions.
- The unavailability of regional-level data for beef cattle farming and processing can hinder the development of the beef sector action plan.

Grain and legume supply chains maps:

Wheat supply chain map

Name of the commodity and region: Wheat, Central Queensland

Date: 30th September, 2022

		Feature	Data entry and sources of data
Product	Product characteristics	Food type	Grain
		Product category	Processed
		Perishability and shelf life	Not perishable
		Seasonality	Generally planted in March-April and harvested in August-September.
		Bulkiness	Bulk product
		Product life cycle	Wheat is an annual plant. In CQ and Australia it is grown commercially as an annual winter crop.
		Product variety	Multiple varieties exist in Australia. In CQ some common varieties are Condomine, Hellfire, Raider, Rockstar, Mustang.
		Product innovativeness	Not many product innovations in the Central Queensland region.
	Product supply	Type of product processing	Handled as bulk product.
		Farmgate-to-shipping time	Most of the wheat is sent to GrainCorp for distribution and export. Some types of low-grade wheat are sent to feedlot. Brisbane port is the main port for export which is about 700 km distance from the region. Some grains are exported through Gladstone port, but the volume is very small.
		Product value	Product value is high in the export market. The gross margin for irrigated wheat in CQ region is AUD 1,280 per hectare.
		Value adding	Value added products exists in QLD but not in this region.
		Supply volume and uncertainty	Supply uncertainty is low. However, it can be affected due to extreme weather conditions (drought, flood)
		Stock ability	Moderate. The harvested products need to be stored in the silos (on farm or in the distribution centre).
		Delivery lead time	Long delivery lead time due to shortage of transport trucks.
	Product demand	Market type and distance	Goes to the export market through Brisbane port. Low-grade wheat goes to local feedlots.
		Access to market	CQ wheat has access to major international markets.
		Consumer segmentation	1. Domestic consumers, 2. Export market, 3. Value added industries (flour mills).

Infrastructure	**Hard structure**	**Number of entities**	Supply chain structure is very streamlined and consists of 4/5 entities. However, the product goes from producers to end users (feedlots) in some particular cases (number of entities 3, input providers, producers, consumers)
		Type of networks	The supply chain is organised vertically. Some extent of coordination exists among producers through the Australian wheat board. However, no collaboration exists among supply chain actors.
	Soft structure	**Level of dependency**	Producers are heavily dependent on input providers and marketers (e.g., GrainCorp), and moderately dependent on exporters.
	Instruments & Resources	**Transport**	Trucks are used for transporting the product to storage silos and distribution centres.
		Facilities	Storage facilities exist in most of the production areas
		Technology	Digital technologies are used in this region in limited capacities. The internet network is not strong in the grain production areas.
		Labour force	Labour force is a challenge for the wheat industry.
Process	**Singlehandedness**	**Single-handed production and business**	Majority of the tasks associated with supplying wheat is handled by producers in coordination with other supply chain entities.
	Coordination	**Communication and information sharing**	Exists among supply chain actors.
		Power distribution	The power is distributed among supply chain actors, and there is power shift depending on the circumstance. Extreme weather conditions can be a factor influencing the shift of power among supply chain actors.
	Collaboration	**Shared strategies and interests**	Non-existent among supply chain actors.
		Shared business culture	Some extent of shared values among producers.
		Trust and commitment	Trust and commitment exist among producers and distributors in an informal way.
	Consolidation	**Brand consolidation**	Does not exist
		Freight consolidation	Does not exist
Factors	**Legal factors**	**Government policies, regulations and support**	There are some basic policy and regulation protocols for the wheat production.
	Relational factors	**Relationship with investors**	No external investors exist at the production level.
		Relationship with industries	Close relationship with the beef industry (feedlots) which use grains as stock feed.
	Developmental factors	**Research and development**	Very limited research work on the product in local institutions.
	Environmental factors	**Natural or human-induced risks**	Extreme weather conditions affect the supply chain.

Chickpea supply chain map

Name of the commodity and region: Chickpeas, Central Queensland

Date: 30th September, 2022

		Feature	Data entry and sources of data
Product	Product characteristics	**Food type**	Pulse
		Product category	Processed
		Perishability and shelf life	Not perishable
		Seasonality	Generally planted in winter (May-June) and harvested in late spring or early summer (October-November).
		Bulkiness	Bulk product
		Product life cycle	Chickpeas are a rotational annual winter crop plant. In CQ and Australia it is grown commercially as an annual summer crop.
		Product variety	Two types exist in CQ, Kabuli and Deshi.
		Product innovativeness	Not many product innovations in the Central Queensland region.
	Product supply	**Type of product processing**	Handled as a bulk product.
		Farmgate-to-shipping time	High grade Chickpeas are sent to distributors (Bean Growers) for distribution and export. However, in some cases chickpeas are sent to feedlots as stock feed.
		Product value	Product value is currently not high in the export market. The average gross margin of irrigated Chickpea in CQ is AUD 2,194 per hectare.
		Value adding	Value added products exist in QLD but not in this region.
		Supply volume and uncertainty	Supply uncertainty is low. According to ABS, CQ produced about 43% of QLD chickpeas in 2019-20 which is about 71,000 tonnes.
		Stock ability	Moderate. The harvested products need to be stored in silos (on farm or in distribution centres).
		Delivery lead time	Long delivery lead time, as the distribution centres are outside the region and because of shortage in transport logistics.
	Product demand	**Market type and distance**	Mostly export market. Major export destinations are Bangladesh, Pakistan, UAE
		Access to market	QLD chickpeas have access to major international markets.
		Consumer segmentation	1. Domestic consumers 2. Export market

Infrastructure	**Hard structure**	**Number of entities**	Supply chain structure is very streamlined and consists of 4/5 entities.
		Type of networks	The supply chain is organised vertically. Some extent of coordination exists among producers and distributors/exporters. However, no collaboration exists among supply chain actors.
	Soft structure	**Level of dependency**	Producers are heavily dependent on input providers and distributors/exporters.
	Instruments & Resources	**Transport**	Trucks are used for transporting the product to storage silos and distribution centres.
		Facilities	Storage facilities are moderately available in most of the production areas
		Technology	Digital technologies are used in this region in limited capacities. The internet network is not strong in the production areas.
		Labour force	Labour force is a challenge for some production areas.
Process	**Singlehandedness**	**Single-handed production and business**	Majority of the tasks associated with supplying chickpeas is handled by producers in coordination with other supply chain entities.
	Coordination	**Communication and information sharing**	Exists among supply chain actors.
		Power distribution	Exporters hold the most power as the majority of production go to export markets.
	Collaboration	**Shared strategies and interests**	Non-existent exist among supply chain actors.
		Shared business culture	There is some extent of shared values among producers.
		Trust and commitment	Trust and commitment exist among producers and distributors/exporters in an informal way.
	Consolidation	**Brand consolidation**	Does not exist
		Freight consolidation	Does not exist
Factors	**Legal factors**	**Government policies, regulations and support**	There are some basic policy and regulation protocols for the Chickpeas production.
	Relational factors	**Relationship with investors**	No external investors at the production level.
		Relationship with industries	Close relationship with the beef industry (feedlots) which uses chickpeas as stock feed.
	Developmental factors	**Research and development**	Very limited research work is currently going on in local institutions.
	Environmental factors	**Natural or human-induced risks**	Extreme weather conditions can affect the supply chain.

Sorghum supply chain map

Name of the commodity and region: Sorghum, Central Queensland

Date: 30th September, 2022

		Feature	Data entry and sources of data
Product	Product characteristics	Food type	Grain
		Product category	Processed
		Perishability and shelf life	Not perishable
		Seasonality	Generally planted on September-October and harvested on March-May.
		Bulkiness	Bulk product
		Product life cycle	Sorghum is an annual plant. In CQ and Australia it is grown commercially as an annual summer crop.
		Product variety	Multiple varieties exist in Australia. In CQ a common variety is Buster.
		Product innovativeness	Not many product innovations in the Central Queensland region.
	Product supply	Type of product processing	Handled as bulk product.
		Farmgate-to-shipping time	High grade sorghum is sent to GrainCorp for distribution and export. However, in CQ region sorghum are sent to feedlot.
		Product value	Product value is currently not high in the export market. The average gross margin for irrigated sorghum in CQ region is AUD 1,487 per hectare.
		Value adding	Value added products exist in QLD but not in this region.
		Supply volume and uncertainty	Supply uncertainty is low. According to ABS, about 14.5% of QLD sorghum is produced in CQ (on average).
		Stock ability	Moderate. The harvested products need to be stored in silos (on farm or in distribution centres).
		Delivery lead time	Short delivery lead time as the product often goes to local feedlots.
	Product demand	Market type and distance	Domestic market is dominant for CQ sorghum. All case studies reported that produced sorghum is supplied to local feedlots.
		Access to market	QLD sorghum has access to major international markets. However, it is not evident that CQ exports sorghum from the region.
		Consumer segmentation	Domestic consumers

Infrastructure	**Hard structure**	**Number of entities**	Supply chain structure is very streamlined and consists of 3 entities (input provider, producers, consumers/feedlots)
		Type of networks	The supply chain is organised vertically. Some extent of coordination exists among producers and end users (feedlots). However, no collaboration exists among supply chain actors.
	Soft structure	**Level of dependency**	Producers are moderately dependent on input providers and distributors/agents.
	Instruments & Resources	**Transport**	Trucks are used for transporting the product to storage silos and distribution centres.
		Facilities	Storage facilities exist in most of the production areas
		Technology	Digital technologies are used in this region in limited capacities. The internet network is not strong in the grain production areas.
		Labour force	Labour force is a challenge for the sorghum industry.
Process	**Singlehandedness**	**Single-handed production and business**	Majority of the tasks associated with supplying sorghum is handled by producers in coordination with other supply chain entities.
	Coordination	**Communication and information sharing**	Exists among supply chain actors.
		Power distribution	Producers hold the power to select the appropriate market for their product.
	Collaboration	**Shared strategies and interests**	Non-existent among supply chain actors.
		Shared business culture	There is some extent of shared values among producers.
		Trust and commitment	Trust and commitment exist among producers and consumers (feedlots) in an informal way.
	Consolidation	**Brand consolidation**	Does not exist
		Freight consolidation	Does not exist
Factors	**Legal factors**	**Government policies, regulations and support**	Some basic policy and regulation protocols for the sorghum production.
	Relational factors	**Relationship with investors**	No external investors exist at the production level.
		Relationship with industries	Close relationship with the beef industry (feedlots) which uses grains as stock feed.
	Developmental factors	**Research and development**	Very limited research work is currently going on in local institutions.
	Environmental factors	**Natural or human-induced risks**	Extreme weather conditions affect the supply chain.

Box 6: Opportunities and Challenges: Grain and legume supply chain

Opportunities:

- The development of the Rookwood weir will supply 72,000 ML of medium-priority water in the region for agriculture and urban use. This additional water availability would underpin the development of irrigated high-value grains in this region.
- The Gladstone port has grain handling and containerised shipment facilities which could be used more extensively for grains and pulses export from this region.
- The Inland port at Emerald provides the opportunity for efficient transportation and distribution of grain and pulse.
- Road and rail connections from the Inland port to Gladstone port would strengthen the supply chain.
- Agencies and Industries including GRDC, QDAF, Agriventis, Peanut Australia and CQUniversity are involved in research and development to improve the production efficiency of grains and legumes in this region.

Challenges:

- Unpredictable weather events, such as cyclones, floods and drought, are major constraints to increasing the grain production in this region.
- The unavailability of regional-level production and domestic and export market data for grains and legumes has been identified as another hindrance to developing and implementing strategic action plans.
- Labour force shortage is a challenge in the grain and pulse industries.

Cotton supply chain map

Name of the commodity and region: Cotton, Central Queensland

Date: 30th September, 2022

		Feature	Data entry and sources of data
Product	Product characteristics	**Food type**	Crop
		Product category	Processed
		Perishability and shelf life	Not perishable
		Seasonality	Generally planted in October and harvested in June-July.
		Bulkiness	Bulk product
		Product life cycle	Cotton is a perennial plant. However, in CQ and Australia it is grown commercially as an annual summer crop.
		Product variety	Multiple varieties (about 52) of genetically modified cotton exist in Australia. In this region 4 varieties are predominantly produced.
		Product innovativeness	Not many product innovations in the Central Queensland region.
	Product supply	**Type of product processing**	Handled as bulk product in form of cotton bales.
		Farmgate-to-shipping time	Most of the cotton is ginned locally and then sent to the Brisbane port for export. Brisbane port is about 700 km distance from the region.
		Product value	Product value is high in the export market. Almost 100% of cotton is exported from CQ region as well as from Australia. The average gross margin for irrigated cotton in CQ is about AUD 4,500 per hectare
		Value adding	Value added products exist (cotton seed oil) in QLD but not in this region.
		Supply volume and uncertainty	Supply uncertainty is low. However, it can be affected due to extreme weather conditions (drought, flood)
		Stock ability	High as the harvested products are stored on the field.
		Delivery lead time	Delivery lead time is minimal because cotton gins are available in this region.
	Product demand	**Market type and distance**	Goes to the export market through Brisbane port.
		Access to market	CQ cotton has access to the international market.
		Consumer segmentation	None exist as the cotton lint goes to the fibre industry of the importing country.

Infrastructure	Hard structure	Number of entities	Supply chain structure is very streamlined and consists of 4/5 entities.
		Type of networks	The supply chain is organised vertically. However, no collaboration exists among actors.
	Soft structure	Level of dependency	Producers are heavily dependent on input providers and ginneries.
	Instruments & Resources	Transport	Trucks are used for transporting the product to the gin and to the port.
		Facilities	A well-developed processing industry (3 cotton gins) exists in the region.
		Technology	Not much use of technologies for cotton production.
		Labour force	Labour force is a challenge for the cotton industry.
Process	Singlehandedness	Single-handed production and business	Majority of the tasks associated with supplying cotton are handled by producers in coordination with other supply chain entities.
	Coordination	Communication and information sharing	Exists among supply chain actors.
		Power distribution	Merchants have the most power to control the market price. No visible power distribution exists within the supply chain.
	Collaboration	Shared strategies and interests	None exist among supply chain actors.
		Shared business culture	There is some extent of shared values among producers.
		Trust and commitment	Trust and commitment exist among producers and cotton gins in an informal way.
	Consolidation	Brand consolidation	Does not exist
		Freight consolidation	Does not exist
Factors	Legal factors	Government policies, regulations and support	There are some basic policy and regulation protocols related to the cotton production.
	Relational factors	Relationship with investors	There are no external investors at the production level.
		Relationship with industries	Close relationship with the beef industry to supply cotton seeds as fodder.
	Developmental factors	Research and development	Limited research work is going on in local research institutions.
	Environmental factors	Natural or human-induced risks	Extreme weather conditions often affect the supply chain.

Box 7: Opportunities and Challenges: Cotton supply chain

Opportunities:

- The development of the Rookwood weir will supply 72,000 ML of medium-priority water in the region for agriculture and urban use. This additional water availability would underpin the development of irrigated cropping including cotton in this region.
- Continuous research on improving water efficiency in cotton production is an advantage to the cotton producers in the Central Queensland region.
- QLD only supply less than 2% of the huge demand for cotton in Vietnam, China, and Bangladesh and there is high potential to increase the export market share through production intensification.
- QLD does not have weaving mills and most of the cotton goes to the export market. There is a potential of developing the fibre market by establishing the weaving and fibre/fabric industry in QLD.

Challenges:

- Unpredictable weather events, such as cyclones, floods, and drought, are major constraints to escalating cotton production in this region.
- The gross margin for irrigated cotton production is high but not for rain-fed cotton. So, higher water prices would be a challenge for cotton growers to compete with other cropping farmers.
- Technical and skilled labour force shortage is a challenge in the cotton industries.

Fruits supply chain maps:

Mandarin supply chain map

Name of the commodity and region: Mandarins, Central Queensland

Date: 30th October, 2022

		Feature	Data entry and sources of data
Product	Product characteristics	**Food type**	Fruits
		Product category	Raw and processed
		Perishability and shelf life	Perishable, potential storage life 2 to 4 weeks in a temperature-controlled environment
		Seasonality	Mandarins are available from April to October
		Bulkiness	Boxed product
		Product life cycle	Mandarin is a perennial evergreen plant, and its average lifespan is 50 years. The fruit can be stored in temperature-controlled area for 2 to 4 weeks.
		Product variety	Common varieties are Murcott, Imperial, Aphora, and Phoenix
		Product innovativeness	Not many product innovations in the Central Queensland region.
	Product supply	**Type of product processing**	Handled as boxed product.
		Farmgate-to-shipping time	Most of the mandarins are exported through Brisbane port which is about 700 km distance from the region.
		Product value	Product value is high in the export market. The gross margin for mandarin in CQ region is AUD 23,000 per hectare.
		Value adding	Value added products exist in QLD but not in this region.
		Supply volume and uncertainty	Supply uncertainty is low. Major producers of mandarin in the CQ region contribute to the total export.
		Stock ability	Moderate. The harvested products need to be stored in a temperature-controlled environment.
		Delivery lead time	Delivery lead time is moderate because of the distance from the shipping port.
	Product demand	**Market type and distance**	Mostly export market. Major export destinations are China, Thailand and Philippines.
		Access to market	QLD mandarin has access to major international markets.
		Consumer segmentation	1. Domestic consumers 2. Export market

Infrastructure	Hard structure	Number of entities	Supply chain structure is very streamline and consists of 4/5 entities.
		Type of networks	The supply chain is organised vertically.
	Soft structure	Level of dependency	Producers are heavily dependent on input providers and moderately dependent on distributors/exporters.
	Instruments & Resources	Transport	Trucks are used for transporting product to the distribution centres. Adequate transport facility.
		Facilities	Storage facilities are moderately available in most of the production areas
		Technology	Digital technologies are used in this region in limited capacities.
		Labour force	Labour force is a challenge for some production areas.
Process	Singlehandedness	Single-handed production and business	Producers develop strategies and share information with other entities in the supply chain through collaboration.
	Coordination	Communication and information sharing	Exists among supply chain actors.
		Power distribution	Producers hold the most power because of the volume of production.
	Collaboration	Shared strategies and interests	Exists in limited capacities among supply chain actors.
		Shared business culture	There is some extent of shared values among producers.
		Trust and commitment	Trust and commitment exist among producers and distributors/exporters in an informal way.
	Consolidation	Brand consolidation	Major producers use their own brand.
		Freight consolidation	Does not exist
Factors	Legal factors	Government policies, regulations and support	There are some basic policy and regulation protocols for the mandarin production.
	Relational factors	Relationship with investors	No external investors exist at the production level.
		Relationship with industries	Close relationship with the Growcom and Hort Innovation.
	Developmental factors	Research and development	Very limited research work is currently going on in local institutions.
	Environmental factors	Natural or human-induced risks	Extreme weather conditions affect the supply chain.

Grapes supply chain map

Name of the commodity and region: Grapes, Central Queensland

Date: 30th October, 2022

		Feature	Data entry and sources of data
Product	Product characteristics	**Food type**	Fruits
		Product category	Raw and processed
		Perishability and shelf life	Highly perishable.
		Seasonality	The grape season starts in November and closes in May.
		Bulkiness	Boxed product
		Product life cycle	Grapes are woody perennial vines. The vine matures for production after three years of plantation.
		Product variety	Some common varieties in the CQ region are Flame seedless, Menindee seedless, Sweet globe, and Sweet sapphire.
		Product innovativeness	Not many product innovations in the Central Queensland region.
	Product supply	**Type of product processing**	Handled as boxed product.
		Farmgate-to-shipping time	Most of the grapes produced in CQ go to the domestic market through merchants/agents. Distribution centres are located in Brisbane which is about 700 km distance from the region.
		Product value	Product value is high in the export market. The gross margin for grapes in northern Queensland region is about AUD 17,600 per hectare.
		Value adding	Value added products exist in QLD but not in this region.
		Supply volume and uncertainty	Supply uncertainty is low. Small scale producers in CQ region can supply a consistent volume of grapes to the domestic market. However, opportunities for upscaling production volume are limited as most of the producers are small to medium scale farmers.
		Stock ability	Moderate. The harvested products need to be stored in a temperature-controlled environment.
		Delivery lead time	Delivery lead time is moderate because of the distance from the distribution centre.
	Product demand	**Market type and distance**	Mostly domestic markets.
		Access to market	QLD grapes has access to major international markets including Indonesia, China, Japan.
		Consumer segmentation	1. Domestic consumers 2. Export market (limited)

Infrastructure	Hard structure	Number of entities	The supply chain structure is very streamlined and consists of 4/5 entities.
		Type of networks	The supply chain is organised vertically. Some collaboration exists via the Australian Table Grape Association.
	Soft structure	Level of dependency	Producers are heavily dependent on input providers and merchants/agents or distributors/exporters.
	Instruments & Resources	Transport	Trucks are used for transporting the product to distribution centres. Moderately adequate transport facilities.
		Facilities	Storage facilities are moderately available in most of the production areas
		Technology	Digital technologies are used in this region in limited capacities.
		Labour force	Shortage of skilled labour force is a challenge for most of the production areas.
Process	Singlehandedness	Single-handed production and business	Majority of the tasks associated with supplying grapes is handled by producers in coordination with other supply chain entities and with industry bodies.
	Coordination	Communication and information sharing	Exists among supply chain actors.
		Power distribution	Merchants / agents hold the most power because of their access to different markets.
	Collaboration	Shared strategies and interests	Exists in limited capacities among supply chain actors.
		Shared business culture	There is some extent of shared values among producers.
		Trust and commitment	Trust and commitment exist among producers and distributors/exporters in an informal way.
	Consolidation	Brand consolidation	Does not exist
		Freight consolidation	Exists among producers as the production volume is small.
Factors	Legal factors	Government policies, regulations and support	There are some basic policy and regulation protocols for the grapes production. Fresh products must be produced under one of the five standards namely, Freshcare, Food Safety & Quality Code, GLOBAL, G.A.P. and British Retail Consortium.
	Relational factors	Relationship with investors	No external investors exist at the production level.
		Relationship with industries	Close relationship with the Growcom and Australian Table Grape Association (ATGA).
	Developmental factors	Research and development	Very limited research work is currently going on in local institutions.
	Environmental factors	Natural or human-induced risks	Extreme weather conditions affect the supply chain.

Box 8: Opportunities and Challenges: Fruits supply chain

Opportunities

- The development of the Rookwood weir will supply 72,000 ML of medium-priority water in the region for agriculture and urban use. This additional water availability would underpin the development of high-value tree crops, including mandarin and macadamia in the lower Fitzroy catchment areas.
- Further upscaling of production capacities and investment opportunities on both the table grape and mandarin commodities are yet to be explored.
- There is a huge demand for Australian mandarins in Asian countries, so intensifying the mandarin production system would be an opportunity for many local growers.

Challenges

- The cultivated areas and production volume of mandarins in the CQ region have been significantly understated in the ABS datasets due to the data confidentiality policy.
- The cold supply chain and cold transportation system are not adequate for upscaling production. There is a need to improve the efficiency of the cold supply chain for these perishable commodities.
- Major exporting port Brisbane is about twelve hours drive away from the production region.
- Shortage of skilled labour force.

4.4 Variation in secondary production data and ground truthing exercise

Some quantitative data for the selected commodities were collected primarily from government statistical websites. ABS, ABARES and QGSO are used as the major sources of data. MLA has rich data sets, and MLA data about beef were considered for use in this report. Although the data are accurate for most of the selected commodities, there are some data inconsistencies as they are reported on different websites. The major concern is the breakdowns of data at the regional level and at the short temporal level (e.g., fortnight, monthly data) are not readily available in most cases. As Central Queensland is an SA4 region in Queensland, agricultural data for the region are available on ABS websites. However, further breakdowns of data would be required for supply chain base analysis at the local government level.

As a part of the project, the research team endeavoured a ground truthing exercise in consultation with producers and industries bodies of the five selected commodities. Two sets of interview protocol for each of the selected commodities were prepared to cover all supply chain features of the mapping tool and to undertake the ground truthing exercise. The interview protocol for industry bodies and experts consists of both open-ended and structural questions with more emphasis on production and export data for ground truthing purpose.

The key organisations which we targeted for the ground truthing of the seven selected commodities are listed below.

Beef: MLA, CQLX, JBS, TAY's, RRC, AgForce

Cotton: Cotton Australia board, Central Highlands Cotton Growers' and Irrigators Association, Emerald gin

Chickpeas: Pulse Australia, GrainCorp, Inland Port

Wheat and Sorghum: GrainCorp, GRDC, Australian Wheat Board, QDAF, Inland port

Mandarin: ABS, CHDC report, Local producer

Table grapes: ABS, AgTrend

The research team interviewed 25 stakeholders including producers, processors, and industry representatives. In addition to the five key commodities, mandarin and grape producers were also interviewed. Out of the 25 stakeholders, only 8 are industry representatives from the beef and cotton industry. Although the research team made their best effort, they were not able to recruit any participants from the grain and pulse industry. The participation in this research project was voluntary and many industry representatives chose not to participate.

The research team also considered secondary data collected from the ABS, ABARES, QGSO and AgTrend QLD. The data collected from these sources were collated and presented to relevant stakeholders for validation and identification of data gaps. However, this report presents the available secondary data to indicate the variation in the existing agriculture production data.

In addition, ABS, QGSO, and ABARES reported production data in form of volume and value, while QDAF produced AgTrend QLD data based on the present GVP data about different agricultural commodities at the state level. QDAF also produced an Ag Trend Spatial map, which is useful to locate the cultivated area for particular commodities. One private company, Data Farming, also produced agricultural production data using satellite images. The research team also attempted to procure some time-series data from this company but did not proceed because of the high cost for accessing those data. The following table (Table 23) indicates the data variation at the state level on the basis of ABS and AgTrend data.

Table 22: Comparing ABS and AgTrend data for selected agricultural commodities in QLD

GVP of selected commodities (million AUD)															
	Cattle and calf disposal*			Wheat			Chickpeas			Sorghum			Cotton		
Year	**ABS**	**AgTrend**	**Variation agreement****	**ABS**	**AgTrend**	**Variation agreement**	**ABS**	**AgTrend**	**Variation agreement**	**ABS**	**AgTrend**	**Variation agreement**	**ABS**	**AgTrend**	**Variation agreement**
2021	5901.8	5,901.80	1.00	519.4	470.1	0.91	151	143	0.95	355.7	321.3	0.90	540.2	524.1	0.97
2020	6546.9	6,546.90	1.00	163.3	246	1.51	122.3	133	1.09	121.6	101	0.83	75.4	102	1.35
2019	5802.6	5,802.60	1.00	178.9	179	1.00	n.a.	136	n.a.	319.3	319	1.00	278.6	279	1.00
2018	5472.6	5,472.60	1.00	246.2	246	1.00	n.a.	377	n.a.	302.4	302	1.00	881.8	882	1.00
2017	5,731.20	5,731.20	1.00	361.4	361	1.00	n.a.	744	n.a.	139.4	139	1.00	621.8	622	1.00
2016	5,860.60	5,860.60	1.00	383.6	384	1.00	291.1	471	1.62	312	312	1.00	465.8	466	1.00
2015	5,076.00	5,076.00	1.00	328.6	329	1.00	n.a.	117	n.a.	485.8	486	1.00	383.2	383	1.00
2014	3,890.10	3,890.00	1.00	339.2	339	1.00	n.a.	118	n.a.	261.2	261	1.00	697.7	698	1.00
2013	3,460.80	3,247.00	0.94	511.5	511.5	1.00	n.a.	175	n.a.	360.4	360	1.00	677.1	677.1	1.00
2012	3,450.10	3,450.10	1.00	413	413	1.00	103.2	57.2	0.55	278.5	278	1.00	981	981	1.00
2011	3,418.00	3,418.00	1.00	378.4	302	0.80	55.5	49	0.88	251.7	320	1.27	776.1	660	0.85
2010	3,174.30	3,229.00	1.02	301.1	265	0.88	n.a.	60	n.a.	171.9	155	0.90	301.1	355	1.18
2009	3,365.60	3,365.60	1.00	535.6	535.6	1.00	56.6	50	0.88	355.7	355.7	1.00	325.2	325.2	1.00
2008	3314.7	3,314.70	1.00	353.4	353.4	1.00	n.a.	50	n.a.	637.2	637.2	1.00	79.2	79.2	1.00

*The cattle and calves disposal includes live cattle data.

Source: AgTrend, https://www.daf.qld.gov.au/strategic-direction/datafarm/qld-agtrends

** A variation agreement value of 1 indicates perfect agreement between the ABS and AgTrend dataset. Cells shaded in green indicate where AgTrend data exceeded ABS data. Cells shaded in red indicated where ABS data exceeded AgTrend data. na: data not available.

It can be seen that apart from data about chickpeas, most of the data are in good agreement and the relative variation is from 5 to 10%. The chickpea production data were missing for several years as they were combined with the total pulse production (includes chickpeas, mung bean, soybean etc). AgTrend has the pulse production data for all years, however, there some issues in these data. For instance, according to AgTrend, the GVP of chickpeas for QLD in 2017 was 744 million AUD. The same GVP was also mentioned in ABS but for the total pulse. More insight on the production and export data for the selected commodities are listed below.

Beef: The data set for beef was prepared using data from ABS and MLA. ABS reported the number of herds in QLD, as well as in CQ on their data portal. MLA reported a wide range of data on beef and beef export, but the regional level data were missing. Also, inconsistencies exist in data about prices of Australian beef in the international market. According to ABS trade data, for instance, the average price of Australian beef in the world market was AUD 9.22/kg but the international market price was lower than this price. In addition, regional level data of beef production and processing are not available.

Through the ground truthing exercise (using stakeholder interviews) the research team identified that the existing data in ABS and MLA are consistent with the field level data. The stakeholders also indicated that there could be some errors, but it would be lower than 5%. The average price is not the ideal figure for research and decision-making purposes because of high price variation among different cuts of beef. The regional level production data are available in ABS. However, the export data for CQ was not found during the ground truthing process. Table 24 summarizes the collected data about QLD and CQ beef. In table 20, the beef production in CQ was estimated based on the ratio of meat cattle in QLD and in CQ.

Table 23: Beef production data for QLD and estimated data for CQ

Years	Number of meet cattle QLD	Number of meat cattle CQ (% of QLD)	QLD meat cattle slaughtered for Beef Production (numbers)	Estimated CQ meat cattle slaughtered (numbers)	QLD beef production (tonnes)	Estimated CQ beef production (tonnes)
2021	10,605,366	1,912,150 (18%)	2,903,000	523,412	990,473	178,583
2020	10,381,265	1,763,168 (17%)	3,293,200	559,322	1,151,327	195,543
2019	11,156,287	2,202,601 (19.7%)	3,942,700	778,413	1,108,921	218,936
2018	11,909,945	2,463,809 (20.7%)	3,682,400	761,778	1,035,755	214,267
2017	10,992,601	1,987,777 (18.1%)	3,396,300	614,148	1,028,356	185,956
2016	10,390,122	1,871,628 (18%)	3,436,900	619,107	1,207,757	217,560

The export data both in volume and values are available in QGSO datasets at the state level. We have made some estimation for CQ beef export and presented the estimated data in Table 25. The export data are based on the volume of specific commodity handled on the port. However, a particular port might not handle the meat produced in a single region. For instance, all the beef exported from CQ region is sent to the Brisbane port, which handled beef from other regions as well. Hence it is difficult to identify the accurate beef export figure from CQ.

Table 24: Beef export data for QLD and estimated data for CQ

Years	QLD Beef export Volume in tonne (% of QLD production)	QLD Beef export value (Million AUD)	Estimated CQ Beef export Volume in tonne	Estimated CQ Beef export Value (Million AUD)
2021	575,122 (58%)	4,841.0	103,695	872.8
2020	723,608 (63%)	6,219.1	122,899	1,056.3
2019	698,106 (63%)	5,370.8	137,828	1,060.4
2018	644,719 (62%)	4,517.9	133,373	934.6
2017	584,319 (57%)	4,152.1	105,662	750.8
2016	672,597 (56%)	4,716.0	121,159	849.5

It is noted that ABS and QGSO data indicate that about 60% QLD beef has been exported in recent years. During the ground truthing stage, the stakeholders suggested that the percentage should be around 70%. However, the research team could not find substantial data to support this argument.

Wheat: Most of the data regarding production, export and price of wheat were collected from the ABS website. There are some inconsistencies in data about prices of wheat and its production quantity in CQ. From 2017-18 there was a constant decline in wheat production in QLD. Historically, CQ produced about 14% of QLD wheat. However, in 2019-20 this number jumped to over 36%. Data indicated that the average export price of Australian wheat is higher than the international market price of wheat. The export quantity of wheat from QLD is very fluctuating. The research team tried to contact and interview representatives from GrainCorp, Inland Port, and GRDC to check the international and domestic wheat price, as well as export volume data of central Queensland. Unfortunately, no one from the above organisations could participate in this research project; and the ground truthing was based on the information provided by local producers. The production of wheat in QLD and CQ are listed in Table 26. On average CQ produced about 12% of QLD wheat, which jumped up to 36% in 2019-20. QLD experienced severe drought in 2019-20 and the production in the Southeast QLD was heavily affected by the weather conditions, and that may cause the variation in data.

Table 25: Wheat production in QLD and CQ

Years	QLD wheat production in tonnes	CQ wheat production in tonnes	Percentage of QLD production
2021	1,594,192	125,218	8%
2020	418,500	151,774	36%
2019	419,700	60,285	14%
2018	765,400	96,011	13%
2017	1,501,600	192,456	13%
2016	1,315,900	91,289	7%
2015	986,900	149,990	15%

Chickpeas: Chickpeas data were collected from the ABS database and ABARES websites. At the regional level, the production data were missing for several years as chickpeas production data were merged with other pulse production categories. Australia is the largest chickpea exporter in the world, and in 2020-21, Australia exported about 434,917 tonnes of chickpeas including the re-exported volume (Table 27). It shows in the data that the export volume of chickpeas from QLD was significantly higher than the combined volume of production and import in QLD. This could be because chickpeas produced in NSW were exported and re-exported through the QLD ports. The research team attempted to interview representatives of Pulse Australia but was not successful. During the ground truthing, the local producers suggested that in order to get a better price, sometimes producers supply their products to local feedlots and the amount may not be counted in the QLD Production.

Table 26: QLD chickpea production and export data

Years	QLD Chickpeas production in tonnes	QLD Chickpea import in tonnes	QLD Chickpea export in tonnes (including re-export)	% of QLD (production + import)
2020-21	275,000	53,162	434,917	133%
2019-20	162,082	14,258	275,760	156%
2018-19	117,673	14,796	252,855	191%
2017-18	467,007	10,876	733,054	153%
2016-17	1,150,000	132,830	1,416,942	110%
2015-16	370,580	266,355	753,860	118%

Sorghum: Sorghum data were also collected from the ABS database and ABARES websites. On average, CQ produced about 14% of QLD Sorghum. Sorghum export from QLD has been increased in recent years but the data about export volume and value for the CQ region were not available. China, Japan, Papua New Guinea, New Zealand and Taiwan are the major export destinations of QLD sorghum. The data indicated that the average export price of Australian sorghum is higher than the average international market price. However, the research team could not validate the ABS data during the ground truthing stage because of non-participation by the peak industry bodies.

Cotton: Most of data about production, export and price of cotton were collected from ABS websites. Similar to wheat, there are some inconsistencies in data about the production quantity of cotton in CQ. On average, CQ produced about

15% of QLD cotton. ABS data indicated that in 2019-20, the CQ region produced about 65% of QLD cotton and this figure is very high. The export quantity of cotton from QLD is higher compared to its total production volume. This could be because cotton produced in NSW was exported through the QLD ports.

At the ground truthing stage, the research team interviewed representatives from Cotton Australia Board, Central Highlands Cotton Growers and Irrigators Association, and local cotton gins. Through this process, the research team collected local production data and compared with ABS data (presented in Table 28). It is observed that ABS data about QLD cotton production are consistent with the local data, apart from the year 2019-20. In 2019-20, QLD was hit by severe drought and because of that there might be errors in ABS' estimated data. The average relative variation is below 2% without the outlier in 2019-20.

During the ground truthing, the research team collected data from local cotton gins and found that the cotton produced in this region needs to go through the ginning process to produce cotton lint. It is believed that local data presented in this report are close to the actual production volume. ABS cotton production data for CQ has large variation compared with local data. On average the relative variation is over 25%. Ground truthing stage also verified that in 2019-20 CQ actually produced about 50% of QLD cotton while this figure in ABS statistics was 66%. High variation in ABS data indicates that ABS data for regional cotton production are not reliable for research purposes.

Table 27: QLD cotton production data form ABS and local sources

Years	QLD cotton production in tonnes (ABS data)	QLD cotton production in tonnes (Local data)	Relative Variation in QLD data	CQ Cotton production in tonnes (ABS data)	CQ Cotton production in tonnes (Local data)	Relative Variation in CQ data
2020-21	209,035	213,859	2.3%	27,070	26,645	-1.6%
2019-20	30,846	38,881	20.7%	20,036	19,695	-1.7%
2018-19	163,530	163,530	0.0%	26,851	43,685	38.5%
2017-18	319,870	319,871	0.0%	97,143	58,742	-65.4%
2016-17	315,600	329,959	4.4%	38,146	47,759	20.1%
2015-16	234,063	236,944	1.2%	31,213	40,129	22.2%

Cotton export data are available in the QGSO's tread statistics at the state level. However, the export data for CQ region are not available in public domains. QGSO's export data are only available until the years 2017-18 and are presented in Table 29.

Table 28: QLD cotton export data

Years	QLD cotton Export volume in tonnes (QGSO data)	Percentage of QLD cotton production
2017-18	90,356	28%
2016-17	360,123	114%
2015-16	217,834	93%
2014-15	327,973	169%
2013-14	435,880	147%

The percentage of cotton produced in QLD going to the export market is inconsistent. This could be because of issues related to stock rollover, re-export, and usage of QLD ports to export cotton from other regions, or simply because of estimation errors. Interviews with industry representatives revealed that almost 99% of cotton produced in QLD is exported. The information is not well reflected in the QGSO trade data and hence needs to be treated with caution.

5 Discussion and Conclusion

5.1 Summary of theoretical and empirical findings

5.1.1 Framework and mapping tool development

Our construction of a framework and mapping tool for characterising agricultural supply chains went through two main stages: The first is the "Developmental Stage", in which we identified the theoretical domains through a comprehensive literature review followed by generation of components, dimensions and features of the proposed framework. The second is the "Validation Stage", when a selected panel of experts evaluated the framework/mapping tool and rated and commented on the item relevance to the supply chain components, dimensions and features (Lynn, 1986).

In the Developmental Stage, drawing on a combination of deductive and inductive literature review approaches, we reviewed studies related to agricultural supply chains and their common characteristics. In order to ensure that the most common and standardised themes are selected and included in the review, we have made reference to several frameworks which we found relevant, and deductively identified four components comprising the proposed framework, namely product, infrastructure, process, and factors. Inductive literature examination, in addition, revealed a complex picture of agricultural supply chains, and provides much evidence suggesting that there are various supply chain dimensions and features associated with the four components of the proposed framework, that need to be taken into account in describing supply chains in the agriculture sector. Findings from the literature, thus, support our proposal of the four fundamental components constituting an agricultural supply chain.

The review of common characteristics of agricultural supply chains in the literature towards developing a baseline framework were presented as follows:

- Level 1: Four fundamental components of the framework are product, infrastructure, process, and factors. The interplay/ influentiality /relationship between the four components is represented using bi-directional and uni-directional arrows (see Figure 8).

- Level 2: There are three major dimensions constituting the product component, namely **product characteristics**, **product supply**, and **product demand**; three main dimensions making up the infrastructure component, that is, **hard structure**, **soft structure**, and **instruments and resources**; four major dimensions comprising the process component, namely **single-handedness**, **coordination**, **collaboration** and **consolidation**; and four main dimensions forming the factors component, that is, **legal factors**, **relational factors**, **developmental factors**, and **environmental factors**.

- Level 3: Each dimension at the second level of the framework is associated with a number of supply chain features. These features include: food type, product category, perishability, seasonality, bulkiness (**product characteristics**), type of product processing, make-to-order lead time, product life circle, product variety, product innovativeness, product value, value adding, supply uncertainty, stock ability, delivery lead time (**product supply**), market type, market distance, access to market, demand uncertainty, consumer segmentation (**product demand**), number of entities, types of networks (**hard structure**), level of dependency (**soft structure**), transport, technology, labour force (**instruments and resources**), single-handed production, single-handed business (**single-handedness**), contracting, communication, informational sharing, power distribution (**coordination**), shared strategies and interests, shared business culture, trust and commitment (**collaboration**), brand consolidation, freight consolidation (**consolidation**), government policies and regulations, government support (**legal factors**), investors, external industries (**relational factors**), research and development (**developmental factors**), and natural or human-induced risks (**environmental factors**).

The framework was, then, expanded in a tabular form to create a mapping tool for data presentation (see Table 19). The mapping tool contains all supply chain components, dimensions, and features from the framework in three layered columns and includes an additional column in which each feature is explained in detail.

5.1.2 Framework and mapping tool validation

In the Validation Stage, the framework and mapping tool were validated quantitatively and qualitatively by a group of experts who have theoretical and/or practical knowledge about and experience of supply chains in the agriculture sector, through a survey and workshop. The experts, in general, recognised the quality and usefulness of the framework and mapping tool. Drawing on our analysis and interpretation of the survey and workshop discussion data, the experts' feedback on the framework and mapping tool was discussed in detail. In responding to their comments, we have made some minor changes, as follows:

1. **Naming** (applied in both the framework and mapping tool): Modifying the name of the item "perishability", and instead, using the name "perishability and shelf life"; modifying the name of the item "supply uncertainty", and instead, using the name "supply volume and uncertainty"; renaming the feature "(relationships with) external industries", and replacing it with "(relationships with) industries".

2. **Moving** (applied in both the framework and mapping tool): Moving the three items "product life cycle", "product variety", and "product innovativeness" from the "product supply" category to the "product characteristics" category.

3. **Combining** (applied in both the framework and mapping tool): Combining the items "market type" and "market distance" into one; combining the items "single-handed production" and "single-handed business" and replacing them with "single handed production and business"; combining "communication" and "information sharing" into one; and combining the items "government policies and regulations" and "government support", and replacing them with "government policies, regulations, and support".

4. **Adding** (applied in both the framework and mapping tool): Adding a new item named "facilities", which includes processing facilities and storage facilities, to the infrastructure component, under the "instruments and resources" dimension.

5. **Removing** (applied in both the framework and mapping tool): Removing the item "demand uncertainty" from the "product demand" dimension; and removing the feature "contracting" from the "coordination" dimension.

6. **Explaining** (applied in the mapping tool only): Editing and providing a clearer explanation of the following items: "product life cycle", "consumer segmentation", "transport" (including the issue of "road conditions" in the explanation), and "power distribution" (including the issue of "price control" in the explanation); as well as providing more explanation of the newly named term "perishability and shelf life", "supply volume and uncertainty", "(relationships with) industries".

Discussion on the framework and mapping tool with stakeholders on-the-ground, thus, enabled tailored improvements during refinement. This holistic approach allowed us to develop a more accurate and complete framework and mapping tool, which are applicable for both researchers and general users who are involved in agricultural supply chains in practice in not only central Queensland, but also other agricultural contexts. The refined framework and mapping tool can be found at Figure 8 and Table 19.

5.1.3 Issues and variation in collecting and correcting agricultural production data

We also examined existing agricultural data collection and correction methods, that are beneficial for effective use of the data for supply chain mapping. We indicated that despite efforts, agricultural data published by governments/ government-affiliated authorities may still contain some inaccuracy, errors or flaws, that may mislead researchers/data end-users. The relative standard error in data for some agricultural commodities published by ABS, for instance, is reported as quite high.

We therefore reviewed the current practice of and initiatives for minimising agriculture data gaps in the world and in Australia. The review suggests that different methods have been developed to estimate agricultural production in international contexts, such as crop cuts, farmer survey, grain weight data, sampling for harvest unit, expert assessment, crop modelling, allometric method, remote sensing techniques. It also reveals that in order to examine data collection processes and streamline information flows, different agricultural monitoring systems have been deployed on the regional, national, and global scale, such as the Global information and early warning system (GIEWS), the MARS crop yield forecasting system, or the CropWatch, and so on.

In Australia, agricultural data—which are often criticised for their inaccuracy—are mainly provided by the Australian Bureau of Statistics (ABS). The Australian Government set four main streams for improving the national agricultural statistical system: Consolidation of collection, alternative data sources and collection methods, future collection methods and data sources, and stakeholder engagement. We presented different data collection approaches used for the Australian context, including traditional and new data collection techniques adopted by ABS and other organisations, such as survey, utilisation of administrative data, or use of remote sensing data. Main data correction techniques applied by ABS include using "big data" and "remote sensing satellite data".

We have then developed a function that can be used to rank the priority of commodities in a region. This approach for prioritising commodities can be seen to be useful for selecting priority commodities, as some commodities can be produced in a small area but have high value, but for some other commodities, the production volume is high, but the value is not very high. Finally, we provided examples of the prioritising techniques and commodity value/volume by: (1) priority-ranking some agricultural commodities in Central Queensland, and (2) presenting some information about export value and volume of major crops and horticulture commodities in Queensland. Our review and discussion suggest that there is a scope for improvement in the data collection, monitoring and correction methods used in Australia, particularly for the central Queensland region.

5.1.4 Major agricultural products and supply chains in Central Queensland

As part of the research findings, data/information about some main agricultural products in Central Queensland have been discussed in line with the four major components of the framework/mapping tool, namely product, infrastructure, process, and factors (where applicable) in a general sense.

Among the products, beef seems to be the most important in the region in terms of production and export value. Beef is available throughout the year, but it is perishable and needs special requirements for storing and transporting, and often faces threats due to natural disasters and global climate. In terms of infrastructure, the region is well-equipped for beef production. Cattle farming can be a family or collaboration business. Beef production is often supported by governments and other industries.

Another important product is wheat, a seasonal/weather-influenced but non-perishable product, which needs high-level quality management to meet the demand of consumers in international export markets. Central Queensland, in general, has sufficient facilities for wheat production, which is generally handled by different supply chain members/parties.

Queensland produces nearly half of the Australian chickpeas, an annual crop product, which is quite bulky but non-perishable, and highly attractive in terms of research and investment. Central Queensland region supplies up to 100,000 tonnes for export in bulk, mostly to Bangladesh. The product is often exported to many Asian and North American markets. Infrastructure in the region is suitable to further expansion of chickpea production.

Central Queensland region is also a large sorghum exporter. Sorghum seeds, a dry and non-perishable product, are exported to many countries, but production fluctuates due to weather and other issues. Transportation for this product in Gladstone is well-conditioned. Sorghum is a good alternative to incorporates to the farming system in the region.

Cotton, a high-water demand and bulky product with low bulk density, is often exported to Asian markets. Over 15% of Queensland's cotton is grown in the CQ region. Transportation infrastructure for this product in CQ is available. Continuous research on improving water efficiency in the region may be an advantage to continue the cultivation of the product.

In addition to the above five major products, we also provided a brief overview of other commercial commodities, such as vegetables and herbs, mandarin, mango, lychee, and table grapes; and of emerging crops such as macadamia and aquaculture.

5.1.5 Supply chain maps of selected agricultural commodities

The mapping tool has been applied to initially describe the agricultural supply chains of five case products in the Central Queensland region, using the trial (primary and secondary) data sets. The collected data and the mapping of selected commodities indicate that the supply chains are not identical for the different commodities and even for a single commodity there are diverse supply chains. A beef supply chain is much more complex compared to the other agricultural commodities because of the presence of additional supply chain actors in feedlot and saleyard. Also, a single entity can play multiple roles in the beef supply chain. A beef producer could also be the input provider if the person handled on-farm breeding. A feedlot could have their own cattle and process their cattle with other producers' cattle. The cotton supply chain is much simpler as the number of entities is less compared to the beef supply chain. The cotton gin holds the power to control the market. However, the price is taken from the international market as almost 100% of cotton produced in Australia goes to the export market. The grain supply chain is streamlined, and grain producers send their inferior product to the feedlot as fodder. In this case, products go directly to the consumers from the production site. All the supply chain mapping tools were presented in section 4.3.

5.2 Contributions of the study

5.2.1 Theoretical contribution

5.2.1.1 Contribution in relation to the framework and mapping tool

This study presents a literature review on agricultural supply chain characteristics, which was the basis for developing a baseline framework for describing agricultural supply chains and a mapping tool for collecting information on and characterising of agricultural supply chains in great depth. Content validation through expert review enabled tailored improvements and reliability of the framework and mapping tool.

In constructing the framework and mapping tool, we propose a more holistic look at agricultural supply chain characteristics from a multi-theoretic perspective, where we attempt to portray and integrate productive, structural, relational, operative, marketable, and externally influenced aspects of supply chains in a comprehensive manner. These aspects reflect in multiple supply chain dimensions, product characteristics, product supply, product demand (productive, operative or marketable aspects); hard structure, soft structure, instruments and resources (structural or relational aspects); single-handedness, coordination, collaboration and consolidation (relational aspects); legal factors, relational factors, developmental factors, and environmental factors (externally-influenced aspects)—comprising the four fundamental components of supply chains – product, infrastructure, process, and factors. Our present work, thus, adds value by providing a comprehensive understanding of agricultural supply chains as well as building a theoretical tool (the framework) which will appeal to researchers, and a practical tool (the mapping tool) which can be useful for supply chain stakeholders and those who are concerned with issues related to supply chains in the agriculture sector.

As such, the baseline framework we have developed, which outlines the product, infrastructure, process and factors of/in agricultural supply chains, is a powerful quadripartite-component framework of agricultural supply chain description, which is solidly grounded in the literature and validated by a panel of experts and can be used as a theoretical lens for future research on agricultural supply chains in Australia and in international contexts. The framework has also been used as a skeleton for building a mapping tool for collecting information on and characterising of agricultural supply chains, which provides a basis for further supply chain analysis and evaluation.

5.2.1.2 Contribution in relation to data management

The study, in addition, provides a critical perspective in examining issues in collecting, monitoring, estimating and correcting agricultural data for research or practical purposes, such as for mapping supply chains of case commodities in the present report, or suggesting strategies for more effective export collaboration in the market. As large data sets (published by governments, for instance) are often used for research and policy development, flaws in the data may mislead researchers/data end-users and their research outputs or production/supply activities.

We have suggested some appropriate methods of data collection and correction for the area of concern, that hopefully contribute to potential instruments for improvement of agricultural data. Our literature review and discussion suggest that there is a scope for improvement in the data collection and correction methods used in Australia, particularly for the central Queensland region. These suggestions can be applied widely to agricultural data in other Australian regions and in other countries. Although we focus on agricultural data, our discussion also contributes to alert data collectors and users to similar issues related to collection, correction and variation of other kinds of data such as health, financial or housing data.

5.2.2 Practical contribution

5.2.1.1 Contribution in relation to the framework and mapping tool

Given that efficient agricultural supply chains are important to ensure the continued provision of food and maintain income generation for the region (Schrobback et al. 2020), understanding how supply chains work and mapping supply chains using up to date and reliable data is of critical significance. A mapping tool is, thus, needed to conduct these tasks. The mapping tool we have developed, which combines multiple supply chain dimensions, features and characteristics, will allow general end-users to describe and explore certain agricultural supply chains in detail. The mapping tool, thus, is highly applicable as it can be used to build **a digital database** of systematic information about agricultural supply chains of different products in many contexts (including central Queensland and northern Australia including FNQ, NQ and MIW regions). The supply chain maps of the five case commodities we have provided can be seen as useful examples utilising the mapping tool to build such a database. Available data will allow simplistic and/or sophisticated analysis, evaluation and comparison of supply chains of similar commodities and industries in the region, as well as identification of issues and opportunities across the chain networks (Schrobback et al. 2020).

Comprehensive, systematic and detailed data/information about supply chains of commercially viable large scale agricultural commodities in one or more regions can be collected and managed using the digital form of this mapping tool. The mapping tool can not only indicate volume and value of different agricultural products but can enable the gaps and bottlenecks that exist to be readily identified for targeted response, for example addressing major transport corridors including road, air and water. The mapping tool, in addition, can be seen an instrument for the development of horizontally connected and vertically integrated supply chain networks and markets (i.e., domestic retail, domestic value added, and international).

Firms, companies and other actors in agricultural supply chains who need to simultaneously consider productive, structural, relational, operative, marketable, and externally influenced aspects of supply chains in organising, designing and managing their supply chain may consider the mapping tool as a useful guide in building a systematic map of data. These meaningful data will enable easier tracking, more clarity and better understandings of the network, enhanced communication and transferable and exchangeable knowledge, effective and strategic planning & decision making, and reduced misalignments and risks at a broader scale. The data, which are collected using the mapping tool, will be informative for supply chain actors to determine indicators to follow up on chain structure, operation, and performance, and make informed (rather than general or "one size fits all") solutions in supply chain practice. At a higher level, mapping supply chains using the tool we provide would better inform managers and government institutions to be informed about supply chains' operation, such that it is important for them to prioritise investments into addressing issues and opportunities for each supply chain. (Romsdal et al., 2011; Schrobback et al. 2020).

Long-term benefits from using this mapping tool in systematising agricultural data may also include enhanced supply chain efficiencies, better quality and long-term investment, increased GDP, more jobs and a skilled workforce, as well as happy, healthy, and highly skilled communities.

5.2.1.2 Contribution in relation to using agricultural data in Australia

As we have indicated, reliable agricultural production data are vital for understanding supply and demand gaps of different agricultural commodities as well as planning for shortage or surplus of production. However, agricultural data published by governments or government-affiliated authorities may still contain some inaccuracies or errors, which may mislead researchers/data end-users. Our review on data collection, estimation and correction methods may be applied to manage data about different commodities in different agricultural regions in Australia. Given the contribution of the agriculture sector to Australia's national economy, improved agricultural data would be of huge importance for effective data use among producers, marketers, distributors, and retailers etc., or in transport and logistics industries, and domestic and exports markets' supply chains, as well as for long-term land use and resource planning.

5.3 Translation of the project findings

5.3.1 Translation approach

In an attempt to suggest strategies for connection between knowledge producers and knowledge implementers of the present project, we draw on Graham et al.'s (2006, pp.18-21) knowledge-to-action framework to highlight different phases of conducting and applying the research, which can be accomplished by different (groups of) individual and collective stakeholders at different times. The knowledge-to-action framework consists of two major components, namely KNOWLEDGE CREATION and ACTION CYCLE. Knowledge creation (including three main steps: knowledge inquiry, knowledge synthesis and knowledge product) has been achieved through conducting the present project, while action cycle (including identifying a problem and selecting relevant knowledge, adapting knowledge to the local context, assessing barriers, selecting, tailoring and implementing interventions, monitoring knowledge use, evaluating outcomes, and sustaining knowledge use) is a longer pathway of translation of the knowledge to practical applications. Each step in the action cycle can be influenced by its preceding step, it is better to have feedback between the steps to make sure that the translation process can go as expected. The ten steps of knowledge creation and action cycle in relation to the present study can be understood as follows:

(1) Knowledge inquiry is the process of collecting multiple previous studies of variable quality on the related topic and refine them in a purposive manner to make them valid and useful for readers and potential users, this generates what is called the first-generation knowledge. In this project, knowledge inquiry includes identifying the aim of the research (aiming at developing a baseline framework and a mapping tool for supply chain characterisation), putting forward a research question for the first research activity (i.e., what is known in the literature about common characteristics of agricultural supply chains), and searching relevant literature for addressing the question. Shortly, they can be referred to as SUPPLY CHAIN QUESTION AND LITERATURE

(2) Knowledge synthesis is where researchers apply one or more than one method to identify, make sense of, appraise, and synthesise studies relevant to the research question, and present them in a systematic and theoretical manner. This allows the second-generation knowledge to be elaborated. In this project, knowledge synthesis is the process of conducting deductive and inductive literature reviews on common characteristics (including components, dimensions and features) of agricultural supply chains towards development of a baseline framework and mapping tool. This stage can be labelled as SUPPLY CHAIN REVIEW.

(3) Knowledge products, which is the third-generation knowledge, is a creative process, where researchers present the knowledge which they have synthesised in a clear, concise, and user-friendly format to meet users' needs, and thereby facilitating their uptake and application of knowledge. The present project's knowledge products are the supply chain baseline framework, which was developed from the knowledge synthesis stage. We also tailor, customise and repackage the product to the needs of different intended groups of users, including researchers and general stakeholders, by expanding the framework into a mapping tool (in a tabular format). In addition, an important activity in the present study's process of knowledge production was validation of items in the framework and mapping tool. The "polishing the products" activity allowed us to improve the clarity of the concepts proposed in the framework/mapping tool as well as its comprehensiveness and reliability. This stage can be shortly named as “development of supply chain framework and mapping tool”.

(4) Identifying a problem and selecting relevant knowledge is the initial stage of the knowledge-to-action translation process after the three steps of knowledge creation has been completed. This is where researchers and stakeholders identify or become aware of the knowledge (supply chain framework and mapping tool in this case), and then determine that there is a knowledge-practice gap that needs to be filled or resolved. In relation to the present project, the knowledge-practice gap can be related to how to make the framework and mapping tool applicable. For the framework which targets researchers as its main users, perhaps nothing needs to be done at this stage, as researchers, if they are interested in making use of this framework, will be able to maintain, modify and adapt so it would suit their research purpose. The mapping tool, which targets general stakeholders is, however, just an “on-paper” tool in its current form. In order to have a real and powerful tool to systematically gather agricultural supply chain information, as stated earlier, it needs to be digitalised. In other words, a usable digital/online mapping tool, which draws on the tool introduced in the present study, needs to be developed. It is hence critical to address this knowledge-practice gap to facilitate the next steps of the knowledge-to-action process. This important stage can be called “digitalisation of mapping tool”.

(5) Adapting knowledge to the local context is another important step, that helps localise the knowledge products. At this stage, researchers and stakeholders can work together to make decisions about the relevance, usefulness, and appropriateness of the mapping tool and its dimension/feature categories to their setting and circumstances and customise the tool to the particular agricultural commodities in particular regions. As we stated earlier, it is impractical to expect that this mapping tool, and all its dimensions/features, can be applied to gather information about all agricultural supply chains in the same way. In other words, for some agricultural products in a certain region, some features (such as perishability or bulkiness) may be “must-have” information, but for some other products, these features are not very important. It is therefore necessary that the digital mapping tool should be designed in a way which allows a maximum of flexibility and inclusiveness, so that it can be applied to different products and different regions. The design of the digital mapping tool for a particular region, in addition, should prioritise dimensions/features which are considered to be most important for the region’s planning strategies in relation to the products. Including and managing “required” and “optional” features in the digital mapping tool can be a useful way to do that. This step, generally, can be referred to as “adaptation of mapping tool”.

(6) Assessing barriers that may limit uptake of the knowledge and research products in practice is the next step which needs to be taken into careful consideration. In relation to the present study, we suggest that there are three main barriers in using the mapping tool to gather information about agricultural supply chains, namely data barriers, personnel barriers and financial barriers. (1) Data Barriers: As we previously indicated, the most crucial barrier is related to possible inaccuracies or flaws in data which are entered in the database of different agricultural products using the digital mapping tool. Inaccurate data and information may mislead data users and prevent them from building/understanding a comprehensive and reliable map of the supply chain of the products. In addition to quantitative/documentary data, qualitative data about the supply chain’s operation and management (e.g., level of dependency, information sharing and communication, etc.) are needed to build better insights into how the supply chain of a product works. Moreover, qualitative data are not “accurate” or “correct” in the sense we often evaluate and understand quantitative and documentary data; and thus, it often takes more time to collect, handle and attest qualitative data to ensure their validity and reliability. (2) Personnel Barriers: Another possible barrier is about who should be the one who looks after this mapping tool and uses it to gather data, as data about particular agricultural products, which align with the different components, dimensions and features of the mapping tool, often come from different sources and are sometimes not easy to be found and collected. Different parties/stakeholders (industry peak bodies, producers, specialists, marketers, wholesalers, governments, etc.) may possess different parts of data. The parts of data need to come together to shape complete supply chain maps. (3) Financial barriers: Digitalisation of the mapping tool, developing, maintaining and managing a database of agricultural supply chains may be costly. The question of who should provide financial support or who should be financially responsible for these costs, needs to be seriously considered in the preparation stage of the knowledge-to-action process.

Although these barriers are not about the knowledge product itself, they need to be managed as the mapping tool can only be used effectively alongside capable and productive personnel, as well as with a high-quality and reliable data set. This action step, thus, can be seen as “data, personnel and financial assessment”.

(7) Selecting, tailoring and implementing interventions is the step where actions are taken to deal with the identified barriers (above), and to facilitate awareness and implementation of knowledge. As indicated above, barriers related to quantitative, documentary and qualitative data, as discussed above, can be a drawback in using the mapping tool to build a database about supply chains of different agricultural products. In the present study (Section 3.2), we have already reviewed some methods for dealing with inaccuracies or flaws in quantitative and documentary data, which have been used in Australia and other contexts. The literature review and discussion in this Section suggest that there is a scope for improvement in the data collection, monitoring and correction methods used in Australia, particularly for the central Queensland region. Regarding qualitative data, additional techniques such as triangulation, comparison, member check, peer debriefing, and so on. may be useful to ensure the validity and reliability of data. Regarding personnel, different parties/stakeholders would have their own strategies to get the data available to them. However, in order to build a rich database about agricultural products, collaboration among the parties is of critical importance. Industry peak bodies may be one of the parties who could manage this database. Regarding financial issues, it is important to determine who would commit financial sponsorship, management and safety for the project, and/or what can be sustainable financial sources for the project, given that building and maintaining a high-quality database is a long-term and costly task. This step, in summary, can be labelled as “data, personnel and financial management”.

(8) Monitoring knowledge use is the phase where it is important to define different types of knowledge which can be applied in practice in order to determine whether the interventions (above) have been sufficient to bring about the expected change after the initial introduction of the adapted knowledge and reassessment of, the barriers and interventions if necessary. In relation to the present project, this is the stage where the database of supply chain information is built. During and after such a process, different parties may define the types of knowledge use that suits their own purpose. The knowledge use can be (1) conceptual use of knowledge (changes in understandings and attitudes, such as being aware that having a rich database about supply chains of different agricultural products in the region would be advantageous for many parties), (2) instrumental use (changes in practice or behaviour, such as being willing to be accountable about supply chain information and contribute to information sharing in building the database), and (3) strategic use (focusing on specific power or profit goals, such as comparing supply chains in the region, as well as their strengths and weaknesses, drawing on the information in the database, to determine strategic agricultural commodities of the region, which need more careful planning and investment. This is also one of the long-term impacts which we suggested in conducting the present project). At this phase, it is necessary to identify other barriers and further interventions, which are needed to attain the goal of knowledge translation, depending on what types of knowledge is the focuse (conceptual, instrumental or strategic). This step can be shortly named as “development, management and utilisation of a database”.

(9) Evaluating outcomes is an important step which is needed to evaluate whether the knowledge-to-action process is successful, to what extent and determine the impact of the use of the knowledge. For the supply chain mapping tool, it may take a long time to see and evaluate the outcomes and impact of using the database, which are related to effective supply chain organisation and management, more effective production and transportation, higher volume of quality products for export, and so on. This stage can be called “evaluation of the impact of supply chain maps”.

(10) Sustaining knowledge use, the last phase of the knowledge-to-action cycle, can be seen as a “sustainability phase”. This is when there are more barriers occurring during the on-going use of the product (the mapping tool and database in this case), and stakeholders may need to select, tailor and implement further interventions in order to maintain and monitor the on-going knowledge use effectively. The barriers, for example, can be related to the need to update the data in the database/supply chain maps regularly, given the nature of the active and rapidly changing sector, as well as of data and information which are changing from day to day. Sustaining knowledge use, thus, can be seen as a feedback loop that cycles through the knowledge-to-action process. In relation to the present study, this step can be labelled as “update and refinement of supply chain maps”.

In summary, the 10 major steps of the present research’s knowledge-to-action process can be represented in Figure 24:

Figure 24: Knowledge-to-action process of supply chain mapping tool
Source: Adapted from Crockett (2017) and Graham et al.'s (2006)

5.3.2 Translation pathway: Guidelines for end-users

Drawing on the knowledge to action process discussed above, we provide here some recommendations for stakeholders who work with or are involved in, the agriculture sector, who are interested in building and using agricultural supply chain maps for their region. We suggest that all group or individual stakeholders can, to different extents, contribute to this task. Key recommendations are listed in Table 30:

Table 29: Mapping tool guidelines for end-users

End-users	What to do
Researchers, supply chain and economic development practitioners	• Applying or adapting the framework to different research purposes. • Working with the stakeholder who leads the task of building a supply chain database to digitalise the mapping tool. • Working with the stakeholder who leads the task to assess barriers related to data and personnel. • Contributing to evaluating the impact of supply chain maps
Industry peak bodies (have potential to lead the task of building supply chain database)	• Working with researchers/practitioners to digitalise and adapt the mapping tool. • Working with researchers and other stakeholders to assess barriers related to data and personnel. • Building and managing the supply chain database/supply chain maps • Using information from the database/supply chain maps to make decisions. • Working with researchers and other stakeholders to evaluate the impact of supply chain maps
Farmers/Producers	• Contributing information to the supply chain database if possible. • Using information taken from the database/supply chain maps to make decisions on their own production
Manufacturers	• Contributing information/data to the supply chain database. • Using information taken from the database/supply chain maps to make decisions on their own manufacturing and processing
Distributors	- Contributing information/data to the supply chain database. - Using information taken from the database/supply chain maps to make decisions on their distribution of agricultural products
Exporters/Wholesalers/retailers	- Contributing information/data to the supply chain database. - Using information taken from the database/supply chain maps to make decisions on providing agricultural products for export markets and to consumers
Investors/Governments	- Contributing information/data to the supply chain database. - Using information taken from the database/supply chain maps to make decisions on management, policy, funding, investment and other issues.

5.4 End use and end-users of the research output

In the current research, we have developed a state-of-art agricultural supply chain mapping tool. In addition, we have explored some data gaps between the ABS-published data and the ground-level data. We have also presented a translation pathway for the current research findings and guidelines for the end users. It is believed that these research findings will help three groups of stakeholders: producers, industry bodies and government bodies (both local and state).

Producers: The supply chain mapping tool will provide a simplified platform for the producers for record keeping and identifying potential future opportunities. An updated mapping tool would inform the producers about the potential market, accessibility to different markets and legal and environmental factors associated with the export markets. These will help them in decision-making and sending their product to the appropriate market to maximize revenue. The mapping tool should also inform the producers about the logistics and infrastructure within the region, which they could access to enhance the efficiency of the supply chain. This mapping tool may also help the producers to recognise the existing collaboration within the supply chain and lead them to join in such collaboration. Product innovation and value-added products within a region may attract new producers and they might find this information from the mapping tool. It was mentioned earlier that all relevant data for the mapping tool need to be collected from different sources, and the producers could contribute to the mapping tool by updating their information regularly.

Government bodies: The local government would be the greatest beneficiary from the output of this research, and they would have a significant role to keep the tool and data updated. It is understandable that not all LGA would be interested in every single agricultural commodity, and they can focus on the most established and most promising commodities within their LGA. In the current study, we have selected five commodities with another two commodities, which are locally specialized, as case studies. Table 31 represents the production volume of these commodities within six LGA within CQ in 2020-21. It is evident that most of the CQ agricultural productions come from two LGAs, CHRC and BSC. However, the recent development of the Rookwood weir may lead to a production boost in the Rockhampton regional council. CHRC could focus their attention on all case study commodities and develop the mapping tools for best practice scenarios. It needs to be noted that mandarin production in the central highland region was not included in the ABS statistics because of business confidentiality. On the other hand, BSC would be interested in the five prime commodities and hosting these mapping tools.

Table 30: LGA specific production of selected agricultural commodities in CQ in 2020-2021

	Agricultural commodities						
LGAs	**No of meat cattle**	**Wheat (tonnes)**	**Chickpea (tonnes)**	**Sorghum (tonnes)**	**Cotton (tonnes)**	**Mandarin (tonnes)**	**Table grapes (tonnes)**
RRC	81,989	1,174.0	55.0	2,478.0	11.7	NA	NA
CHRC	895,872	84,715.0	40,553.7	122,292.2	13,434.0	NA	5,920.0
GRC	109,794	NA	NA	138.0	NA	NA	NA
BSC	580,165	38,710.8	3,524.9	29,744.3	13,569.0	33.0	NA
LSC	237,440	272.0	NA	974.0	NA	351.0	NA
Woorabinda	6,890	346.0	NA	363.0	54.8	NA	NA
CQ	1,912,150	125,218.0	44,272.5	155,989.6	27,070.0	384.4	5,920.3

- NA: not available.

The applications of the mapping tool would be manifold in the LGA setting. This mapping tool would provide information regarding the strength and weaknesses of the different agricultural supply chains within the region. If an LGA is specialized in beef production, local and state government need to ensure the smooth movement of the product through the supply chain. The mapping tool could be used as a strong communication tool between the government bodies and the producers to identify the bottleneck in the supply chain and resolve them in collaboration. The mapping tool would also be a good platform to inform the producers and investors about the recent development within the region. The government bodies in collaboration with the industry bodies could update the factor-related components in the mapping tool. These would attract new producers within the region to access new markets and engage in collaboration. Attracting investors and engaging new producers in the region would improve the economic outlook of the region.

Industry bodies: Industry bodies of the selected commodities are in a good position to host the mapping tool and update it regularly. The mapping tool would provide the industry body with a clear picture of the supply chain and where further development is required. An individual farmer could use their mapping tool to track the supply chain of their produce. However, for further improvement both in efficiency and production the producers need to follow the best practice scenario. Industry bodies are well placed to collect data from numerous producers to develop the best practice scenario mapping tool. Individual producers then could be able to compare their cases with the best practice case and modify accordingly. The mapping tool would be a great showcasing tool for the industry bodies to attract new investors. The industry body could also use the mapping to identify relevant stakeholders to develop collaboration among the supply chain actors.

5.5 Stakeholder forum discussion

The research team organised two face-to-face stakeholder forums in Emerald and Rockhampton in February and March 2023 respectively to disseminate the project findings and identify the way forward. Participants from the different stages of the agriculture supply chain such as producer, industry bodies and government officers participated in the stakeholder forums. Sixteen stakeholders attended the Emerald stakeholder forum, while ten stakeholders attended the Rockhampton forum. The research team presented the project outputs and opened the floor for discussion. The key discussion themes were 1) usability of the agriculture supply chain (ASC) mapping tool, 2) implementation of the ASC Mapping Tool, and 3) development & management of the ASC Mapping Tool.

During the discussion on the usability of the mapping tool, stakeholders from both forums agreed that it is an important tool for the agriculture industry and agriculture-producing regions. The participants acknowledged that the mapping tool would provide a regional snapshot for development updates and help the new producers to understand the complexity of the supply chain. One producer from the Emerald region said that it could help the farm business planning. One regional council representative thought the mapping tool provided one layer of information that could be a part of the existing information that the local government and industry bodies had. One of the industry representatives suggested integrating the tool with other relevant tools developed by DAF and CSIRO (Commonwealth Scientific and Industrial Research Organisation). Regarding the data included in the case study mapping tools of seven selected commodities, most participants believed that the information provided was at the high or medium level. They mentioned that there were opportunities to enhance the mapping tool with more micro-level data. They also suggested making it more visually appealing for potential investors. One of the regional council representatives added that water resource in the region was not highlighted in the mapping tool significantly. However, it could be included under the dimension of infrastructure in the mapping tool. Most participants agreed that the mapping tool could be used as a training / educational tool for stakeholders at different levels. One suggestion from the stakeholders was to include opportunities and challenges of the existing supply chain in the mapping tool. This would clearly indicate the bottleneck in the supply chain, and then it would be helpful to identify the solution collaboratively.

Most participants agreed that data entry would be a major challenge for the ASC mapping tool. The research team proposed data updates every three to five years, and there was a consensus among the participants. However, one industry representative raised a question about the type of data and added that quantitative data would be easy to update. The research team confirmed that the mapping tool comprises both quantitative and qualitative data. One of the producers argued that the niche commodity producers might not be reluctant to share their data. One of the industry representatives argued for more detailed data for the case studies. The industry representative added there was room for further development, and the key challenge would be sourcing reliable data. The participants agreed that developing an online webpage for the ASC mapping tool would be helpful to auto-populate data in the mapping tool. Some participants thought that some components need more expansion, for example, the carbon economy could be included in the environmental factor. Some participants thought that the road infrastructure should be more prominent in the mapping tool. One of the producers said the social licences could be fitted in the legal factors as they were important for the processing industries. Some participants discussed the interaction of different components in the mapping tool as they were not explicitly indicated in the mapping tool. The baseline framework had some implicit relationship among the dimensions, indicated by two-way and one-way arrows. Regarding the IoT platform of the mapping tool, the participants did not see much value in developing an app for the mapping tool.

Most participants believed that the management of the mapping tool could be done through a joint venture among the end-users and industry bodies. One industry representative argued that the management option dependent on the level of data. Some participants thought that local government bodies could also be a part of the joint venture for managing the mapping tool. The commercial prospect of the ASC mapping tool was turned down by the participants. One of the regional council representatives argued that the producers and industry bodies would not pay for the licence of the ASC mapping tool as they presumed that they knew all the information available in the tool. The investors might purchase the licence of the tool only if it contained detailed data.

5.6 Recommendations and future research

This project has developed a baseline framework and mapping tool to characterise agricultural supply chains, identified issues in the collection and reporting of agricultural datasets, presented information about commercially viable agricultural products in the CQ region, and mapped the supply chains of seven case commodities using the ASC mapping tool. Based on the findings of the study, key recommendations are presented below:

Utilise ASC baseline framework and mapping tool: The ASC framework comprises four domains (product, infrastructure, process, and factors) which are useful for considering supply chain activities from theoretical and practical perspectives. The accompanying mapping tool offers direct benefits to supply chain actors, who will be able to use it to better understand the different combinations of supply chain characteristics and supply chain members in terms of operation, efficiency, responsiveness, and compatibility. Therefore, the study has recommended to digitise the mapping tool on an online platform, so the agricultural supply chain actors would be able to use this for their decision making and developing strategic collaboration among them.

Enhancing resilience to input supply chain price shocks: One of the key challenges for the agricultural supply chain in the CQ region is to securing input supply for agricultural production. In most cases, the inputs are supplied from outside the CQ region and that increases the cost for the producers as the transportation costs are added in. Also, the recent price hike of fertilizers makes cropping and horticulture production less profitable. There is a need for developing resilience in the supply chain to external price shock. Producers, input providers, local and State government bodies could work together to develop resilience in the agriculture input supply chain.

New export market discovery: QLD chickpea production and export experienced a rapid downfall from 2017-18 when India increased the import tariff for chickpeas. Currently, the QLD chickpeas industry is recovering by exporting to two other south Asian countries Bangladesh and Pakistan. The participant in the stakeholder forum also acknowledge that the domestic market is saturated and there is a need to identify potential export markets. The exporters should be prepared for any disruption in the existing export market by identifying and engaging with alternative export markets. Therefore, this study suggests that the exporters, industry and the government should work together to unveil new export destinations.

Product innovation: CQ produced almost all the commodities that are produced in other regions in Queensland but the value chain opportunities in this region is very limited. Therefore, the study suggests that local and state governments and industry bodies should organise long term planning and resources for value chain industries within the CQ region for some commercially viable commodities.

Developing skilled labour force: Skilled labour shortage is one of the common challenges faced by local producers. Some stakeholders also expressed their concern about the closing of multiple agricultural colleges. This restricts the direct pathway for developing skilled labour forces. A regional university such as CQUniversity should take more responsibility to develop and offer additional courses that might contribute to the regional agricultural industry.

Improve transport and logistic systems: Most stakeholders identified that CQ has moderate transport and logistics system for the agricultural industry. A further improvement in the transport and logistic system would reduce the product delivery lead time and enhance the supply chain efficiency.

Better utilization of Gladstone port: Gladstone port is a major seaport in CQ and is mainly used for mineral transportation. However, the port has a grain handling facility which is currently underutilized. Most of the stakeholders were wondering if the port could be better utilized by shipping locally produced commodities including grains, legumes and even cotton. The port representative emphasised to find the anchor business/commodities to operate the grain handing facility more efficiently. The seasonal production volume is required to identify anchor businesses. .Digitalisation of the proposed mapping tool and regular data updates would help the port authority to prepare a operational plan to utilize grain handling facility within the port.

Enhancing the governance structure for fair power distribution among the supply chain actors: The producers are affected by the uneven power distribution within the supply chains. Whenever a single entity holds the maximum power, that may lead to price discrimination. In the beef industry, producers can only send their cattle to meat processing (abattoirs) and after processing the producers don’t have any control over the beef and can’t send the product to the desired market. In the cotton supply chain, the producers can send their product to their desired market after ginning.

However, there is only one cotton seed supplier in Australia, which create an unbalanced power distribution. This problem can be solved by setting up strategic governance mechanisms among the supply chain actors.

Further research for ASC mapping tool implementation: In building the mapping tool, we have highlighted that this tool will allow general end-users to systematically collect relevant data/information to describe and explore certain agricultural supply chains in detail. We expect that the tool will be practical, functional, applicable, and user-friendly, which is useful for all those who are involved and interested in agricultural supply chain characterisation not only in Central Queensland, but also in other agricultural context in the world (adaption may be needed to make the tool appropriate to particular settings and circumstances). There may be, however, possible risks associated with supply chain mapping, such as: issues related to inaccurate data (which we mentioned previously), missing important data, personnel needed to look after the mapping tool and database, or difficulties in (regularly) updating new data/information and changes in the supply chains (Schrobback et al., 2020). These risks should be properly managed for effective use of the mapping tool. We recommend future research on the following areas:

- **Digitalisation of mapping tool:** It would be beneficial for the agricultural supply chain actors to create a webpage and/or app based on the mapping tool presented in this study. The web portal would be inter-connected with the ABS/ABARES data set and automatically draws data when they are published. However, some data may need to be introduced to the tool manually. During the stakeholder forum the participants agreed on developing web-based portal for the mapping tool, however, they were not in favour of developing the app.

- **Utilisation of the mapping tool to develop collaboration among the supply chain actors:** The supply chain mapping tool will enable the supply chain actors to visualize the entire supply chain and identify the bottlenecks within the system. It would also help them to recognize the other entities who might help them to resolve the bottlenecks through collaboration. This could eventuate in a community of practice of sorts amongst the supply chain communities. Future studies could investigate such prospects for agricultural commodities with inefficient supply chains.

- **Development of a data collection mechanism at the farm level:** This study identified the variation in the agricultural production data at the regional level which impedes future planning and investment. Through a ground-truthing approach, the research team has collected some data from the producers and industry bodies. A similar approach can be adopted in future studies in collaboration with peak industry bodies to develop a production data repository for regional locations.

- **Utilising the mapping tool for training and educational purpose:** The mapping tool would be a great resource for the new entrant in the production and industry sector. Future research could identify the potential of the mapping tool as an educational resource.

- **Commercialisation of the mapping tool:** It would be worth conducting further research on the commercial prospect of the mapping tool. The data collected from the ABS will only present the mapping tool at the state or regional level. To tailor the supply chain mapping tool at the micro (farm) level, producers need to use their own data set for the mapping tool. Royalty fees for the mapping tool apps can be collected from the interested parties and that would help to raise revenue for further research and development work. However, the commercialization of the mapping tool on the current format may not be feasible for the small and medium scale producers but a sophisticated development of the mapping tool with data analytic would be beneficial for the large-scale producers, investors, exporters, importers, distributors, retailers, local and state governments.

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Appendices

Appendix 1

Table: Agricultural Commodities of Central Queensland (2019-2020) (Descending order based on the gross value of the commodities)

Commodity description	Estimate	Value of agricultural commodities (Gross value ($)	Number of agricultural businesses
Livestock - Cattle - Total cattle (no.)	1,771,853	1,115,946,522	2030
Cereal crops - Wheat for grain - Production (t)	151,774	59,215,572	150
Other crops - Pulses and legumes - Chickpeas - Production (t)	70,826	53,428,331	83
Other crops - Cotton (irrigated and non-irrigated) - Lint production (kg)	20,036,259	48,965,245	40
Cereal crops - Sorghum for grain - Production (t)	68,543	26,612,435	123
Fruit and nuts - Grapes - Total - Production (t)	5,692	23,447,045	22
Hay and silage - Total pasture, cereal and other crops cut for hay and silage - Production(t)	84,931	22,011,817	363
Other crops - Pulses and legumes - Other pulses - Production (t)	16,902	19,418,957	59
Cereal crops - Maize for grain - Production (t)	19,348	9,503,090	36
Fruit and nuts - Nuts - Macadamias - Production (t) (g)	1,502	9,386,768	4
Livestock - Pigs - Total (no.)	15,600	9,336,398	1
Fruit and nuts - Plantation fruit - Pineapples - Production (t)	9,751	8,613,021	17
Cereal crops - Barley for grain - Production (t)	11,537	4,248,455	13
Fruit and nuts - Orchard fruit - Mangoes - Production (t)	764	1,808,759	9
Cereal crops - Oats for grain - Production (t)	4,047	1,671,584	13
Livestock - All other livestock n.e.c. (no.) (p)	10,410	1,103,019	969

Livestock - Poultry and eggs - Live poultry - All other poultry (no.)	42,604	811,866	22
Cereal crops - All other cereals for grain or seed - Production (t)	750	293,606	5
Livestock - Sheep and lambs - Total (no.)	18,154	190,158	29
Fruit and nuts - Orchard fruit - Mandarins - Production (t)	74	167,247	13
Fruit and nuts - Orchard fruit - Avocados - Production (t)	36	144,889	2
Fruit and nuts - Orchard fruit - Oranges - Production (t)	74	123,139	2
Other crops - Oilseeds - Other oilseeds - Production (t)	129	106,837	4
Vegetables - Melons - Production (t) (i)	57	51,874	2
Vegetables - Pumpkins - Production (t)	11	10,467	2
Vegetables - Tomatoes - Production (t)	4	9,842	1
Vegetables - Sweet corn - Production (t)	4	8,361	1
Vegetables - Cauliflowers - Production (t)	4	4,066	2
Fruit and nuts - Plantation fruit - Bananas - Production (t)	Some local production	217	1

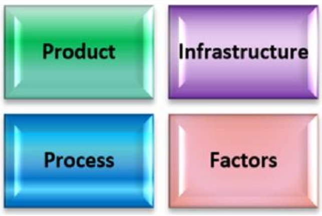
Source: ABS, 2021c, Value of Agricultural Commodities Produced, Australia, 2019-20, Cat. No. 75030DO001_201920

ABS 2021d, Agricultural Commodities, Australia–2019-20, Cat No. 71210DO001_201920

Appendix 2

Agricultural Supply Chain Baseline Study
MAPPING TOOL SURVEY 2022

We have developed a mapping tool for agricultural supply chain characterisation, in which we identify four domains of agricultural supply chains, namely Product, Infrastructure, Process, and Factors. This survey is to find out your perspectives on supply chain features associated with these four domains.



The questionnaire will take about 10-15 minutes to complete. While you are answering questions in this survey, please refer to the mapping tool attached in the email we sent you recently.

We very much appreciate your assistance in completing the survey.

Thank you.

Assoc. Prof. Delwar Akbar
Centre for Regional Economies and Supply Chains (CRESC), CQUniversity
Email: d.akbar@cqu.edu.au. Phone: 074923 2316.

YOUR CONSENT

Before you proceed to the survey, could you confirm that you understand that:

- An information sheet about the research project on Central Queensland regional agricultural supply chain baseline study has been provided to me, which I have read and understood.
- I understand that my participation in this research is entirely voluntary. My non-participation or withdrawal of consent will have no consequences.
- I understand that I will have the right not to provide information that is of personal nature and/or commercially sensitive.
- I understand that any information or personal details gathered during the study will remain confidential and that all responses are anonymous. I also understand that the research team may not be able to remove my responses once they are submitted.
- I understand that findings from this questionnaire will be used to develop publicly available reports, journal articles or conference presentations.
- I am aware that I can contact the research team directly should I have any questions or concerns about my participation in this study.
- If I have concerns or complaints regarding the way the research is or has been conducted, I can contact the Ethics Officer at CQUniversity via phone: 07 4923 2603 or email: ethics@cqu.edu.au.
- I am confirming that I am 18 years old or above.

○ I understand and give consent

○ I have decided not to participate further in this research

1. Which of the following sectors do you identify most with? (i.e., which one are you currently working in?)

- ◯ Industry peak body
- ◯ Producer/grower
- ◯ Marketer/exporter
- ◯ Federal government
- ◯ State government
- ◯ Local government
- ◯ Researcher
- ◯ Other (Please specify)

2. How important is it to include ……………..(the below items) in the mapping tool as a feature in the **PRODUCT** domain of agricultural supply chains (the items are related to **product characteristics**)?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Food type	◯	◯	◯	◯	◯
Product category	◯	◯	◯	◯	◯
Perishability	◯	◯	◯	◯	◯
Seasonality	◯	◯	◯	◯	◯
Bulkiness	◯	◯	◯	◯	◯

3. How important is it to include ……………..(the below items) in the mapping tool as a feature in the **PRODUCT** domain of agricultural supply chains (the items are related to **product supply**)?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Type of product processing	◯	◯	◯	◯	◯
Farmgate-to-shipping time	◯	◯	◯	◯	◯
Product life cycle	◯	◯	◯	◯	◯
Product variety	◯	◯	◯	◯	◯
Product innovativeness	◯	◯	◯	◯	◯
Product value	◯	◯	◯	◯	◯
Value adding	◯	◯	◯	◯	◯
Supply uncertainty	◯	◯	◯	◯	◯
Stock ability	◯	◯	◯	◯	◯
Delivery lead time	◯	◯	◯	◯	◯

4. How important is it to include ....(the below items) in the mapping tool as a feature in the **PRODUCT** domain of agricultural supply chains (the items are related to **product demand**)?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Market type	◯	◯	◯	◯	◯
Market distance	◯	◯	◯	◯	◯
Access to market	◯	◯	◯	◯	◯
Demand uncertainty	◯	◯	◯	◯	◯
Consumer segmentation	◯	◯	◯	◯	◯

5. Do you think the above items are sufficient to describe major features related to supply chain **PRODUCT**?

◯ Yes

◯ No (please specify)

6. How important is it to include .... (the below items) in the mapping tool as a feature in the **INFRASTRUCTURE** domain of agricultural supply chains?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Number of entities	◯	◯	◯	◯	◯
Type of networks	◯	◯	◯	◯	◯
Level of dependency	◯	◯	◯	◯	◯
Transport	◯	◯	◯	◯	◯
Technology	◯	◯	◯	◯	◯
Labour force	◯	◯	◯	◯	◯

7. Do you think the above items are sufficient to describe major features related to supply chain **INFRASTRUCTURE**?

◯ Yes

◯ No (please specify)

8. How important is it to include ……………… (the below items) in the mapping tool as a feature in the **PROCESS** domain of agricultural supply chains?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Single-handed production	◯	◯	◯	◯	◯
Single-handed business	◯	◯	◯	◯	◯
Contracting	◯	◯	◯	◯	◯
Communication	◯	◯	◯	◯	◯
Information sharing	◯	◯	◯	◯	◯
Power distribution	◯	◯	◯	◯	◯
Shared strategies and interests	◯	◯	◯	◯	◯
Shared business culture	◯	◯	◯	◯	◯
Trust and commitment	◯	◯	◯	◯	◯
Brand consolidation	◯	◯	◯	◯	◯
Freight consolidation	◯	◯	◯	◯	◯

9. Do you think the above items are sufficient to describe major features related to supply chain **PROCESS**?

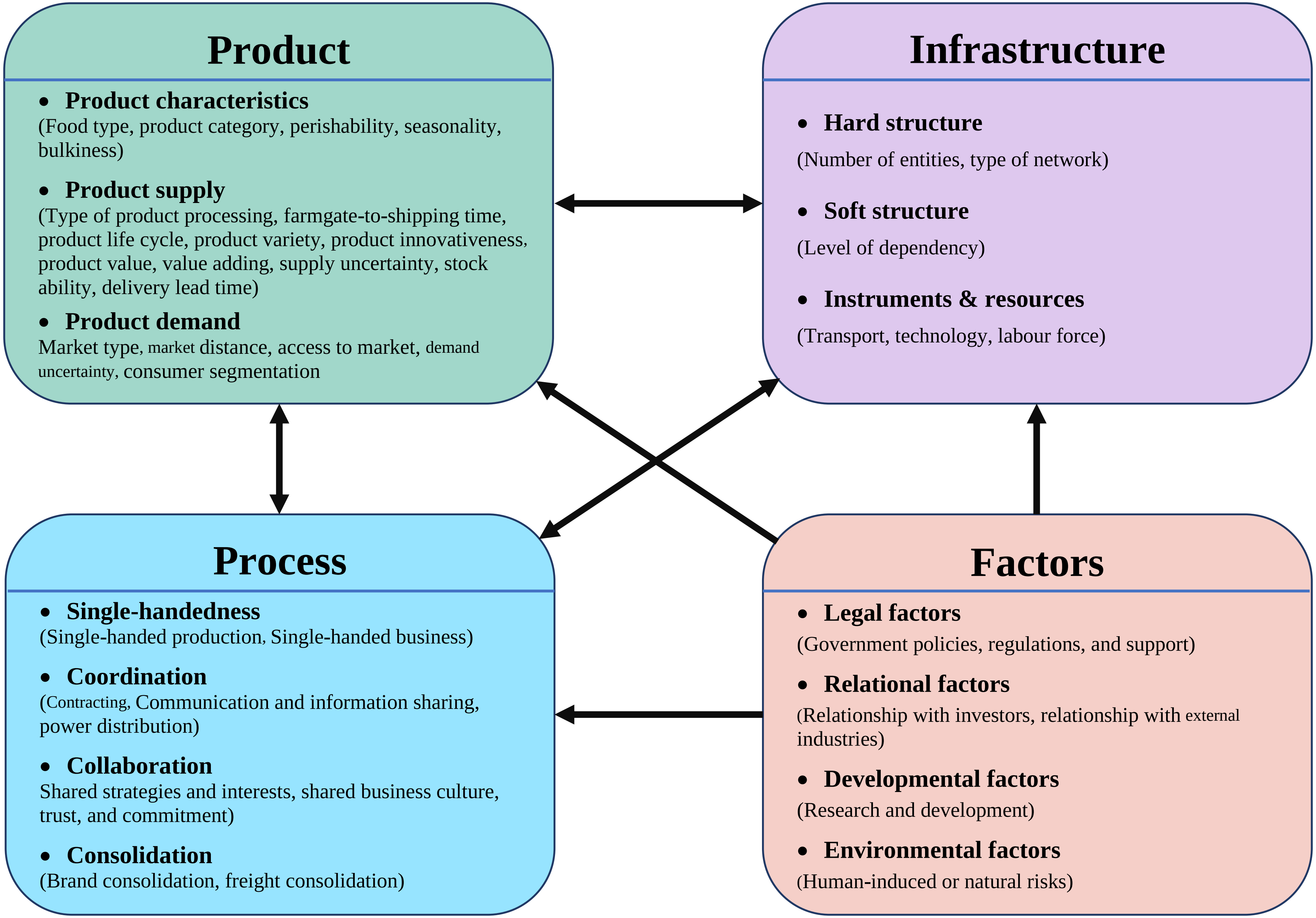
◯ Yes
◯ No (please specify)

10. How important is it to include ……………… (the below items) in the mapping tool as a feature in the **FACTORS** domain of agricultural supply chains?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Government policies and regulations	◯	◯	◯	◯	◯
Government support	◯	◯	◯	◯	◯
Relationship with investors	◯	◯	◯	◯	◯
Relationship with external industries	◯	◯	◯	◯	◯
Research and development	◯	◯	◯	◯	◯
Natural or human-induced risk	◯	◯	◯	◯	◯

11. Do you think the above items are sufficient to describe major features related to **FACTORS** that influence supply chains?

◯ Yes
◯ No (please specify)


Product
Product characteristics
(Food type, product category, perishability, seasonality, bulkiness)
Product supply
(Type of product processing, farmgate-to-shipping time, product life cycle, product variety, product innovativeness, product value, value adding, supply uncertainty, stock ability, delivery lead time)
Product demand
Market type, market distance, access to market, demand uncertainty, consumer segmentation
Infrastructure
Hard structure
(Number of entities, type of network)
Soft structure
(Level of dependency)
Instruments & resources
(Transport, technology, labour force)
Process
Single-handedness
(Single-handed production, Single-handed business)
Coordination
(Contracting, Communication and information sharing, power distribution)
Collaboration
Shared strategies and interests, shared business culture, trust, and commitment)
Consolidation
(Brand consolidation, freight consolidation)
Factors
Legal factors
(Government policies, regulations, and support)
Relational factors
(Relationship with investors, relationship with external industries)
Developmental factors
(Research and development)
Environmental factors
(Human-induced or natural risks)

Appendix 4

Table: Mapping tool for agricultural supply chain characterisation (DRAFT version)

Supply chain name and location:

……

Date: ………

		Feature	Explanation	Data entry
Product	Product characteristics	**Food type**	Type of food the supply chain provides (horticulture, grain, animal protein, dairy, aquaculture product, *non-food* agriculture product…)	
		Product category	Product category on which the supply chain is based (processed, lightly processed, fresh…)	
		Perishability	Level of perishability the food has (low/high perishable, long-life…)	
		Seasonality	Availability of the product in certain seasons (spring, summer, autumn, winter, rainy, dry season…)	
		Bulkiness	Level of bulkiness the product has (bulky, non-bulky…)	
	Product supply	**Type of product processing**	Specific features of the supply chain related to the handling and temperature control (chilled, cold, frozen, normal room temperature, handle, cattle handle, or mixed-processing types…)	
		Farmgate-to-shipping time	Average time needed for transporting the product, from farm-gate to processing centre and from processing centre to ship/aeroplane (number of days…)	
		Product life cycle	Complete lifespan of a product, from raw materials until final disposal (short, average or long-life cycle…)	
		Product variety	Number of different product forms which a supply chain offers to consumers (one, two, three…) [please specify].	
		Product innovativeness	Application of a new attribute in a product to make it more attractive to consumers (new preservation technology, new package...)	
		Product value	Nutritional/economic value, and safety/environmental/ethics credence of the product (high/low nutritional/economic value, high/low economic value, high/low safety/environmental/ethics credence …)	
		Value adding	Value added to a product by processing it as desired by customers ($/unit…)	
		Supply uncertainty	Supply uncertainty (high, low…) related to materials/product availability, product amount, or in-time delivery.	
		Stock ability	Capacity to stock the product (high, low, flexible…)	
		Delivery lead time	Duration between the time (individual and/or firm) customers place their order to the time they receive their product (number of hours, days, weeks, months…)	

	Product demand	**Market type**	Type(s) of market and market segmentations the supply chain has access to (local, international, domestic, export, low/high-value market…)	
		Market distance	Spatial distance between producers and consumers of the product (number of kms from production location…)	
		Access to market	Supply chain's market accessibility (yes, no, high, low, which markets…)	
		Demand uncertainty	Level of instability of and difficulties in predicting consumer preferences and expectations of the product (high, low, which markets…)	
		Consumer segmentation	Consumer segmentations based on demographic and socio-economic characteristics which the supply chain targets (domestic, overseas, high-income, highly educated, female, young…)	
Infrastructure	Hard structure	**Number of entities**	Number of individuals, firms, companies and other entities participating in the supply chain, including both upstream and downstream entities (three, four, five….) [please specify].	
		Type of networks	Way of organising the supply chain (vertical, horizontal, hybrid…)	
	Soft structure	**Level of dependency**	Level of dependency between entities in the supply chain (high, low, mixed…)	
	Instruments & Resources	**Transport**	Types of transport needed (e.g., road, rail, air…); and accessibility or availability of transport (yes, no, high, low…)	
		Technology	Availability of or capacity to apply new farm/non-farm technologies in production, harvest, distribution and/or transportation (yes, no, high, low…)	
		Labour force	Supply chain's size of labour force (small, average, large, flexible…); seasonality of labour (production/harvest time, holiday time…); and employment structures (permanent labour, casual labour…)	

Process	Singlehandedness	**Single-handed production**	All production processes/activities undertaken by an independent entity, with no long-term collaboration with others (yes, no…) [please specify if yes].	
		Single-handed business	All transport, distribution, marketing and sale processes/activities undertaken by an independent entity, with no long-term collaboration with others (yes, no…) [please specify if yes].	
	Coordination	**Contracting**	Contract-based supply chain activities (yes, no…) [please specify if yes].	
		Communication	Communication among entities in the supply chain (open, limited, flexible, effective, ineffective…)	
		Information sharing	Level of information sharing among entities in the supply chain (high, low, effective, ineffective…)	
		Power distribution	Way of sharing and managing power among entities in the supply chain (balanced, imbalanced…)	
	Collaboration	**Shared strategies and interests**	Business strategies and interests shared and approved by all entities in the supply chain (yes, no…) [please specify if yes].	
		Shared business culture	Values understood, approved, and voluntarily complied with by all members in the supply chain (yes, no…) [please specify if yes].	
		Trust and commitment	Level of trust and commitment among entities in the supply chain (high, low…)	
	Consolidation	**Brand consolidation**	Act of bringing smaller brands together under the umbrella of a “stronger” or bigger brand (yes, no…) [please specify if yes].	
		Freight consolidation	Combination of the transportation of multiple products to save costs (yes, no…) [please specify if yes].	

Factors	**Legal factors**	**Government policies and regulations**	Government policies and regulations that facilitate or constrain supply chain activities (yes, no…) [please specify if yes].	
		Government support	Government support to some food products or supply chain activities (yes, no…) [please specify if yes].	
	Relational factors	**Relationship with investors**	Involvement of one or more than one investor in the supply chain (yes, no…) [please specify if yes].	
		Relationship with external industries	Entities from other sectors which have influence on the supply chain activities (yes, no…) [please specify if yes].	
	Developmental factors	**Research and development**	Supply chain's internal research or collaborative research with technical service providers, engineering firms, universities or research institutions (yes, no…) [please specify if yes].	
	Environmental factors	**Natural or human-induced risks**	Weather conditions, disasters, diseases, or epidemics that influence the supply chain activities (yes, no…) [please specify if yes].	