Northern Australia: Food & Fibre Supply Chains Study PROJECT REPORT

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Acknowledgments

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Through the course of the study we consulted with a large number of people within the farming industry, departmental agencies, agribusiness and farm consultants, and transport and logistics sectors. Everyone was generous with their time, for which we acknowledge their contributions. These interactions are listed in Appendix 2.1 to the report.

The detailed commodity analysis was prepared by staff in the Agricultural Commodities and Trade Branch of the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), including Benjamin Agbenyegah, Beth Deards, Robert Leith, Clay Mifsud, David Mobsby and Caitlin Murray.

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Executive summary

Project overview and rationale

A number of opportunities have stimulated renewed interest in agricultural development for northern Australia. These include the proximity to Asian markets that are growing in both size and prosperity; increasing global demand for food and natural fibre; and the development of economically sustainable and vibrant regional communities, particularly as a consequence of expansion of mining and energy extraction developments. In addition to providing communities with skills, these industries can establish infrastructure that can assist agricultural development.

Expanding agricultural development in northern Australia presents three direct challenges:

(a) sourcing the capital investment to support the high cost of 'greenfields' agricultural development
(b) cost-effectively and sustainably growing crops in the northern environment, and getting them to market via efficient supply chains
(c) establishing new and viable export markets for crops that are not simply accommodated by the global commodities trade – for example, high-value perishable fruit and vegetable products with seasonality of supply.

Successfully addressing these challenges is critical to establishing and realising the value proposition for northern agricultural expansion.

To address these challenges, this project has been undertaken by ABARES and CSIRO on behalf of the Office of Northern Australia; the Western Australian, Northern Territory and Queensland governments; Regional Development Australia – Pilbara; and the Rural Industries Research and Development Corporation. The aim of the study was to provide policy makers with a clear indication of the location and scale of medium and longer term opportunities for agricultural production across northern Australia, and critical issues relating to supply chain and infrastructure investment that may help to foster these opportunities.

The project focused on two broad classes of supply chains across six case study regions, acting as exemplars of northern Australia more broadly. The supply chains were classified into the following two main types:

- large-volume production, where supply chain activity and infrastructure are shaped by the need for aggregated transport and processing at low cost; this broadacre category also included industrial crops such as cotton, sugar and sandalwood
- small-volume, high-value production, often highly perishable, where supply chain activity and infrastructure are shaped by the requirement to respond nimbly to market opportunities.

Six regional case studies were undertaken:

- the Ord River Irrigation Area, including expansion into the Northern Territory
- the Katherine–Mataranka region (groundwater-based horticulture)
- the Pilbara, with a focus on water available through mine dewatering
- the Flinders and Gilbert Rivers region (north Queensland)
- central Queensland, with a focus on the Dawson River valley and additional water made available from coal seam gas extraction to supplement the existing irrigation area
- the Darling Downs – Maranoa region, assuming that additional water becomes available from coal seam gas extraction.

For each of the case study regions, a range of issues that are important for success of agricultural development were examined:

- Market opportunities and risk were assessed by exploring market outlooks for a range of commodities, with a particular emphasis on Asia, and exploring new markets and emerging market opportunities.
- Production risk was assessed by
  - examining the climate in each region, both historical and projected, and the implications for crop productivity
  - determining the production potential for a range of crops, using both simulation modelling and observed production.
- Farm-scale financial implications were assessed by undertaking gross margin analyses for a wide range of crops, tailored to each region. This drew on existing gross margin analyses and new analyses for crops that are not grown in the case study regions.
- Supply chain logistics for transport and non-transport–related infrastructure (storage, processing facilities, power, water) for cropping in each of the regions was assessed for both existing and new markets, using newly developed supply chain models.

For each region, two contrasting scenarios of scaled-up production were developed, to examine the regional implications for agricultural development. As part of these scenarios, practical investment priorities to improve productivity and competitiveness of fibre and food supply chains were identified, as were linkages and synergies between different agricultural commodities. The regional economic implications of the scaled-up developments were assessed using regional economic models.

Key messages

1. Irrigated agriculture in northern Australia has the potential to add considerable value to regional economies

Irrigated agriculture can produce a gross value of production of between $500,000 and $1,200,000/GL of water used for broadacre crops, and well over $10 million/GL for high-value crops. Scenarios of scaled-up irrigated agriculture using a range of broadacre, high-value and industrial crops to match the water potentially available in the different regions showed gross values of production that ranged from $20 million to nearly $1 billion (Table 1.1). Under the assumptions used in this study, the aggregate value of production from the 120,000 ha of potentially new irrigated agriculture across the six regions was between $1 billion and $1.5 billion.

Table 1.1 Regional summary of irrigation scenarios used in the study and values of production

REGION	WATER AVAILABLE FOR ALLOCATION (GL) AND ITS SOURCEA	AREA (ha)	CROPS GROWN IN SCENARIOS	TOTAL VALUE OF PRODUCTION PER ANNUM
Ord	865, surface	50,000	Rice, maize, mungbeans, chia, rockmelons, mangoes, sugarcane, cotton, sandalwood	$0.5 to $1 billion
Mataranka	18, groundwater	2,500	Maize, peanuts, mangoes, watermelons	$60 to $130 million
Gilbert Flinders	300, surface 250, surface	30,000 15,000	Maize, peanuts, rice, sorghum, chickpeas, mungbeans, soybeans, sugarcane, cotton, hay	$195 to $315 million
Pilbara	120, groundwater	8,000	Maize, peanuts, mungbeans, cotton, guar, lablab hay, forage sorghum	$43 to $49 million
Dawson	40, groundwater	8,000	Maize, wheat, chickpeas, mungbeans, soybeans, lablab hay	$25 to $30 million
Darling Downs – Maranoa	30, groundwater	5,000	Maize, wheat, chickpeas, sweet corn, watermelons, forage sorghum	$20 to $35 million

a These are volumes for allocation and do not include losses experienced on farm.

2. Securing water for irrigated agriculture does not guarantee positive financial returns

The significant potential of irrigated agriculture to add value to regional economies will be realised where there is a significant area of profitable production. Growing crops profitably in northern Australia remains a challenge, influenced by crop volume, value and location. Based on existing supply chains, gross margins for a range of broadacre, high-value and industrial crops ranged from highly negative to highly positive. Poor gross margins were more common for high-volume, low-value crops and industrial crops where distances to market or processing facilities were significant. This featured more frequently in the Western Australian and Northern Territory regions (Pilbara, Ord, Mataranka) than in Queensland (Flinders–Gilbert, Dawson Valley, Darling Downs – Maranoa), where markets and processing facilities were closer to potential production sites. Crops such as rice, sugarcane and cotton can generate highly positive gross margins where processing facilities are close to production sites. Horticultural crops and specialist niche products, such as sandalwood oil (although not yet commercially proven), can return high gross margins, but returns are also very sensitive to price fluctuations associated with variability in supply, demand and production.

There are opportunities for double crop rotations (two crops in a year) for some annual broadacre crop rotations, and this can greatly increase overall returns. Achieving these more intensive rotations will depend on location, crop types, suitable cropping system, land suitability, and reliability of water to support two crops in a year.

The gross margins assessed included costs associated with managing known pests and diseases. The proximity of northern Australia to Indonesia and Papua New Guinea makes it more vulnerable to incursions of new pests and diseases. If new invasions occur, financial returns would be at risk.

3. Supply chains are a significant constraint in some locations

Freight costs were a very high percentage of the value and total cost of production where high-volume, broadacre crops had to be transported large distances. For example, in the Ord region, freight can comprise over half of crop value. Freight costs for horticultural products could also be a significant cost component, representing between 10% and 25% of the value of the product, depending on location.

High freight costs result from the transport of nearly all agricultural products by road to southern Australia. For some locations and crops, highly favourable backloading rates can be negotiated because refrigerated vans that have brought produce to northern populations (e.g. Darwin, Kununurra) are otherwise returning southwards empty. Without these favourable backloading rates, profit margins would be greatly reduced. Although there is generally sufficient backloading capacity to service existing agricultural and horticultural production in regions close to main highways, development that enables increased production in new and expanded irrigation areas will require additional transport capacity. This may result in higher transport costs because it is unlikely that the additional production would be able to be accommodated in existing backloading arrangements. There is also likely to be competition between neighbouring regions for this transport capacity – for example, competition between Ord and Mataranka. Developing cooperative arrangements between regions may help reduce the need for overinvestment in transport capacity.

There is almost no transport of horticultural produce by sea or air from northern Australian ports (excluding Brisbane) because of the concentration of freight routes to ports in major southern capital cities on the coast. It is currently cheaper to transport horticultural products by road to southern airports and seaports, where imports have made empty refrigerated containers available, than to relocate refrigerated containers to northern Australia. The same situation applies to air freight of perishable goods. In addition, shipping schedules are currently not well matched to seasonal production of perishable goods. This is a significant constraint for both current production and expanded irrigation development.

Creating refrigerated container slots and shipping schedules that match seasonal production in northern Australia could reduce the costs of shipping from northern ports, assuming that cost-effective quarantine and treatment protocols can be implemented. In Wyndham, for example, costs of exporting horticultural produce could be reduced from more than $250/t to less than $150/t. Other opportunities for more efficient export of horticultural produce include air freight from a new airport in Toowoomba.

4. New markets are critical, especially for high-value horticultural production

There are only limited growth opportunities for domestic consumption of horticultural produce. Prices drop rapidly when supply exceeds this demand and this can pose particular challenges for production in northern Australia that is already exposed to high cost structures. In part, the oversupply issue can be reduced by targeting timing of production (e.g. early season mangoes) to avoid competition with other regions. However, the increases in production that could be expected in northern Australia based on the scenarios of expanded production explored in this study suggest that the need for new export markets is essential. A combination of the challenges of long timeframes to develop workable export protocols, the high costs of production in Australia associated with input and labour costs and the need for more direct routes for export product make this difficult.

World demand for food and fibre products is expected to increase significantly into the future because of a larger global population, growth in per-person incomes and increasing urbanisation. Most of this growth in consumption is expected to come from Asia, providing many export market opportunities for northern Australian agricultural production.

The opportunities for new markets include, but are not limited to, horticultural production. As Asian food consumption patterns continue to shift from traditional diets oriented around starchy staples to more varied diets, growing demand in meat and dairy products is also expected. This leads to expansion of pig and poultry production in Asia as well as cattle feedlots, presenting expanding opportunities for exports of feedgrains and other stockfeeds such as oilseed meals and hay. There is also growing demand for both raw and refined sugar in Asian markets, which already import around 80% of Australia's sugar exports. For example, growing sugarcane in the north-west of Australia opens up the option for refining sugar in a nearby location, such as Surabaya. Likewise, as food demand expands in the region, broadacre crops such as mungbean, maize and rice could be grown and shipped cost-effectively to nearby countries.

To meet this new and changing demand, it will be important to reduce import barriers in these Asian countries to ensure that imports can complement domestic production. Additionally, with other key exporting nations likely to also respond by increasing their exports, Australia needs to remain competitive to capitalise on the opportunities that higher global demand will provide.

5. Processing facilities and supporting infrastructure are needed in most regions

Most industrial crops and some broadacre crops analysed in this study require local milling, ginning or shelling facilities to generate positive gross margins. Local processing facilities significantly reduce transport costs by reducing the quantity of non-saleable product requiring transport.

For the Ord and Flinders–Gilbert regions, where scenarios included large areas of irrigation, there is sufficient area to grow enough sugarcane (30,000 ha) to support a sugar mill of minimum viable capacity. The minimum area to support a cotton gin is around 7500 ha (assuming around 9 bales/ha); in both these regions, the scale of irrigable area was sufficient to support establishment of a cotton gin. A rice mill already exists close enough to the Flinders and Gilbert region (Brandon, near Ayr) to support rice cropping, and, in one of the scenarios used in the Ord region, there was enough rice grown to justify investment in a rice mill, with potential for the rice to be exported directly to Asia.

The potentially irrigable area in the Pilbara (8,000 ha) is sufficient to sustain processing facilities for crops such as cotton and peanuts, but not large enough to sustain sugar processing. Processing facilities for cotton and peanuts are absent in Western Australia, so scenarios for irrigation in the Pilbara region suggested that one or the other was necessary to support production of these crops.

In the Mataranka region, where the production area was assessed as considerably smaller (2,500 ha), there was potential production from peanuts sufficient to support a drying and shelling plant. Cotton could be grown in the region, but it would be dependent on the presence of a gin in Kununurra.

The Dawson Valley and Darling Downs – Maranoa regions already have processing facilities for major crops (e.g. cotton, pulse crops). However, there may be scope to support a multipurpose oilseed crushing plant in the Dawson Valley, capable of processing cottonseed, soybeans and sunflowers to produce both oil and high-protein meals for the surrounding livestock industries.

There are possibilities for linking and 'piggybacking' different processing facilities. For example, in the Ord, it may be possible to use co-generation from a sugar mill to power a cotton gin and/or rice mill, and to align milling/ginning seasons so that they are complementary, for efficient use of labour.

6. There are opportunities to integrate crop production with the beef industry to create a value-add in both sectors

Broadacre grain and forage crops are not viable where large domestic transport distances are required. For the Pilbara, Ord, Mataranka and Flinders–Gilbert regions, there are opportunities to use grains such as maize and sorghum, and high-quality hay in more intensive local beef-feeding systems. When used locally, both grains and forage hay crops could generate positive gross margins. For example, gross margins for maize in the Katherine region could be increased by around $500/ha through incorporation into beef-feeding systems, even with an assumption of lower returns per tonne (selling as feed rather than food). This not only provides a market for such grains within the region but offers some market diversity for the beef industry, which is strongly dependent on the live export trade in these regions. Abattoirs are needed for this scenario to be realised, and new meat processing facilities are under construction near Darwin and Broome. For the Flinders and Gilbert regions, existing meatworks in Townsville can accommodate increased supply. In central and southern Queensland, the production of grain and forage hay/silage for feedlots is already well established, and the scenarios explored could provide added production into this system.

In addition to grain and forage hay, production of cotton also offers significant opportunities for the extensive beef cattle industry, through the supply of whole cottonseed as a by-product of lint production. Cottonseed is high in protein and energy, and is well suited to addressing seasonal nutritional constraints associated with tropical pastures in the dry season.

7. Infrastructure investment needs differ significantly between regions

The study has highlighted that investment needs differ significantly between regions because of differences in the scale of irrigated development, market opportunities and supply chains.

Ord – Ample water and suitable soils, and a large amount of the primary irrigation infrastructure are in place. Significant investment is under way to scale-up the cropping area to use the available water. The most significant needs for this region are processing facilities and new north-facing transport infrastructure, supply chains and markets. A sugar mill and associated co-generation facilities would require an investment of more than $425 million; a cotton gin and rice mill would each require around $20 million. In addition, the road infrastructure to Wyndham port, upgrades to the port for deeper berthing capacity, refrigerated container slots, and storage facilities at the port for sugar and/or grains would require an investment of $215 million.

Mataranka – This region's agricultural potential is smaller in scale, and the emphasis in the scenarios was on expanded high-value crop production. The focus in this region needs to be on soft infrastructure over a sustained period to develop new export markets, and reliable and regular shipping routes from Darwin to Asia and the Middle East that can cost-effectively freight refrigerated containers. Processing facilities requiring a lower capital investment, such as a peanut drying and shelling plant (around $3 million), may be justified under a scenario of at least 1500 ha of peanut production. The potential area of agricultural production is unlikely to be large enough to sustain processing facilities for cotton or sugarcane.

Flinders–Gilbert – The primary infrastructure constraint in the Flinders and Gilbert regions is water storage. This constraint needs to be overcome, with water provided through in-stream storages and/or on-farm storages. To irrigate 45,000 ha with reasonable reliability will require an investment of more than $1 billion. Once that is in place, there needs to be significant investment in processing infrastructure – for example, a sugar mill in Georgetown (around $400 million) or cotton gin in Charters Towers ($40 million). Some increased storage capacity for sugar and/or grains would be required at or near Townsville port, but the road infrastructure and distances from the cropping regions to the ports are not major limitations.

Pilbara – Investment in processing infrastructure for cotton ($20 million) and peanuts ($4 million) would be required for a scenario involving these crops, as neither of these processing facilities currently exists in Western Australia. An alternative scenario focuses on grains and forage for the local beef industry, given the context of this irrigation opportunity (i.e. mine dewatering in a resource-rich area surrounded by pastoral leases). This would require investment in, and integration with, the beef industry. Because this region is completely 'greenfields', significant investment in intellectual capital with agricultural experience will be required.

Dawson – This region is well established agriculturally, and the main investment requirements would be providing additional capacity to the existing cotton gin in the region at minimal cost. One additional option is to establish a multipurpose oilseed crushing plant within the region to process an expansion in an oilseed crop such as soybeans, and to process the large amount of cottonseed produced in the region. This could involve an investment of $30 million for a modestly sized crushing plant of 60,000 t/year. Other investment priorities include making the current grain handling and storage process more efficient and effective, including rail and road infrastructure.

Darling Downs – Maranoa – infrastructure development is well established, little investment is required although clustering of grain storages and depots would be beneficial as would better coordinated road and rail networks.

8. Investment plans need to be designed to accommodate unexpected shocks

Historically, some large-scale agricultural investments have faltered where there were unrealistic expectations about the time required to start generating positive returns on capital, and the risk/reward trade-off associated with rapid upscaling. Risk analysis in this study shows that, especially in the early stages of new developments (the first 10 to 15 years), a number of challenges are likely to confront businesses and test their viability. These include bad years as a result of extreme weather events, price collapses, pests and/or diseases, and management failures. The general and expected pattern of good seasons and poor seasons and how they fall in the investment cycle can also influence longer-term outcomes.

9. Labour supply and agribusiness services are important to achieving successful new agricultural initiatives

Labour supply can act as a constraint on development opportunities in northern Australia. Although labour supply did not form part of the analysis of this study, issues associated with labour were raised by various stakeholders in all regions. Seasonal labour needs are at present largely met by tourists on working holidays who can extend their stay in Australia by working in regional areas. It is not clear whether there would be enough labour from this source to meet additional demand under scenarios of expanded agricultural production in northern Australia, particularly in the regions involving high-value, labour-intensive horticultural products.

Most established large-scale agricultural precincts have a well-developed agribusiness sector to support agricultural production. This will be essential for expanded agricultural areas in northern Australia. Many of the areas assessed in this study compete with the resources sector for skilled labour, so incentives and approaches to attract skilled labour in the agribusiness sector will be required.

10. Successful agricultural development will depend on understanding the entire system, including climate, soils, water resources, pests, agronomy, management, processing, supply chains and markets

Lessons from past agricultural developments and the analysis undertaken in this study indicate that successful agricultural development at scale requires all components of the system to be considered holistically. This would appear to be particularly important in the context of northern Australia because each component of the system – climate, soils, agronomy, pests and diseases, farm operations, management, planning, supply chains, infrastructure, labour, services and markets – can individually act as a significant constraint to profitable and sustainable enterprises. Managing the complexity of these component factors, as well as scaling-up at a considered pace and being prepared for considerable (5 to 15 year) lags before positive returns on investment are achieved, are critical for success in the long term.

11. Regional economies are projected to expand but changes to national economic welfare are negligible.

All case study regions achieve higher regional economic growth with the additional investment. The Ord River region benefits the most in percentage terms from its proposed investment, reflecting the relatively large size of the proposed investment compared with the size of the economy. Most regions also see faster employment growth arising from the investment, with wages up 2 per cent in real terms by the end of the projection period.

The benefits from increasing agricultural activity in regions are balanced to some extent by slower growth in other industries because of increased competition for labour. At a national level, the proposed investments produce negligible changes in GDP to 2029–30 as resources are drawn from southern Australia to support the proposed investment.

1 Project rationale and overview

1.1 Background

Agricultural development in northern Australia has been variously described as the last frontier, the new frontier and the next frontier. All of these epithets convey a sense that the areas are waiting to be opened up for settlement and economic development. Indeed, for well over a century there has been a succession of public and private initiatives to either promote or initiate intensive agriculture in northern Australia. These initiatives have met with mixed fortune, some ending in disappointment and dashed hopes, while others have been successful and continue today, such as large-scale broadacre cropping in the lower Burdekin River catchment or more intensive tropical horticultural and vegetable production ventures dotted across northern Australia.

Renewed interest in agricultural development for northern Australia is being driven by a number of opportunities. These include the proximity to Asian markets that are growing in both size and prosperity, increasing global demand for food and natural fibre, and the development of economically sustainable and vibrant regional communities, particularly as a consequence of expansion of mining and energy extraction developments and supporting infrastructure. The growth in the Asian economy offers particular opportunities because it is expected to more than double by 2030. However, growing economies in the region do not necessarily guarantee business success for northern Australian agriculture, since there has been little growth in exports to Asia from northern Australia in the last decade outside of the resources sector (Boston Consulting Group, 2012).

Three direct challenges facing expanded agricultural development in northern Australia are:

- sourcing the capital investment to support the high cost of 'greenfields' agricultural development
- cost-effectively and sustainably growing crops in the northern environment and getting them to market via efficient supply chains
- establishing new and viable export markets for crops that are not a natural part of the global commodities trade—for example, high-value, perishable fruit and vegetable products with seasonality of supplies.

Successfully addressing these challenges is critical to establishing the value proposition for northern agricultural expansion. Efficient infrastructure and food supply chains are paramount in growing a competitive and productive agricultural sector to seize opportunities from changing patterns in global food consumption, and particularly in growing markets in Asia. A thorough understanding is needed of the outlook for present and prospective agricultural industries in northern Australia, including bulk commodities that trade on world markets, new industries and markets, and high-value perishable and/or niche-based crops. Determining supply chain investment priorities is vital in this context, as these developments have the potential to improve productivity and to position producers in northern Australia to take advantage of emerging opportunities. If not sufficiently understood and developed, a lack of investment in agricultural supply chains will limit future growth.

Development opportunities are inherently systemic, because the establishment of efficient and effective supply chains essentially depends on having reliable and cost-effective production underpinning the chains. Northern Australia provides some particular challenges and opportunities for intensive agricultural development. The climate provides comparative advantage for growing tropical fruits and vegetables compared with the temperate regions of southern Australia. More than 70 years of agronomic research has been applied to a wide range of crops suitable for northern conditions, and there are now in place varieties and farming systems that are adapted to the tropical climate and soils of northern Australia.

Annual rainfall is generally high compared with southern Australia but it occurs over a relatively short wet season and there is considerable year-to-year variability. As a result, the major rivers can deliver large quantities of water suitable for irrigation, but the flows are strongly seasonal and the water is not always available in the best locations for siting intensive agriculture. Large flows are more common in lower parts of the catchments that are of low relief and prone to seasonal flooding. In upper reaches of the catchments rainfall is usually lower and there are relatively limited opportunities for impoundments (Webster, 2009). As a result, for surface water, large-scale irrigated developments will necessarily be limited to relatively few locations. There are some significant development opportunities available through exploitation of ground water. These include ancient water reserves where there is sufficient transmissivity to enable regular pumping, aquifers that are more rainfall dependent on recharge (e.g. Tindall aquifer in the Mataranka region of the Northern Territory [DNRETAS, 2011], La Grange aquifer near Broome in Western Australia [WA Department of Water, 2010]) or where water has become available through mine dewatering (e.g. Pilbara region). Although the soils of northern Australia can provide significant structural, nutrient and salinity constraints to cropping, the availability of suitable soils is not a major limiting constraint because about 17 million hectares of soils have been identified as being at least moderately suitable for intensive, irrigated agriculture (Webster et al., 2009).

The use of soil and water resources for an expanded agricultural industry in northern Australia must be managed in a sustainable way. The Northern Australia Land and Water Science Review (2009) raised many of the issues that need to be addressed and since then more specific studies have examined soil and water resources—for example, the Flinders and Gilbert Agricultural Resource Assessment (Petheram et al., 2013a,b). Major issues relate to reliability of water supply, avoiding unsuitable soils such as those prone to salinity or high erodibility, freshwater and riparian ecology of streams that have impoundments or significant flow offtakes, accommodating Indigenous interests, and recharge rates of groundwater aquifers. All jurisdictions are signatories to the National Water Initiative (NWI, 2004), which provides a national framework for developing and managing water resources that must be considered in any water development. In addition, the National Water Commission has developed principles for managing northern Australian water resources (NWC, 2012). These include:

- fully adopt and implement the National Water Initiative water reform framework
- undertake transparent and inclusive water planning
- shared understanding of water resources, based on robust science and socio-economic information
- recognise Indigenous interests
- strengthen cross-jurisdictional institutions.

Pests and diseases pose a significant risk to more intensive agriculture in northern Australia. The tropical climate provides fewer natural breaks to life cycles of many pests and diseases. This was highlighted in the early stages of development in the Ord region where insect pests were the major cause of cotton not succeeding as a crop in that environment at that time. Northern Australia is also close to Indonesia and Papua New Guinea, which have many pests and diseases not yet present in Australia. Australia's favourable biosecurity status is particularly important to Australia's $32 billion agricultural export industry. To help protect this status, the Northern Australia Quarantine Strategy (NAQS) was implemented in 1989 as an activity within the Australian Government Department of Agriculture. NAQS aims to facilitate the detection of pests, weeds and diseases across northern Australia through three key elements: scientific surveillance, Torres Strait border operations and public awareness (ANAO, 2012). Irrigated landscapes across northern Australia may provide additional opportunities for any new pests and diseases to establish; consequently, new developments will need to work closely with Commonwealth, state and territory jurisdictions in managing biosecurity risks.

These issues of markets, supply chains, crop production and reliability, and sustainable use of the resource base, need to be addressed in an integrated way rather than in isolation. It is with this background that the Northern Australia Food and Fibre Supply Chains Study was initiated. The work was supported by a consortium of stakeholders, each with an interest in understanding the opportunities for more intensive agriculture and horticulture in northern Australia. These include the Australian, Queensland, Northern Territory and Western Australian governments, the Rural Industries Research and Development Corporation and Regional Development Australia – Pilbara.

1.2 Project objectives/deliverables

The aim of the study was to provide policy makers with a clear indication of medium- and longer-term opportunities for agricultural production across northern Australia, and critical supply chain and infrastructure investment issues that may help to foster those opportunities.

More specific project aims were to:

- analyse the long-term outlook for relevant agricultural commodities; both large-volume commodity production industries such as grains, sugar, cotton, pulses; and high-value, small-volume and emerging production industries such as tropical fruits, Asian vegetables, chia and guar
- describe broad market opportunities, risks and options that are likely to foster longer-term growth, and the operational and infrastructure elements of the supply chain required to support them
- identify strategic investments or practical improvements that could be made across supply chains, to improve longer-term prospects
- build on other relevant projects focusing on agriculture across northern Australia, including the North Queensland Irrigated Agriculture Strategy, work being undertaken by CSIRO on mosaic irrigation and work completed on the further potential expansion of the Ord Irrigation Scheme
- consult extensively with industry, primary producer groups and other relevant stakeholders.

1.3 Overview of project approach

The project focused on two broad classes of supply chains across six case study regions acting as exemplars of northern Australia more broadly. The supply chains were classified into the following two main types:

- large-volume production, where supply chain activity and infrastructure is shaped by the need for aggregated transport and processing at low cost. This broadacre category also included industrial crops such as cotton, sugar and sandalwood
- small-volume, high-value production, often highly perishable, where supply chain activity and infrastructure is shaped by the requirement to respond nimbly to market opportunities.

Six regional case studies were undertaken:

- the Ord River Irrigation Area, including expansion into the Northern Territory
- the Katherine–Mataranka region (groundwater-based horticulture)
- the Pilbara, with a focus on water available through mine dewatering
- the Flinders and Gilbert Rivers region (north Queensland)
- Central Queensland, with a focus on the Dawson River valley and additional water made available from coal seam gas extraction to supplement the existing irrigation area
- Darling Downs – Maranoa region, assuming additional water becomes available from coal seam gas extraction.

As context for this Food and Fibre Supply Chains Study, key differences and challenges in agriculture between the south and the north were described, including a detailed assessment of some past large-scale agricultural developments in northern Australia.

For each of the case study regions, a range of issues important for agricultural development success were examined:

- Market opportunities and risk were assessed by exploring market outlooks for a range of commodities, with a particular emphasis on Asia, and exploring new markets and emerging market opportunities.
- Production risk was assessed by
  - examining the climate in each region, both historical and projected changes into the future, and the implications for crop productivity

– determining the production potential for a range of crops, using both simulation modelling and observed production.

- Farm-scale financial implications were assessed by undertaking gross margin analyses for a wide range of crops, tailored to each region. This drew on existing gross margin analyses and new analyses for crops that are not grown in the case study regions.
- Supply chain logistics for transport and non-transport–related infrastructure (storage, processing facilities, power, water) for cropping in each of the regions was assessed for both existing and new markets, using newly developed supply chain models.

For each region, two contrasting scenarios of scaled-up production were developed, to examine the regional implications for agricultural development. As part of these scenarios, practical investment priorities to improve productivity and competiveness of fibre and food supply chains were identified, as were linkages and synergies between different agricultural commodities. The regional economic implications of the scaled developments were assessed using regional economic models.

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2 Methods

2.1 Conceptual framework

This study of food and fibre supply chains is necessarily an integrated science and economics study of the biophysical, market and strategic drivers of potential agricultural development in northern Australia. Figure 2.1 schematically outlines the components of the study and the analysis undertaken or questions asked for each component:

- *Overview of agricultural potential* overviews the production potential for the range of crops in each case study region, given its biophysical drivers of soil, water and climate.
- An *Assessment of market potential* is conducted for a range of broadacre food and feed crops, intensive high-value crops and fibre, and other industrial non-food crops to determine areas of potential demand and opportunities at home and abroad, if production was expanded.
- *Supply chain modelling* – transport and non-transport infrastructure – are examined and costed.
- *Alternative strategic plans* are proposed – two cropping scenarios are examined in each region along with their respective infrastructure and logistics requirements.
- *Economic assessments* are examined to calculate gross margins and therefore assess farm-scale implications of alternative cropping strategies. Taking results from all components, *regional economic modelling* determines economy-wide impacts on regional economies, northern Australia and southern Australia.
- *Conclusions* compares scenarios and poses feasible alternative strategic plans.

The methods and models used in each component are explained in further detail in the following sections of this chapter.

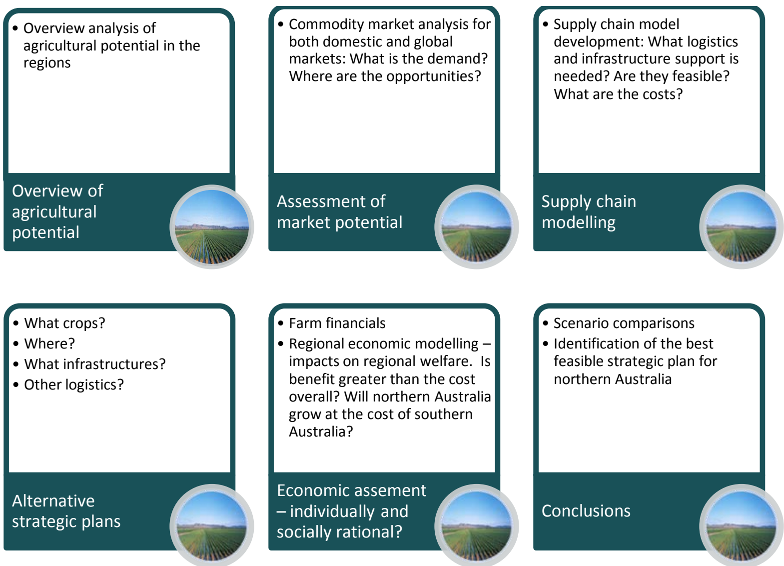

Figure 2.1 Conceptual framework for the Northern Australian Food and Fibre Supply Chains project

2.2 Consultations in regions

The project began with a series of consultations within regions and in major centres of government and business (i.e. Perth, Karratha, Kununurra, Darwin, Townsville, Brisbane). The aim was to gather views and information from a range of stakeholders, including peak industry representatives, agribusiness and agricultural consultants, commercial growers from individual family operations to major investors, the mining industry, transport and freight companies, port authorities, wholesale markets, exporters, local government, and state and territory government departments of agriculture, water resources, land management and regional development. These discussions continued throughout the project to varying degrees of intensity. A list of consultations is shown in Appendix 2.1.

2.3 Assessment of agricultural potential

2.3.1 CLIMATE ANALYSIS

Historical climate

Historical rainfall data was sourced from the national rainfall database SILO, which is administered by the Queensland Government.[1] This database provides long-term historical data and improved methods for dealing with gaps in records by infilling with nearby stations, spatially interpolated to the station of interest (Jeffrey et al., 2001). The primary historical climate data is provided by the Bureau of Meteorology. Since these historical records became more reliable from the late 1950s and early 1960s, this analysis concentrates on the record for the last 50 years.

The data that were used included rainfall, evaporation, maximum temperature and minimum temperature for seven climate stations (Table 2.1). Two climate stations were used for the Flinders and Gilbert region because of the large spatial scale of these two catchments and their distinctive climates.

Table 2.1 Climate stations that were used in the climate analysis and their locations

REGION	STATION NAME	STATION NO.	LATITUDE (S)	LONGITUDE (E)	ELEVATION (m AHD)
Pilbara	Wittenoom	5026	22.2425	118.3358	460
Ord	Kununurra	2038	15.7828	128.7353	47
Mataranka	Katherine Council	14902	14.4589	132.2572	106
Gilbert	Croydon Township	29012	18.2044	142.2447	115
Flinders	Richmond Post Office	30045	20.7289	143.1425	211
Central Queensland	Baralaba Post Office	39004	24.1819	149.8117	100
Southern Queensland	Roma Post Office	43030	26.5719	148.7897	299

Future climate

Because there was interest in considering future scenarios for cropping systems, future climate projections were produced. Global climate models (GCMs) are used to produce future climate projections at regional scales and a large range of GCMs are available for future climate projections analysis. For this study, the aim was to provide a broad picture of the potential for climate change to influence irrigated cropping development in northern Australia, rather than a detailed analysis of the impact of climate change on crop production potential. Hence, four GCMs were selected (GFDL-21, HADCM3, MIROC-M and ECHAM5), based on expert analysis of the various models (Appendix 2.2).

Two future emission scenarios – SRES Marker Scenario A1F1 (high emissions) and SRES Marker Scenario A2 (moderate emissions) – and two warming scenarios (high and low) were used in conjunction with the four GCMs to project the climate data to 2030 using the quantile matching method (Kokic et al., 2012; Panjkov, in prep.). The base period for the climate projections was 1970 to 2010 for all stations and scenarios.

Further details of the quantile matching method are described in more detail in Appendix 2.3, but, in brief, the climate distribution from the historical period 1970 to 2010 is transformed using future projections of

[1] www.longpaddock.qld.gov.au

climate. In this way the climate projections are placed in the context of historical climate at individual stations rather than being unconstrained projections at broad regional scales.

2.3.2 **LAND SUITABILITY**

Considerable amounts of reconnaissance-level land systems mapping (at scales of 1:1,000,000 to 1:250,000) have been conducted throughout northern Australia since the early 1940s (e.g. Christian and Stewart, 1953). Some surveys focused on areas of potential agricultural development and provide scales of mapping (1:100,000 to 1:50,000) that are more relevant to regional development planning (e.g. Aldrick and Robinson, 1972; Biggs and Philip, 1995; Schoknecht and Grose, 1996) but these are still too coarse for specific agricultural developments. The soils of northern Australia and their characteristics are generally well known from these surveys (Figure 2.2) but almost none of northern Australia is mapped at fine enough scale for individual developments. This means that the soil and land-related limitations at specific locations that have been proposed for agricultural development will still require more detailed assessment before development and ongoing monitoring, to assess the impacts of use. More recent detailed investigations have occurred in developing agricultural areas, such as the Ord River in Western Australia, Daly Basin in the Northern Territory, and the Dawson, Flinders and Gilbert Rivers in Queensland (e.g. Smolinski et al. ,2011; Bartley et al., 2013).

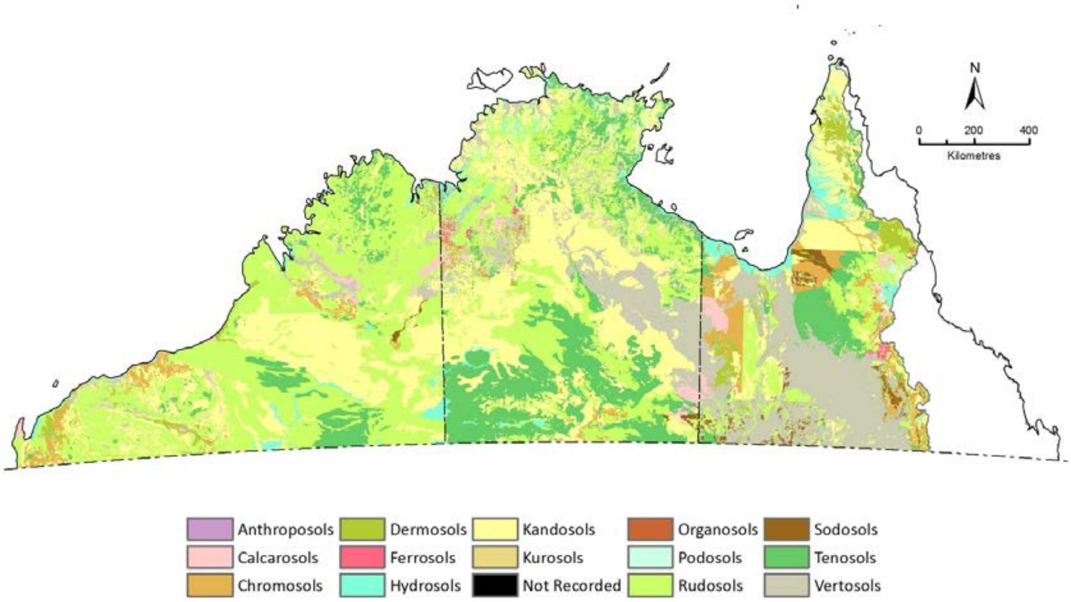

Figure 2.2 Dominant mapped soil types (Australian Soil Classification orders) for northern Australia
Source: ASRIS (2014)

Land suitability frameworks have been developed for various agricultural areas, and crop and land management options (e.g. Forster and Sugars, 2000). These frameworks assess a particular cropping enterprise (such as irrigated annual crops, perennial crops or forestry) and the necessary management considerations, based on the known limitations of the soil and land resources (e.g. soil depth, texture, rockiness, land slope or erodibility). Wilson et al. (2009, 2013) applied a broad land suitability framework across the north of Australia using the best available and nationally consistent soil data that is collated within the Australian Soil Resource Information System (ASRIS, 2014).

These initial assessments (Figure 2.3) show the potential suitability for a range of cropping enterprises, based on the soil and land resources of northern Australia, but need to be integrated with other data on soil and land issues (such as salinity, nutrient availability and flooding), other natural resources (such as water and native vegetation) and socio-economic data (e.g. infrastructure, markets) before the viability and sustainability of certain areas can be assessed. This report provides that initial integrated assessment.

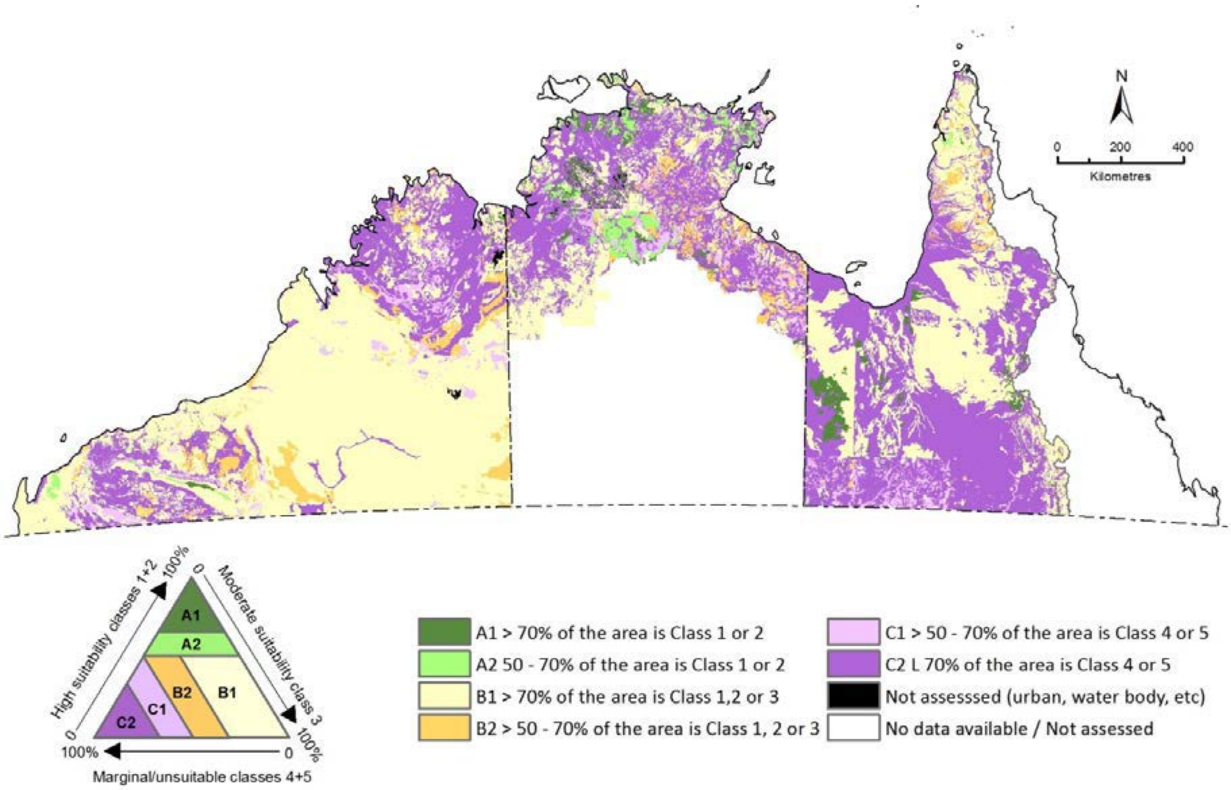

Figure 2.3 Suitability for irrigated perennial crops
Source: Wilson et al. (2013)

This approach has been applied to the six case study regions that were selected for this project, to characterise the opportunities and limitations of the soil resources that may affect agricultural potential.

2.3.3 CROP PRODUCTION

Choice of crops

A wide range of crops could have been assessed within each region. The potential range of crops included those already grown in the particular region, crops that are presently grown in other northern regions and crops that have yet to be commercially proven in northern Australia. From these options, crops were selected for review after consultation with regional stakeholders or groups and individuals who have a responsibility for crop research, development and extension within state or territory jurisdictions.

For each region, the crops selected for review included at least one crop from each of the categories of broadacre food, intensive horticulture or industrial crops. A forage crop for hay production was also included for two of the case study regions. The crops by regions are shown in Table 2.2

Table 2.2 Crops assessed within each of the six case study regions

CROP	FLINDERS & GILBERT	ORD	PILBARA	MATARANKA	DAWSON	DARLING DOWNS – MARANOA
Broadacre food						
Rice	X	X				
Sorghum/maize	X	X	X	X	X	X
Chickpea/mungbean	X	X	X	X	X	X
Peanut	X	X	X	X	X	X
Chia	X	X				
Soybean					X	X
Wheat					X	X
Intensive food						
Mango	X	X		X		
Banana	X	X				
Cucurbits		X	X	X		
Vegetables						X
Industrial/other						
Sugarcane	X	X				
Cotton	X	X	X	X	X	X
Hemp	X	X				
Sandalwood	X	X		X		
Guar	X		X			
Poppy				X		
Cassava (biofuel)	X				X	
Forage sorghum	X		X			X
Lablab forage			X		X	X

Crop production assessments

Simulation modelling of broadacre food and industrial crops

Cropping systems encompass complex physical processes of crop growth, soil water and nutrient dynamics, and decomposition in continuous interaction with each other and the local climate. Farmers traditionally learn to manage this complexity through continual practice and seasonal experience, while researchers undertake experiments to explore and understand these interactions. The inherent complexity of cropping systems will usually limit the capacity of experience and research to predict future outcomes, especially when the constraints to exploration and experience in time and space are considered. Crop simulation models that use long-term historic climate data can be cost-efficiently employed to explore these interactions through multiple simulations.

The Agricultural Production Systems Simulator (APSIM) is a crop growth and yield modelling framework that simulates biophysical processes in cropping systems; in particular, where there is interest in the economic and ecological outcomes of management practice conducted under climatic risk (Keating et al., 2003). The APSIM model has been used to evaluate a broad range of cropping system issues, including on-farm decision making, seasonal climate forecasting and risk assessment for government policy making (Keating et al., 2003); and impact of changes to cropping systems and agronomic practices on the water balance of dryland regions (Verburg et al., 2003). APSIM has also been useful in predicting performance of commercial crops (Carberry et al., 2009). Validated crop models in APSIM have been used in assessments of the cropping potential for a range of prospective crops in northern Australia (Carberry et al., 1991; Yeates, 2001; Pearson and Langridge, 2008).

The APSIM models have been developed to capture growth and yield potential for crops that are limited by water, nutrients and seasonal climate variability. The predictive capacity of simulation models is, of course, subject to the accuracy of the input data that is used for each simulation trial (scenario). The key inputs required by APSIM are long-term daily climate records, soil characteristics (e.g. plant-available water capacity) and parameter settings for managing irrigation and crop agronomy. The crop models assume best practice is applied for weed and insect pest management, and in this analysis also assumes 100% efficiency in the application of irrigation.

For this study, the APSIM model was used for the range of broadacre food and industrial crops for which specific crop models were available, including chickpea, mungbean, peanut, soybean, maize, sorghum, forages, sugarcane, cotton and rice. Within each region, historical daily climate records, characteristics of representative soils (e.g. physical structure, water-holding capacity and nutrient levels), and appropriate agronomic and management practices were used to parameterise APSIM. A range of other broadacre crops were assessed in this study for which APSIM models are yet to be calibrated or tested. These crops include chia, guar, hemp, sandalwood, cassava and poppy. Yields from experimental and commercial plantings were used to estimate production for these crops, and, where there was no field data, published estimates were also used.

Estimating yields for horticultural crops

No available modelling capability is currently available in the APSIM framework for the horticultural crops that were considered for this study (banana, cucurbits and mango). Estimates of the yield for these crops in each region were based on reported production from commercial and experimental plantings in northern Australia, and validated using a simple 'heat sum' approach to determine season lengths.

The heat sum approach uses knowledge of the minimum, optimum and maximum temperatures for an individual crops growth, and assumes a linear relationship between the minimum and optimum, and the optimum and maximum. At a daily average temperature equal to the minimum and maximum temperatures the heat sum is zero. At a daily average temperature equal to the optimum temperature for crop growth the heat sum is equal to the optimum temperature. The daily heat sum value is calculated for each day, and summed to determine thermal time (in degree days).

The planting season for cucurbits (watermelon and rockmelon) was determined as starting when the five-day average maximum temperature was less than 35.5 °C and concluded when the five-day average minimum temperature was less than 15 °C. Cucurbits have an optimum temperature of 30 °C for growing, a maximum of 36 °C and a minimum of 15 °C. Using the heat sum approach, cucurbits reach harvest at 1150-degree days after planting.

Mangoes were considered to have flowered when the three-day average minimum temperature was less than 15 °C. The minimum temperature of the following five weeks was used to proportionally determine yield (through pollination being sensitive to temperature). The number of days where the minimum temperature was less than 10 °C or greater than 20 °C was given a value of zero. The number of days with a minimum temperature between 15 and 20 °C was given a value of 0.7, and the number of days with a minimum temperature between 10 and 15 °C was assigned a value of 1. The sum of these values as a proportion of 35 was used to determine the yearly yield as a proportion of the maximum yield for a region. The maximum yield was determined from local commercial production values.

The banana planting window started when the five-day minimum temperature averaged more than 15 °C. Banana has a minimum temperature of 14 °C, an optimum temperature of 30 °C and a maximum temperature of 40 °C. Banana is susceptible to frost, and days with a minimum below 2 °C start to cause a

5% yield reduction from maximum attainable yield, which is cumulative for the number of days below this threshold to –3 °C, when crop death occurs. The thermal time from planting to harvest is 3500-degree days.

2.3.4 **PESTS AND DISEASES**

For every crop, a list of insect pests and fungal pathogens that use that crop as a major host was identified (CABI, 2007). Chia is the only crop for which there are no known pests or fungal pathogens in the published literature.

The worldwide distribution of each insect and pathogen species was determined (CABI, 2007). If a species' distribution included Australia, then its arrival and establishment likelihood was given a value of 1. If a species' distribution did not include Australia, an arrival and establishment likelihood was calculated as follows.

Arrival

Quantifying the many potential pathways by which multiple invasive species could arrive at a particular country is extremely challenging. However, the numbers of invasive species in a region or country has been consistently shown to be related to gross levels of trade (Dalmazzone, 2000; Vila and Pujadas, 2001; Levine and D'Antonio, 2003; Westphal et al., 2008; Desprez-Loustau, 2009; Marini et al., 2011). Accordingly, the value of each country's annual mean (2000 to 2009) importation (in US$ millions) from each trading partner (IMF, 2011) as a proportion of total imports from all trading partners was used as a proxy for species arrival likelihood.

Establishment

Establishment was extracted from a self-organising map (SOM) analysis of species worldwide distributions (Paini et al., 2010). The species distribution for each of 1294 insect pests and fungal pathogens in 124 countries was extracted (CABI, 2007) and placed into a 124 × 1296 matrix of 1s and 0s; 1 represented a species presence in a country and 0 represented absence. A SOM is a type of artificial neural network capable of converting high-dimensional data into a two-dimensional map, pictorially showing which data points are most similar. The SOM is therefore a clustering method. Full details of the method can be obtained from Kohonen (2001) and Worner and Gevrey (2006), but, essentially, each region occupies a multidimensional space determined by a vector of the presence/absence data. In this case, each region will have a 1296-element vector made up of 1s (present) or 0s (absent) to determine its position in a 1296-dimension space. The SOM is an elastic network of neurons that are projected into this multidimensional space and interact with the regions. The vector that determines each neuron's position in this space is termed the neuron weight vector. The number of neurons in a SOM is partially determined by the heuristic rule, $5\sqrt{n}$, where n is the number of samples (in our case, 124 countries) (Vesanto et al., 2000). In addition, the two largest eigenvalues are calculated from the dataset and the ratio of length and width of the SOM is set to those eigenvalues. Given this ratio, the final number of neurons is set at close as possible to the heuristic rule. The maps size in this analysis was 9 × 6 (54 neurons), with the standard hexagonal configuration.

Though the initial projection of these neurons into the multidimensional space can be done randomly, a linear initialisation is recommended, which aligns the SOM corresponding to the first two eigenvalues discussed above. This linear initialisation distributes the neurons in a way that is more representative of the raw data and significantly reduces the time taken to train the network and complete the analysis (Kohonen, 2001).

When the analysis is initiated, each country is assessed and the closest neuron to this country in the multidimensional space is identified as the best matching unit (BMU). The neuron weight vector of the BMU is adjusted so the neuron moves closer to the country. All countries are assessed simultaneously (batch algorithm). Because all neurons in the SOM are connected similar to a large 'elastic net', the process of one neuron moving closer to a country exerts a gravitational force that drags other neurons in the SOM. This gravitational effect is strongest on the nearest neurons to the BMU and decreases with neurons further away. The simultaneous analysis of all countries completes one iteration, and the recommended number of iterations is 500 × number of neurons (for this analysis – 500 × 54 = 27,000). With each iteration, the gravitational effect of one neuron on neighbouring neurons decreases and the distance a BMU is moved closer to a country also decreases. Over time, the SOM spreads out to occupy approximately the same area that the countries occupy in the multidimensional space. When the analysis is complete, each country will be assigned to a BMU that is its closest neuron. Some countries will have the same BMU, because they have similar assemblages of invasive species and hence are found close to each other in the multidimensional space. Each of the 1296 elements of the neuron weight vector of a BMU corresponds to each of the 1296 invasive species in the analysis and will have a value between 0 and 1, which is a measure of the strength of association of the invasive species with the assemblage of invasive species of any country assigned to that BMU. The strength of association for a species can be interpreted as an index of establishment likelihood for that species in a region (Worner and Gevrey, 2006; Paini et al., 2010, 2011). On completion of the analysis, an establishment index can be determined for every species in every country included in the analysis.

Invasion

The invasion likelihood, I_{ps} for each invasive species, *p*, from each source country, *s*, conducting trade with Australia was calculated only if that invasive species was present in the source country, absent from Australia, and a known pest or pathogen of the crop being assessed (as stated above, if a species was already present in Australia, its invasion likelihood was given a value of 1:

$$I_{ps} = A_{ps}E_{p}$$

where A_{ps} is the arrival likelihood of species, *p*, to Australia from source country, *s*, and E_p is the establishment likelihood of species, *p*, in Australia.

Total invasion likelihood

The total invasion likelihood, TI_c, from all species known to be a threat to a particular crop, *c*, was calculated:

$$TI_c = 1 - \prod_p [1 - I_{ps}]$$

Biosecurity risk

Impact was defined as a value between 0 and 1, which indicates the proportion of crop damaged or lost as a result of a pest or pathogen. For such a large number of pests and diseases, it was impossible to estimate with any accuracy the true potential impacts of each species. As such, three possible levels were therefore assessed: 0.1, 0.4 and 0.7.

Biosecurity risk was calculated as a product of total invasion likelihood TI_c for a crop, *c*, and one of the three possible levels of impact.

2.4 Market analysis of crop commodities

The commodity market analysis in Appendix 4.1 is a desktop study of the current market conditions and assessment of future market opportunities for 25 crops that are currently grown or could be grown in northern Australia and have potential for increased production if irrigation was expanded. Although there has been a market analysis of all 25 commodities, not all were assessed in the crop scenarios within the six case study regions (see Table 2.2). The commodities in the market analysis are listed in Table 2.3.

Table 2.3 Commodities in the market analysis

BROADACRE FOOD/FEED CROPS	INTENSIVE FOOD CROPS	FIBRE AND OTHER INDUSTRIAL CROPS
Barley	Avocado	Cassava
Chia	Banana	Cotton
Chickpea	Cocoa	Guar
Grain sorghum	Cucurbits	Hay/forage crops
Maize	Macadamia nuts	Industrial hemp
Mungbean	Mango	Poppies
Peanut	Olive	Sandalwood
Rice		Sugar
Soybean		
Wheat		

2.4.1 HISTORICAL DATA

Historical data and market intelligence has been obtained from a variety of sources:

- Domestic data on agricultural commodity production, including gross values of production, has mostly been obtained from the Australian Bureau of Statistics (ABS). Where small-area data were available aligning with the case study regions, relevant regional data on production and gross values of production are provided.
- Consumption data and information on price trends are generally obtained from a variety of sources, including industry organisations and media commentary.
- Australian trade data is obtained from the ABS international trade database, which is derived from Australian Customs data on export and import of goods.
- International market information covers world production, consumption, stocks and trade, most of which is obtained from the United Nations Commodity Trade Statistics Database (UNComtrade) or the Food and Agriculture Organization of the United Nations Statistics Database (FAOSTAT).
- Some data and market commentary on recent developments, in particular commodity markets, were also obtained from international industry organisations to supplement UN and FAO databases.

Considerable differences exist between the various commodities in the quality, quantity and coverage of readily available information.

Price projections to 2030 were provided for the range of commodities where sufficient historical price data allowed. The basis for the price projections was the price paths generated from ABARES agrifood model, which was developed for a series of studies on global food demand and supply to 2050 (Linehan et al., 2012a,b) and the ABARES study on long-term food consumption trends in Asia (ABARES, 2013).

Price forecasts are derived mainly from the assessment of future consumption and production of a commodity. An advantage of a model is that it can encapsulate many complex interactions in the market in a consistent way. ABARES' agrifood model is an economic simulation of global agricultural supply, demand and trade.

The short- and medium-term price paths presented in the market analysis for those commodities ABARES regularly forecasts – broadacre cereal, legume and oilseed crops, sugar and cotton – were constructed using ABARES' medium-term forecasts published in the March 2014 edition of *Agricultural commodities*. These projections are to 2018–19. The long-run projections, beyond 2018–19, are made applying average annual price growth rates generated by the agrifood model. For the remaining commodities, the price paths from the agrifood model have been used for medium- and long-term projections.

Assumptions surrounding commodity prices are made in US dollars for most commodities, so exchange rate assumptions are required to establish the Australian dollar prices for each commodity. For the period to 2018–19, exchange rates are assumed to follow assumptions published in ABARES March 2014 edition of *Agricultural commodities*. For the years from 2018–19 to 2029–30, the exchange rate is assumed to average US$1 to A$0.83.

Sensitivity scenarios were also developed around the price projections, again drawing from the ABARES agrifood model projections. Adjusting projections of total factor productivity (TFP) improvement used in the model by plus or minus 10% provided higher and lower price scenarios than the baseline projections.

The annual growth rates for commodity prices generated by the agrifood model and applied to projections in this study are outlined in Table 2.4, including the TFP scenarios. A detailed description of the model can be found in Linehan et al. (2012b).

Table 2.4 Agrifood model annual growth rates for commodity price projections
Real US$ price growth rates.

COMMODITY GROUP	BASELINE %	HIGH PRICE SCENARIO TFP –10%	LOW PRICE SCENARIO TFP + 10%
Cereals	0.27	0.67	–0.09
Vegetables and fruit	0.14	0.33	–0.07
Oilseed meals	0.04	0.35	–0.27
Oilseed oils	0.28	0.49	0.08
Other food	0.16	0.42	–0.10

TFP = total factor productivity

2.5 Farm financial analyses – gross margins

In this report, the economic impact of regional development scenarios that involve potential changes in the volume or value of either existing crops or new crops has at its core an evaluation of changes in aggregate crop gross margins. This section briefly details the manner in which a series of gross margins has been assembled for the array of broadacre field, horticultural and plantation crops for each of the regions that were covered by this study. It also provides some detail on how the gross margins are incorporated into the wider regional scenario-building component of this study.

2.5.1 GROSS MARGIN – A SIMPLE DEFINITION

Gross margins are widely used in farm business management accounting practice, and farm planning and decision analysis (Malcolm et al., 2005). They are a simple profitability concept and measure the 'gross profit margin', which is the gross income generated by a single farm activity less the direct (variable) costs incurred in earning that income:

- Gross (profit) margin = total revenue from undertaking a farm activity *less* the direct or variable production, marketing and transport costs associated with the activity.

In farm business management applications, the gross margin of all farm activities are typically aggregated to estimate the 'total gross margin' of the farm business, which is available to cover total farm overhead (fixed) costs and generate a residual 'net profit margin' or more simply 'net profit':

- Net profit (margin) = total gross margin *less* the fixed or overhead costs of conducting the enterprise.

When the impact of changes to farm activity mixes are being considered, the overhead (fixed) cost component of the profit equation is typically omitted from immediate consideration. By definition, these fixed costs do not vary with changes in production levels and have no immediate effect on the contribution that changing activity mixes or intensities have on aggregate levels of farm gross margins. As such, they give no additional information for managers concerning resource allocation performance other than whether or not a positive net profit is actually made.[2]

Gross margin analyses are also frequently employed at higher levels of farm enterprise aggregation, including, for example, studies of the impact of new technologies or farm practices on sectoral, regional or national income levels (e.g. Holmes, 2009; Holmes, et al., 2011). For the present study, changes in the level of regional income attributed to a change in the level of on-farm activity within a region, resulting from, for example, reductions in processing or transport costs, are estimated as net changes in the gross margin per hectare of a representative crop aggregated across the projected area grown to the crop before and after the change is implemented. The overhead costs associated with operating farm enterprises in the region are not factored in to the impact projections because the changes in projected gross margins adequately provide estimates of the magnitudes of *changes* in regional farm sector profitability.

2.5.2 **REPRESENTATIVE REGIONAL CROP GROSS MARGIN**

Changes in economic values of regional agricultural activity resulting from changes, for example, in regional transport, processing or marketing infrastructure is based on projections of changes in the aggregate total farm gross margin for the affected region. A three-stage process is employed in this study for the calculation of this aggregate total farm gross margin. The first stage involves the collation of a set of *baseline gross margin* estimates for an array of field, horticultural and plantation crops in each of the study regions. These estimates are calculated for a *representative* farm (typical of the local farming system, climate and resource endowment) located in the region and are presented on a *gross margin per hectare* basis. The second stage involves creating *scenarios* of development opportunities and making assumptions concerning projected changes in either the input costs or output prices for the different crops or the technical efficiency (input–output ratios) with which they are grown. The resulting *scenario gross margin* estimates are then applied in a third stage to the area already grown to the crops under review or to expanded areas of those crops consistent with the nature of the specific scenario.

Historically, estimates of gross margin per hectare or unit weight of the major field, horticultural and plantation crops that are grown in various regions were generally provided each year by the economics and agronomy staff employed by the various agricultural departments in the three northern jurisdictions. With changing service directions, organisational structures and reduced employment of regional economics staff in the last decade, the formal generation of annual crop gross margins by public agencies has been significantly reduced. However, the project team interacted closely with regional economists and agronomists to generate gross margins for each of the six case study regions. This approach was supplemented by collating a mix of computer simulated crop yield, cost and price data that have been drawn from archival sources, trade publications, technical advice sourced from public and private technical experts, and local agribusiness operations.

A semi-standard template was created for calculating the individual crop gross margins and was then adapted to meet the particular characteristics of a given crop. For example, most annual broadacre field crops (especially cereals – grain sorghum, maize and rice) fit the standard template with little modification. Some field and horticultural crops with multiple grades of produce (e.g. chickpea, mango), and perennial and semi-perennial crops with partial planting and fallows or longer-term establishment profiles (e.g. sugarcane, banana and Indian sandalwood) required adaptations to the template to allow for the specific agronomic and marketing context associated with the particular crop. In all cases the general format included an estimation of prices, average yields and, where applicable, proportions allocated to different grades to give an estimate of annual (mean) gross returns per hectare.

Cartage or freight charges (per hectare equivalent) and any other levies applied on farm yields (e.g. research and development) were deducted from the gross revenue estimate to give a 'farm gate' gross revenue estimate. Variable costs were estimated for machinery field operations (e.g. ploughing, planting,

[2] It is important, however, to recognise the systemic nature of farm enterprises and the impact that individual farm activities may have on the total activity mix. If expansion of an activity requires a significant capital investment then gross margin analyses should be complemented with more advanced *capital budgeting* techniques (e.g. discounting, cost–benefit analysis).

fertiliser application), fertilisers, chemicals (herbicides, insecticides, fungicides and defoliants), irrigation, field labour (e.g. scouting, chipping), harvesting and marketing. The estimates for principal grain/fruit or fibre yields and by-product yields were derived using the APSIM crop yield simulation model (Keating et al. 2003), and associated irrigation and fertiliser input levels were applied to the relevant cost components. The gross margin per hectare was then derived as the difference between the 'farm gate' gross revenue and the total variable costs. An example of a template is presented in Figure 2.4.

Crop:									
District:	Not Specified					**Area:**	50	ha	
									PER HA
INCOME ($/ha)									
Price/tonne							$200.00	$/tonne	$10,000.00
less: Cartage							$0.00	$/tonne	$0.00
Freight							$0.00	$/tonne	$0.00
Drying							$0.00	$/tonne	$0.00
Storage							$0.00	$/tonne	$0.00
Levies							$0.00	$/tonne	$0.00
ON-FARM PRICE ($/tonne)							$200.00	$/tonne	
crop YIELD							50.0	t/ha	
GROSS INCOME ($/ha)									**$10,000.00**
VARIABLE COSTS ($/ha)									
Machinery Operations (F.O.R.M.)									
Primary tillage					1	x	$2.00	/ha	$2.00
Secondary tillage					1	x	$2.00	/ha	$2.00
Fertiliser application					1	x	$2.00	/ha	$2.00
Inter-row tillage					1	x	$2.00	/ha	$2.00
Boom spraying					1	x	$2.00	/ha	$2.00
Planting					1	x	$2.00	/ha	$2.00
Fallow spray	1	sprays	x	2	L	x	$2.00	/L	$4.00
Seed				4	kg	x	$2.00	/kg	$8.00
Fertiliser				0.5	kg	x	$250.00	/tonne	$125.00
Herbicide	1	sprays	x	2	L	x	$10.00	/L	$20.00
Insecticide	1	sprays	x	5	L	x	$5.00	/L	$25.00
Fungicide	1	sprays	x	10	L	x	$6.00	/L	$60.00
Regulant	1	sprays	x	45	L	x	$30.00	/L	$1,350.00
Aerial spray				1	operation	x	$350.00	/ha	$350.00
Scouting				1	operation	X	$45.00	/ha	$45.00
Irrigation				2.5	ML	x	$5.00	/ML	$12.50
Casual labour							$45.00	/ha	$45.00
Insurance							$4.00	/ha	$4.00
TOTAL PRE-HARVEST COSTS									**$2,060.50**
Harvest spray	1	sprays	x	4	L	x	$70.00	/L	$280.00
Harvesting									
Own Harvesting Costs							$0.00	/ha	$0.00
Contract header				1	ha/hour	@	$65.00	/hr	$65.00
plus fuel				35	L/ha	x	$2.00	/L	$70.00
TOTAL HARVEST COSTS									**$415.00**
TOTAL VARIABLE COSTS ($/ha)									**$2,475.50**
GROSS MARGIN ($/ha)									**$7,524.50**

Figure 2.4 Schematic illustration of a crop gross margin template

2.5.3 APPLYING REGIONAL GROSS MARGIN ESTIMATES TO DEVELOPMENT OF SCENARIOS

Regional crop gross margins form an integral component of the regional infrastructure and development modelling employed in this study, as illustrated schematically in Figure 2.5.

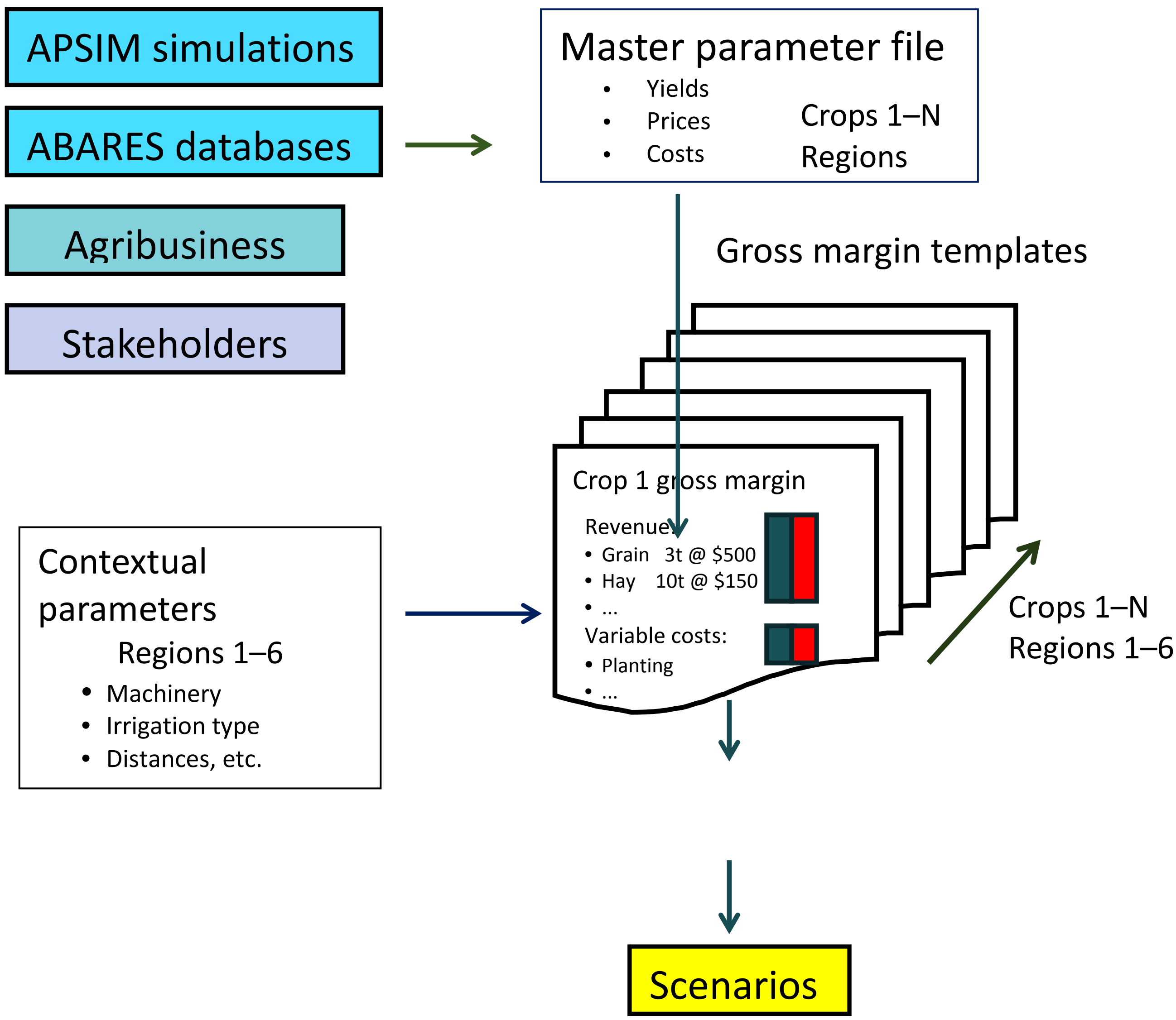

Figure 2.5 Schematic representation of the process by which the regional crop gross margin templates are incorporated within the regions development scenario modelling process

This analysis was developed by selecting a crop in each case study region to explore the variability in gross margins and vulnerability of the farm to increasing levels of debt. The variation in the gross margin was calculated from the variability in APSIM crop yields as well as the historical variation in crop prices. The gross margin distribution was used to show the likelihood and severity of good and bad years compared with the most likely result. This builds on a single number estimate to reflect the chance of better and poorer years.

Over time, a farmer is likely to have a balance of 'better' and 'poorer' years. However, from a debt servicing point of view, the sequence of 'better' and 'poorer' years following capital investment can have a large effect on the debt levels and business viability. This was explored by assuming 'low' and 'medium' debt levels for different crops and an interest rate of 7%. Random samples were taken from the yield and price distributions to create three crop and price scenarios. The number of 'better' and 'poorer' years was the same in both the 'better years early' and the 'poorer years early' scenarios – the difference being the order the years occur. A third scenario was developed that maintained the random sequence and added 'shocks' to the yield to explore the vulnerability to 'failed' years. A 'failed' year was defined as a yield of 20% of the most likely yield. In all cases, the ABARES price path was also considered for the period of analysis to capture trends in prices. Note that the analysis based on gross margins does not show farm profit because it does not include fixed or overhead expenses such as depreciation for equipment and buildings.

2.6 Supply chains and logistics

A characteristic of the supply chains for agricultural produce and farm inputs in northern Australia is that they are both geographically long and dispersed between the point of production and domestic markets or shipping ports. For some high-value crops, transport and shipping distances of over 3000 km are common (e.g. transport of mangoes from Darwin to Melbourne via Adelaide) along roads that are often inaccessible during the wet season. Because of the long distances, transport costs often exceed 30% of the market value of the fresh or processed crop. Although the case study regions for this project are accessible to shipping ports (e.g. Wyndham, Darwin, Townsville) for export, some of these ports either do not have immediately suitable loading or storage infrastructure for the relevant crops, or would involve very high costs (compared with southern ports) due to the lack of available containers and the low volumes of product being shipped out. New or increased crop production in the case study regions may increase pressure on existing infrastructure (road, storage, vehicles, port) or create opportunities to decrease unit costs of logistics via increased transport and shipping volumes.

A supply chain costing model was developed to identify the logistics costs for each crop by region and to evaluate infrastructure opportunities or restrictions. The scope of the supply chain analysis is between farm gate (postharvest) and the port or distribution centre. Depending on the crop, the supply chain paths will vary in terms of segments (transport, processing, storage) and destinations. The supply chain scope, range of pathways and the variables included in the analysis are illustrated schematically in Figure 2.6. For some crops (e.g. peanuts), the scope of the analysis did not include the post-processing steps (e.g. secondary transport) because of either the unknown or large number of possible post-processing pathways (e.g. several markets) for that part of the supply chain.

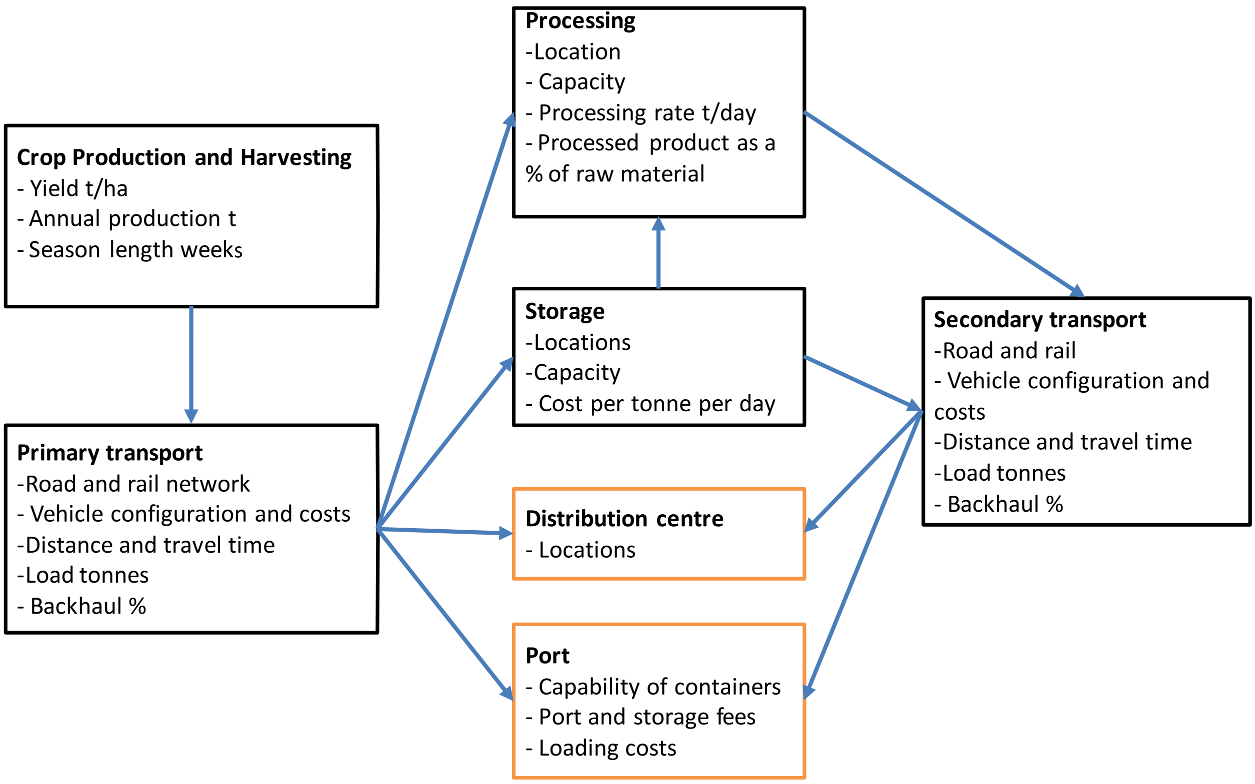

Figure 2.6 Schematic outline of supply chain model and main variables

The logistics model was built on a Microsoft Excel® spreadsheet, and allows the user to create the supply chain for each regional case study and crop, to determine the logistics costs per tonne of product handled or for the whole case study region. While, the model is largely focused on transport costs, the other major supply chain cost elements of processing, packaging and storage are included where data are available. For land transport, the main cost components or drivers are:

- cost ($) per kilometre, which depends on vehicle type (B-double, Type 1, Type 2, refrigerated, train) and average speed
- fixed cost ($) for pick-up, which depends on the crop type
- capacity of the transport vehicle (tonnes), which is different for each crop
- distance travelled (least cost route) and road grade, which determine the average speed per road segment
- backload percentage, which is available for every origin to destination and crop type.

The model contains tables of these components that are relevant to all crops, all case studies and all of the identified supply chain paths. An example screenshot of the supply chain model is presented in Appendix 2.4. Transport costs are modelled from the bottom up, using the published Freight Metrics tool.[3] Freight Metrics combines cost components of fuel consumption, wear and maintenance, salaries for drivers, depreciation, vehicle type, profit, etc. When benchmarked against some actual transport costs that were paid by a selection of livestock, mango and grains producers, the projected costs were within 10% for longer trips (>250 km). By using a ground-up model of transport costs, it is possible to test the sensitivity of the projected transport costs to changes in road conditions due, for example, to assumed investments in upgrades or bypasses. This cannot be done by solely using price data that are provided by producers and transport operators. Prices paid to transport providers are highly variable, depending on the level of competition for services by the time of year, the particular costing structure used by the transport company and their ability to secure backhaul loads for each trip.

Very low volumes of agricultural products are shipped out of northern Australia by sea transport, with sugar on the east coast being a notable exception. These low shipping volumes, coupled with inefficient placement of refrigerated containers and the low frequency of export shipping from the north, provided challenges for developing costings for containerised and bulk agricultural commodities in the supply chain scenarios. Based on discussions with freight companies and shipping lines, costings were developed on the assumption of increased volumes.

The supply chain model does not consider capital costs, but rather informs infrastructure investment scenarios of the operational logistics costs versus the baseline case. Throughout this report, road transport is described using various configurations of road trains. A conventional Type 1 road train pulls two 40-foot standard trailers (Figure 2.7), with a total vehicle length not exceeding 36.5 m (Australian Government Heavy Vehicle National Law 2014) and a gross combination mass not exceeding 82.5 t (weight restrictions based on Queensland guidelines). A Type 2 road train typically pulls three 40-foot trailers, with a total vehicle length not exceeding 53.5 m and a gross combination mass not exceeding 122.5 t.

[3] www.freightmetrics.com.au

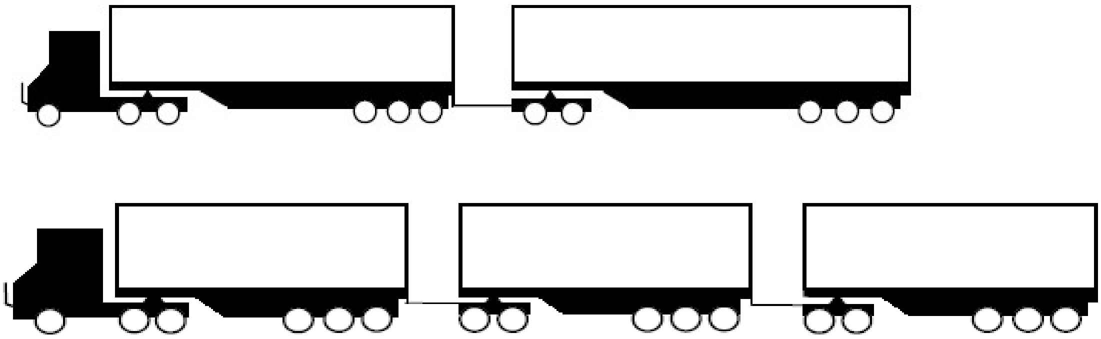

Figure 2.7 Typical Type 1 (top) and Type 2 (bottom) road trains
Source: Commonwealth of Australia National Class 2 Heavy Vehicle Road Train Authorisation notice 2014

2.7 Regional-scale assessments

Within each region, scenarios were developed for crop production at a scale that was based on the hectares that could feasibly be supported by available water. In some cases (e.g. Ord, Mataranka) the amount of available water was based on specific water allocation plans, while in other regions (e.g. Flinders and Gilbert region) the estimates were based on the best available information of the likely prospectivity for water availability (Petheram et al., 2013a, 2013b). These regional-scale water availability and use scenarios are summarised in Table 2.5.

Table 2.5 Scale of irrigation developments within the different regions used to assess aggregated outcomes

REGION	WATER AVAILABLE FOR ALLOCATION (GL)[a]	ANNUAL RELIABILITY (%)	DEVELOPMENT AREA (ha)	APPROXIMATE WATER USE (ML/ha)[B]
Pilbara[c]	120; groundwater	95	8,000	10–15
Ord	865; surface water	95[d]	50,000	5–15
Mataranka	18[e]; groundwater	90 (5 GL; high) 70 (13 GL; medium)	2,500	5–8[f]
Gilbert	300; surface water	85	30,000	5–12
Flinders	250; surface water	70–80	15,000	5–12
Dawson	40[g], decreasing to 20 over 10 years; groundwater	95	8,000	3–7
Darling Downs – Maranoa	30, decreasing to 15 over 15 years; groundwater	95	5,000	3–5

a Water available at the farm gate; does not include on farm losses
b Assumes some water losses associated with field application
c Potentially >250 GL is available, but given the spatially diverse nature of the resource, temporal limits on availability of surplus mine water (i.e. finite limit to ore extraction operations that supply the water) and likelihood that not all mine de-water will be available, a conservative approach to water resource availability has been assumed.
d Even in the 5% years that are not 100% reliable, it is likely that >50% water will be available,
e The upper limit of allocation is 36 GL but, beyond 18 GL, reliability becomes low.
f Assumes dominant use by horticulture, with lower water use and higher efficient methods (e.g. trickle/tape)
g Presently, approximately 50 GL of water is currently available, with an irrigation area of 7500 ha. This scenario would provide an additional 7000 ha, with a reliability of 95%.

The assumed scale of development varies considerably across the regions. For example, the Ord River Irrigation Area draws on a large and reliable water storage, with 865 GL of water available for irrigation within the current water allocation plans. By contrast, the Tindall aquifer at Mataranka is a much smaller water resource and only capable of servicing around 2500 hectares of additional irrigated land per year. In three of the regions (Pilbara, Dawson and Darling Downs), irrigation is possible because surplus water is made available from mining or gas drilling operations.

Two contrasting cropping scenarios were developed for each case study region. Although the nature of these scenarios varies according to the particular circumstances of each region, there were two broad groupings of cropping opportunities: one set of scenarios tended to focus on developing new processing infrastructure at local scales to service a broadacre food or industrial crop, while a second set of scenarios examined mixed cropping or horticulture and, where appropriate, explored their export potential. In the Dawson and Darling Downs regions, the scenarios were based more on cropping differences, because of existing processing infrastructure supporting the broadacre cropping industry.

As the permutation of possible crops, rotations and scale of planting are almost infinite, these two contrasting scenarios were used to illustrate the implications of development for infrastructure, transport needs and regional economies within each region. For example, for transport, it informs additional infrastructure requirements in terms of vehicle trips per day, vehicle fleet, storage capacity (bulk and containerised) and processing capacity. Infrastructure investments to meet these requirements include road upgrades (to allow road trains or improve all-season access) or road diversions, storage (new and expanded), port facilities (e.g. refrigerated container points, cranes for container movements) and processing facilities. Examples are provided of different infrastructure investment options to process or transport crops. It is not intended that these scenarios be interpreted as preferred scenarios; they are a representation of what may be possible in an effort to gain insights on associated infrastructure and supply chain needs that would be relevant to a wide range of scenarios.

The risks associated with development at a larger scale were assessed by examining runs of years through a 10- to 15-year start-up investment phase and how that influences the ability to recover the capital investment. These ‘runs of years’ were created by choosing combinations of average, poorer and better years from the distribution of gross margins in a sensitivity table that varies price and yield. Runs of better and poorer years and their timing in the 10- to 15-year investment period were used to simulate shocks or risks to the investment.

2.8 Regional economic implications

2.8.1 OVERVIEW OF MODELLING APPROACH

Building on the supply chain results for the scenarios described in Table 2.5, the ABARES AusRegion model was used to estimate the regional economic and employment impacts for the scenarios. AusRegion is a dynamic computable general equilibrium (CGE) model of the Australian economy that depicts the economy from the bottom up at the substate regional level, the level of the eight states and territories, and the national level. In representing the Australian economy in its entirety, including the interactions and interdependencies between industries, households and government, AusRegion takes full account of any flow on and interrelated impacts in parts of the economy that are not directly affected by the event being tested. Being dynamic, AusRegion is able to project annual results to 2029–30.

For this study the model has been developed further to explicitly represent transport margins for exports, enabling modelling of changes to transport costs implicit in road and port development envisaged in some scenarios. Additionally, AusRegion separately accounts for government investment and private sector investment. The model has been amended to allow exports from each region to be determined independently from other regions and the export demand function has been reviewed to reflect more accurately the agricultural commodities of interest in this study.

2.8.2 DATA

The regional and commodity aggregations in AusRegion are flexible and reconfigured to suit each project. The data underlying the regional disaggregation (Figure 2.8) for this project is based on 2005–06 statistical local area (SLA) data produced by the Australian Bureau of Statistics (ABS, 2006). It is not possible to get the detailed information needed to run AusRegion at a smaller scale. Therefore, the regional boundaries used in AusRegion are larger than those used elsewhere in this study. For example, the Ord River region as defined in AusRegion extends from the west coast to the Northern Territory border whereas the investment in the Ord River case study is centred on Kununurra.

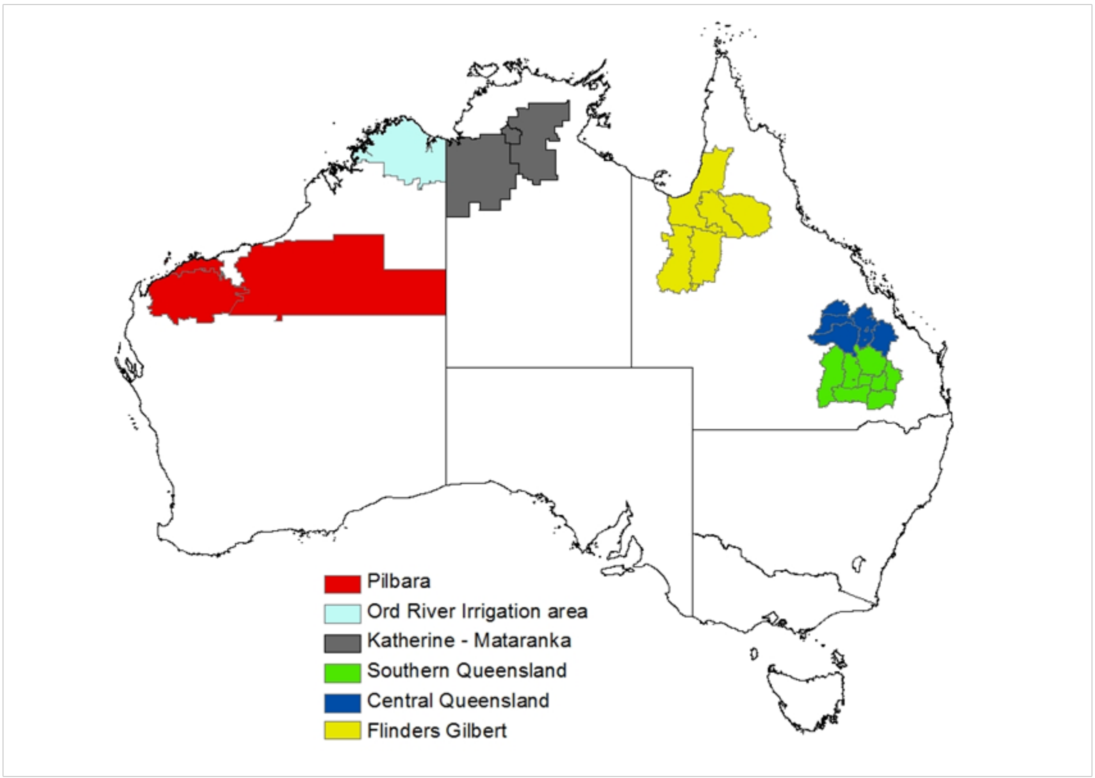

Figure 2.8 AusRegion regional disaggregation
Pilbara comprises the statistical local areas (SLAs) of Ashburton, East Pilbara and Roebourne; Ord River comprises the SLA of Wyndham – East Kimberley; Katherine–Mataranka comprises the SLAs of Victoria, Katherine, Elsey and Mataranka; Southern Queensland comprises the SLAs of Booringa, Roma, Chinchilla, Taroom, Tara, Bungi, Murilla, Waroo and Bendemere; Central Queensland comprises the SLAs of Emerald, Bauhinia, Duaringa, Banana, Peak Downs and Woorabinda; and Flinders Gilbert comprises the SLAs of Carpentaria, Croydon, Etheridge, Cloncurry and McKinlay. AusRegion also has representation of the rest of Western Australia, Northern Territory and Queensland, and the other states and territories.

The commodity aggregation includes the finest level of detail available on the cropping sectors using both ABS agricultural census and ABARES farm survey data, and considerable detail in the transport sector reflecting the focus of this study (Table 2.6).

Table 2.6 AusRegion commodity mapping

AUSREGION COMMODITY	AGRICULTURE COMMODITIES
Grains	Rice, sorghum, maize, chickpea, mungbean, peanut, chia
Beef cattle	
Other livestock	
Cotton	Cotton
Sugarcane	Sugarcane
Horticulture	Mango, banana, cucurbits, potatoes, cassava
Other agriculture	Hemp, kenaf, forage sorghum
Forestry	Sandalwood
Forestry products	
Fishery	
Mining	
Food	
Sugar	
Other manufacturing	
Electricity supply	
Electricity generation	
Construction	
Land transport	
Water transport	
Air transport	
Other services	

2.8.3 THE REFERENCE CASE

The AusRegion reference case is a ‘business as usual’ scenario of the Australian economy. It is developed from the model equations and exogenous information on changes in population, economy-wide productivity and output of agricultural industries at regional, state and national levels. The reference case is also informed by the projections of world prices and export demand described in Chapter 4 and Appendix 4.1.

AusRegion results are presented ‘relative to the reference case’. That is, we report the scenario result as the difference in the variable of interest between business as usual and the proposed scenario at a point in time.

2.8.4 **MODELLING THE SCENARIOS**

Each of the scenarios is modelled in two phases: a construction phase, building the infrastructure; and a production phase, increasing output from the agriculture sector. Under some scenarios the phases overlap, for example in the Ord, as the area of irrigated land increases, productivity and production also increase.

In the construction phase, the investment is exogenously imposed on the model, through the government or private investment variables as appropriate. In the production phase, it is the projected changes in land supply, production and the cost of transport determined from the farm level and logistics modelling that are exogenously imposed.

The effects of these investments flow through the regional and national economies as follows:

- increasing economic activity through the construction of new infrastructure
- increasing downstream and upstream economic activity generated by the expansion in agriculture; increased port activity, for example
- diverting labour to agriculture from other sectors in the region
- increasing the regional labour force through migration
- changing economic activity elsewhere in Australia; for example, to what extent does the increased agricultural production displace production elsewhere.

2.8.5 **PRESENTING RESULTS**

The combined economic effect of these changes is reported as the per cent change in gross regional product (GRP), regional exports, employment and real wages. Changes in state, territory and national economic welfare (gross state product (GSP) and gross domestic product (GDP)) are also presented to highlight the state and national consequences of government investment.

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3 DIFFERENCES BETWEEN SOUTHERN AND NORTHERN AUSTRALIA

3.1 Population

Although the land mass of northern Australia comprises 37% of the continent, north of the Tropic of Capricorn it has only 5% of the national human population. There are approximately 1.2 million people living in northern Australia, which equates to an average density of less than 0.5 persons per square kilometre, compared with an average of three persons per square kilometre for Australia as a whole. The majority of people in northern Australia live in the major urban and regional centres of coastal Queensland and in Darwin. Aboriginal people comprise less than 3% of the Australian population but around 32% of the population of the Northern Territory and smaller proportions of the populations of Queensland and Western Australia north of the Tropic of Capricorn.

Securing an adequate and reliable supply of labour is a major challenge for the agricultural sector in northern Australia. This is exacerbated by the resource sector in northern Australia, which can provide higher wages than those in the agricultural sector. Seasonal labour for the horticultural industry is mostly in the form of 'backpacker' tourists, who can extend their holiday and working visas (417) for a second year if they work for 3 months in a regional location in the areas of Plant and Animal Cultivation, Fishing and Pearling, Tree Farming and Felling, or Mining and Construction. Shortages of core skills have also been addressed, in part by issuing 457 visas (skilled migration), although recent tightening of that program has reduced the opportunities for agriculture in northern Australia.

3.2 Infrastructure and services

In line with a small population, available infrastructure and services to support northern Australian agriculture are generally lacking in comparison with the rest of Australia. This is highlighted in Figure 3.1, which shows that for infrastructure and essential services and human capital, northern Australia lags further behind the rest of Australia than for all other indicators.

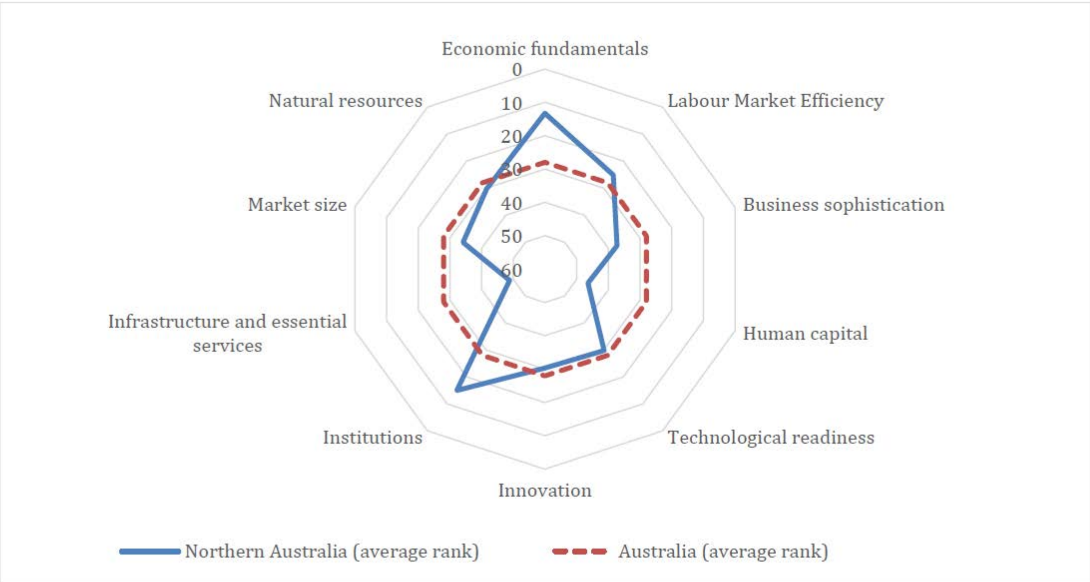

Figure 3.1 How northern Australia compares with the rest of Australia across a range of indicators
Source: Regional Australia Institute (2013)

Infrastructure and services have a strong bearing on the success of new investments in regional development, especially for industries such as agriculture and mining. Figure 3.2 shows that with the exception of police and hospital services, northern Australia lacks competitiveness in critical areas such as transport infrastructure and education services. The long distance between points of production and suitable port infrastructure is also a major driver of the lack of competitiveness of infrastructure in northern Australia.

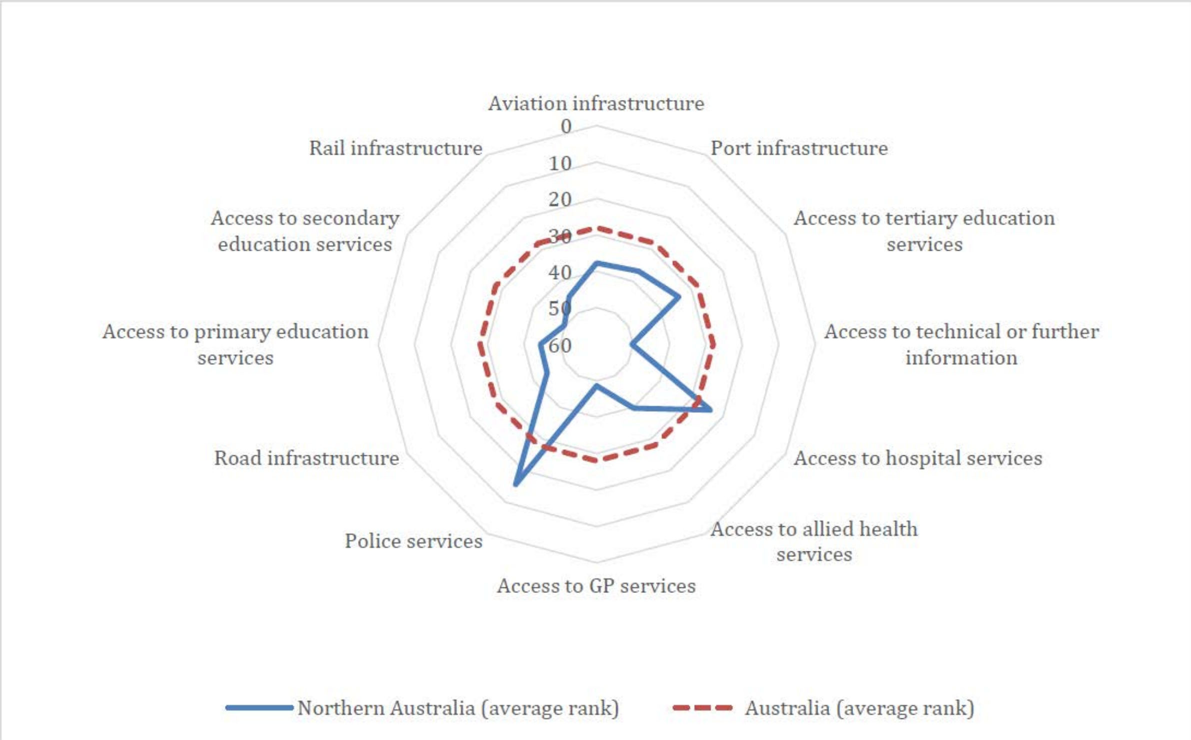

Figure 3.2 How northern Australia compares with the rest of Australia for infrastructure and services
Source: Regional Australia Institute (2013)

3.3 Climate

Northern Australia has a tropical climate that varies from wet tropical on the north-east coast, semi-arid tropical for much of the savannahs that stretch across northern Australia, and arid in the inland regions of western Queensland, the Northern Territory and the Pilbara region of Western Australia. Rainfall across northern Australia is highest in summer, with annual average rainfall varying from 3000 mm in the wet tropics to 300 mm in the more arid regions. The semi-arid tropical regions, which make up most of the land suitable for new or expanded irrigated agricultural developments, have annual rainfall totals that range from 500 to 1100 mm.

Annual rainfall across northern Australia tends to be higher than in southern Australia (Figure 3.3). The main defining feature is that the rainfall is highest in summer, and for many locations over 90% of annual rainfall occurs between November and April. In contrast, the Mediterranean-like climate of southern Australia results in most rain occurring in from late autumn to early spring (May to September).

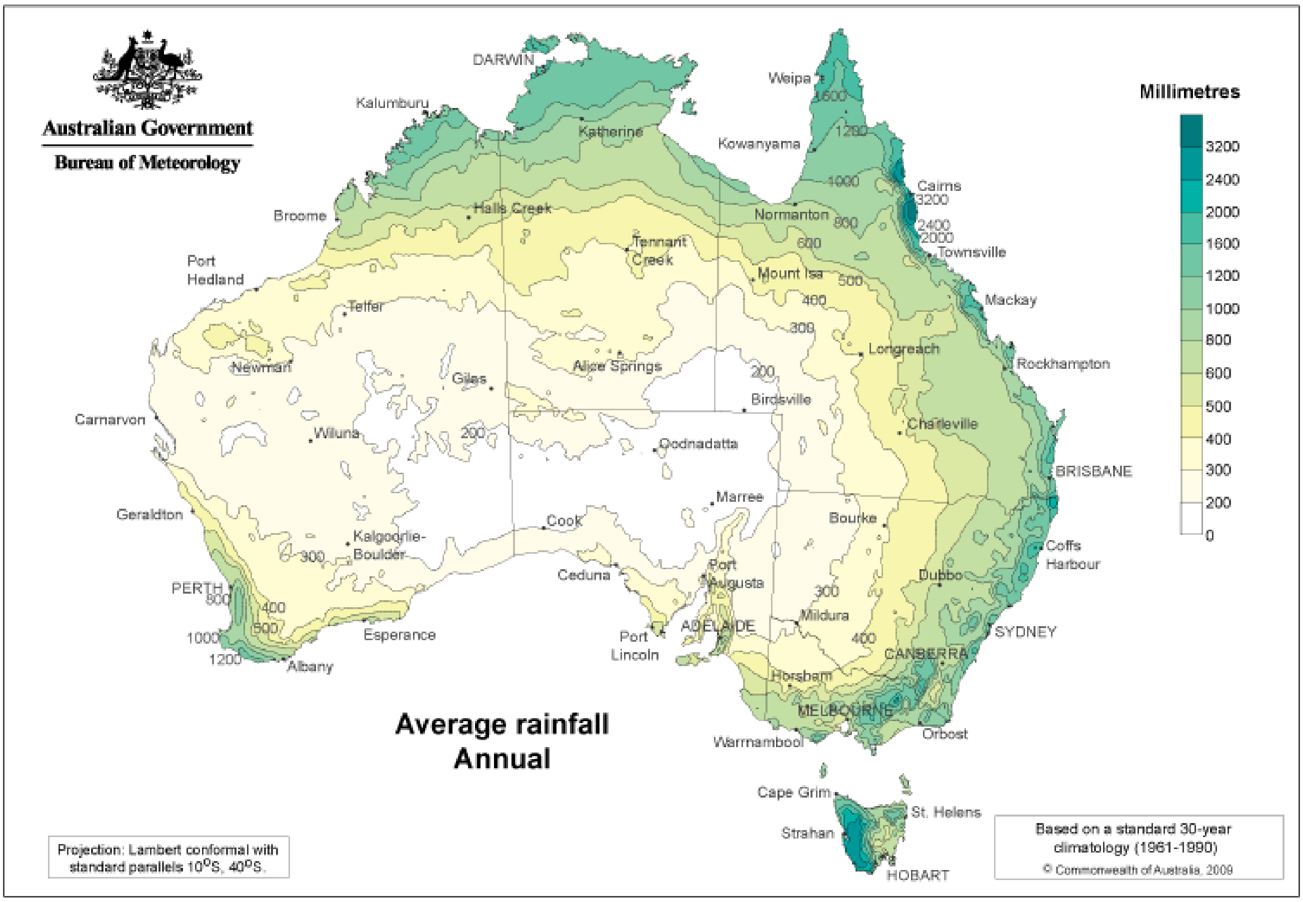

Figure 3.3 Mean annual rainfall across Australia

Source: Bureau of Meteorology: www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp

Rainfall patterns are also generally much more variable in northern Australia than in southern Australia. For the same annual average rainfall, the interannual variability expressed as the coefficient of variation (CV) is generally higher in northern Australia (Figure 3.4). This high variability has significant implications for access to water resources for development and the reliability of water storages. As streamflow variability increases, and assuming the same level of reliability of supply, the required storage capacity needs to increase to be able to meet the same level of demand.

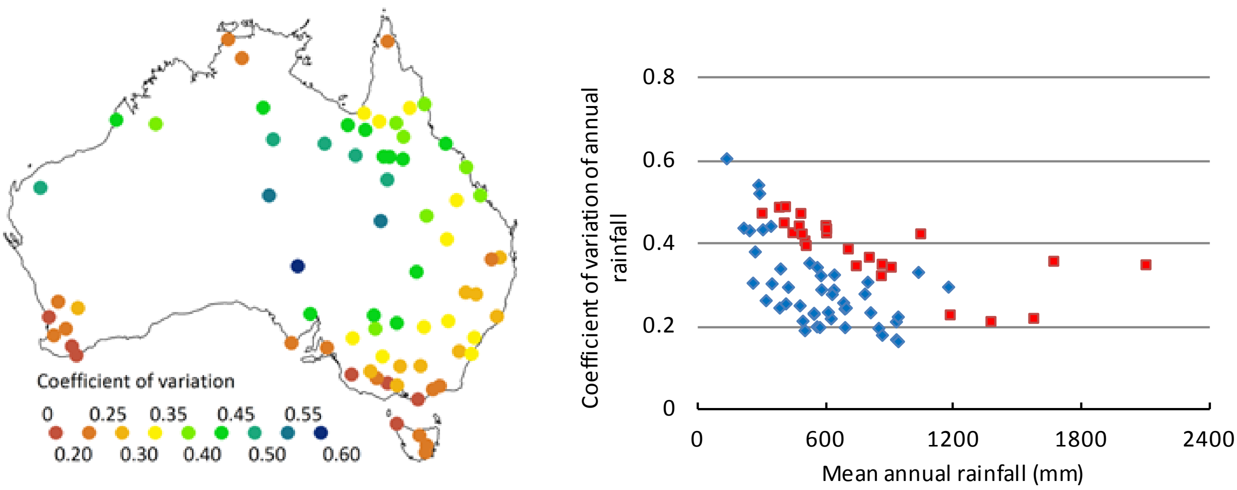

Figure 3.4 Left: Coefficient of variation of annual rainfall for 71 high-quality rainfall stations around Australia under historical climate. Right: The coefficient of variation of annual rainfall plotted against mean annual rainfall for 71 rainfall stations around Australia; red squares indicate rainfall stations north of the Tropic of Capricorn

Source: Turnadge et al. (2013)

Being a tropical climate, summers are hot and winters are mild across northern Australia. High potential evaporation rates are associated with the high temperatures, and apart from the wet tropics these range from 2400 to 4000 mm (Figure 3.5). This compares with annual potential evaporation rates of 1600 to 2000 mm in the main irrigation areas of south-eastern Australia. The high potential evaporation rates in northern Australia have implications for water storages because annual water losses can be high even before water is applied to crops.

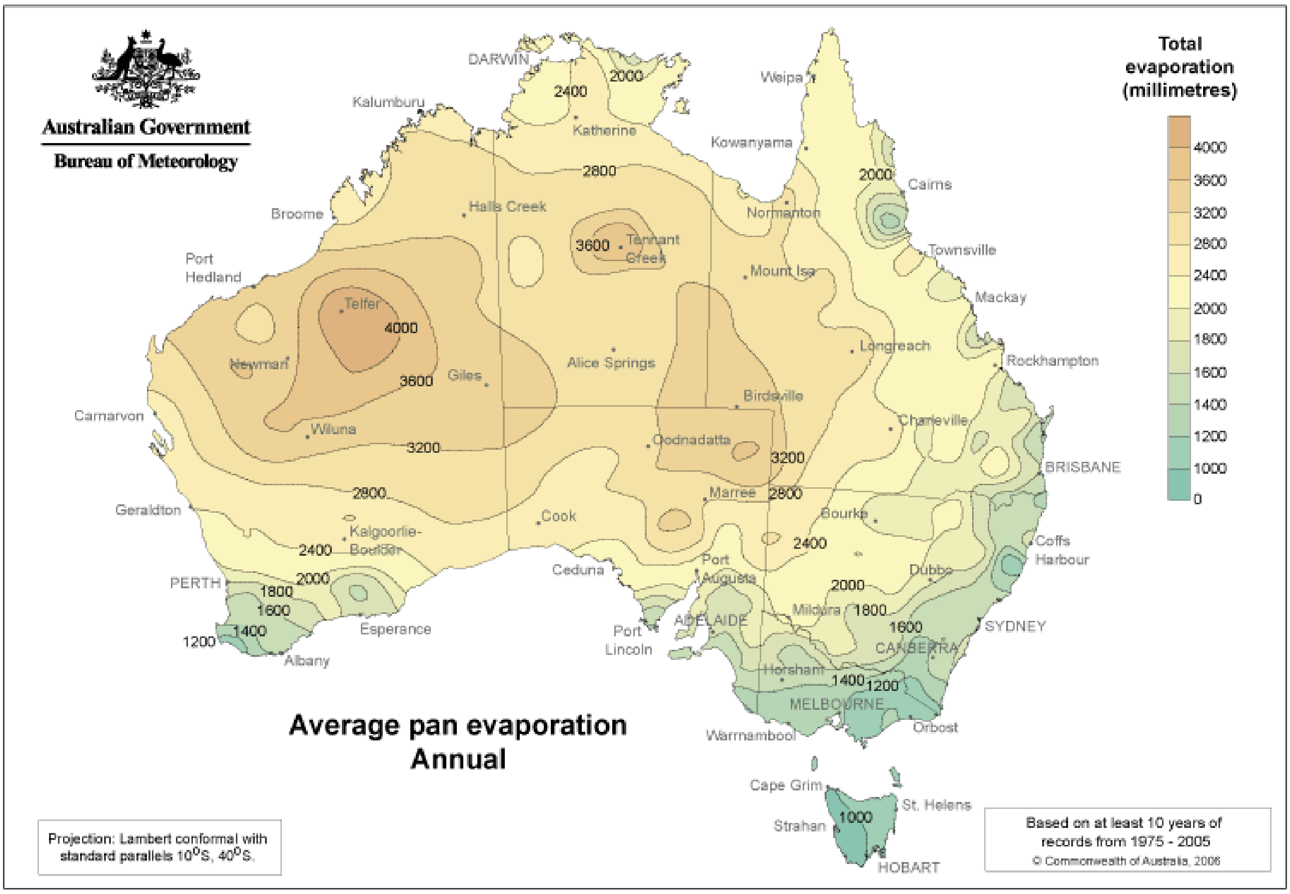

Figure 3.5 Annual evaporation rates as measured by pan evaporation

Source: Bureau of Meteorology: www.bom.gov.au/jsp/ncc/climate_averages/evaporation/index.jsp

The very hot summers can impact on the ability to grow some crops (e.g. cucurbits), and may cause stress to other annual crops during critical stages of seedling establishment, flowering or grain fill. The mild winters allow a number of summer annual crops to be grown under irrigation at this time of the year. However, night temperatures can still be cool enough to limit the growth of some crops during the dry season (e.g. in most locations, cotton needs to be grown in summer, with the exception of Kununurra and Katherine).

A significant competitive advantage of the tropical climate compared with southern Australia is that tropical fruits and vegetables can be grown, and especially out of season, although the subtropics of south-east Queensland and northern New South Wales are also capable of growing many tropical fruits.

3.4 Water resources

3.4.1 SURFACE WATER

Consistent with a strongly seasonal rainfall pattern, rivers in northern Australia are highly seasonal in their flow characteristics and much more so than in southern Australia (Petheram et al., 2008). As many of these rivers stop flowing in the dry season, in the absence of groundwater, large-scale irrigation of crops in the dry season is dependent on water storages. Some small-scale irrigation can occur from perennial rivers, streams and waterholes, but this is usually limited to between tens and hundreds of hectares. In addition to the high seasonality of flow, which reflects the intra-annual variability in rainfall, the interannual variability in streamflows is typically large, approximately two to three times more variable than streamflow in other parts of the world that have the same climate type as northern Australia (Petheram et al., 2008). Commercially viable large-scale irrigation developments rely on high levels of water supply reliability, which necessitates large-scale storages that can carry over water from one year to the next to even out this variation.

Estimates of the potentially divertible yield of water from northern Australian rivers have been made (Figure 3.6) by Petheram et al. (2009), based on mean annual runoff within each of the river catchments and the potentially divertible yield percentage as developed by the Australian Water Resources Commission (AWRC, 1987). Divertible yield estimates were made at the point of lowest practical downstream development and assumed the construction of one or more dams or other large storage structures. These estimates ignored social, cultural, environmental and economic considerations.

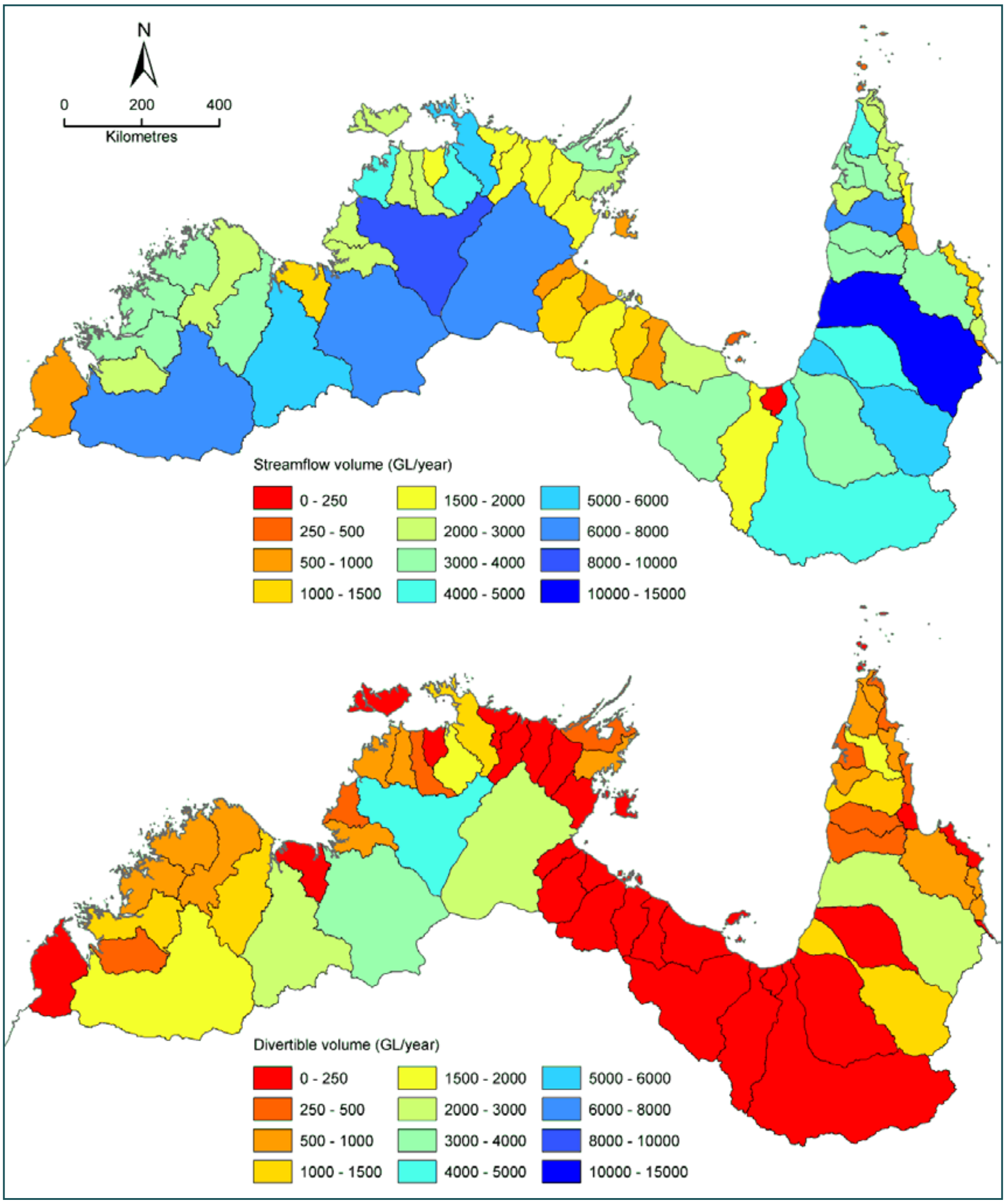

Figure 3.6 Streamflow volume in northern catchments as computed in the Northern Australian Sustainable Yields project (top) and potentially divertible streamflow volume (bottom)

Source Petheram et al. (2009)

Based on these estimates, only 45% of the potential exploitable surface water yield in Australia is located in the north despite the fact that approximately 64% of national total runoff is generated in northern Australia (Petheram et al., 2010). Unfavourable streamflow characteristics, storage constraints and evaporative losses all contribute to the lower available water yields in northern Australia.

3.4.2 GROUNDWATER

Groundwater has the potential to provide water for irrigation in northern Australia, but a lack of good information on groundwater processes makes it difficult to assess and manage this water resource. Not only does the volume of an aquifer need to be known, but also the key recharge and discharge processes need to be understood to responsibly manage a groundwater system. Like rainfall and runoff, these processes can vary considerably within and between years.

Turnadge et al. (2013) produced a groundwater prospectivity assessment for northern Australia, using a new approach. Three basins, the central Daly-Wiso and Georgina, the coastal section of the Canning Basin and the Great Artesian Basin each have estimated extractable groundwater volumes of over 100 GL/year (Table 3.1). These projected figures suggest that, on the basis of the limited available data, approximately 600 GL/year of extractable groundwater, conservatively, may be available in northern Australia.

This amount of groundwater is relatively small compared with extraction rates that are occurring for agriculture in southern Australia (e.g. some 1795 GL are extracted annually from the Murray–Darling Basin). Extraction rates as a proportion of annual recharge tend to be high in already developed areas in southern Australia, and the estimates for northern Australia are based on more conservative extraction rates in the absence of drilling data and field-based assessments.

Table 3.1 Estimated annual groundwater availability from northern Australia at the intra-basin scale

GROUNDWATER RESOURCE	DEVELOPMENT POTENTIAL	ESTIMATED AVAILABLE EXTRACTION (GL/year)
1. Daly, Wiso and Georgina basins	High	> 100
2. Canning Basin	High	> 100
3. Great Artesian Basin	high	> 100
4. Daly, Wiso and Georgina basins, excluding 1	Moderate	10–100
5. Canning Basin, excluding 2	Moderate	10–100
6. Other groundwater resources	Low	< 10

Source: Extracted from Turnadge et al. (2013)

3.5 Soils and land suitability

In most parts of Australia, and especially in northern Australia, soils are ancient, strongly weathered and infertile by world standards. This has important implications for agricultural development. Suitable agricultural soils do exist throughout the north and the overall extent of soils suitable for agriculture is not the major constraint (Webster et al., 2009). Detailed soil studies are needed at regional scales to more accurately determine the areas of suitable soils. For example, the Flinders and Gilbert Agricultural Resource Assessment (Petheram et al., 2013a,b) found that within the Flinders River catchment of northern Queensland there were approximately 8 million hectares of soils moderately (Class 3) suitable for irrigated agriculture. Managing these soils for crop production is no different to managing any other Class 3 soil in Australia, and from that perspective there is little difference between northern and southern Australia.

A larger constraint for irrigation development than the area of suitable soils is their actual proximity to available irrigation water resources. Many of the better soils are found in alluvial areas, but these are often prone to wet-season waterlogging and flooding, with a consequent risk of crop and infrastructure damage. Almost all soils in northern Australia require high fertiliser inputs to provide good crop yields. Organic matter is typically low and many of the soils have inherently low-to-moderate water-holding capacity. Evidence from across Australia suggests that ancient landscapes, like those of the north, are less resilient to change and, once disturbed by agricultural practices, are more likely than younger landscapes to decline in condition (McKenzie et al., 2004).

3.6 Implementing large-scale agriculture in northern Australia: learning from the past

Attempts to undertake large-scale agricultural development in northern Australia is not new. It has a history dating back to at least the first half of the 20th century, so, in addition to understanding the differences between southern Australia and northern Australia, much can be learned from past development initiatives in the north. Bauer (1978) and Fisher et al. (1978) provided a review of the factors affecting the outcomes of these early agricultural developments. Building on those reports, a new analysis (described in Appendix 3.1) was undertaken as part of this project to determine the critical factors in success or failure of agricultural developments in northern Australia.

Key points to emerge from an assessment of 13 past developments include:

- The natural environment (climate, soils, pests and diseases) makes agriculture in northern Australia challenging. However, for the agricultural developments that were assessed, with a couple of exceptions (e.g. insect pests and cotton in the early phase of the Ord River Irrigation Area development), environmental factors were not the primary reason for lack of success.
- Management, planning and finances were assessed to be the most important factors in determining the ongoing viability of agricultural developments. In particular, unrealistic expectations for achieving a reasonable return on investment in the first few years brought a number of developments to a premature end. Two key factors contributed to the overestimated returns: overly optimistic expectations of being able to rapidly scale-up the area of land developed, and not coming to grips with the operating environment and taking time to build up experience at smaller scales. It is clear from this assessment that allowing adequate time to achieve a return on investment is required for longer-term viability.
- Supply chains and markets were important factors in determining the success of a number of the developments. Processing facilities for broadacre commodities that require processing need to be located within reasonable distance from production and at a sufficient scale to make them viable in the long term. In more remote regions, higher-value products such as fruit, vegetables and niche crops have been more successful, even though high supply chain costs to both domestic and export markets remain impediments to expansion.

The analysis has shown that for developments to be successful, all factors relating to climate, soils, agronomy, pests, farm operations, crop and irrigation management, planning, supply chains and markets need to be brought together within a comprehensive systems design. Particular attention needs to be paid to scaling-up at a considered pace and being prepared for reasonable lags before positive returns on investment are achieved.

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4 COMMODITY MARKET ANALYSIS

4.1 Agricultural production in northern Australia

Agricultural production is a significant contributor to the northern Australian economy. In 2010–11 the gross value of agricultural production in the region north of the Tropic of Capricorn was $5.2 billion, with cattle production the dominant industry valued at $3.0 billion (57% of value of agricultural production) (ABARES, 2013a). The second-largest industry in value was sugarcane production, at $781.5 million (15% of value of agricultural production). Fruit and nut production was valued at $574.5 million (11%), and vegetable growing, for both seed and consumption, was valued at $310.5 million (6%). The production of cereals, legumes and oilseeds, important to several Queensland regions, was valued at $204.1 million in 2010–11 (4%).

Although cattle production currently dominates, interest in expanding and diversifying agricultural production and therefore developing the northern Australian rural economy is increasing. Factors driving this interest include favourable demand prospects for Australia's food and fibre production, and proximity to emerging international markets, particularly in Asia, where food demand is growing rapidly. As a result of these perceived opportunities, the Australian Government and northern jurisdictions are striving to develop policy environments that encourage the agricultural sector to take advantage of growing food demand and develop regional economies in northern Australia.

To capitalise on future market opportunities and to ensure the best chance of investment success in expanding agricultural production, identifying market and trade opportunities that are likely to foster long-term growth is paramount. To do this, we need a thorough understanding of the market outlooks for the range of current and prospective agricultural industries in northern Australia. This chapter and the detailed commodity analysis in Appendix 4.1 provide information on the markets for a range of commodities currently produced, or potentially could be produced, in many regions of northern Australia. The detailed analysis examines demand in major markets, the major global suppliers of each commodity and the extent of competition from other world suppliers that potential Australian exporters could face. Some indication is given of the trade barriers currently placing constraints on the expansion of trade, and an assessment of potential opportunities for each commodity on both domestic and international markets is presented. These potential opportunities are also summarised in each of the case study chapters for the commodities relevant to the cropping scenarios analysed for each region.

4.2 Drivers of global agrifood and fibre demand

Underpinning projections for world and domestic prices for each commodity and potential opportunities are results from work ABARES has been conducting. In ongoing research, ABARES has been examining the outlook for world agrifood markets to 2050 and assessing the implications for Australia's food exports, particularly with respect to Asian food demand and supply. ABARES projections indicate that, between 2007 and 2050, the real value of world agrifood consumption may increase by 77% (in 2007 US dollars), or 1.3% per year on average (Figure 4.1) (Linehan et al., 2012, 2013).

World demand for agrifood products is expected to increase significantly to 2050 because of a larger global population, growth in per-person incomes and increasing urbanisation, especially in developing countries. These factors also influence demand for natural fibre products for textile and clothing manufacture, although strong competition with man-made fibres is expected to continue. Food consumption patterns continue to shift from traditional diets oriented around starchy staples to more varied diets with greater quantities of higher-value and higher-protein foods (particularly meat and dairy products). Consumption of fruits and vegetables, cereals and vegetable oils is also projected to increase significantly (Figure 4.2).

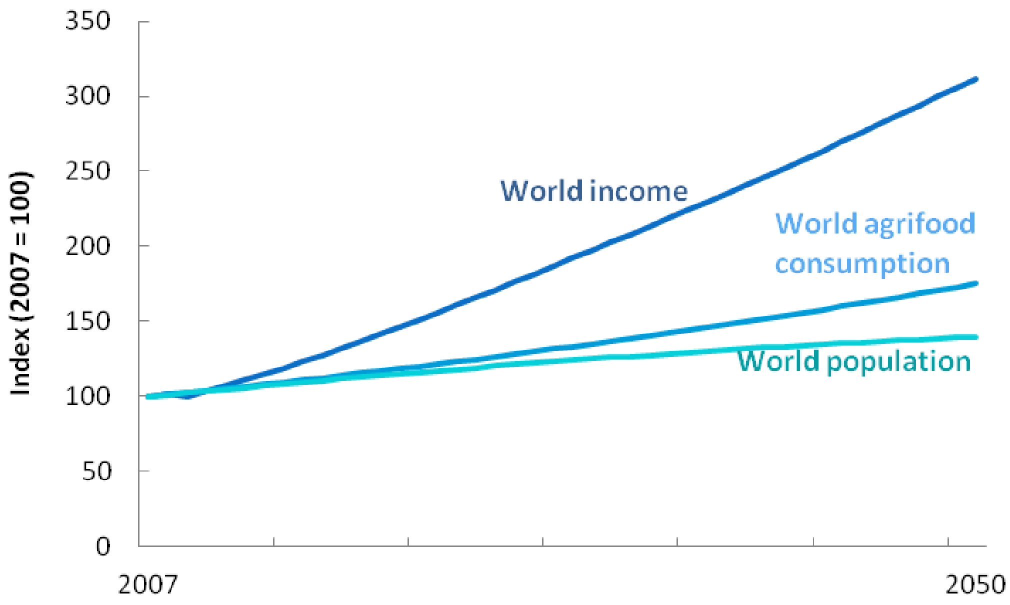

Figure 4.1 Growth in world agrifood demand, income and population

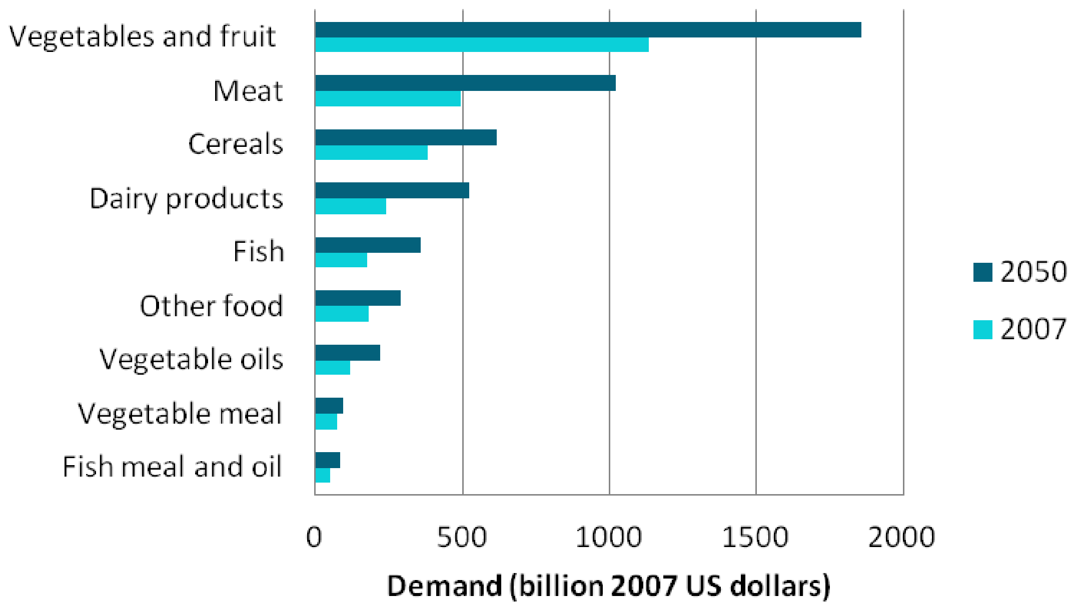

Figure 4.2 World agrifood demand by commodity grouping

In Asia, income and population growth is projected to lead to significantly higher demand for many food commodities (Figure 4.3), but this varies by market. Growth in food consumption in China is projected to be strongest for dairy products, meat and sugar, and limited for cereals as per-person consumption of rice declines over time. In India, a large proportion of the population follows a vegetarian diet; therefore, projected growth in consumption is largest for dairy products, and fruits and vegetables. For Association of Southeast Asian Nations (ASEAN) member states as a whole, the real value of fruit and vegetable consumption is projected to nearly double between 2007 and 2050, the real value of beef consumption is expected to be 120% higher, and the value of dairy consumption is projected to treble. Growth in food consumption to 2050 in Japan and the Republic of Korea is projected to be limited; this reflects already high incomes and food consumption per person, combined with expectations of declining populations and modest future income growth.

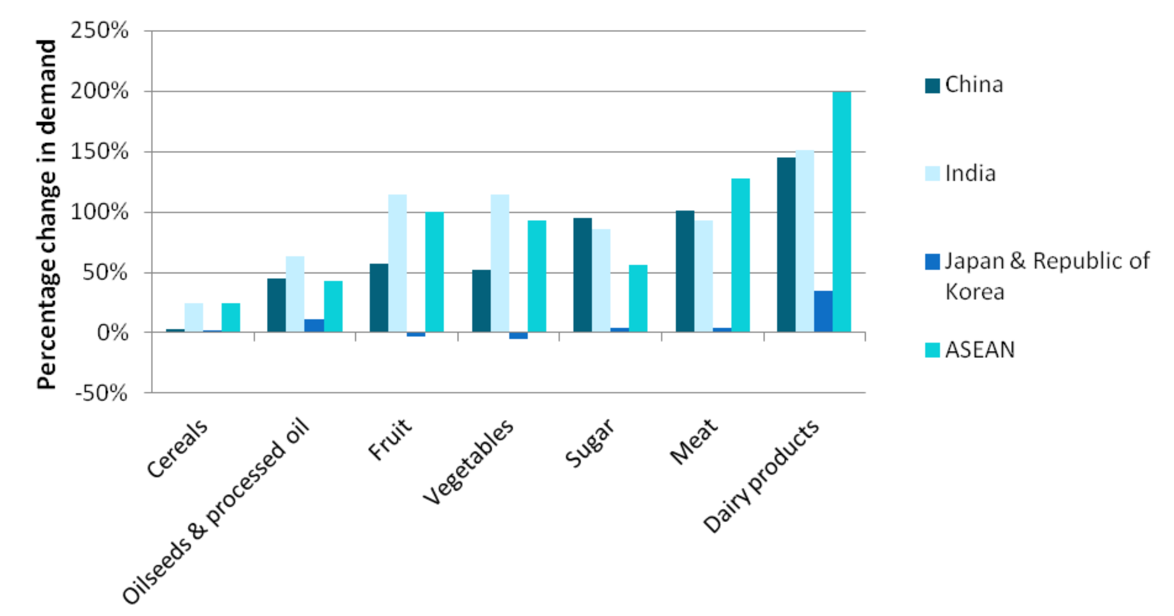

Figure 4.3 Projected changes in demand value between 2007 and 2050, Asian markets
Source: ABARES (2013b)

Asia has accounted for 50% of global agricultural production growth in recent decades. Improvements in total factor productivity have driven this growth. However, resource constraints and other challenges may slow Asia's future growth rates in agricultural production. Projections indicate that increases in food production in Asia will not be sufficient to meet growth in food consumption for many commodities. As a result, Asian import demand is likely to increase to complement domestic production (Figure 4.4) (ABARES, 2013b).

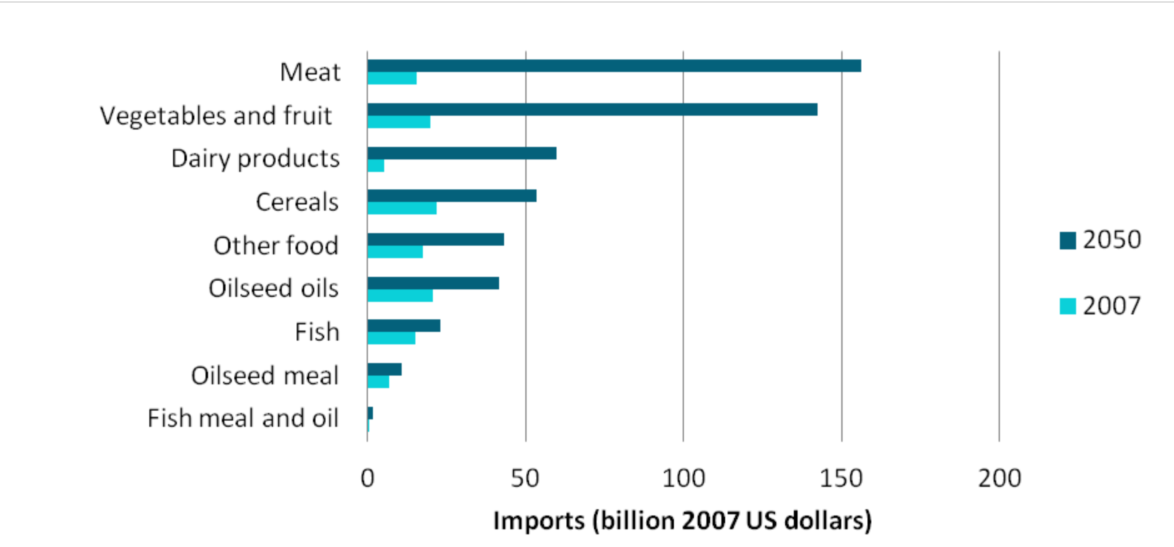

Figure 4.4 Asian agrifood imports

China, a net exporter of fruit in 2007, is projected to be a small net importer of fruit by 2050. With expanding domestic livestock production, import demand for feed grains such as maize is projected to rise. The projected growth in demand for fruit and vegetables is expected to result in India becoming a significant net importer of horticulture products and a small net importer of wheat by 2050. In ASEAN countries, imports of wheat are projected to rise by 40% between 2007 and 2050, as no significant amount of wheat is produced in the region. Net imports of fruit and vegetables are also projected to increase in the ASEAN group of countries and growth in consumption of beef and dairy products is also expected to be largely met by increased net imports.

4.3 Market opportunities for northern Australian commodities

A market analysis has been conducted for a range of commodities that are currently grown, or can potentially be grown, in northern Australia under expanded irrigation. Table 4.1 lists the commodities covered in the analysis and summarises detailed market analyses for each provided in Appendix 4.1. However, a range of issues affecting market opportunities on the domestic market and international markets are common across many commodities and are described below.

Table 4.1 Northern Australian commodities assessed

BROADACRE FOOD AND FEED CROPS]	INTENSIVE FOOD CROPS	FIBRE AND OTHER NON-FOOD CROPS
Barley	Avocados	Cassava
Chia	Bananas	Cotton
Chickpeas	Cocoa	Guar
Grain sorghum	Cucurbits	Hay/forage
Maize	Macadamia nuts	Industrial hemp
Mungbean	Mangoes	Poppies
Peanut	Olives	Sandalwood
Rice		
Soybean		
Sugar		
Wheat		

4.3.1 DOMESTIC MARKET

Potential for increased production to be absorbed by the domestic market has its limits. For horticultural or other products which are currently mainly consumed domestically, significant expansion in production that exceeds growth in demand may result in oversupply. This would place downward pressure on prices and hence growers' returns. To some extent oversupply can be averted by harvesting at different times of the year to avoid competing with production in other parts of Australia, for example early season mangoes in the Ord and Katherine. However, early season or counter-seasonal production may face competition from imports. For crops in this situation – such as mangoes, avocados, peanuts, soybeans and rice – quality and price will need to be competitive against imports. This may be a challenging task, given the high costs of production in northern Australia associated with transport, labour and other inputs.

For a number of commodities there is potential for increased Australian production to replace imports as well as to satisfy growing export demand. Peanuts, rice, soybeans, as well as relatively new crops such as guar and industrial hemp, can all be seen in this category. However, this can only be achieved if crops can be profitably and competitively produced relative to the price of imports. Some commodities can be classified as high-quality niche production, such as cocoa bean and olives. These are competing with high volume commodity imports and therefore demand price premiums for quality. Nevertheless production needs to be such a scale as to minimise production costs.

4.3.2 EXPORT MARKETS AND INTERNATIONAL COMPETITION

Higher global demand for food and fibre is expected to increase significantly into the future because of a larger global population, growth in per-person incomes and increasing urbanisation. As previously highlighted, most of this growth in consumption is expected to come from Asia, providing many export opportunities for northern Australian agricultural production given its geographic proximity to the strongly growing Asian markets. The opportunities for new markets include, but are not limited to, horticultural production. As Asian food consumption patterns continue to shift from traditional diets oriented around starchy staples to more varied diets, growing demand for meat and dairy products is also expected. This leads to expansion of pig and poultry production in Asia as well as cattle feedlots, presenting growing opportunity for exports of feedgrains such as maize, barley and feed grade wheat and other stockfeeds such as oilseed meals and hay.

With other key exporting nations likely to also respond by increasing their exports, Australia needs to remain competitive to capitalise on the opportunities higher global demand will provide. Figure 4.5 shows Australia ranked 15th in the world in terms of the value of agricultural exports. There are a range of larger competitors already exporting into Asian markets of interest, many of which are themselves Asian countries – for example China, Indonesia, Thailand and Malaysia.

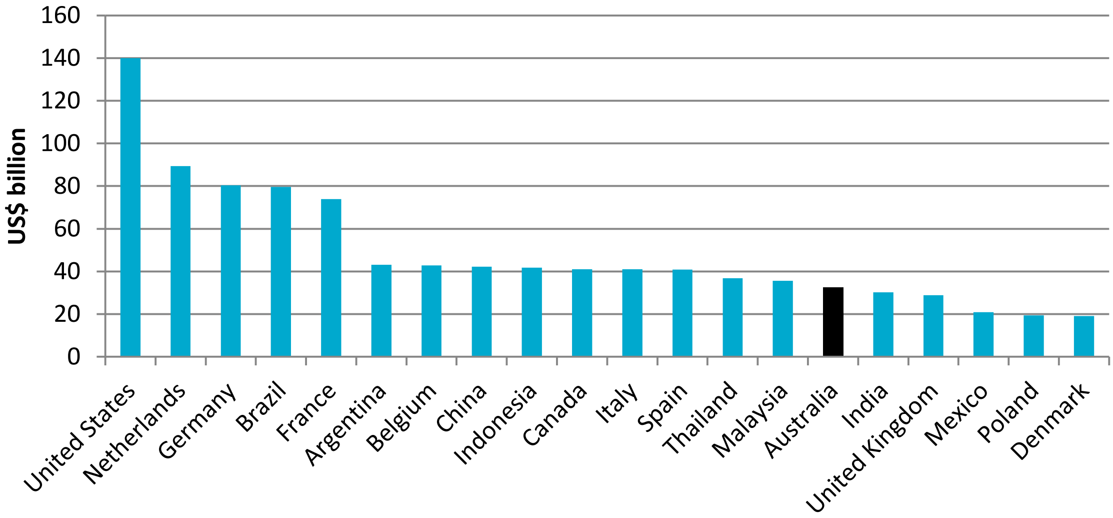

Figure 4.5 Top 20 world exporters of agricultural products, 2011
Notes: Global value of agricultural exports US$1314 billion.
Source: FAO (2014)

Table 4.2 Markets and opportunities for northern Australian commodities

COMMODITY	MAJOR MARKETS	COMPETITION	TRADE BARRIERS	MARKET OPPORTUNITIES
Barley	70% of production exported. Major markets for feed barley – Saudi Arabia, Japan; malting barley – China.	Australia is the world's largest exporter Competitors are Ukraine, European Union, Russian Federation, Canada and Argentina.	Zero or low tariffs in most markets China applies 3% tariff. In Japan barley imports will be tariff free under JAEPA.	*Domestic market* • Consumption of malt for beer making is expected to increase; however, there will be competition from rising beer imports. • The grain-fed cattle industry is expected to be pressured by increased competition in Japan from US beef exports. However, consumption by the pig and poultry industries is forecast to increase, supporting demand for feed barley. *International markets* • Beer production is expected to rise in Vietnam and Thailand, providing export markets for malting barley.
Chia	The Chia Company exports to over 30 countries. No detailed data available.	Mexico is the largest producer and exporter.	Detail not available.	*International markets* • Chia consumption across the world is growing. Demand currently outstrips supply, resulting in high prices.
Chickpea	Australia's production is mostly exported (86% in 2011–12). Main destinations are Pakistan, India and Bangladesh. Middle East and Turkey are also important markets.	Australia is world's largest exporter. Competitors are India, Russian Federation, Canada, Argentina, Mexico and Turkey.	Pakistan, Bangladesh and India currently apply zero tariffs. India provides a domestic minimum support price that exceeds international prices.	*Domestic market* • Demand growth is expected to come from the large South Asian and Middle Eastern migrant communities in Australia. *International markets* • Continuing growth in demand from South Asia is likely, given projections of population growth and the largely vegetarian diet.
Grain sorghum	Used by Australian intensive livestock industries – feedlot cattle, pigs and poultry. Also used in ethanol production. Production has become more export oriented in recent years (around 50%) – major markets are Japan, China, New Zealand and South Africa.	United States dominates global trade, followed by Argentina and Australia.	Exports face either zero or low tariffs in Australia's main export destinations – Japan applies 0% tariff while China applies 2% tariff.	*Domestic market* • The grain-fed cattle industry is expected to be affected by increased competition in the Japanese beef market from United States exports, but demand from the pig and poultry industry is forecast to increase over the medium term. *International markets* • The dominant market for Australian exports is Japan, although the Chinese market is projected to grow substantially. • Historically, China used sorghum in the manufacture of hard liquor, and livestock feed was a less significant use. However, feed use in China is expected to increase over the medium to longer term.

COMMODITY	MAJOR MARKETS	COMPETITION	TRADE BARRIERS	MARKET OPPORTUNITIES
Maize	Largely domestically consumed until recently – livestock feeding 54% of domestic consumption; food and industrial use, 46%. Exports increased to 23% of production in 2011–12 — Japan and Republic of Korea the most important markets.	United States dominates global trade, followed by Argentina, Brazil and Ukraine.	Zero tariffs apply in Japan while a tariff quota applies in Republic of Korea. Under KAFTA, tariffs on seed and feed maize are to be phased out by 2032.	*Domestic market* • Consumption by the pig and poultry industry is forecast to increase over medium term. *International markets* • Growing Asian demand for maize as a feed grain is projected, particularly from China and growing livestock industries in ASEAN countries (especially Indonesia and Vietnam). • China's demand is expected to exceed supply over the medium to long term. However, Australia does not currently have access to the Chinese market for maize. Strong competition from United States exports can be expected.
Mungbean	Currently, Australian mungbean production is largely destined for export – India and Indonesia are the most important markets for Australian exports.	Myanmar and China are world's largest exporters. While India is one of the largest producers, its exports are small.	Indonesia applies 2.5% tariff and Vietnam applies 5% tariff. India's bound tariff rate is 30%, but zero rate is applied.	*Domestic market* • There are opportunities to market mungbeans to domestic food manufacturers. Mungbeans have a range of potential food industry applications in the form of starch, flour or paste. *International market* • Uses for food industry applications allow mechanised harvesting which provides cost advantages, improving international market competitiveness.
Peanut	Most Australian peanut production is consumed domestically. Peanut imports are mostly from Argentina, China and Nicaragua. Australian peanuts are exported to New Zealand, Japan, Fiji and China. Peanut oil imports are from Singapore and France. Australian peanut oil is exported to China, the United States, New Zealand and the Republic of Korea.	Global trade in peanuts is small (8% of world production). Major exporters are India, Argentina, China and the United States	Both Japan and Republic of Korea apply tariff quotas to peanut imports. Under JAEPA, peanuts imported for oil extraction are to be tariff free, while tariffs for shelled peanuts within the existing quota will be phased out by 2025. There will be no tariff reductions under KAFTA.	*Domestic market* • Australia is a net importer of peanuts, both unprocessed and processed, so there is opportunity for import substitution, depending on competitiveness. *International markets* • Peanut exports could be expanded to current Asian markets. For example, China is the largest supplier to Japan, but China's domestic consumption is increasing. Provides opportunity for Australian peanut exports to Japan. Similarly for the Republic of Korea. • Potential to expand peanut oil exports, particularly of high oleic peanut oil, which has limited world supply – would require stable supply of suitable peanuts and export market development.
Rice	Australia is a small exporter on a global scale (2% of	Major exporters are India,	Japan and Taiwan operate tariff rate quotas for imports of rice and rice-	*Domestic market*

COMMODITY	MAJOR MARKETS	COMPETITION	TRADE BARRIERS	MARKET OPPORTUNITIES
	world trade). Exports of Australian rice vary with domestic production, which is highly dependent on water availability. In a non-drought year up to 80% is exported.	Thailand and Vietnam. Largest importers were Indonesia, Nigeria, the European Union, Iran and United Arab Emirates.	based products.	• There is potential for increased production of Australian rice, particularly tropical varieties, to replace imports and service growing domestic demand. *International markets* • Growth in international demand for Australian rice is expected from Japan, Taiwan and the Middle East. However, exports to Japan and Taiwan are likely to continue to be limited by trade barriers.
Soybeans	Most Australian soybeans are consumed domestically. Small exports to Japan, Republic of Korea, Malaysia, Taiwan and the Pacific Islands. Most soybean imports are from China. Australia is a net importer of soybean meal (mostly from Argentina and the United States) and soybean oil (from Malaysia, Brazil and Argentina).	Global soybean trade is primarily sourced from Brazil, the United States and Argentina.	Soybeans face zero tariffs in Japan, Malaysia and Taiwan. Many other countries in Asia apply tariffs or tariff rate quotas. Under KAFTA, soybeans for human consumption to be tariff free within quota; other soybeans will have tariffs halved by 2024.	*Domestic market* • Opportunity exists for increasing supply of soybean meal to the domestic market, which currently relies on imports to meet increasing demand from the growing chicken and pig industries. • Increased production of soybean meal would result in production of soybean oil from the crush, which would require marketing domestically or for export. *International markets* • There could be opportunity to expand exports of edible-grade soybeans to Asian markets such as Japan, Taiwan, Thailand, Singapore and Indonesia, all of which have growing demand for edible soybeans, depending on competitiveness.
Wheat	Currently, two-thirds of Australian wheat exports are shipped to North Asia (Japan and the Republic of Korea) and ASEAN countries (Indonesia, Vietnam and Malaysia). Other important markets include the Middle East and North Africa.	The United States is the world's largest exporter with Australia ranked fourth. World exports are dominated by the European Union, the Black Sea region, North America, Argentina and Australia.	Wheat exports face zero or low tariffs in Australia's major markets. Under KAFTA, wheat imports will be tariff free. Under JAEPA feed wheat will be tariff free while tariff rate quotas remain on other wheat.	*Domestic markets* • Food consumption of wheat is expected to grow in line with population growth. • The growing poultry industry is expected to increase domestic demand for feed wheat. *International markets* • There is potential for increasing wheat exports to Asia as diets move towards wheat-based products. • Demand for feed use is expected to rise, particularly in Indonesia, Vietnam and Malaysia.
Intensive food crops				
Avocadoes	Australian production is largely focused on domestic market – exports 4% of domestic production in	Australia is a net importer – most imports are from New Zealand. Mexico is the world's	Australian avocado exports are currently subject to few tariff barriers.	*International markets* • Avocados are transported to Singapore and Malaysia from Australia by air in 8 hours, compared with imports from Mexico, which can take up to 30 days.

COMMODITY	MAJOR MARKETS	COMPETITION	TRADE BARRIERS	MARKET OPPORTUNITIES
	2012–13. Exports to Singapore, Thailand, Malaysia, Hong Kong and United Arab Emirates.	largest exporter, followed by Chile and Peru.		• Greatest opportunities are likely to be limited to the export of whole fruit in high-income Asian economies where consumers are willing to pay a premium for a high-quality product. • Australian exports are unlikely to compete with lower-priced fruit from Mexico in the United States market.
Bananas	Almost all of Australia's banana production is consumed domestically. More bananas are sold than any other fruit on the domestic market. Only minimal quantities exported – New Zealand and Nauru have been the main markets in recent years.	Ecuador, Colombia, Costa Rica, Guatemala and the Philippines represent 70% of world exports.	No tariffs applied by Nauru or New Zealand. Ad valorem or specific tariffs apply in most ASEAN countries (apart from Singapore and Brunei which are tariff free). China applies a 10% tariff.	*Domestic markets* • Rising health consciousness is expected to lead to increased fruit consumption. A key advantage for the industry is the ongoing popularity of bananas. • A key risk is the ongoing threat of extreme weather (e.g. cyclones) – industry may need to continue to mitigate this threat by shifting some production to regions further inland. *International markets* • Fruit import demand from Asian countries such as China is expected to continue to grow in the medium to longer term. • Export opportunities lie in Australia's ability to provide price competitive counter-seasonal supply to Northern Hemisphere markets.
Cocoa beans	Australia imports small quantities of cocoa beans from countries in the Pacific, Central America and Africa. Cocoa ingredients for chocolate are mostly from Singapore. Australia exports small amounts of cocoa beans to New Zealand, China, Indonesia and Fiji.	World's largest exporter of cocoa beans is Ivory Coast. Indonesia is largest exporter in Asia and, in Central America, Ecuador is largest exporter.	New Zealand applies no tariff to cocoa bean imports, China applies an 8% tariff while Indonesia and Fiji each apply a 5% tariff.	*Domestic markets* • Increasing numbers of boutique chocolate makers in Australia provide a market for quality Australian-grown cocoa bean and cocoa bean products. • However, the quality and price of Australian-grown cocoa bean will need to be competitive against imports. *International markets* • Global demand is expected to continue growing, but ageing tree stocks, stagnating yields and low productivity in major producing regions are likely to limit growth in supply. • Smallholders produce 95% of world cocoa, limiting productivity growth. • Export opportunities would depend on price competitiveness of Australian products.
Cucurbits	Production is focused on domestic market – less than 2% of pumpkin production and less than 10% of melons are exported. Largest overseas market for	World's largest pumpkin exporter is Spain, followed by New Zealand, Mexico and Morocco. World's largest melon exporters are Mexico,	New Zealand, Singapore and UAE apply zero tariffs. Exports attract 5% tariff in Indonesia.	*Domestic markets* • Rising nutritional awareness is expected to continue to have a positive impact on consumption of cucurbits. Although consumer preference determine whether consumption will increase against other fruits and vegetables.

COMMODITY	MAJOR MARKETS	COMPETITION	TRADE BARRIERS	MARKET OPPORTUNITIES
	pumpkins is Singapore and for melons is New Zealand.	Spain, Iran, Honduras, Guatemala and the United States.		*International markets* • Over the medium to longer term, cucurbit exports have the potential to benefit from increased consumption of fruit and vegetables in many Asian countries. However, strong competition from Asian domestic consumption is expected.
Macadamias	Over two-thirds of Australian macadamia production is exported. The largest markets for Australian macadamia kernel (80% of export value) are Japan, China and the United States. Nut-in-shell exports (20% of export value) are almost all exported to China where they are processed and either sold domestically or re-exported.	Around one-third of domestic consumption is imported, mainly from China, Vietnam and Zimbabwe. Australia's market share in many export markets has declined as supplies from South Africa increased.	China's tariff is 12%. The European Union, Japan and Taiwan impose tariffs of 2%, 5% and 7.5%, respectively. Under KAFTA, Korea's 30% tariff will be phased out in 2019.	*International markets* • The Republic of Korea is an emerging market for Australian macadamias and will benefit from the free trade agreement with the Republic of Korea. • Taiwan is also an emerging market for Australian macadamias. Australia accounts for the largest share of Taiwan's macadamia imports, with competition coming mainly from South Africa.
Mangoes	80% sold as fresh produce; 20% processed. Of fresh fruit, 90% sold on domestic market. Key export markets are Hong Kong, Singapore, Vietnam and Malaysia, and, in the Middle East, the United Arab Emirates, Lebanon and Qatar.	Mexico is the leading global exporter (90% to United States), followed by India, Thailand and Brazil.		*Domestic markets* • Expanding mango production in WA and NT regions has the advantage of providing earlier season mangoes, avoiding competition with Queensland supplies, although competition from imports remains. *International markets* • Although Thailand is the major exporter of mangoes to the Asian region, rapidly increasing import demand in Asia provides an opportunity to increase Australia's small market share in niche high-value markets, with high-quality fruit.
Olives	Industry's focus is the domestic market with small exports of olive oil and table olives. Exports of olive oil are to the United States, Italy and China. Exports of table olives are to New Zealand	Main exporters of olive oil are Spain, Italy and Greece. Main table olive exporters are Spain, Greece, Morocco and Turkey.	China imposes tariffs of 10% on olive oil. EU tariffs are set at between 110 and 135 euros per 100 kilograms. EU tariffs are 6.4% for fresh olives and 12.8% for preserved.	*Domestic markets* • Australia is the highest consumer of olive products outside of the Mediterranean region, on a per person basis, so the greatest opportunity lies in replacing imports if domestic production is competitive. *International markets* • Opportunities are in markets where there are few tariff barriers and where consumers are willing to pay a premium for high-quality products. It is unlikely Australian exports can compete on price with the European

COMMODITY	MAJOR MARKETS	COMPETITION	TRADE BARRIERS	MARKET OPPORTUNITIES
	and Singapore.			Union.
Cassava	Not yet grown commercially in Australia. Cassava trials in Burdekin.	Thailand is the world's largest exporter of cassava, mostly supplying China.	Not available	*Domestic market* • Opportunities for domestic production exist in ethanol production rather than food purposes. • There is opportunity to replace significant imports of cassava starch, which is imported for food processing uses.
Industrial crops				
Cotton	Around 95% of Australian cotton production is exported. China accounts for around 70% of total cotton exports; Indonesia and Thailand account for 10% and 7%, respectively.	Main competitors into Asian markets are India, the United States, Uzbekistan and Brazil.	China's bound and applied tariffs are 40%, for both raw cotton and semi-processed. Indonesia applies zero tariff on raw cotton and 5% on semi-processed.	*Domestic market* • There is expected to be very limited additional demand for ginned cotton in Australia. International markets • Demand from other ASEAN countries such as Cambodia and Vietnam is expected to grow in the medium term.
Guar	Guar is still in the early stages of being established as an industry in Australia. Australia current imports guar gum from India and re-exports small quantities to New Zealand and Papua New Guinea.	India is the world's largest producer of guar gum.	China is the only major importer of guar imposing trade barriers – a 15% tariff on the import of guar gum and 7% on guar splits.	*Domestic markets* • Although attempts to establish a viable guar industry in Australia have been unsuccessful in the past, demand stemming from the oil and gas industry for hydraulic fracturing (fracking) has provided greater incentive for guar gum processing to start in Australia.
Hay/forage	Around 40 per cent of the hay produced and sold commercially in Australia is exported. Japan is the largest market but has been declining in recent years. The Republic of Korea has been increasing in importance as have Taiwan and China.			*Domestic markets* • Development of meat processing in northern Australia provides opportunity for increased use of hay for finishing cattle for slaughter in northern Australia. • Reinvigoration of live cattle exports in northern Australia should result in increasing amount of hay used by livestock holding-depots and on livestock transport ships. *International markets* • Increasing demand for meat protein and growing commercial feedlots in developing countries provide opportunities for expanding exports of hay to markets such as China, Indonesia, Malaysia, Vietnam, the United Arab

COMMODITY	MAJOR MARKETS	COMPETITION	TRADE BARRIERS	MARKET OPPORTUNITIES
				Emirates, Saudi Arabia and Qatar.
Industrial hemp	Australia is a net importer of hemp products – around a quarter of domestic consumption of hemp seed imported from Canada; hemp fibre and yarn are imported from the Netherlands and China.	China is one of the largest exporters of hemp textiles. Canada exports industrial hemp seed, oil and oilcake. The United Kingdom is the largest EU exporter of hemp fibre.	China imposes a 6% tariff on imports. Indonesia and Thailand apply 5% tariff. Republic of Korea will reduce 2% tariff to zero by 2017 under KAFTA.	*Domestic markets* • Australia is a net importer of hemp fibre, so there is potential for increased production of industrial hemp fibre to supply the domestic market, replacing imports. International markets • Increased production of industrial hemp could lead to trade opportunities with the United States, where there is growing demand for hemp seed and hemp seed products. However, Australia would need to compete with Canada, the largest supplier of the United States market.
Poppies	Australia is largest producer and exporter of concentrates of poppy straw. The largest markets for concentrates of poppy straw are the United Kingdom, the United States, France and Australia.	France, Spain, Turkey and India are the main competitors for morphine-rich opiate raw materials while France and Spain are the main competitors for thebaine-rich materials.	Global production and licit trade is heavily controlled under the 1961 Single Convention on Narcotic Drugs.	*Domestic markets* • Production of poppies in northern Australia offers potential – the warmer climate would shorten the growing period and potentially allow two crops per season. *International markets* • Demand for opiates is expected to increase, driven by ageing populations and increasing use of painkilling and anti-addiction medications. • As developing countries increase in affluence, and spending on health care rises, world demand for opiate-based pain management is expected to rise.
Sandalwood	Australian sandalwood currently supplies well over half of all sandalwood traded globally. Around 60% exported to Taiwan. Other significant markets include Malaysia, Singapore, India and Thailand.	India's supply has been depleted by overharvesting. Other suppliers include Indonesia, East Timor and Sri Lanka. Limited supplies are also available from the Pacific region.		*International markets* • Global supplies of sandalwood have been depleted by overharvesting of wild plantations. • There is steady demand for powdered sandalwood for incense, for religious worship and ceremonies in Asia. • Increasing demand for sandalwood oil in Europe and North America for natural cosmetic products. • Demand is developing for sandalwood oil in pharmaceuticals.
Sugar	Around 20% of Australian production is consumed domestically with the remaining 80% exported. Major markets are Republic of Korea, Japan, Malaysia	Australia was the third-largest exporter behind Brazil and Thailand. Other major exporters are India and Mexico.	Importing countries such as the United States and the European Union impose import duties and quotas to support (higher) domestic prices for their high cost sugar industries.	*Domestic markets* • Although there is limited potential for increasing domestic food use of sugar, there is potential for sugarcane to be the feedstock in ethanol production. *International markets* • There is rising demand for both raw and refined sugar in Asian markets,

COMMODITY	MAJOR MARKETS	COMPETITION	TRADE BARRIERS	MARKET OPPORTUNITIES
	and Indonesia.			which currently import around 80% of Australia's sugar exports. • Indonesia has emerged as Australia's second-largest market after the Republic of Korea.

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5 ORD REGIONAL ANALYSIS

5.1 Summary and key messages

- The Ord River Irrigation Area has the capacity to provide a large volume of water (currently 865 GL/year) with high reliability to support agricultural production on significant areas of broadly suitable soils.
- Primary infrastructure (e.g. dam, channels, roads) is already in place, and this, combined with reliable water, provides the region with some advantage relative to undeveloped regions.
- A tropical, monsoonal climate, coupled with limited ability to undertake farming operations in the wet season limits summer annual crops. However, most summer crops can be grown during the mild, dry season, and crop yields are broadly comparable with other regions in northern Australia. An exception to this is mangoes, which have lower yields than other mango-growing regions in tropical Australia.
- Using existing domestic supply chains and infrastructure, gross margins across 15 crops range from highly negative to highly positive. All crop gross margins are affected by high input costs (e.g. labour, fertiliser) and high freight costs, because nearly all produce is currently transported to southern markets.
- Horticultural crops can generate high returns but gross margins are very price sensitive, and, when coupled with high input costs, margins can fluctuate from highly positive to highly negative over periods of weeks. Freight costs represent 10 to 30% of the costs of production, and labour costs associated with harvesting and packing represent a further 20 to 30% of the costs of production.
- Gross margins for broadacre, low-value crops were generally negative because freight costs to southern markets or processing facilities represented around 40 to 50% of the gross value of the product. Pulse crops generated small, positive gross margins.
- For industrial crops, sugarcane generated gross margins of around $1000/ha, based on the presence of a local sugar mill. Cotton and hemp generated negative gross margins because, in this baseline supply chain scenario, raw product was shipped significant distances for processing.
- Sandalwood and chia are two new crops grown under controlled commercial arrangements. Chia has a high value for what is classified as a broadacre crop and because its yield is quite low compared with other broadacre crops (e.g. 1.1 t/ha vs 11.8 t/ha for maize), freight costs are modest. Sandalwood is not yet commercially proven but based on estimates of production and the current and projected high prices for sandalwood oil, it generates very high gross margins.
- Using supply chain scenarios of (a) local processing mills, (b) locally developed supply chains (e.g. sorghum grain integrated into regional beef production systems) or (c) regular and cost-effective shipping routes from Wyndham to South-East Asia, gross margins for all crops significantly increased and for a number of crops they moved from being unviable to feasible. These analyses highlighted the potential for much improved financial outcomes by shifting the supply chains to local processing and/or Asian markets.
- Two regional scenarios of 50,000 ha of irrigated production were explored. Each scenario involved broadacre crops, horticultural production and sandalwood, though only the second scenario included industrial crops of sugarcane and cotton. The first scenario assumed a modest investment in processing infrastructure (a rice mill) and the existence of a regular and cost-effective shipping service (bulk and containers) from Wyndham, with limited consideration for a port upgrade. The second scenario assumed a significant investment in local processing infrastructure for industrial crops in the form of a sugar mill and a cotton gin. Each scenario included six or seven crops.
- Both scenarios generated high gross values of production at the regional scale (between $0.57 billion and $0.98 billion/year). The high projected returns from sandalwood skewed these values somewhat, but even without sandalwood returns were between $250 million and $500 million/year.

- Scenario 1 had a strong focus on export to Asia and highlighted the significant benefits that can be gained if such cost-effective supply chains can be established. This is not just important in terms of supply chain costs but also in the context of new markets, particularly for horticulture because of easily saturated demand in domestic markets.
- Scenario 2 required significant capital investment in the form of a sugar mill and a cotton gin (approximately $500 million). 'Piggyback' benefits were identified in potential for co-generation from the sugar mill to supply electricity for cotton ginning operations or nearby mining operations.
- Both scenarios require additional supply of vehicles in the region. For expanded production that is destined for southern markets, this is well above what can be serviced from existing backloading arrangements.
- In association with scenario 2, a brief assessment of supporting infrastructure investment needs and options was undertaken. Approximately $215 million in additional investment would be required in the form of a Kununurra heavy vehicle bypass, a new bridge over the Ord River, a new bulk sugar storage facility at Wyndham port and upgrading of the port to handle bulk sugar ships. Alternative options were canvassed, including trucking raw sugar to Darwin or constructing dedicated rail facilities to Wyndham port from Katherine, to link to the existing Alice Springs to Darwin rail line. These various options need to be assessed in more detail, but based on the simple assumptions used in this analysis, investing in supporting infrastructure via Wyndham would appear to be more attractive. This infrastructure would have other benefits for other sectors (e.g. mining) in the region.
- Significant impediments to achieving scaled up and profitable agricultural production in the Ord River region include:
  - uncertain return on capital invested in agricultural ventures, especially the time it may take to generate positive returns
  - sourcing capital to fund development of major processing facilities, road infrastructure, deeper water port upgrades, and storage and handling facilities
  - overcoming the 'catch 22' of insufficient volumes of production to warrant investment by shipping companies in more regular routes to South-East Asia for bulk and containerised goods and the lack of confidence within the farming community to scale-up crop production without secure and cost-effective supply chains to the north
  - the limited number of export protocols in place with Asian countries and the sometimes high cost of treatments for pests and diseases associated with export protocols.
- In percentage terms, regional economic welfare of the Ord River is significantly higher with the proposed investment because that investment is large when compared with the regional economy.

5.2 Description of region: existing agriculture, scale of irrigation and development

Agriculture in the Ord River region dates back to the late 19th century when pastoralism in the form of beef cattle grazing was established. The possibilities for crop production had been noted by earlier exploration (e.g. Grey, 1841), and the potential for irrigated agriculture through damming the Ord River was first raised in the early part of the 20th century. The potential for cotton production was briefly examined in the early 1920s (Basinski and Wood, 1985) and, in the late 1920s, the future Premier of Western Australia Mr Frank Wise also examined the prospects for agricultural development in the region. A royal commission in 1940, examining problems with the pastoral industry in the region, recommended that land along the Ord River be formally assessed for its irrigation potential (Fyfe, 1940). The opportunity for a dam of a significant scale was identified by Dumas (1944) in studies that followed the royal commission recommendations.

In anticipation of the potential for irrigation along the Ord River, the Kimberley Research Station was established in 1946 as a joint initiative between the Western Australia Government and the Commonwealth. The main aim was to explore the agronomy of crops that could be grown under irrigated conditions in the hot, monsoonal climate of the Kimberley region.

Early research efforts concentrated on the suitability of a range of crops for irrigated agriculture in northern Australia, including sugarcane, rice, oilseeds and cotton (Basinski and Wood, 1985). This research identified the main constraints posed by climate, soils and pests, which led to further research on how to overcome those constraints.

On the back of promising results from the Kimberley Research Station, the Commonwealth provided a grant to establish the Ord River Diversion Dam, which was completed in 1963. The town of Kununurra was established in 1960 to support the development of irrigated agriculture in the region. The main Ord River Dam, which forms Lake Argyle, was completed in 1972.

The Ord River Irrigation Area (ORIA) presently comprises over 14,000 ha of irrigated farming land (Figure 5.1). Many different crops have been grown in the Ord region, including cotton, sugar, rice, grain, pulses, mango, melons, pumpkin, banana, chia and sandalwood. About 7000 ha is planted to sandalwood, with the remaining 7000 ha spread among melons, pumpkin, chia, mango, grains and pulses, and a range of other crops.

Beyond the specific challenges of developing appropriate agronomic practices to grow crops in a hot, tropical environment, major constraints to farming in the Ord River region have historically been the distance from markets and associated high transport costs, lack of supporting infrastructure, insufficient scale of operations to support commercially viable local processing facilities (e.g. sugar mill, cotton gin) and lack of skilled labour.

In an effort to overcome some of these constraints, new investment is occurring to greatly expand the ORIA. Channel and road infrastructure to Ord Stage 2 have been completed, which will deliver a further 13,400 ha of irrigated farming land. An additional 14,500 ha is being considered for development on the Northern Territory side of the border and a further 6500 ha in Western Australia on lighter soils (Cockatoo Sands). These planned expansion phases would establish approximately 50,000 ha of farming land in production within the next decade.

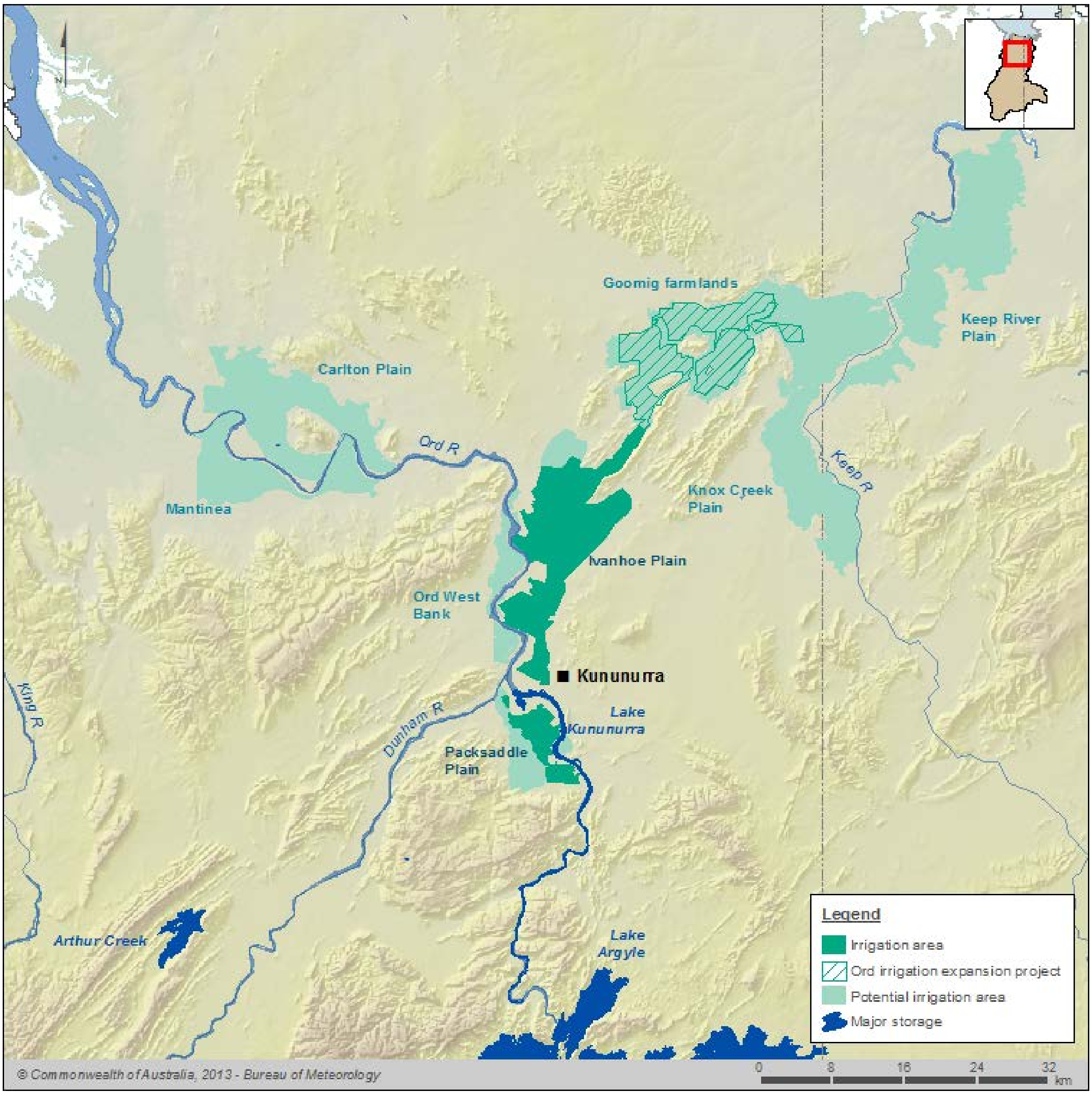

Figure 5.1 Map of the current and proposed Ord River Irrigation Area
Source: Bureau of Meteorology National Water Account: www.bom.gov.au/water/nwa

5.3 Climate: existing and future trends

5.3.1 CURRENT CLIMATE

The Ord region has a semi-arid climate that is strongly influenced by the tropical monsoon and an average rainfall (1963 to 2013) of 840 mm, of which approximately 90% occurs from December to April (Figure 5.2). The short growing season, while reliable, means that dryland cropping is too risky. The lack of rainfall in the dry season means that crops grown in this period rely entirely on irrigation, from surface storages, permanent streams or groundwater. Potential evaporation rates are high (>2700 mm/year pan evaporation), with a seasonal cycle that has implications for crop water demand in irrigation schemes. In addition, evaporative loss from storages can be high. Even though evaporation rates are higher late in the dry season, compared with other regions they tend to remain relatively high (minimum 200 mm/month) year round.

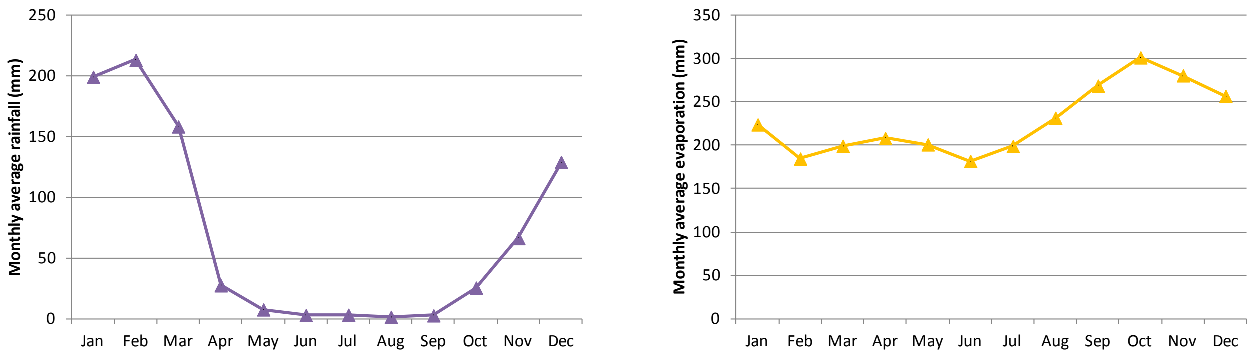

Figure 5.2 Monthly average rainfall (left) and pan evaporation (right) at Kununurra

In contrast to many other agricultural regions across northern Australia, the Ord region experiences relatively low year-to-year variability in annual rainfall. A good measure of annual rainfall variability is the coefficient of variation (CV), calculated as the standard deviation of mean annual rainfall divided by the mean annual rainfall. The higher the CV, the more variable is the mean annual rainfall. The CV for Kununurra is 0.27, while for other areas of Australia with a similar mean annual rainfall total the CV is broadly in the range of 0.25 to 0.30. It is considerably lower than in northern Queensland, where the CV of annual rainfall is approximately 0.4. Even so, rainfall anomalies can be as high as +600 and –400 mm (Figure 5.3).

This lower variability in rainfall is a result of the tropical monsoon, which is relatively reliable in these low latitudes. The region also experiences runs of wet and dry years, which are highlighted in Figure 5.3. There can be sequences of years where the rainfall is below average, but this is not as dramatic as areas in eastern Australia that are more strongly influenced by the El Niño-Southern Oscillation. This, combined with a very large water storage (Lake Argyle has a capacity of 10,700 GL), means that rainfall variability does not have a significant impact on water reliability.

This rainfall sequence (Figure 5.3) also reveals a trend in recent decades of higher rainfall as a result of a greater frequency of above-average years and a decreased frequency of dry years. It is unknown whether this trend of increased rainfall will persist (see Section 5.3.2).

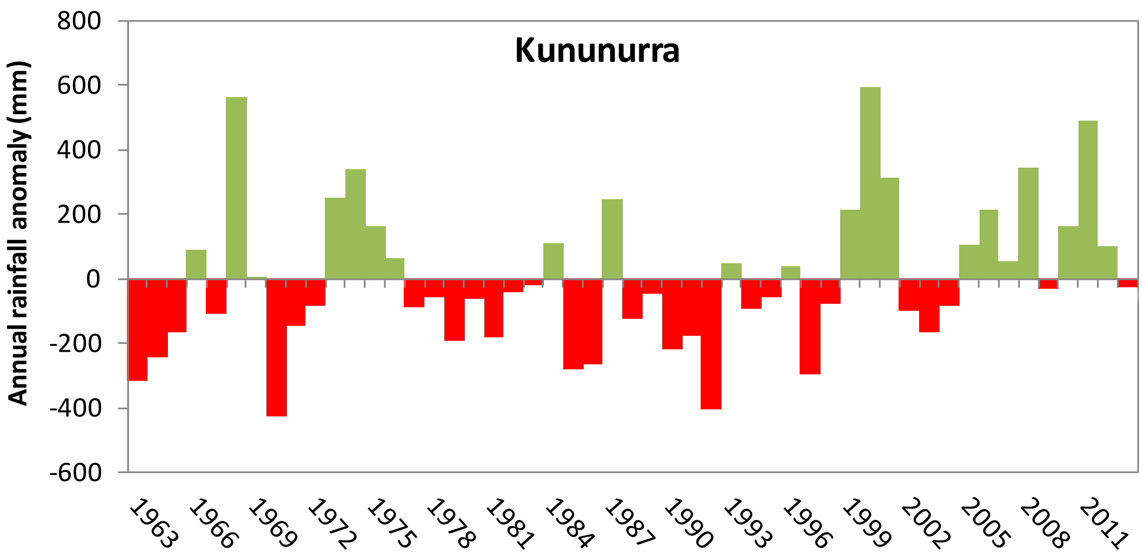

Figure 5.3 Runs of wet and dry years at Kununurra, measured by the difference in annual rainfall from the long-term average (1963 to 2013)

Wet years are denoted by the green bars and dry years by the red bars.

5.3.2 FUTURE CLIMATE

Climate projections for 2030 were assessed using four global climate models: ECHAM5, GFDL-21, HADCM3 and MIROC. Global climate models are physical representations of the main drivers of the climate system. Future climate is modelled by perturbing the carbon dioxide concentrations in the model, which has implications for temperature and rainfall. In this study, two future emission scenarios of carbon dioxide were used, based on the Intergovernmental Panel on Climate Change – one was a high emissions scenario (A1FI) and the second a moderate emissions scenario (A2). The results from the global climate models, which provide results at a regional scale, were then used to transform the historical station records for Kununurra (see Section 2.3.1).

Rainfall projections for 2030 under the two emission scenarios show no distinct rainfall trend, based on the climate change models used in this study (Figure 5.4). Two models show a small increase in rainfall (3 to 5%) while two suggest a small decrease (1 to 6%). Based on this analysis, projected changes in rainfall are small and uncertain and would not appear to be a major factor in planning for crop production out to 2030.

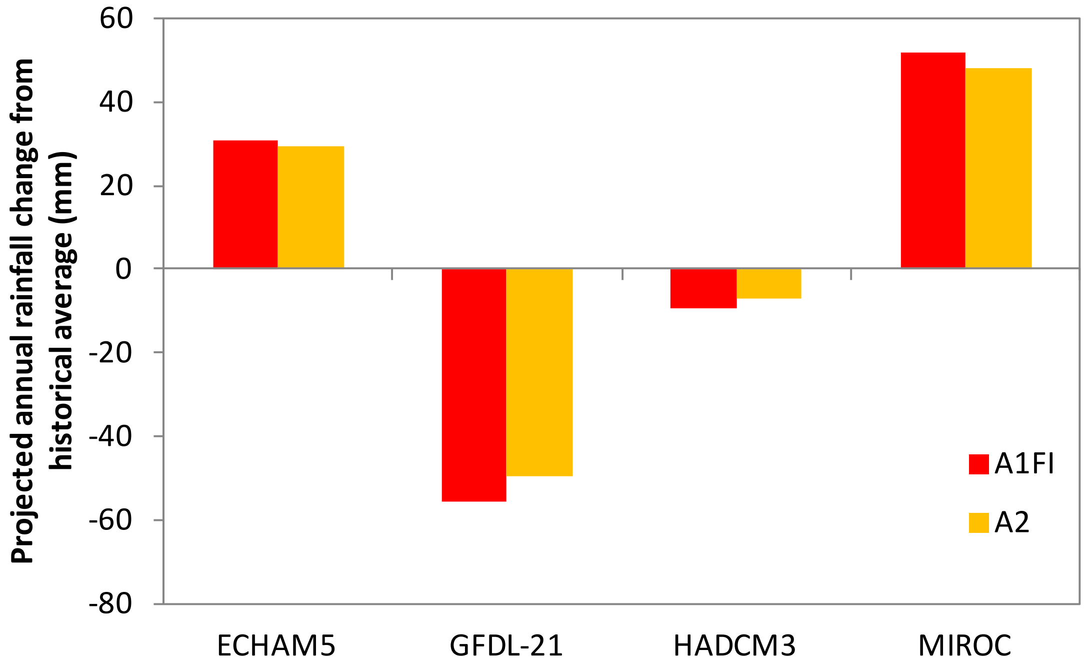

Figure 5.4 Rainfall projections for 2030 based on two emission scenarios (A1FI – high, A2 – moderate), using four global climate models
The rainfall projection is the difference in millimetres from the recent historical average annual rainfall (1970 to 2010).

Unlike rainfall, the projected trend in temperature is much more certain, with a projected increase in temperature to 2030 of 0.7 to 1.3°C. Since the overall temperatures in the tropics are high, a small increase in overall mean temperature is likely to have a significant impact on extreme temperatures. This is highlighted in Figure 5.5, which shows that the number of days in excess of 40 °C will increase from 26 days/year to between 50 and 65 days/year. This would impact on crops that are sensitive to high temperatures (e.g. some horticultural crops, rice growth in the wet season or grain fill in October/November for dry-season rice). Prolonged periods of extreme temperature will also have an impact on labour efficiency, labour supply, and health and safety. It will also lower the 'livability' of the Ord region and it will be harder to attract permanent residents.

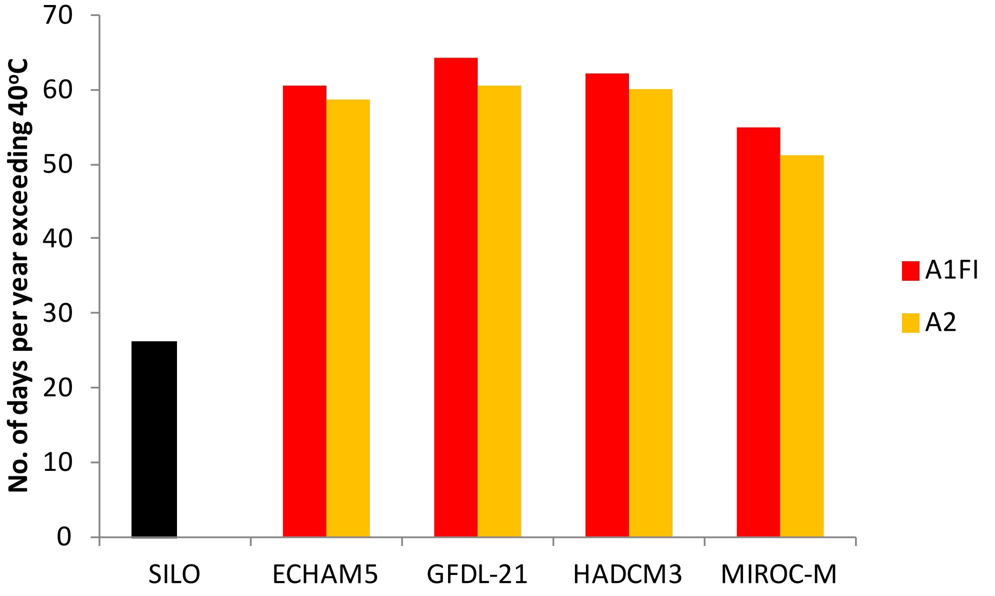

Figure 5.5 Number of days per year in Kununurra projected to exceed 40 °C in 2030 for two emission scenarios (A1FI – high emissions, A2 – moderate emissions), using four global climate models, compared with historical climate (SILO data from 1970 to 2010, black column)

5.4 Water resources

The Ord catchment is situated in the east Kimberley and straddles the Western Australia and Northern Territory border. It has a catchment area of approximately 55,000 km^2, drained by the Ord River, which flows into the Cambridge Gulf of the Timor Sea (Figure 5.6). The catchment is predominantly comprised of rugged hills and mountains dominated by limestone, sandstone and volcanic rocks (DNR, 1976).

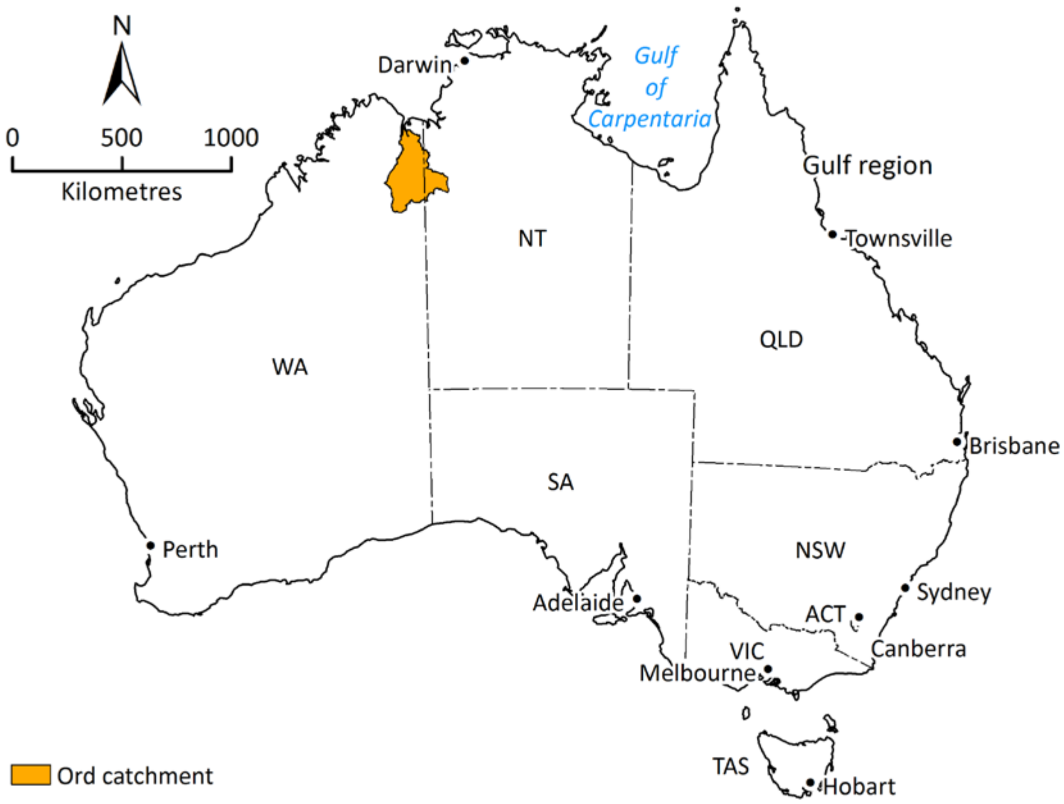

Figure 5.6 Location of the Ord catchment

The Ord River Dam, which created Lake Argyle, was completed in 1972 and is sited in an incised gorge in Carr Boyd Range. Approximately 80% of the Ord River catchment lies upstream of Lake Argyle, and water flowing from the dam enters the Ord River Diversion Dam (Lake Kununurra). This provides a downstream temporary storage and head for irrigation offtake for the ORIA. Of the Ord's five major tributaries, only the Dunham River has a confluence downstream from Lake Argyle, approximately 3 km below the Ord River Diversion Dam.

Before regulation, streamflow in the lower Ord River was strongly seasonal, dominated by large flood events during the wet season and no flow during the dry season. Streamflow was highly variable between years, despite relatively reliable wet-season rainfall. Regulation has resulted in seasonal flows, which once peaked during January to March, more evenly distributed, with highest flows during February to April. The lower Ord River now flows continuously during the dry season in response to releases from Lake Argyle for hydro-electric power, irrigation and environmental water provisions. Table 5.1 presents data on streamflow for selected gauging stations in the Ord catchment.

Table 5.1 Simulated streamflow metrics at selected gauging stations in the Ord catchment between 1930 and 2007, assuming current dam and infrastructure development

The 20th, 50th and 80th refer to the 20th, 50th and 80th percentile exceedance, respectively. Cease to flow indicates the percentage of time that no streamflow was observed at each of the streamflow gauging stations in the catchment.

STATION ID	STATION NAME	CATCH-MENT AREA (km^2)	STREAMFLOW (GL)				CEASE TO FLOW (%)
			20th	50th (median)	80th	Mean	
809302	Coolibah Pocket (inflow to Lake Argyle)	45,195	6589	3468	1602	4257	5
NA	Discharge from Dunham	5,626	868	395	185	576	16
NA	Flow below confluence of Ord and Dunham	51,805	4442	2818	1965	3594	0

Source: Data and modelling are based on Petheram et al. (2009)

Where the Ord River emerges from the Carr Boyd Range, fluvial deposits lie within the meanders and adjacent to the river (O'Boy et al., 2001). It is on some of these deposits that the irrigation districts of the ORIA lie. Packsaddle Plain lies next to the Ord River Diversion Dam and downstream of it are the irrigation districts Ivanhoe Plain, Buttons Gap and Martins Location. These predominantly lowland alluvial plains are up to 10 km wide, flat and bounded by rocky ranges composed predominantly of outcropping sandstone and basalt. Ground surface elevation varies by only around 10 m throughout the irrigated parts of the irrigation area. The surrounding ranges rise 300 to 400 m above the plains and are comprised predominantly of shallow, stony and rocky soils (Ruprecht and Rogers, 1999).

Groundwater exists in the unconsolidated alluvial sediments, regolith and bedrocks throughout the ORIA. The unconsolidated alluvial sediments broadly constitute a number of interfingered stratigraphic layers, ranging from aquifers of high permeability in the sand and gravel palaeo-channels (e.g. beneath Ivanhoe Central) to aquifers of low permeability, which are located in the clay, silt and silty-sand units (e.g. Martins Location, Ivanhoe North) and where the palaeo-channel deposits pinch out against basement rock (O'Boy et al., 2001).

Before vegetation clearing and irrigation development, groundwater levels beneath Ivanhoe and Packsaddle Plains were deep and likely to have been recharged predominantly by infiltration of surface water during seasonal flood events (O'Boy et al., 2001). Direct groundwater recharge from rainfall was probably minor because the watertable was deep and the soil unsaturated zone could rapidly absorb and store seasonal rainfall without significant deep drainage (Banyard, 1983).

During the past 50 years, the aquifers and groundwater flow systems beneath the irrigation area have been dramatically modified by water balance changes associated with vegetation clearing, the construction of surface water storage and conveyance structures, and flood irrigation. The watertable beneath the Ivanhoe Plain has risen by as much as 15 to 20 m since the 1960s and, although groundwater levels are now above the river level, the groundwater effectively does not drain to the river because of poor connectivity (Smith et al., 2006). Within the Ivanhoe Plain the potential risk of irrigation-induced salinity is greatest in the most northerly region because here the palaeo-channel, which acts as a preferential flow path for groundwater, is absent. More recently, the watertable beneath the Northern Ivanhoe Plain has intercepted the irrigation surface drains, which now act as conduits for groundwater discharge (Smith et al., 2006).

Groundwater levels rose rapidly under the Packsaddle Plain in response to the filling of Lake Kununurra in the early 1960s and watertables have now equilibrated with the lake level. Groundwater leakage from supply channels is a further source of recharge to the groundwater system in the ORIA (Barr et al., 2003), although this is less evident in those regions with a high transmissivity (Smith et al., 2006).

5.4.1 EXISTING WATER USE AND REGULATION

The ORIA is a 13,000-ha surface water irrigation scheme (IRSC, 2005) that was first established in the mid-1960s with water sourced from the Ord River Diversion Dam (Lake Kununurra). Construction of the main Ord River Dam was part of the second stage of development, but approval for the development of an additional 64,000 ha was withheld until the scheme could demonstrate economic viability (ORIAR, 1979). The scheme was initially established as a cotton-growing region. It endured much scrutiny and criticism before crop diversification, improved varieties and better pest management led to the first commercial success. Rice and later sugarcane were introduced, as well as mango, melons and other fruits, and, more recently, sandalwood.

Despite being artificial structures, both Lakes Kununurra and Argyle have been included on the Ramsar List of Wetlands of International Importance, mainly for their ecological values and waterbird populations.

Current levels of water entitlements are 865 GL for irrigation (WA Department of Water, 2013), a high power demand of 327 GWh, minimum hydropower guarantee above a level of 78 m AHD in Lake Argyle and specific releases to meet environmental water provisions.

CSIRO (2009) report the level of use for water diverted from the Ord system for current irrigation allocations is only 8%. However, if hydropower generation is also considered the level of use is 57%. Including net evaporation and environmental water provisions, the degree of regulation (the sum of the controlled release of water and evaporation from the dam expressed as a ratio of the total inflow to the dam) of the Ord River Dam is high, about 0.8. Table 5.2 provides a summary of the two major dams in the Ord catchment

Table 5.2 Summary of constructed dams in the Ord catchment

NAME OF DAM	NEAREST TOWN	TYPE OF DAM	ORIGINAL PURPOSE	YEAR CONSTRUCTED	HEIGHT ABOVE BED LEVEL (m)	STORAGE CAPACITY AT FULL SUPPLY LEVEL (GL)	AVERAGE ANNUAL RELEASE (GL)*
Ord River Dam	Kununurra	Earthfill embankment	Irrigation, hydropower	1972	99	10,800	2417
Ord River Diversion Dam	Kununurra	Earthfill embankment	Irrigation	1963	20	101	

5.5 Land suitability for cropping

The Ord River valley is well known for the extensive clay plains (Vertosols) that support current irrigation development (Figure 5.7). These soils, known locally as the Cununurra clays, can be moderately to strongly alkaline (pH >7.0) and are generally deep, with good water-holding capaity.

Proposed irrigation expansion (approximately 30,000 ha, including the Northern Territory) in the north-east of the study region, around the Weaber Plains and Knox Creek areas, would also use extensive areas of Vertosols. A major proportion of these areas, however, comprise a Vertosol type known locally as Aquitaine clays, which are potentially productive but can also have significant limitations.

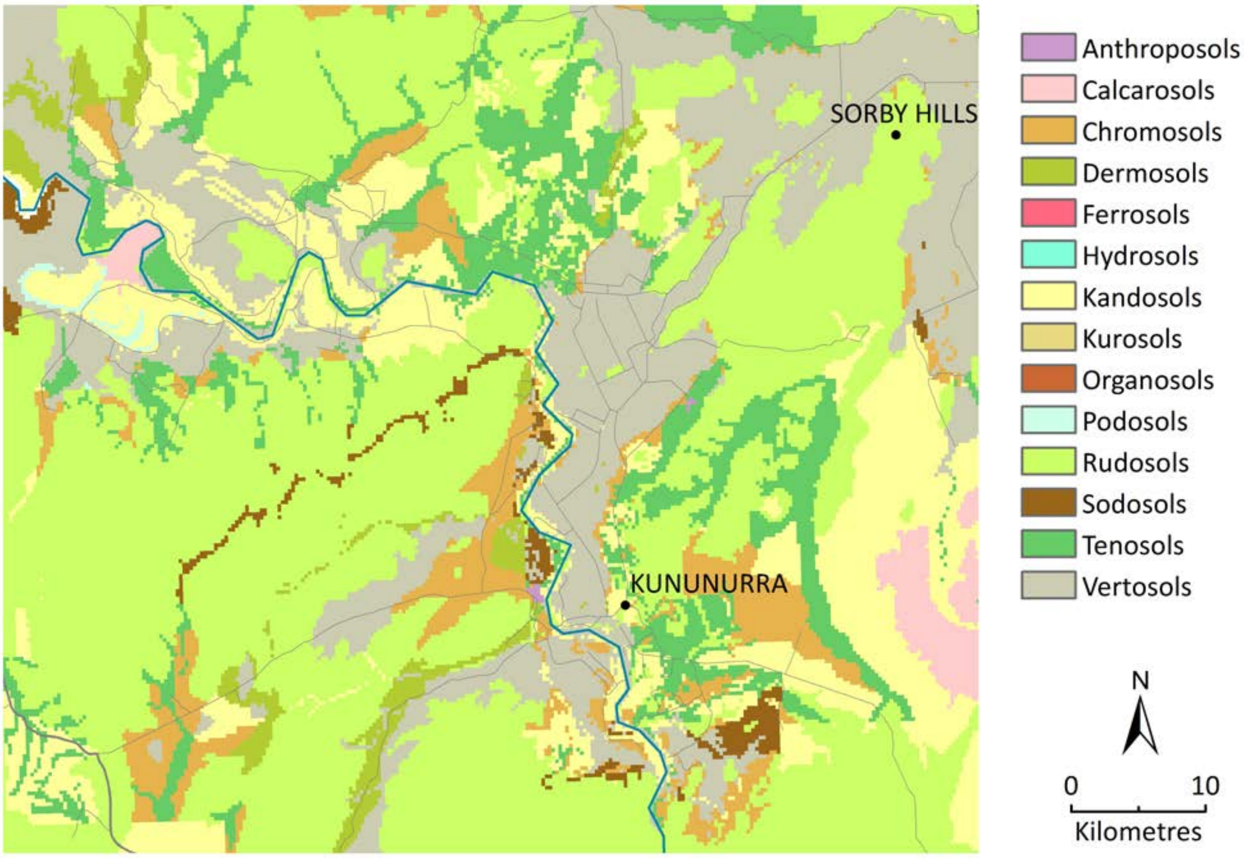

Figure 5.7 Dominant mapped Australian Soil Classification orders, Ord study area
Source: ASRIS (2014)

The Cununurra clays are generally suitable for most crops that are currently grown in the area (Figure 5.8a). However, they are not suitable for long-term, flood-irrigated rice (Figure 5.8b) due to their internal drainage characteristics, which can lead to deep drainage to the groundwater. The suitability of the Aquitaine clays is limited due to their hard-setting, blocky topsoils (particularly when dry), hydromorphic (water repelling) properties and low landscapes positions, which make them prone to extended periods of wet-season innundation. These soils may also have high salt content, which could be mobilised through inappropriate irrigation practices, and need to be managed carefully.

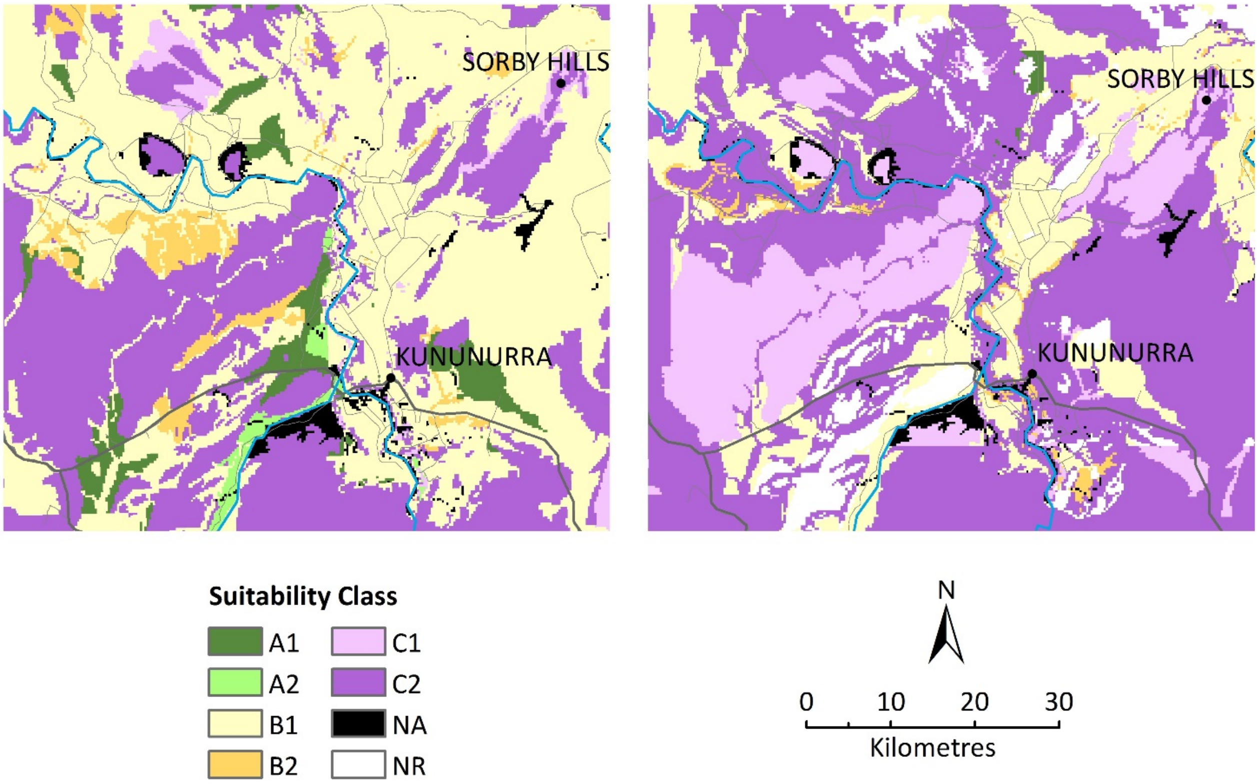

Figure 5.8 Suitability for (a) irrigated perennial crops (left) (b) irrigated rice (right) in the Ord study area
A1 >70% of the area is Class 1 or 2; A2 50 to 70% of the area is Class 1 or 2; B1 > 0% of the area is Class 1,2 or 3; B2 >50 to 70% of the area is Class 1, 2 or 3; C1 > 50 to 70% of the area is Class 4 or 5; C2 >70% of the area is Class 4 or 5, where Class 1 is suitable land with negligible limitations and Class 5 is unsuitable land.
Source: Wilson et al. (2009)

Smaller areas of sandy Kandosol soils (Cockatoo sands) surround the main irrigation developments and have some moderate agricultural suitability, particularly for crops not as well suited to the heavy clay soils. Limitations related to the lighter soil textures, including lower water-holding capacity and the potential erodibility of the gently sloping lands, need to be considered and managed appropriately.

5.6 Pest and disease risk

A total of 471 species were identified as potential pests or pathogens of any of the 18 crops evaluated for the Ord region; many of these were pests or pathogens of multiple crops (Appendix 5.1, separate document). For most crops, the likelihood of at least one of these pests or pathogens invading the region is 1 (100% likelihood) (Table 5.3), because many are already present in Australia and at least one is present within Western Australia (with the exception of banana and sandalwood). Despite the large numbers of pests and pathogens assessed, only a small proportion of species have been identified as major or significant pests of each crop (CABI, 2011) (Appendix 5.1, separate document). However, for many of these crops (rice, sorghum, mungbean, peanut, mango, watermelon, rockmelon, pumpkin, potato, cotton, hemp and kenaf), at least one of the major pests is already found within Western Australia and therefore represents a significant threat, with a potentially high impact.

Table 5.3 Invasion likelihoods, most likely impact and overall biosecurity risk from insect pest and fungal pathogens to proposed crops of the Ord region, Western Australia

Values of 1 denote almost certain likelihood, very high impact and very high risk, while values of 0 reflect no likelihood, impact or risk.

CROP	INVASION LIKELIHOOD	IMPACT	RISK
Broadacre food			
Rice	1	0.4	0.4
Sorghum	1	0.1	0.1
Maize	1	0.4	0.4
Chickpea	1	0.1	0.1
Mungbean	1	0.4	0.4
Peanut	1	0.4	0.4
Chia[a]			
High value			
Mango	1	0.1	0.1
Banana	0.94738	0.4	0.379
Watermelon	1	0.4	0.4
Rockmelon	1	0.4	0.4
Pumpkin	1	0.4	0.4
Potato	1	0.4	0.4
Industrial/other			
Sugarcane	1	0.4	0.4
Cotton	1	0.4	0.4
Hemp	1	0.1	0.1
Kenaf	0.99988	0.1	0.099
Sandalwood	0.060685	0.1	0.061

a Chia has no known insect pests or fungal pathogens.

5.7 Crop production

5.7.1 BROAD OVERVIEW OF CROP TYPES AND AGRONOMY

The potential productivity of a range of broadacre, high-value and industrial crops was investigated for the Ord regional analysis. This analysis includes high-volume products such as cereals and pulses, high-value products such as horticulture, and industrial products that require further processing, often nearby, such as sugarcane.

Broadacre cropping is characterised by large-scale (area), relatively low input, high-volume production of a commodity with a relatively low unit value (in per-tonne terms). Cereal and pulse production are the two most common forms of broadacre production in Australia, and a number of cereal and pulse crops have previously been grown in the Ord region.

Dryland and irrigated cereal production is well established in Australia, with around 20 million hectares grown annually. Cereal crops are either winter or summer grown, with summer crops dominating the northern parts of Australia's cereal-cropping area. Summer-grown cereal crops included in this analysis for the Ord region include rice, sorghum and maize.

Pulses are legume crops that, like cereal crops, are grown for the grain. Being legumes, these crops 'fix' atmospheric nitrogen and minimise the need for inorganic nitrogen fertiliser. Because this fixed nitrogen is also available to subsequent crops, pulses are often grown in rotation with high nitrogen-demanding crops such as cereals.

Approximately 2 million hectares of pulse crops are grown annually in Australia. Many pulse crops have a relatively short growing season, and are well suited to opportunistic production when there is sufficient available water (either stored in soil or available from irrigation). The pulse crops considered in this analysis for the Ord region are chickpea and mungbean.

Chia is a 'niche' crop that fits into the broadacre category in this analysis. It is neither a cereal nor a pulse but is part of the mint family, and is now grown on a large scale globally and harvested for its grain. There is a small, established chia industry in the Ord region, but its production and marketing statistics are largely commercial in confidence. Consequently, the following analysis for chia should be regarded as providing only broad estimates.

High-value cropping includes horticultural crops that are typically produced on much smaller areas than broadacre crops, with higher input costs per hectare and a high-value product. Horticulture crops are often perishable, require a high labour force for 'picking and packing', and specialised postharvest conditions such as refrigeration or controlled atmosphere storage. Horticulture crops are either perennial, such as tree crops where a planting lasts many years, or annual such as cucurbits (e.g. rockmelons), where the crop is destroyed after harvest.

Horticulture production is an important industry for Australia, occurring in every state, and accounting for approximately 20% of the farm-gate value of Australian agriculture. Production is highly seasonal, and annual crops will often include staggered planting on a single farm during the growing season to extend the harvest time.

Market price of horticulture products can be highly volatile, and subject to multiple supply, demand and substitution forces. The importance of freshness in many horticultural products means seasonality of supply is important in the market, with the Ord region potentially having advantages by being able to supply southern markets with 'out of season' produce. The high-value crops considered in this analysis for the Ord region include mango (both the established Kensington Pride and 'new', higher producing varieties), which have been developed under Plant Breeder's Rights (PBR), banana, watermelon and rockmelon.

For the purpose of this study, industrial crops are defined as those that require a major processing step in their production soon after harvest. Industrial crops are generally high volume relative to value, with processing facilities sited nearby to reduce transport costs between where they are grown and where they are processed. The industrial crops considered in analysis of the Ord region include cotton, sugarcane, sandalwood and hemp.

Dryland and irrigated cotton production is well established in Australia, with the annual area grown generally changing in response to water availability. Commercial cotton production has been attempted a number of times in northern Australia, including in the ORIA. Mistakes in capital, climatic adaptability and pest control were major challenges for early attempts to establish commercially viable cotton crops. Since the introduction of genetically modified (GM) cotton in 1996, yields and incomes from cotton crops have increased in most regions of Australia. The key benefits of GM cotton (compared with conventional cotton) are savings in insecticide and herbicide use, and improved tillage management. Recent work in the Ord region has been on developing management guidelines for cotton (Yeates et al., 2007), based on these new varieties and growing them in the dry season, with expectations of yields in excess of 9 bales/ha.

Sugarcane is a well-established industry in coastal Queensland and northern New South Wales. Although sugarcane is a perennial plant, it is commercially grown as an annual crop, with the entire biomass harvested between 12 and 16 months after planting. Sugarcane plants reshoot (called ratooning) and grow for a further 12 months before being harvested again. The crop can actually ratoon many times, but is usually replanted after three to five ratoons because yield decreases with each ratoon crop. Sugarcane is usually harvested between June and December in eastern Australia; however, in the Ord region, where May is cool and dry, the harvest could begin in May. Sugarcane has been previously grown with success in the Ord region, with a sugar mill operating for a number of years to process the crop. However, the capacity of the mill (60,000 t/year) was not large enough to support ongoing commercial production.

A growing Indian sandalwood industry currently occupies approximately 7000 ha of the ORIA. This crop is essentially a plantation crop that has a longer-term planting to harvest cycle (approximately 15 years). Commercial harvesting began in 2014. The initial yields are expected to be low because the survival rate of early plantings was low (approximately 20%) compared with current survival rates (more than 80%). Heartwood yields can vary enormously between individual trees. For example, for a small group of 32 trees harvested in Kununurra, the average heartwood yield was only 1.5 t/ha, with a range from zero to about 8 t/ha (Brand et al., 2012). However, in that study, tree densities were much lower than current commercial plantings. Sandalwood is an unusual commercial crop in that it is a hemi-parasite requiring macronutrients from the roots of the host leguminous trees. It has taken some time to develop the appropriate cultural techniques to ensure good survival and growth of sandalwood, and the early plantings assessed by Brand et al. (2012) were likely to affected by suboptimal host–sandalwood relationships. Oil extracted from sandalwood has a very high value, and consistent oil yields across an entire plantation requires good management over the entire growing period (often more than 15 years).

Industrial hemp, also known as Indian hemp, is grown for fibre that can be used to produce textiles, composite building materials, insulation and paper. It can also be used as a biomass source to produce ethanol. The crop is presently only grown on a small commercial scale, mostly in southern Australia. Most varieties of industrial hemp are sensitive to daylength and are most productive in areas with long summer days. Commercially grown industrial hemp varieties need to have concentrations of tetrahydrocannabinol (THC) that do not exceed 1%. The seed from industrial hemp is valued as a food product and contains no THC but it cannot be legally grown in Australia as a food crop. There was a reasonable amount of research undertaken on industrial hemp in the 1980s and 1990s, but there is a lack of high-producing varieties suited to low latitude, tropical climates.

5.7.2 MARKET ANALYSIS OF CROPS

A range of market opportunities exist for the crops that are currently grown in the Ord catchment and also for those that potentially could be grown under an expansion of the irrigation area. This section highlights some of these opportunities for the range of broadacre, high-value and industrial crops that are analysed in the cropping scenarios for the Ord region. A more detailed market analysis of each commodity is given in Appendix 4.1.

Broadacre crops

Rice

The ability to grow tropical rice varieties offers an advantage to rice producers in the Ord region. This also includes brown rice, which receives a premium in health food markets. Domestic use of rice in Australia has increased over the past decade. Australia, a small exporter of rice on a global scale, exported 585,000 t of rice and imported 145,000 t in 2012–13, with around 34% of domestic demand fulfilled by imports. There is potential for increased production of Australian rice, particularly of tropical varieties, to replace imports and service growing domestic demand if it can be profitably and competitively produced relative to the price of imports.

International demand for Australian rice is expected to increase in Japan, Taiwan and the Middle East as incomes rise and trade liberalisation increases. However, in each of these markets, Australian rice exports would need to be competitively priced compared with supplies from other major exporting countries. Exports to Japan are likely to continue to be limited by trade barriers.

Grain sorghum

Grain sorghum is largely consumed in intensive livestock industries, such as feedlot cattle, pigs and poultry. Feedlot cattle are the main consumers of grain sorghum, consuming around half of all grain sorghum used for feed. Domestic marketing opportunities will depend largely on livestock numbers in intensive feed industries. Over the medium term, the lot-fed cattle industry is likely to continue to feel pressure from United States competition in the important grain-fed beef markets of Japan and the Republic of Korea. Poultry numbers are projected to rise, supporting the demand for grain sorghum. Reduced tariffs under the Korea–Australia Free Trade Agreement and the Japan–Australia Economic Partnership Agreement improve those prospects.

Australia exported around half of its grain sorghum production in 2010–11 and 2011–12. While Japan historically has been the major trading partner, China has recently become an important export destination, taking 25% of exports in 2012–13 and this is forecast to grow substantially. Australia's main competitors in overseas markets are the United States and Argentina, both generally lower-cost suppliers than Australia. United States grain sorghum exports are projected to be maintained over the medium term, while exports from Argentina are forecast to increase slightly.

In addition to livestock feed demand, sorghum can be processed into ethanol. For example, an ethanol plant in Dalby, Queensland, has the capacity to process around 200,000 t of sorghum to produce 80 million litres of ethanol annually. In 2011–12, biofuels represented around 1% of Australia's petrol and diesel production. The latest long-term projection of Australian energy supply and demand to 2050 by the Bureau of Resources and Energy Economics is for bioenergy production in Australia to grow by 3.9% per year.

Maize

In Australia, feeding maize to livestock accounts for around 54% of total domestic consumption, and food and industrial consumption accounts for the balance. Maize is a minor component of the livestock feed complex, but more than 90% of feed maize is consumed by poultry or pigs; only a small amount is consumed by feedlot cattle.

The most important export markets for maize are Japan and the Republic of Korea, but Australian maize comprises less than 1% of these countries' imports. Main competitors in these countries are the United States, Argentina and Brazil. The size of Japan and Korea as import markets has been falling in recent years, and growth in world maize imports has been driven by Latin American and member states of the Association of Southeast Asian Nations (ASEAN).

Asia is expected to be a driver of world maize consumption, largely as a result of growing demand for maize as a feed grain. This may present export opportunities. However, Australia does not have access to China's market due to non-tariff barriers. Domestic marketing opportunities for maize will depend largely on poultry and pig numbers, which are projected to rise over the medium term.

Chickpea

Most of Australia's chickpea production is exported. Australia is the world's largest chickpea exporter, accounting for 44% of global chickpea trade in 2011. Continuing growth in demand from South Asia for pulses is likely given projections of population growth and the largely vegetarian Hindu diet. Ongoing shortfalls in South Asian production will provide opportunities for Australian chickpea exporters.

Opportunities exist to provide the large South Asian and Middle Eastern migrant communities in Australia with domestically produced chickpeas.

Mungbean

Australian production of mungbeans has almost doubled in the two decades to 2012–13 and is largely destined for export. In 2011–12, Australia shipped 50% of mungbean exports to India with another 22% sent to ASEAN member states. Within the ASEAN region, Indonesia was the largest importer of Australian mungbeans. India and ASEAN will continue to be growing markets for Australian mungbeans.

Domestically, and internationally, opportunities exist to market mungbeans as a functional food to domestic food manufacturers and consumers. Mungbeans have a range of potential applications such as starch, flour and paste, and can also be used as an additive to other foods.

Peanut

Australian peanuts are mostly used on the domestic market, with food consumption the primary use. Australia is usually a net importer of peanuts, except in years of large production, and imports both processed and unprocessed peanuts mostly from Argentina, China and Nicaragua. Australia exports unprocessed peanuts – 1100 t in 2011–12 – mainly to New Zealand, Japan, Fiji and China. Processed peanuts – 1700 t in 2011–12 – were exported mainly to New Zealand, the Republic of Korea and Japan.

China and India together produce more than half of the world's peanuts. China is also the largest consumer of peanuts for food, followed by Indonesia, the United States and Nigeria. China and India are the largest crushers of peanuts and consumers of peanuts meal and oil. While China was once the primary supplier in international markets, growing domestic consumption has reduced exports.

Should local production expand, there is potential for some import substitution of peanuts for food use and also peanut meal for intensive livestock production. Any expansion in production could also be shipped to current export markets, particularly Japan and the Republic of Korea. The major supplier to these markets is China but, with its own domestic consumption increasing, there may be opportunity for Australian exports to expand in these markets. Likewise, net exports from the United States, the second-largest supplier to Japan, are projected by the United States Department of Agriculture to fall over the medium term, providing opportunity for Australian exports in Japan.

Opportunity also lies in supplying high oleic peanut oil to the world market, but capitalising on this opportunity would require a large-scale stable supply of high oleic peanuts and export market development. However, unless significant price premiums can be achieved, production would need to be at such a scale as to reduce production costs to increase grower profitability. Given the small peanut oil market in Australia, expansion requires export market development.

Chia

Chia was first established commercially in the ORIA in 2005 as a dry-season crop. Currently, nearly all Australian production of chia is contracted to The Chia Company. In Australia, The Chia Company produces whole chia seeds, chia bran, ground chia seed and chia oil for wholesale and retail sale and exports these products to 36 countries. The company also sells bulk ingredients to a number of food manufacturers, including Kellogg's, Baker's Delight, PepsiCo and Allied Bakeries.

Chia consumption is growing globally. In Australia, health concerns and nutritional awareness are providing opportunities for producers, manufacturers and marketers to develop and promote healthier food alternatives. Therefore, there are opportunities for the domestic market to further market chia to interested consumers.

Internationally, the United States and Asia are the largest markets for Australian chia. Central and South American chia production poses the greatest competition to Australian chia in North America because of the geographic proximity of these regions, therefore, greater opportunity lies in expanding chia sales in the growth markets of Asia.

High-value crops

Mango

Mangoes in the Ord region and other parts of northern Western Australia, along with those grown in the Northern Territory, are among the earliest harvested, with the harvest beginning in September. This is followed by harvest in Queensland's dry tropical regions (Townsville, Burdekin and Bowen) in mid-November, other regions of Queensland in December and northern New South Wales in January.

The Australian mango industry is domestically focused, with 80% sold as fresh produce and the remaining 20% processed. Of the fresh fruit, around 90% is sold on the Australian domestic market, which is well supplied in season. Increased mango production in the Northern Territory over the past five years means that the availability of early season mangoes has increased for domestic consumers.

Imports are low but have been growing steadily over the past decade. Supply from imports is counter-seasonal to Australian production. However, as the Australian season extends with growing production of early season mangoes, it is likely there will be increasing overlap in supply to the market.

Key export markets for mangoes are Hong Kong (42% of export volumes in 2012–13), the ASEAN member states (21%), the Middle East (18%) and New Zealand (13%). Important ASEAN markets are Singapore, Vietnam and Malaysia. However, Australia is a small producer of mangoes on a global scale at only 0.1% of world production.

International trade in mangoes represents only 3% of volumes produced because the fruit is highly perishable and easily damaged, making exporting fresh mangoes difficult. The highest mango consumption is in Asia. In Asia, unripe mangoes are especially popular, while in western countries ripe mangoes are mainly eaten. Increased production of mangoes in Australia would provide export opportunities for unripe and ripe mangoes to Asia. Thailand offers strong competition in this region because it is the main supplier of mangoes to Malaysia, China and Singapore. Japan sources mangoes from Mexico, the Philippines and Thailand.

Bananas

The banana-growing industry is one of Australia’s largest fresh fruit crops in terms of production value, and the largest horticulture industry in Queensland. The Western Australian banana industry accounted for 1.5% of production in 2011–12, mainly in the Gascoyne irrigation district near Carnarvon and from new plantings being established in the ORIA.

Almost all of Australia’s banana production is consumed domestically as fresh produce. More bananas are sold than any other fruit on the domestic market, and they are purchased by over 90% of Australian households. A key advantage for the industry has been the ongoing popularity of bananas. The industry has also benefited from rising health consciousness and an associated trend towards increased fruit consumption. For this reason, there is scope for some continuing growth of demand on the domestic market. However, because Australian banana production is mainly consumed domestically, any significant increase in production that exceeds growth in demand would place downward pressure on prices and hence growers’ returns.

Only minimal amounts of Australian bananas are exported, in most recent years going to New Zealand and Nauru. Australia does not import fresh bananas or plantains. So far no country has met Australia’s strict biosecurity requirements for fresh banana imports, so international markets exert very little influence on the Australian banana industry.

While exports are currently minimal, the industry has been striving to develop new export markets, particularly in Asia where population and income growth rates are high. The industry’s opportunity lies in its counter-seasonal supply advantage into the Northern Hemisphere markets. Japan provides a potential market as it is a high-income country and a major global importer of bananas. China also, with its growing urban population and growing incomes, provides a potential market as a large importer of bananas.

Cucurbits

The cucurbit industry’s exposure to international markets is limited, with most production sold into the domestic retail and foodservice markets. In 2012–13, Australia exported 1500 t of pumpkin with the largest markets being Singapore (62%), Papua New Guinea, Indonesia and the United Arab Emirates. Only around 5 to 6% of melon production is exported, with New Zealand – the largest market – taking 38% of total melon exports in 2012–13. Imports of both pumpkins and melons are negligible.

China is the world’s largest pumpkin producer, accounting for 28% of global production in 2011, followed by India (19%) and the Russian Federation (5%). Exporters include Spain, accounting for 45% of exports in

2011, followed by New Zealand, Mexico and Morocco. The United States and the European Union are some of the largest consumers of pumpkins in the world and together account for around 80% of imports.

World melon production has almost trebled over the past two decades, with two-thirds of global watermelon and just over half of all other melons now produced by China. China is also one of the world's largest melon-consuming countries – second to the United States and ahead of the European Union. The United States and China are also the world's largest importers of watermelons, together accounting for over one-third of world imports in 2011. For other melons, the largest import markets are the United States and the European Union.

Rising nutritional awareness is expected to have an impact on demand for cucurbits in the domestic market. Northern Australian production is counter-seasonal to southern Australian production and therefore extends their availability to consumers. However, any specific effects on the consumption of pumpkins and melons will depend on consumer preference towards them compared with other fruits and vegetables and their relative prices against other fruits and vegetable. There are perhaps greater opportunities for producers to export high-quality fresh produce to Northern Hemisphere countries, particularly to ASEAN member states and the Middle East, which are already important markets for Australian exports of pumpkins and melons. Although China is a major producer of melons, it is also one of the largest importers and so offers market opportunities for Australian exporters of high-quality melons.

Industrial crops

Sugarcane

Australia is a relatively small sugar producer on a global scale but is currently the world's third-largest exporter of sugar. Around 80% is exported to international markets and the remaining 20% is consumed domestically. Although high compared with other developed countries, consumption of sugar in Australia has stagnated as demand for sugar is adversely affected by increased health awareness driving Australian consumers to increasingly substitute sugar with alternatives such as artificial sweeteners. Future growth in the domestic market will likely be limited, driven largely by population growth. Also, Australia's ageing population could potentially affect domestic sugar demand in the future as children and teenagers take the largest components of the final-user market. This limited opportunity in the domestic market will increase the industry's reliance on international markets.

Overseas demand for sugar is growing and should support exports. Australia exports raw and refined sugar mainly to Asian markets, particularly the Republic of Korea, Japan, Malaysia and Indonesia. In the longer term, increasing sugar consumption in developing countries, especially in Asia, will be in response to rising incomes and strong population growth in these countries, which should offset lower demand for sugar in developed countries. Indonesia, particularly, has emerged as one of the largest importers of Australian sugar and is now the second-largest market after the Republic of Korea.

Cotton

Australia is the sixth-largest producer of cotton in the world. In 2012–13, Australia produced 1 million tonnes of cotton lint and 1.4 million tonnes of cottonseed. The level of Australian cotton production depends largely on the availability of irrigation water. Currently, about 95% of Australian cotton production takes place in the Murray–Darling Basin (MDB) region and more than 90% is irrigated. The increased diversions of irrigation water to environmental uses under the MDB Plan are expected to have a minor effect on Australian cotton production over the medium term, but the prospects of significant expansion in irrigated plantings in the MDB are limited by water availability.

Australian cotton yields are the highest in the world at around 260% higher than the global average. Around 95% of Australian cotton lint is exported to international markets, mainly in Asia, while a large proportion of cotton seed is consumed in Australia. Cotton seed as a by-product is crushed for cooking oil and the cotton seed meal is used for stock feed.

Given Australia's small textile manufacturing sector, domestic textile mills only consume around 3% of the cotton industry's output. It is unlikely that additional demand for ginned cotton will be created domestically because labour costs in textile manufacturing are much cheaper overseas. In the 10 years to 2012–13, Asian markets accounted for 98% of total Australian lint exports, with the remainder exported to Europe. China has now emerged as the largest importer of Australian cotton, taking around 70% of Australia's exports in 2012–13. Other important markets are Indonesia, Thailand and the Republic of Korea. Demand from other Asian countries such as Cambodia and Vietnam is expected to grow as wage inflation in China is leading Chinese manufacturers and other global textile companies to move their manufacturing operations to other low-cost nations. Other potential markets for Australian cotton that could be further developed include Bangladesh and Pakistan.

Sandalwood

Culturally significant in India, China and the Middle East, sandalwood heartwood is widely used for religious worship and ceremonies and in a range of wood-based consumer products. Heartwood is also distilled into premium quality oil for use as a fixative in fine fragrances, beauty products, medicines and incense, and as a flavouring agent for chewing-tobacco products. In recent years Australian sandalwood oil has been incorporated into many high-end perfumes and other cosmetic products. Expansion of Indian sandalwood plantations in the Ord and large-scale plantings planned for Queensland and the Northern Territory are being promoted to take advantage of this demand.

Australian sandalwood currently supplies well over half of all sandalwood globally traded annually. Indonesia, East Timor and India are the other main exporters. Global supplies of sandalwood have been depleted by overharvesting of wild plantations. The Indian Government has placed restrictions on exports of Indian sandalwood in response to depletion of natural resources as a result of illegal harvesting.

Australian sandalwood has historically been used in the agabati and incense markets in China, Taiwan, Hong Kong and most other Asian countries. The main importers of sandalwood are Taiwan, China and India. The United States and France are the main importers of sandalwood oil, but there is also demand from North Asia and the Middle East for oil.

Internationally, the key market drivers are the decline in the supplies of sandalwood from India and other traditional sources in Indonesia and the Pacific, and growing populations and affluence in developing nations, particularly in India and China. Provided a steady supply of high-quality sandalwood can be maintained, the preference in Europe and North America for natural products in cosmetics will assure the future market for the oil and perhaps also for the nuts. There are also opportunities for sandalwood products in pharmaceutical uses. At the same time, lower-grade powdered sandalwood products will have a ready market in Asia for incense.

Industrial hemp

Industrial hemp production is either not permitted or is strictly regulated in many countries, to guard against the illegal production of marijuana. In Australia, the state and territory governments control the legalisation and licensing of industrial hemp production. At present, industrial hemp can be legally grown in Victoria, Queensland, Western Australia and New South Wales. The industry is dominated by a few large companies that contract the growing of industrial help to individual farmers.

In Australia, human consumption of hemp seed is presently prohibited under the Australia New Zealand Food Standards Code, but this prohibition is currently under review. If hemp seed is legalised for human consumption in Australia, it is expected that demand would increase, although the impact may be small.

Australia is a net importer of hemp fibre. As such, with increased production of industrial hemp and associated production capacity, Australian producers could potentially supply the domestic market. This will depend on quality and price competitiveness against available imports. Increased production of industrial hemp in Australia could lead to export opportunities to other countries such as the United States, where there is growing demand for hemp seed and hemp seed products. However, Australian exports would have to compete with exports from Canada, the largest supplier to the United States market.

5.7.3 **CROP PRODUCTION ESTIMATES**

Estimates of crop production for identified broadacre, high-value and industrial crops were made using the APSIM (Agricultural Production Systems sIMulator) simulation model (Keating et al., 2003) for crops that ASPIM has the potential to simulate (rice, sorghum, maize, chickpea, mungbean, sugarcane and cotton) (Table 5.4) and various 'heat sum' approaches and expert-based analyses of historical yields for the crops without APSIM capability (see Section 2.3.3).

The soil used in the APSIM simulations was parameterised to represent a Cununurra Clay of the Central Ivanhoe Plain (Section 5.5), a dominant grey clay Vertosol in the Ord region agricultural cropping area. The soil holds 173 mm of water to a depth of 2 m. Historical meteorological data from Kununurra Airport for the period 1900 to 2010 was used in the simulations to generate variation in crop yield and irrigation water required. Analysis of tropical cyclones that have affected the Ord region from 1900 show seven tropical cyclones have crossed the coast in the vicinity of Kununurra that could have affected crop production. The effect of strong winds from tropical cyclones is not simulated with APSIM. The heavy rainfall often associated with tropical cyclones contributes to simulated water budgets, but no affect of flooding or prolonged waterlogging is simulated. As the frequency of tropical cyclones affecting Kununurra is less than 20% of years (seven in 112 years is 6%) the impact is not reflected in the reported 20th percentile either. Nevertheless, the risk tropical cyclones (and heavy rain) pose to the Ord region is not insignificant, depending on the crop and timing of the cyclone.

APSIM assumes best practice for managing a crop in the absence of pest and disease-related stress. Simulations were undertaken to achieve crop growth in non-limiting soil water and nutrient environments. Applied irrigation was triggered in the model using soil water deficit and the potential root zone of each crop. Natural reset points at the end of winter (September), when the soil profile is normally dry, were selected to initialise the soil water, soil nitrogen and surface cover each year so as to only capture the effect of seasonal climate and applied irrigation on crop production. Irrigation management assumed 100% efficiency in applying irrigation to the crop regardless of availability of supply.

The values presented for water applied to a crop do not equal the total water used to produce the crop (Table 5.5). APSIM assumes 100% efficiency of irrigation water supply, and reported figures are 'on crop', not accounting for delivery from the water storage. Water inefficiencies exist in the storage, transport and on-farm application of the water. The outputs from modelling and estimates for non-modelled crops are potential productivity and irrigation water use on a per-hectare basis.

Table 5.4 Crop yields simulated using APSIM (represented by those crops with 20th, 50th and 80th percentile values) or estimated based on production in the region (for other crops except hemp, which is based on published estimates)

APSIM yields for broadacre crops are based on 110 years of simulations (1900 to 2010) and are expressed in tonnes of dry matter per hectare. For the economic assessment these were converted to fresh yields, based on moisture contents of 12 to 14%.

CROP	YIELD PERCENTILE		
Broadacre (t/ha)	**20th**	**50th**	**80th**
Rice	7.3	4.7	3.8
Sorghum	8.4	8.0	7.5
Chickpea	2.3	2.1	1.9
Mungbean	2.4	2.3	2.3
Chia		1.1	
High value			
Mango – Kensington Pride		600 trays/ha	
Mango – Plant Breeder's Rights varieties		2500 trays/ha	
Banana		2000 cartons/ha	
Watermelon		22 t/ha	
Rockmelons		1471 trays/ha	
Industrial/other			
Sugarcane	177.3 t/ha	113.7 t/ha	97.4 t/ha
Cotton	8.8 bales/ha	8.3 bales/ha	6.8 bales
Cotton (dry season)	9.8 bales	9.2 bales	8.8 bales
Sandalwood		8 t/ha heartwood[a]	
Hemp		10.0 t/ha	

a Sandalwood is grown on a 15-year cycle, so yields harvested per hectare will be 1/15th of 8 t/ha.

Table 5.5 Irrigation water use (mm per crop) for the broadacre and industrial crops simulated in APSIM for 110 years (1900 to 2010)

Assumes perfect timing of irrigation (i.e. no field application losses).

CROP	IRRIGATION WATER USE (mm) PERCENTILE		
	20th	**50th**	**80th**
Broadacre			
Rice	946	900	841
Sorghum	401	351	316
Maize	614	540	450
Chickpea	283	253	220
Mungbean	246	231	178
Industrial			
Sugarcane	2126	1480	1480
Cotton	449	382	282
Cotton (dry season)	777	698	636

Rice

Initially, wet-season rice was simulated, but yields were predicted to be low due to heat stress. Consequently, dry-season rice was modelled under raised beds (aerobic system) rather than ponded rice because this greatly reduces bird attack. In addition, the land suitability assessment indicated that the soils are not well suited to long-term flood irrigation. Planting on 30 May led to an increase in heat stress during flowering and grain fill, resulting in depressed yields in some years, so planting at the end of April or in early May is recommended. Conversely, cold stress severely affected rice yields in about 20% of years. Night-time temperatures in the dry season can be quite cool and this cold limitation on dry-season rice physiology has been observed in Kununurra (Sivapalan, 2013). Yields in that particular study averaged 3.8 t/ha across 19 varieties. However, cold-tolerant varieties are available, and in the economic assessment for rice the 80th percentile value (7.3 t/ha dry matter or 8.3 t/ha at 14% moisture content) was assumed on the basis that cold-tolerant varieties were grown.

From panicle initiation onwards the rice crop needs careful water management, which is practically easier to achieve using wet-season rainfall to supplement irrigation in summer-planted crops. The rice varieties simulated in this study were not the 'aromatic' type. However, in the economic analysis we do examine these fragrant rice varieties but because of a lack of confidence in their production potential a yield of 7 t/ha was assumed.

Sorghum

Sorghum was sown in the simulation on 15 March. Although sorghum has a long sowing window, when it is sown after March heat stress during flowering and grain fill can depress yields. Planting before December results in the developing seedling growing in the hottest part of the year, increasing the risk of heat stress. Grain sorghum average yields of 8 t/ha in the Ord are favourable when compared with sorghum grown in established cropping regions in northern Australia. Non-grain (forage) varieties of sorghum can also be grown as forage crops for direct feeding of stock.

Maize

Maize was sown in the simulations on 15 March. Like sorghum, maize can be planted during a wide sowing window, however, management of heat stress during flowering, grain fill and seedling development is required to reduce the risk of yield penalties. The maize yields simulated for the Ord show that maize is very well adapted to the region. Maize can also be grown as a forage crop for livestock.

Chickpea

Chickpea was sown in the simulations on 1 May. Chickpea develops in a relatively short time, and is deep rooted and well suited to opportunistic cropping. There is some merit in planting chickpea after a summer-grown rice crop has been harvested, to take advantage of water stored in the soil that is needed by rice during grain fill. However, as indicated above, wet-season rice may not be the best way of growing rice in the Ord. Kabuli chickpeas, which have a large seed, can be grown in the Ord and can receive a considerable price premium over other smaller-seeded varieties (e.g. $900/t versus $400 to $500/t). Care is needed in how they are grown and their frequency of planting because of susceptibility to ascochyta blight.

Mungbean

Mungbean was sown in the simulations on 15 March. Mungbean matures relatively quickly and, like chickpea, can be opportunistically sown but is often part of planned rotations. Mungbean price can vary greatly with seed quality when sold for human consumption (which generates the highest prices). Rainfall during the later stages of pod fill can have a detrimental effect on grain quality, and consequently price received, so planting is usually timed to ensure a low risk of receiving rainfall at this crucial time.

Chia

Little information is available on chia production in the Ord, given its commercial-in-confidence production model. Based on discussions and published literature, for this analysis yields of 1.1 t/ha were assumed.

Mango

Kensington Pride mangoes are the most common variety of mango grown in Australia and dominate production in the ORIA. Yields average around 8.0 t/ha across the Australian tropics and subtropics but are considerably lower than average in Kununurra, and in this study a baseline yield of 4.2 t/ha was used. Newer varieties such as Honey Gold and Calypso have become the new standard in mango production yield and though higher yields can be obtained (20–25 t/ha), for this study baseline yields of PBR varieties were assumed to be 15 t/ha in the Ord. Mangoes flower from May to August, and from time of flowering to harvest (November to March) water management is crucial for optimum mango development. Cold spells after flowering can have a detrimental effect on mango yield and is often the cause of seasonal variation. However, there is also anecdotal evidence that unusually warm dry seasons will also affect flowering (e.g. 2013 in the Ord). Individual mango trees often exhibit a biennial yield variation.

Banana

Banana production is suited to the climate of the Ord region. Bananas can be planted during most of the year; however, planting is generally timed to avoid young plants developing in the very hottest months. Although banana plants ratoon via suckers and do not require annual planting, they are generally removed after three or four ratoons (depending on disease presence). Fruiting in older banana blocks becomes asynchronous, with harvesting windows extending for much of the year. Cyclones have devastating effects on banana plantations; however, recently developed management techniques mean younger plants can more quickly come back to production after cyclones if they are ‘topped’ before the cyclone. Based on production data for the Ord and potential production, baseline yields of 26 t/ha were adopted in this study.

Melons

Watermelon and rockmelon (cucurbits) are well suited to the Ord region. Planting of cucurbits is generally staggered so that harvest occurs over a longer period, from May until October, reducing the time of peak workload and extending the time for market access. The planting season starts when the daytime air temperature reduces enough so that young plants do not suffer from heat stress (late February to mid-March) and continues until July. Planting can be weekly to fortnightly during this period. Based on production data in the region, baseline yields used in this study are 25 t/ha for rockmelon and 32 t/ha for watermelon.

Sugarcane

Sugarcane was sown in the simulations on 15 May. Harvest date for the plant and the first, second and third ratoon crops was 15 September. The fourth ratoon crop was harvested on 15 June. Sugarcane is a biomass crop, with the simulated yields comparing favourably with those from the best sugarcane producing region in Australian (Burdekin). The climates of the Ord and Burdekin regions are not dissimilar. Water use for sugarcane is substantially higher than most crops because sugarcane is a perennial crop that grows for 12 months, with irrigation only ceasing in the months before harvest, and heavy water use being required in the highest evaporative demand months in the Ord, from October to December.

Cotton

In the simulations, wet-season cotton was sown on 1 January. Rainfall during late crop development can downgrade cotton quality and price, so planting in the Ord region needs to be timed to avoid rainfall at this time. Dry-season sowing of cotton was on 31 March. The Ord is one of the few regions in Australia that can grow cotton over the dry season and there are advantages to doing so in this environment. Yields of dry-season cotton are simulated to be higher, and in terms of farm operations and integrated pest management a dry-season crop is easier to manage.

Processing cotton locally has the additional benefits of producing cottonseed – a valuable, high-protein meal for cattle that is fed either as whole cottonseed or as cottonseed meal. There would also be export potential for cottonseed meal.

Sandalwood

Sandalwood is grown for 15 years and requires good irrigation management during the entire life of the stand (especially on cracking Vertosols) to ensure optimum oil yields. Estimates of commercial production of sandalwood in the Ord are for 10 t/ha of heartwood. In this analysis, a somewhat more conservative estimate of 8 t/ha of heartwood and an oil content of 3.5% were assumed. Agronomic techniques and management of host species have improved greatly since the early plantings in the 1990s, which gives some confidence that yields of around 8 t/ha can be achieved.

Industrial hemp

Although little work has been done on industrial hemp varieties suited to tropical Australia for this analysis, we assumed a yield of 10 t/ha.

5.7.4 **CROPPING CALENDAR**

Cropping calendars identify sowing times and the growing season for different crops. The time during which a crop can be reliably and profitably sown is called the sowing window. Sowing windows vary in both timing and length among crops. The cropping calendar in Table 5.6 identifies sowing windows for the crops analysed for the Ord region. Perennial crops are grown throughout the year and consequently have a less well-defined growing season or planting window. Generally, perennial tree crops are transplanted as small plants (not seeds), and in the Ord region this is usually timed towards the beginning of the wet season to take advantage of wet-season rainfall.

The cropping calendar was developed based on knowledge of these crops in the Ord or derived from elsewhere in the tropics, combined with an understanding of plant physiology, which enables crop response to differences in local climate to be anticipated. The sowing windows identified correspond with the times of sowing that are likely to maximise potential crop yield in the Ord region (Table 5.6). Sometimes, crops can be successfully sown outside the identified sowing windows and only a small yield penalty would apply. In this analysis, sowing dates between August and November were generally avoided because high evaporative demand and low water availability are not conducive to seedling establishment;

it is, however, possible to sow many crops at this time. Note that sowing to achieve maximum potential crop yield may not always be possible. Wet-season difficulties in access and trafficability may prevent sowing at optimum times.

Table 5.6 Calendar of sowing for annual crops in the Ord Region

CROP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Broadacre												
Rice				X	X	X	X	X	X	X	X	
Sorghum			X	X	X	X	X	X	X	X		
Maize			X	X	X	X	X	X	X	X	X	
Chickpea				X	X	X	X	X	X	X		
Mungbean			X	X	X	X	X	X	X	X		
Chia					X	X	X	X	X	X	X	
High value												
Watermelon				X	X	X	X	X	X	X		
Rockmelon				X	X	X	X	X	X	X		
Industrial												
Cotton (dry season)			X	X	X	X	X	X	X	X		
Cotton (wet season)	X	X	X							X	X	X
Hemp	X	X	X						X	X	X	X

5.8 Gross margin analysis: sensitivity to price, production and supply chain costs

The crop gross margin is the difference between the gross income and variable cost of growing a crop.

Variable costs include those associated with crop management, harvesting, transport and marketing. For remote regions like the Ord, the costs of production have historically been relatively high compared with other agricultural regions in southern or eastern Australia. These higher costs can be attributed to both higher costs for inputs such as fertiliser, as well as the costs associated with transport to markets and/or processing facilities.

Table 5.7 provides the gross margins for a range of crops specific to the Ord region. The gross margins do not include overhead costs (e.g. business administration, insurance) or capital costs (e.g. farm equipment, irrigation infrastructure) that must be met even if a crop is not grown. For crops modelled using APSIM and more than 100 years of historical climate data, gross incomes were calculated using the 50th percentile exceedance crop yields over the historical period. For crops that could not be modelled, estimated yields are provided based on production data in the region or in other regions if that crop is currently not grown. Costs of production were based on gross margins developed by local agricultural economists (F Bright, DAFWA, pers. comm.) and agronomists, and by other jurisdictions across northern Australia.

Table 5.7 shows that crops in all three categories (i.e. broadacre, high-value horticulture and industrial crops) can provide positive gross margins. Gross margin analyses should be used with care because they are highly sensitive to price, yield, transport costs and input costs, not just within a particular region but between individual farms. Crop yields generated by APSIM include climate variability but do not include losses due to extreme weather events or pests and diseases, and so may overestimate commercial yields over an extended time.

Table 5.7 Gross margin analysis for existing and potential crops in the Ord region, based on current domestic supply chains

Yields of crops simulated by APSIM on a dry-matter basis have been adjusted upwards to account for moisture content of marketed product.

CROP	LOCATION FOR MARKET OR PROCESSING	YIELD UNIT/ha	MEDIAN YIELD (per ha)	PRICE PER UNIT YIELD ($)	VARIABLE COSTS LESS FREIGHT ($/ha)	FREIGHT COSTS ($/ha)	TOTAL VARIABLE COSTS ($/ha)	GROSS MARGIN ($/ha)
Broadacre								
Rice	Townsville	tonnes	8.3	350	1,989	1,693	3,682	–778
Rice (fragrant)	Townsville	tonnes	7.0	500	1,989	1,428	3,690	83
Sorghum	Perth	tonnes	9.1	240	1,750	1,365	3,417	–931
Maize	Perth	tonnes	11.8	280	1,985	1,770	3,755	–451
Chickpea	Melbourne	tonnes	2.4	900	1,592	550	2,142	18
Mungbean	Perth	tonnes	2.6	925	1,886	390	2,276	129
Chia	Melbourne	tonnes	1.1	3,000	2,213	249	2,462	838
High value								
Mango – Kensington Pride	Perth	trays (7 kg)	600	22	11,479	1,200	12,679	–79
Mango – Plant Breeder's Rights varieties	Perth	trays (7 kg)	2,500	21	34,937	5,000	39,937	7,062
Banana	Adelaide	carton (13 kg)	2,000	19	31,588	7,200	38,788	6,212
Watermelon	Adelaide	tonnes	32	900	16,995	7,680	24,675	4,125
Rockmelon	Adelaide	tray (17 kg)	1,471	19	15,962	5,882	21,844	6,097
Industrial/other								
Sugarcane	Kununurra	tonnes	114	36	2,342	4	2,346	1306
Cotton	Dalby	bales	9.2	500	3,822	2,972	6,794	–1,624
Sandalwood	Albany	kg	315	3,500	7,337[a]	160	7,497	65,287
Hemp	Perth	tonnes	10	195	1,152	1,000	2,152	–231

a Costs include oil extraction based on 1/15 ha harvested each year.

For horticultural crops, which mostly supply domestic markets that have a finite demand and can be easily oversupplied, there can be rapid price movements over days and weeks. This is highlighted in Figure 5.9, which shows movements in the wholesale price of rockmelons at the Sydney markets in 2013. In contrast, significant price movements in broadacre crops commonly play out over months and years (Figure 5.10).

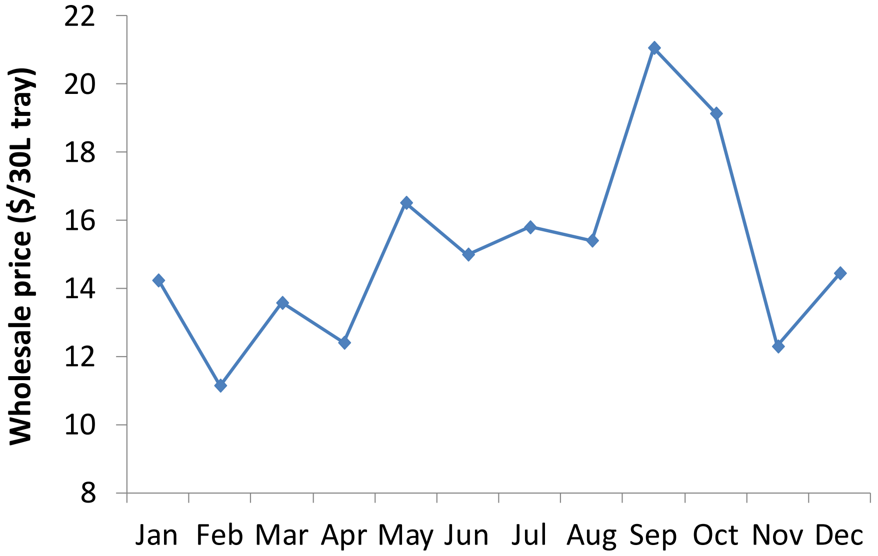

Figure 5.9 Wholesale prices for rockmelons at the Sydney markets during 2013
Source: Data provided by Ausmarket Consultants, Brisbane

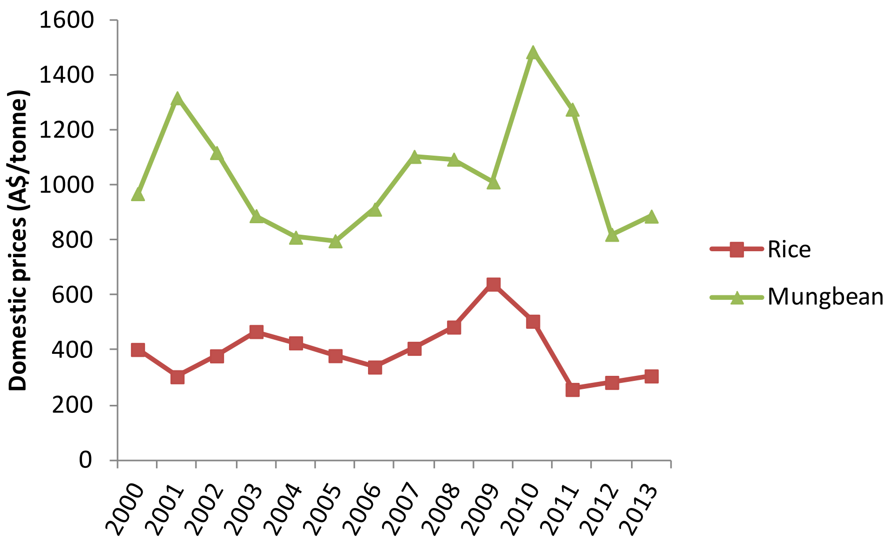

Figure 5.10 Domestic prices for rice and mungbean, 2000 to 2013
Source: Data supplied by ABARES

5.8.1 BROADACRE CROPS

For the broadacre crops, the average gross margins were generally either negative or modestly positive. The exception was chia, which is relatively high value in the category of broadacre crops, though confidence levels on the gross margin analysis for chia is low given the commercial-in-confidence nature of this crop. Under the existing supply chain arrangements for domestic markets, all the broadacre crops are transported large distances to markets from the Ord region. Table 5.8 highlights the high freight costs as a percentage of the total costs of production for the relatively low-value crops of sorghum, maize and rice. For these coarse grain crops to be grown profitably, either lower-cost bulk export to South-East Asia or Papua New Guinea out of Wyndham needs to be established, a local market for grain consumption in beef production systems needs to be developed or higher-value niche markets established.

There is interest, for example, in fragrant rice varieties, which attract a premium for their additional flavour ($150 to $300/t premium). Because fragrant varieties develop more intense flavours in the tropics that in temperate environments, they may have a competitive advantage in northern Australia (S Sivapalan, DAFWA, pers. comm.). However, relatively little agronomic work has been done on yields of fragrant varieties in tropical Australia. In this analysis a lower yield (7.0 t/ha) for fragrant varieties was assumed, given their relatively immature stage of agronomic and variety assessment.

For the relatively small areas of rice grown and harvested in the Ord region in 2010 and 2011, the crop was dried and dehulled before being sent by ship via Wyndham to a rice mill in Papua New Guinea. In this analysis the supply chain for rice involved land transport to the nearest rice mill in Townsville. This adds considerably to the costs of production. Even with the high transport costs to the mill in Townsville, the fragrant rice returned a positive gross margin, albeit quite small.

Table 5.8 Freight costs as a percentage of total value of production and total production costs for a range of crops in the Ord region

Location represents the point of wholesale or processing.

CROP	LOCATION FOR MARKET OR PROCESSING	FREIGHT COSTS AS A PERCENTAGE OF TOTAL VALUE OF PRODUCTION	FREIGHT COSTS AS A PERCENTAGE OF TOTAL COSTS OF PRODUCTION
Broadacre			
Rice	Townsville	58.3	46.0
Rice (fragrant)	Townsville	40.8	41.8
Sorghum	Perth	62.5	43.8
Maize	Perth	53.6	47.1
Chickpea	Melbourne	25.9	20.6
Mungbean	Perth	16.2	16.3
Chia	Melbourne	7.5	10.1
High value			
Mango – Kensigton Pride	Adelaide	9.1	9.5
Mango – Plant Breeder's Rights varieties	Adelaide	9.5	12.5
Banana	Adelaide	18.9	18.6
Watermelon	Adelaide	26.7	31.1
Rockmelon	Adelaide	21.0	26.9
Industrial			
Sugarcane	Kununurra	11.1	19.4
Cotton	Dalby	57.2	43.7
Sandalwood	Albany	0.01	2.1
Hemp	Perth	51.3	46.5

With a much expanded area of irrigated agriculture under development in the Ord region, there appears to be opportunities to link with the already established beef industry to provide integrated production systems. This would provide supply chains for coarse grains such as sorghum and maize without incurring the high freight costs associated with current market destinations.

This analysis assumed that chickpeas are processed in southern Australia, thus incurring relatively high freight costs. There are premium markets for the high-quality, large chickpeas (kabuli) that can be grown in the Ord region. The Ord River District Co-operative markets these whole chickpeas after they have been cleaned, graded and bagged locally in Kununurra, returning higher prices than via bulk processing in mills elsewhere in the country.

Freight costs were a smaller percentage of the total value of production for chia because although the overall yields of chia are relatively low (c. 1.1 t/ha), the prices received per tonne are imputed to be fairly high. We have only modest confidence in these gross margins because chia is largely grown under confidential commercial arrangements and sourcing detailed agronomic, cost and price data remains difficult for this crop.

5.8.2 HIGH-VALUE CROPS

The gross margins for intensive horticultural products were generally all highly positive, with the exception of Kensington Pride mangoes (Table 5.7). All horticultural crops have very high input costs and, as indicated in Figure 5.9, price movements can occur rapidly in response to supplies at a national scale. The sensitivity of gross margins to price of horticultural products grown in the Ord region is highlighted in Table 5.9, which demonstrates that while gross margins per hectare can be high, large losses can also occur when product is oversupplied and prices rapidly fall.

Table 5.9 Gross margin sensitivity ($/ha) to price of horticultural crops in the Ord region
Baseline gross margins are the same as reported in Table 5.7, and the price sensitivities are in steps of +/–15%.

PRICE SENSITIVITY	MANGO — KENSINGTON PRIDE	MANGO – PLANT BREEDER'S RIGHTS	BANANA	WATERMELON	ROCKMELON
–45%	–$5,208.80	–$11,837.13	–$10,797.98	–$5,378.60	–$6,476.75
–30%	–$3,498.80	–$5,537.13	–$5,127.98	–$2,210.60	–$2,285.58
–15%	–$1,788.80	$762.87	$542.02	$957.40	$1,905.60
Baseline	–$78.80	$7,062.87	$6,212.02	$4,125.40	$6,096.78
+15%	$1,631.20	$13,362.87	$11,882.02	$7,293.40	$10,287.95
+30%	$3,341.20	$19,662.87	$17,552.02	$10,461.40	$14,479.13
+45%	$5,051.20	$25,962.87	$23,222.02	$13,629.40	$18,670.31

Kensington Pride mangoes are an exception in this regional analysis and produced poor gross margins overall. This relates to low yields (4.2 t/ha) of Kensington Pride mangoes in the Ord region (validated by Ord region commodity statistics; F Bright, DAFWA, pers. comm.). For higher yielding PBR varieties such as Calypso or Honey Gold, positive gross margins can be achieved.

Intensive horticultural production involves high labour costs, especially those associated with picking, grading and packing operations in the shed. Labour costs for these harvest and postharvest activities typically represent 20 to 30% of total production costs and are therefore a significant influence on net returns from horticulture. Labour supply is highly dependent on backpackers who can obtain a second-year holiday visa if they work for 3 months in a regional area of Australia.

The vast majority of horticultural production from northern Australia is directed towards domestic markets, and the Ord region is no exception. Consequently, transport costs per hectare of production are high in absolute cost terms for all crops and represent a significant percentage of costs of production for watermelons and rockmelons, although they are not as high for mangoes (Table 5.8).

The flow of refrigerated produce from southern Australia to northern Australia into supermarkets and other food outlets provides an opportunity for horticultural producers to take advantage of otherwise empty refrigerated containers returning to capital cities in southern and eastern Australia from Kununurra and Darwin. In the supply chain model developed for this project, backloading was set at high levels to realistically represent the costs incurred by farmers taking advantage of low-return freight costs. On an individual case-by-case basis, freight rates for backloading can be negotiated, which are even less than 100% backloading rates. Without this supply of empty refrigerated containers returning to southern capitals from Kununurra and Darwin, it is likely that transport costs would be prohibitive.

Given the sensitivity of prices to supply in the domestic market and the freight costs incurred in transporting the produce to southern Australia, the opportunity exists to develop export markets with the produce moving out of a port such as Wyndham. Currently, this is generally not feasible due to a combination of factors, including:

- the limited number of markets with export protocols developed
- for some crops, the high costs associated with treatments for pests or disease before export (e.g. vapour heat treatment costs of approximately $14/tray for mangoes)
- a lack of refrigerated container facilities at Wyndham port and the absence of refrigerated containers arriving to provide a cost-effective supply of empty containers for shipment
- volumes of supply too low to generate the shipping trade at regular enough frequency for perishable fruit or vegetables, hence the cost structure is currently prohibitive.

In the supply chain scenarios below, some alternative supply chain costs are assessed assuming current constraining factors are removed. With the potential for agricultural expansion in Ord Stage 2 and increased volumes of mineral products in the region, there are plans to introduce more regular shipping from Wyndham to South-East Asia (C Dunphy, Merchant Shipping, pers. comm.) This is just one example of alternative supply chains.

5.8.3 **INDUSTRIAL CROPS**

Gross margins for the industrial crops provide a distinct contrast in financial returns. For sugar it was assumed that a sugar mill exists in Kununurra and that a price per tonne of cane is paid to farmers by the milling operation for harvested product on farm. It is not economically feasible to transport raw sugarcane more than about 50 km, so a scenario of growing sugarcane without a mill was not considered. Gross margins were lower, but comparable, with those achieved in the main sugar-growing regions in Queensland. Part of the lower gross margin relates to higher costs of production, and to an assumed lower CCS (Commercial Cane Sugar, a measure of recoverable sugar in the cane) for sugar grown in the Ord region. CCS of sugarcane grown in the Ord in the early 2000s was lower than that of Queensland due to higher impurities, particularly ash content.

Cotton returned large negative gross margins because of the high costs of transport to a cotton gin at Dalby. Transport costs for raw cotton are exacerbated by the high volume per unit weight, which means a Type 2 vehicle can only load 19.2 t. This was the supply chain used for the most recently grown cotton in the Ord region in 2011, albeit for trial cotton. For cotton to be grown successfully at a commercial scale, there would need to be a gin located in Kununurra. The impact of this on reducing supply chain costs and generating highly positive gross margins is addressed below. Similarly, hemp showed negative gross margins, again because of the high proportion of freight costs as a percentage of total costs (Table 5.8). As with cotton, processing facilities would need to be located within the region for it to be competitive as a crop.

Commercial yields of sandalwood are yet to be proven, so the gross margins provided for sandalwood are estimates based on independent investment analysis and information provided by Tropical Forest Services (TFS Pty Ltd) to the Australian Securities Exchange. The crop is assumed to be harvested after 15 years. For a cash flow analysis of a timber rotation of this type, it is usual to use a discounted cash flow analysis to calculate net present value. However, since sandalwood in the region is nearing commercial harvest, we adopted a normal gross margin approach, assuming 1/15 ha is harvested each year and 1/15 ha is planted each year with other irrigation and management costs occurring across 1 ha.

The price for sandalwood oil is currently $4500/kg and under some scenarios is projected to increase. However, given the uncertainty of future global demand and supply, a conservative approach has been adopted with an assumed price of $3500/kg. India has closed its sandalwood market so Australia will dominate oil entering the world market because of the large areas planted. Projected yields of sandalwood are yet to be proven but based on estimates of 8 t/ha of heartwood after 15 years (assumes 80% survival rates of seedlings and 20 kg/tree of heartwood), a projected gross margin figure of $65,000/ha was generated. This far exceeds the value of any other crop. Because of the high value of the crop, the transport costs of heartwood to a processing plant located at Albany represent only a very small proportion of total value of production or total costs. If this projected gross margin figure is realistic, it is difficult to foresee how food crops can compete with this particular crop. With this level of profitability, it will put upward pressure on land prices in response to increased investment demand.

5.8.4 DIFFERENT SUPPLY CHAIN OPTIONS AND GROSS MARGINS

Table 5.10 shows gross margins for crops assuming different supply chain options to those used in the gross margin analysis in Table 5.7. Assumptions for the new supply chain options are also provided. The impact of greatly reducing transport costs through establishing local processing facilities (e.g. rice, cotton) or creating local markets (e.g. sorghum) had the effect of raising the gross margins that were previously either negative or just positive under present supply chain conditions (Table 5.7) to levels that have the potential to generate net profits.

For the horticulture crop scenarios where refrigerated containers are shipped to Singapore fortnightly, there was a significant reduction in freight costs compared with road transport to Adelaide or Perth and, consequently, a modest increase in gross margins. The actual increase in gross margins was not as great as the reduction in costs because of additional costs that are associated with quarantine and inspection. The shipping freight costs assumed that the containers are cycled from Wyndham to Singapore and that refrigerated slots have been established at Wyndham port to store and power refrigerated containers. The basis for pursuing this scenario was not so much a potential reduction in freight costs per se but the supply chain feasibility of developing alternative markets where transport costs are competitive with the costs of current supply chains. This is particularly relevant for regional scenarios of expanded horticultural production (see Section 5.9).

Table 5.10 Change in gross margin for a range of selected crops in response to altered location of processing facilities or market destination

CROP	LOCATION FOR MARKET OR PROCESSING-BASELINE	GROSS MARGIN ($/ha)	LOCATION FOR MARKET OR PROCESSING SCENARIO	GROSS MARGIN ($/ha)	ASSUMPTIONS FOR SUPPLY CHAIN SCENARIOS
Broadacre					
Rice	Townsville	–778	Kununurra	883	Rice mill established in Kununurra
Rice (fragrant)	Townsville	83	Kununurra	1476	Rice mill established in Kununurra
Sorghum	Perth	–931	Kununurra	433	Sorghum used in beef production
Maize	Perth	–451	Indonesia	375	Wyndham to Surabaya ship
Chickpea	Melbourne	448	East coast	758	Mill established in Kununurra
High value					
Mango – Plant Breeder’s Rights varieties	Perth	7062	Singapore	7438	Regular Wyndham to Singapore ship, additional quarantine costs
Rockmelon	Adelaide	6097	Singapore	6268	Regular Wyndham to Singapore ship, additional quarantine costs
Industrial					
Cotton	Dalby	–1624	Kununurra	1238	Cotton gin in Kununurra

5.9 Integrated scenario analysis: investment and supply chain options

The analyses in the previous sections focused on individual crops, their production characteristics in the Ord region, farm gross margins and supply chain options for the individual crops. In this section, scenarios are examined for agricultural production at a regional scale, with implications for the regional value of production, supply chain logistics and infrastructure. The section concludes with a case study comparing investment options.

The regional-scale analysis assumes 50,000 ha is available for irrigation, with a 95% reliable water supply, based on the Ord River surface water allocation plan (WA Department of Water, 2013), which has allocated 865 GL of water per year, with 95% reliability.

5.9.1 INVESTMENT AND SUPPLY CHAIN OPTIONS

Two scenarios were chosen to explore crop production systems (Table 5.11).

Scenario 1

The first scenario assumes crop production is scaled up with modest investments in infrastructure, such as a mill for rice and using existing cleaning facilities for pulse crops. Rice mills can be purchased effectively 'off the shelf' and so are cost-effective (e.g. $30 million for a rice mill capable of processing 120,000 to 150,000 t/year). Silos or bunkers would also need to be constructed to store the grain at a cost of $80/t bunkers or $180/t for vertical concrete silos. Therefore, for 40,000 t of storage, the costs would be $3.2 million and $7.2 million, respectively, for bunkers and silos. Rice milling consumes significant energy, with up to 19 kWh/t for drying and 29 kWh/t for milling (Ahiduzzaman and Sadrul Islam, 2009). To process 120,000 t of rice per year would require 5.8 GWh of electricity. The Pacific Hydro plant in Kununurra produces around 210 GWh/year.

In addition to modest investment in processing facilities, the other main strategy in this scenario is a shift towards export from northern ports (Wyndham and Darwin) rather than produce heading to southern cities for domestic markets or for export. This will require some investment in port facilities at Wyndham to put in place a storage facility and powered slots for refrigerated containers to shift perishable horticultural product.

Scenario 2

The second scenario assumes significant investment in major milling facilities for the industrial crops of sugarcane and cotton, with these two crops taking up the majority of the 50,000 ha of cropping. The rationale for including two significant milling facilities in this scenario was to allow some 'piggybacking' of milling operations. Cotton gins require significant amounts of electricity, with each bale of cotton requiring on average 52.3 kWh (Ismail et al., 2011). With a scenario of 7500 ha and a capacity requirement for approximately 75,000 bales/year, this in total will require about 4 GWh of electricity per year. There are opportunities to link the operations of a sugar mill and a cotton gin such that co-generation of electricity from the sugar mill can be used to provide electricity to the cotton gin. Sugar milling operations would likely conclude in November each year and cotton ginning could then proceed over the wet season, since harvested (October/November) cotton modules are protected by a tarpaulin wrapping. This may also provide for efficient use of labour between milling operations.

Infrastructure costs for the two mills are assumed to be $425 million for a sugar mill with a capacity of 3.0 to 3.5 million tonnes of sugarcane per year producing 400,000 to 450,00 t/year of raw sugar, and $20 million for a four-stand cotton gin capable of producing 75,000 bales of cotton per year. Wyndham port would need a major upgrade to accommodate larger bulk-carrying sugar ships and a much larger storage facility than the current 16,000-t storage facility. The flow-on infrastructure needs are discussed later in this section.

Remaining broadacre and horticultural production largely use existing transport routes to southern cities. The exception to this is mungbean, which is shipped to Indonesia via Wyndham.

Table 5.11 Scenarios used to explore implications of scaled-up production at the regional scale

CROP	AREA OF LAND (ha)	CROP YIELD/ha (TONNES)	LOCATION FOR MARKET OR PROCESSING	ASSUMPTIONS FOR REGIONAL SCENARIO
Scenario 1 – light infrastructure				
Rice	15,000	8.3	Kununurra	Rice mill established in Kununurra
Sandalwood	10,000	8.0	Kununurra	Processing plant in Darwin servicing Ord and Katherine sandalwood
Maize/mungbean rotation	10,000	11.8/2.6	Indonesia	Export to Indonesia via bulk shipping from Wyndham
Rockmelon	4,000	25	Singapore	Refrigerated containers out of Wyndham to Singapore
Mango – mixed	3,500	15	Singapore	Refrigerated containers out of Wyndham to Singapore (mainly Plant Breeder's Right varieties)
Chia	7,500	1.1	Various	Export via Darwin
Scenario 2 – significant processing infrastructure investment				
Sugar	25,000	114[a]	Kununurra	Sugar mill constructed in Kununurra
Mungbean (sugar rotation)	5,000	2.6	Indonesia	Mungbean rotation after last ratoon
Cotton	7,500	9.2	Kununurra	Cotton gin constructed in Kununurra
Sandalwood	5,000	8.0	Albany	Processing of heartwood in Albany
Rockmelon	5,000	25	Adelaide	Supplying southern domestic markets
Chia	2,500	1.1	Melbourne	Existing supply chain

a Yield is average per year over 30,000 ha, including the 5000 ha that is fallow cropped with mungbean following the last ratoon.

Results

The regional-scale implications of the two scenarios operating on 50,000 ha in the Ord region are shown in Table 5.12. The two scenarios indicate that between $0.5 billion and $1.0 billion/year in total value of production can be achieved using 50,000 ha of irrigated land. These values are heavily skewed by the large potential contribution provided by sandalwood, given the high value of sandalwood oil at current prices. However, omitting sandalwood from these figures still produces a regional value of production of between $250 million and $500 million. Given the high value per unit area, horticultural crops contribute significantly to the total value of production in the regional-scale scenarios. They also have large variable costs and much of this cost is expended within the region, making a contribution to the regional economy (Section 5.10).

A modest investment in processing infrastructure such as a rice mill ($20 million) and associated storage facilities, combined with efficient export freight networks out of Wyndham and Darwin ports, have the potential to lead to large-scale production outcomes that can generate positive gross margins. Successfully expanding horticultural production to 7500 ha will require the development of new export markets in Asia and beyond, given the sensitivity of domestic markets to oversupply. Establishing a reliable and regular refrigerated container service out of Wyndham or Darwin has the potential to reduce freight costs compared with existing southern-based markets, assuming increased volumes of supply can significantly reduce the current high costs of shipping agricultural commodities to Asia (Table 5.13). The major challenge would appear to be developing a wider range of export markets and overcoming the various regulatory and quarantine barriers. These barriers include both time to negotiate new export protocols (10 years +) and the potentially high costs of meeting quarantine requirements (e.g. vapour heat treatment of mangoes). Given the scale of the challenge in developing new markets, this requires considerable government assistance ranging from bilateral trade agreements to removing technical barriers associated with labelling and packaging requirements to negotiating biosecurity protocols.

The second scenario assumes much greater investment in processing infrastructure, primarily through the establishment of a sugar mill. The cost of a mill is large (approximately 10 times that required for a large rice mill or a large cotton gin at $425 million) but it can provide a diversified set of outcomes through co-generation of electricity, burning of bagasse or addition of an ethanol plant. Producing 400,000 t/year of raw sugar brings with it some additional infrastructure needs in road infrastructure, local transport and shipping. These infrastructure investment requirements are discussed below. The addition of a significant area of cotton provides a second broadacre industrial crop, which can be operated synergistically with the sugar mill and its operations.

Table 5.12 Influence of the two regional scenarios on total flows of product and value of production per year

CROP	TOTAL PRODUCTION (TONNES)	TOTAL VALUE OF PRODUCTION ($)	TOTAL VARIABLE COSTS ($)
Scenario 1 – light Infrastructure			
Rice	124,500	43,575,000	30,465,000
Sandalwood	5,333	580,992,000	74,970,000
Maize	118,000	33,040,000	29,290,000
Mungbean	26000	24,050,000	21,930,000
Rockmelon	100,000	111,800,000	77,320,000
Mango – mixed	52,500	161,700,000	116,693,500
Chia	8,250	24,750,000	17,400,000
Total	434,583	979,907,000	368,068,500
Scenario 2 – significant processing infrastructure investment			
Sugarcane	2,850,000	102,600,000	58,650,000
Mungbean (sugar rotation)	13,000	12,025,000	11,375,000
Cotton	15,732	38,778,000	29,490,000
Sandalwood	2,667	290,496,000	37,485,000
Rockmelon	100,000	111,800,000	81,496,000
Chia	2,750	8,250,000	6,152,500
Total	2,984,149	563,949,000	22,464,8500

Table 5.13 Effect of regular, cost-effective shipping routes to Asia on freight costs of the crops assessed in Scenario 1

CROP	BASELINE DESTINATION	BASELINE FREIGHT COSTS ($/T)	SCENARIO DESTINATION	SCENARIO FREIGHT COSTS ($/T)
Rice	Townsville	204	Kununurra	5
Sandalwood	Albany	208	Darwin	97
Maize	Perth	150	Surabaya	80
Mungbean	Perth	150	Surabaya	80
Rockmelon	Adelaide	271	Singapore	134
Mango	Adelaide	285	Singapore	134
Chia	Melbourne	227	Darwin	97

Transport implications

Both scenarios have significant implications for the infrastructure required to transport goods either to southern markets or to the ports of Wyndham or Darwin. A major infrastructure requirement is vehicles (prime movers and trailers). From the supply chain analysis information presented in Appendixes 5.2 and 5.3 for each of the two scenarios, respectively, minimum fleet requirements have been calculated for refrigerated and non-refrigerated vehicles by month of year, accommodating harvest and transport requirements of each crop. Vehicle requirements for all crops within a region were aggregated into those requiring refrigerated and non-refrigerated transport. Vehicle requirements account for minor rest breaks en route to the destination, and time required for loading and unloading. They do not account for major downtime or maintenance. The gross vehicle requirements by time of year are shown in Figures 5.11 and 5.12. This includes vehicle trips that would be part of a backload (e.g. transport of mango to Adelaide). Net requirements accommodate vehicle reductions via backloading opportunities on some routes. Although backloading is possible on some routes, the proportion of trips that could be serviced as a backload is not yet known.

Vehicle requirements (both standard and refrigerated) are considerably less in Scenario 1 than 2, due to a lower average yield per hectare across the crops and shorter average freight distance to ports in Wyndham and Darwin. The demand peaks for only a few months of the year due to significant overlapping of harvest seasons between the crops. Opportunities for backloading are only available on some routes, such as refrigerated or dry trucks that are returning to Perth or Adelaide. For scenarios involving local transport (e.g. rockmelons between Kununurra and Wyndham port in Scenario 1), there will be no backloading and local, additional transport infrastructure will be required. This limits the potential of reducing gross prime mover requirements via backloading. However, given the short distance between Kununurra and Wyndham, a number of trips can be made each day, which reduces the overall fleet size required.

In Scenario 2, a large fleet of 54 prime movers and associated refrigerated trailers is required due to the large volumes of rockmelon that are transported to Adelaide (18 vehicles/ day) during the harvest season each year. A large amount of general refrigerated freight is transported from southern capitals to retail distribution centres in Kununurra and Darwin. Since Darwin is not a major port of entry for refrigerated produce, most of these refrigerated vehicles would otherwise return south empty. This creates a backloading opportunity for the transport of melons (and other horticultural produce) from the Ord region to Adelaide. This opportunity is used in current melon operations in the Ord region and, indeed, it is likely that melon growing would not be profitable without these backloading transport arrangements (see Section 5.8)

Although there would appear to be sufficient backloading capacity to service current volumes of horticultural production in the Ord region, albeit with some significant logistical challenges, the requirement for 18 vehicles each day would exceed the current number of refrigerated vehicles travelling from southern centres to Kununurra and Darwin. It is estimated that only about 40% of the melon production in Scenario 2 could be serviced by backloading arrangements (G Elkins, Toll Holdings, pers. comm.). The rest of the required cold transport capacity would need to be met by transport operators investing in additional refrigerated trailers. Since refrigerated trailers cost approximately $220,000 each compared with $70,000 for dry-weight trailers, there would need to be an assurance of long-term stable demand to support such transport from the Ord region. Assuming this additional freight capacity was to become available, it would be provided at a higher cost than current backloading rates.

In addition, most of this backload opportunity occurs between Darwin and Adelaide rather than the Katherine to Kununurra part of the trip. This means trucks will travel from Katherine to Kununurra empty and back to Katherine with melons for about a 40% chance of being transported to Adelaide as part of a backhaul trip. With horticultural production increasing in the Katherine–Mataranka region, this would reduce the likelihood of a backload between Kununurra and Adelaide.

The supply chain analysis for horticulture in Scenario 2 highlights the need to assess the flow-on supply chain consequences of increasing production to supply distant domestic markets. Apart from the transport logistic and cost challenges associated with scaling-up production, there is also the issue of increasing supply to a domestic market that is often at demand capacity. This suggests that for expanded horticultural production most attention should focus on Scenario 1 – that is, on developing export markets and direct shipping routes from the north that reduce costs of production and avoid oversupply issues in domestic markets.

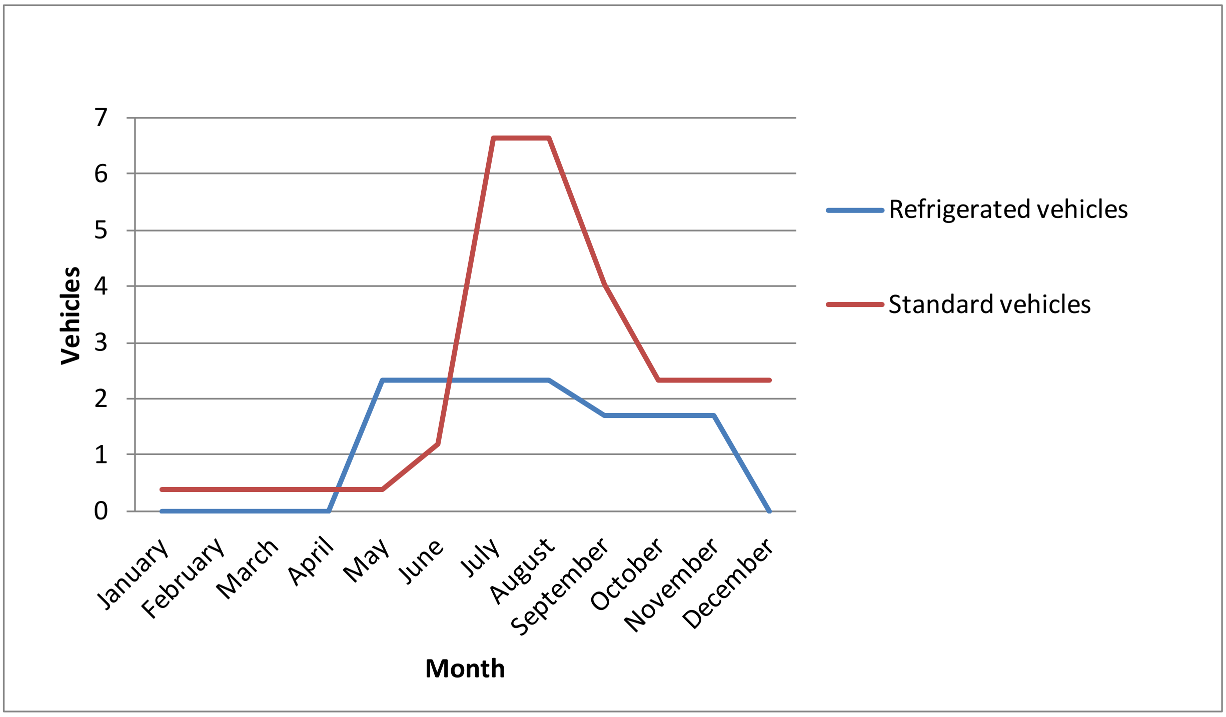

Figure 5.11 Vehicle requirements for 50,000 ha of cropping in Scenario 1
Numbers are based on the number of prime movers, and a Type 2 road train is classed as one vehicle.

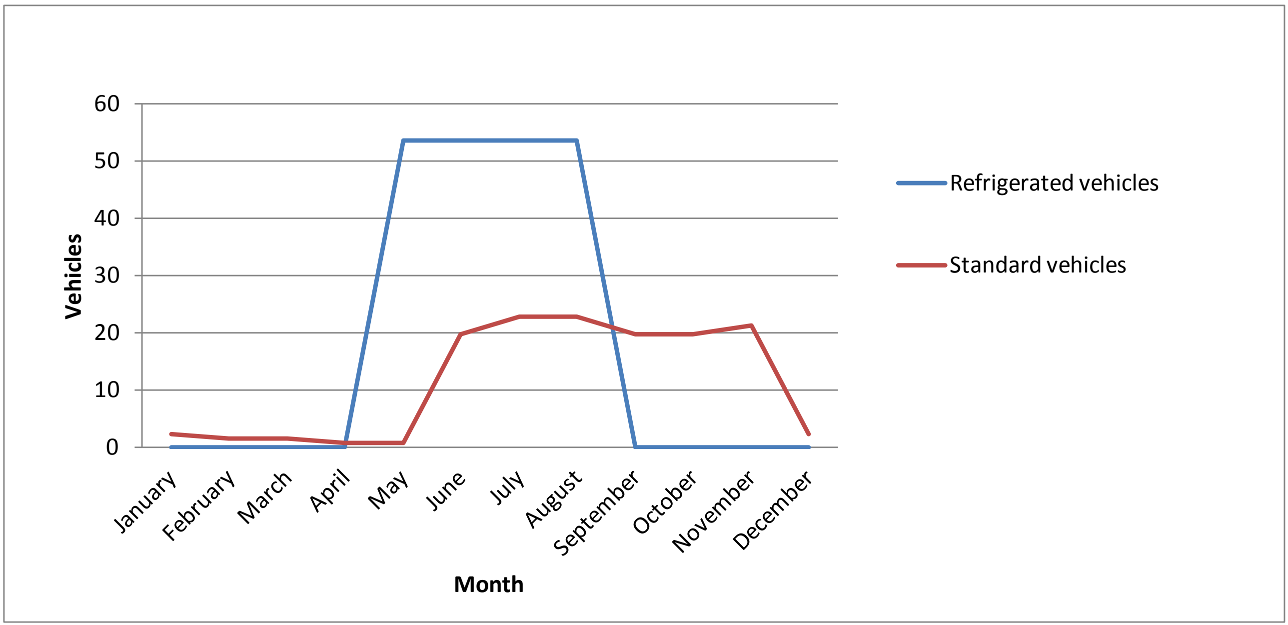

Figure 5.12 Vehicle requirements for 50,000 ha of cropping in Scenario 2
Numbers are based on the number of prime movers, and a Type 2 road train is classed as one vehicle.

Infrastructure

In terms of infrastructure investment, Scenario 2 requires major investment in a sugar mill (c. $425 million) and a cotton gin ($20 million for a four-stand gin). The current scenario assumes that the approximately 350,000 to 400,000 t of raw sugar that is produced is exported via ship from Wyndham. This will require significant additional investment in a heavy vehicle bypass around Kununurra township, which will also require a new bridge over the Ord River as the current diversion dam wall does not have the capacity to carry the heavy vehicle traffic associated with transporting sugar to Wyndham port.

Based on discussions with Cambridge Gulf Limited (operators of Wyndham port) the costs associated with a port upgrade to allow larger ships capable of loading bulk sugar to berth in deeper water and associated loading facilities are around $80 million. A heavy vehicle bypass for Kununurra and a new bridge over the Ord River have been costed at $125 million.[4] Some road upgrades to Wyndham port are also likely to be required. The Western Australia Department of Transport has developed plans for the bypass and bridge construction, but no funding has been provided for its construction.

A new bulk storage facility will be required at Wyndham port with a capacity of 132,000 t to manage annual sugar production of 350,000 to 400,000 t. Assuming a construction cost of $80/t, this will require an investment of just over $10 million.

Overall, additional supporting investments of at least $215 million will be required to successfully export bulk sugar from Wyndham. This infrastructure would provide significant benefits to other agricultural interests, other industries such as mining, sectors such as defence and the wider community. If these costs are shared between government and a range of private interests, then there may be an acceptable return on investment for all interested parties.

In terms of local transport costs and logistics, assuming an average cane yield of 113 t/ha and a CCS content of 13.0, a mill in the Ord region would produce about 367,000 t/year of raw sugar. This would require 30 Type 2 vehicle trips per day of raw sugar or 5220 trips over a 180-day harvest season. The total cost of sugar transport to Wyndham port, 106 km away, would be $4.3 million ($11.71/t), assuming no backloading.

Alternative options to this $215 million investment include the following:

[4] https://www.mainroads.wa.gov.au/BUILDINGROADS/PROJECTS/REGIONAL/Pages/kununurra.aspx#.U1bwTVXa6o8

- Transport the raw sugar via road to Darwin port, which would require an investment of $10 million for a storage facility and associated bulk-handling facilities. However, this would involve transporting the raw sugar 832 km. The total transport cost would be $36.6 million ($83.59/t) per year, assuming no backloading. Backloading would be very limited due to the lack of a need to bring commodities back to Kununurra using specialised sugar transport containers. The extra transport cost of the Darwin option is $30.7 million/year and at nearly $84/t is unlikely to be economically feasible for mill operators, unless they can pass that charge on to growers. This would be approximately $10/t of sugarcane and would reduce farm gross margins to almost zero.
- Construction of a rail line from the sugar mill to Wyndham, a distance of 80 km. Assuming a cost of $2 million per kilometre of rail line (which includes a high river crossing over the Ord River), a capital investment of $160 million would be required, not including the cost of locomotives and rolling stock. Although there may be opportunities for dual use (e.g. ore from nearby mining operations), it is likely this cost would need to be entirely borne by private investment.
- Construction of a rail line between Kununurra and Katherine, which would then link into the Alice Springs to Darwin railway. Assuming rail line construction costs of $1.5 million per kilometre, a capital investment of $758 million would be required, plus the freight costs associated with shifting the raw sugar 800 km to Darwin.

5.9.2 RISK ANALYSIS

The analysis for the two scenarios has used averages of yields and prices, and is based on historical data and simulated crop yields. Future investment needs to be based on a good understanding of risk. Price risk is one variable that needs to be considered when making investments. ABARES produces market outlooks for a range of commodities, which are summarised in Table 5.14 for the crops that are included in the two regional scenarios. These market outlooks are based on medium-term drivers and do not capture shorter-term year-to-year variability. This is highlighted in Figure 5.13, which shows the market outlook for cotton over the next 10 years with the previous 10-years price data superimposed to illustrate the pattern of interannual variability that might be expected on top of the longer-term price trend.

Table 5.14 Ten-year forward price projections for the crops used in the two regional scenarios
Data provided by ABARES; numbers represent real domestic prices (in 2012–13 dollars).

CROP	UNIT	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Maize	$/t	354	310	324	326	313	301	360	359	357	356
Mungbean	$/t	1001	1063	1064	1065	1091	1090	1088	1087	1085	1084
Rice	$/t	306	324	322	317	317	311	311	311	311	311
Mango	$/kg	3.1	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Rockmelon	$/tray	22.3	23.6	23.6	23.7	24.2	24.2	24.1	24.1	24.1	24.0
Watermelon	$/kg	1.17	1.24	1.24	1.24	1.27	1.27	1.27	1.27	1.27	1.26
Cotton	$/bale	504	498	509	510	518	531	530	528	527	526
Sugarcane	$/t	38.0	34.0	40.3	41.2	41.3	42.3	42.3	42.2	42.2	42.1
Sandalwood		na	na	na	na	na	na	na	na	na	na

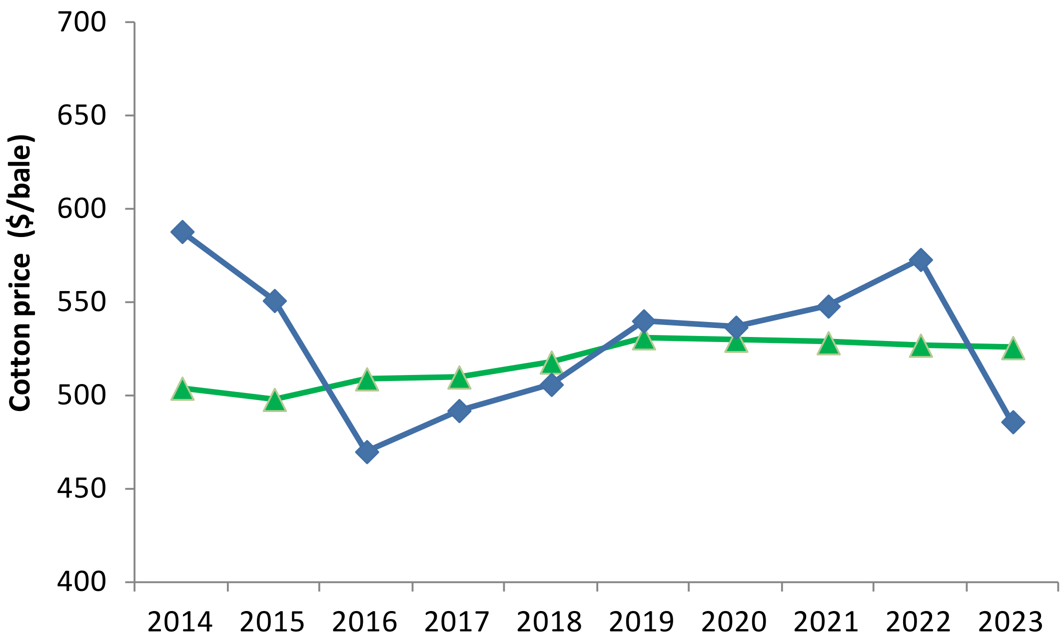

Figure 5.13 Ten-year forward projection for cotton price (green line) with previous 10 years (2004 to 2013) of prices (blue line) superimposed to highlight historical year-to-year price variability

As indicated in Section 5.7, price variation combines with yield variation to produce gross margins that can vary significantly between years. In terms of future risk, it is useful to understand how these two primary drivers of price and yield might influence risk. Figure 5.14 shows a distribution of gross margins for the cotton scenario in the Ord region based on historical yield variation over 100 years (simulated by APSIM), together with historical price variation based on 10 years of ABARES data (Figure 5.13). In this analysis we have used the scenarios of local processing facilities and/or new supply chain freight costs. This shows that for yields simulated using 100 years of climate records, water available every year and price variations for the past 10 years there is a wide variety of outcomes ranging from losses to very high gross margin returns (>$4000/ha). In this example for cotton, relatively few years have a negative gross margin, and this is in part due to the reliability of yields over the 100-year simulation, which does not include extreme events such as a crop failure brought about by disease outbreak.

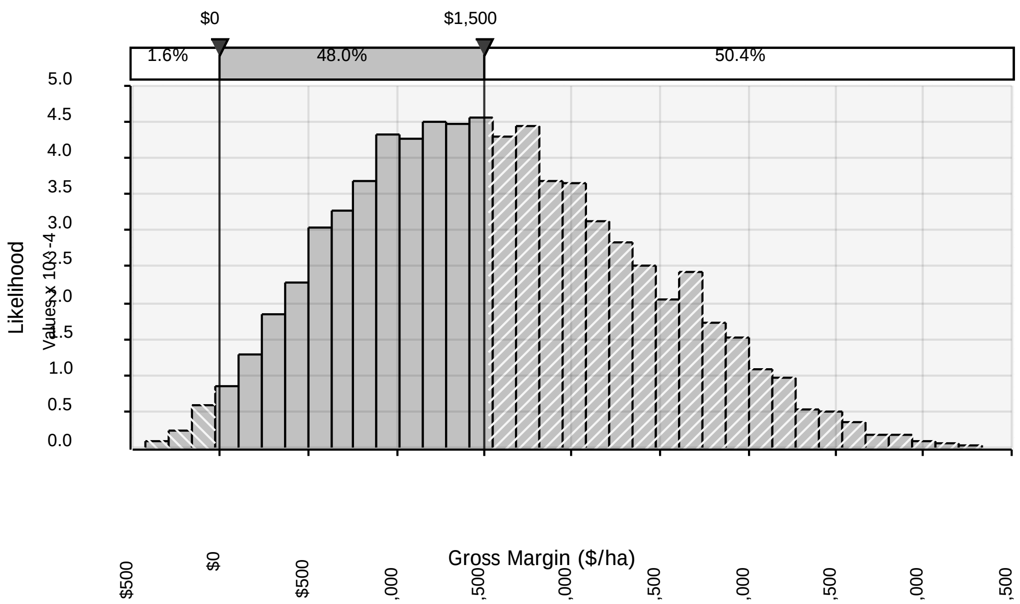

Figure 5.1 Distribution of financial outcomes as measured by gross margin for a combination of yield (100 years) and price (10 years) variation

The historical analysis of agricultural developments in northern Australia (Appendix 3.1) identified the ability to get through the first few years of establishment and scaling-up as a major determinant of success or failure. In the start-up phase it is essential to provide time to learn and adapt agronomic management to suit local conditions without the pressure of unrealistic yields that often underpin cash flow and investment analysis.

The following analysis builds on the variability presented in the gross margin analysis to consider the business vulnerability to a sequence of better and poorer years, and the level of debt. Similar to the gross margin analysis, this risk analysis does not specifically cover farm profit because it does not include fixed or overhead expenses such as depreciation for equipment and buildings. However, the risk being assessed will directly impact on prices and yields, which are adequately captured by changes to the gross margin projections.

Figure 5.15 shows the financial outcome after 10 years, where the types of years experienced occur in different sequences, drawing on the distribution that is presented in Figure 5.14. One sequence assumes a run of poorer years in the first half of the 10-year sequence while a second sequence assumes a higher proportion of good years in the first half of the 10 years. A third sequence is also included where two crop failures (defined as receiving 20% of median yield) occur randomly within the 10-year period of analysis. This is to simulate unexpected extreme events such as pest or disease outbreak or an extreme weather event. The analysis is based on a simple approach whereby there are two levels of starting capital investment/debt ($8000/ha or $12,000/ha) and the gross margin returns are used to reduce (or increase) this capital debt. Interest rates are assumed to be 7%. The debt levels encompass the range of investment needed to develop land from scratch (e.g. Ord Stage 2) through to purchasing already developed and productive irrigated blocks with water allocations. This does not represent a full financial cash flow analysis because fixed overhead costs are not considered, but the objective is to demonstrate how the sequence of years influences the pattern of cash flows and the ability to achieve a return on investment.

The results show that for the higher-debt scenario a range of poorer years at the start of the investment period leads to a period of 5 years or more before capital debt begins to decline. This contrasts with a ‘good’ start to the investment where some of the capital debt can be reduced quickly. Even though this scenario actually experiences the same 10 individual years as the poorer start scenario, albeit distributed differently, it always maintains an advantage. Experiencing two significant crop failures in the 10-year period results in debt increasing with little prospect for recovery. This simple analysis highlights that in addition to good planning and management a certain element of good fortune is needed in the run of years experienced in the start-up phase of any capital-intensive agricultural development.

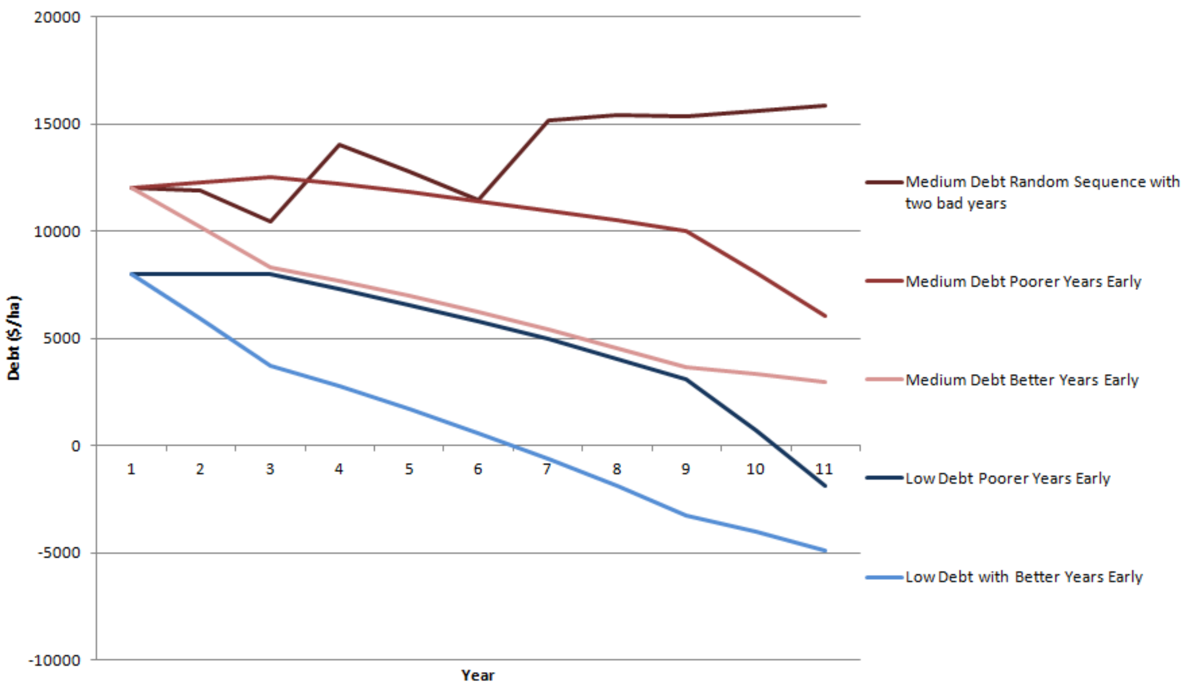

Figure 5.2 Influence of sequence of year types and starting debt level on the ability of cash flows to reduce debt over a 10-year investment period

5.10 Regional economic analysis

5.10.1 **ORD RIVER ECONOMY**

The Ord River region as represented in the ABARES AusRegion model encompasses the Ord River irrigation system and the towns of Kununurra and Wyndham. Mining and agriculture are the two largest industries in the region and are projected to remain important to 2029–30. Under the reference case, economic growth in the Ord River is projected to grow at 4.4% annually, which compares favourably with the Western Australian Gross State Product (GSP) growth rate of 4.1% and the projected GDP growth rate of 2.7%.

5.10.2 **SCENARIO DESCRIPTION**

Each scenario is modelled in two phases—construction and production. In the construction phase, the assumed public and private investment is modelled. Public investment in roads and ports totals $415 million. In Scenario 1, private investment occurs in the rice, horticulture and sandalwood industries (Table 5.15).

The implications of investment on land supply, land productivity and transport costs are modelled. The proposed investments reduce transport costs by up to 50% because products could be exported directly from Wyndham or Darwin rather than being transported to southern ports.

Table 5.15 AusRegion stylised scenario description for the Ord River

Development parameter	Unit	Commodity	Scenario 1
Government investment	$m		415
Private Investment	$m	Beef Cattle	
	$m	Cotton	
	$m	Grains	350
	$m	Horticulture	90
	$m	Sandalwood	75
	$m	Sugar	
	$m	Total private investment	515
Total Investment	$m		930
Land supply	’000ha		50
Transport costs	%	Cotton	
	%	Grains	-50
	%	Horticulture	-40
	%	Sandalwood	-10
	%	Sugar	
Yield	%	Horticulture	30

a Assumed change in transport costs arising from investment. **b** Assumed change in sectoral land productivity arising from private investment**.**

5.10.3 **REGIONAL ECONOMIC OUTCOMES**

The proposed investments will affect economic activity, employment and exports in the Ord River region and have consequences for the Western Australian and Australian economies.

Results are presented for 2029–30, when construction is complete and production is maximised (Table 5.16). Economic welfare in the Ord River is projected to be 69.7% higher than the reference case under Scenario 1. The Ord River economy is the smallest of the case study regions. The very large growth in economic activity under Scenario 1 reflects the effect the proposed $1 billion in investment could have on a small region. Employment growth in the region is faster than Gross Regional Product (GRP) growth, reflecting the labour intensity of agriculture and forestry relative to other sectors. The potential difficulty in sourcing labour and capital for northern Australian investment is discussed elsewhere in this report. These results should be viewed in that context.

The projected GRP growth is comprised of expansion in the agriculture and forestry sectors balanced by some contraction in mining resulting from higher wages and capital costs.

The projected increase in regional GRP leads to a smaller rise in the GSP of Western Australia. The effect on the Australian economy is negligible.

Table 5.16 Economic impacts for the Ord River at 2029–30, % deviation from the reference case

	Unit	Scenario 1
GRP	%	69.7
Employment	%	94.0
Real wages	%	2.0
Exports	%	185.7
Sectoral output		
Agriculture	%	1 486.9
Forestry	%	345.3
Mining	%	-13.4
Other	%	1.9
Western Australian GSP	%	0.3
GDP	%	0.0

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6 MATARANKA REGIONAL ANALYSIS

6.1 Summary and key messages

- The Mataranka region has the capacity to provide underground water to support 2500 ha of irrigated agricultural development on broadly suitable soils.
- There is not a significant requirement for additional public investment in primary infrastructure because the road network is good, mains electricity is readily accessible and there is no requirement to construct a major surface water storage.
- A tropical, semi-arid climate allows many summer crops to be grown year round, and the environment is well suited to produce a range of horticultural commodities that can be high yielding – for example, average yields of mango (Plant Breeder's Rights varieties) more than 20 t/ha and average yields of watermelon more than 50 t/ha.
- Using existing domestic supply chains and infrastructure, gross margins across nine crops varied from negative to highly positive. Crop gross margins were particularly affected by high input costs (e.g. labour, fertiliser) and high freight costs, given that nearly all produce is presently transported to southern markets.
- Horticultural crops can generate high gross margins ($5000 to $10,000/ha), but these margins are highly price sensitive and, when coupled with high input costs, can fluctuate from highly positive to negative over periods as short as weeks. Freight costs constitute 10 to 30% of the costs of production, and labour costs associated with harvesting and packing make up a further 20 to 30% of production costs.
- Gross margins for broadacre annual crops were generally positive but less than $500/ha. However, a commodity such as peanuts generated negative gross margins because transport costs are high when the nuts are transported in shells to Kingaroy along a transport route with limited backloading potential. In general, transport costs for high-volume, low-value crops represented a significant percentage of the gross value of the product.
- The three industrial crops assessed – cotton, sandalwood and poppies – resulted in contrasting gross margins. The nearest cotton gin is located in Emerald (central Queensland) and the costs of transporting raw cotton resulted in negative gross margins. In contrast, poppies and sandalwood, both of which are commercially unproven in this environment, generated highly positive gross margins because of their high value and relatively low per hectare yields, which meant that transport costs were a modest proportion of total costs.
- Using supply chain scenarios of (a) local or regional processing mills, such as a peanut shelling plant in Katherine and a cotton gin in Kununurra; (b) locally developed supply chains (e.g. maize grain integrated into beef production systems); or (c) regular and cost-effective shipping routes from Darwin to South-East Asia, gross margins for all crops significantly increased and for a number of crops changed from being negative to positive. These analyses highlighted the potential for much improved financial outcomes by shifting the supply chains to local processing and/or Asian markets.
- Two regional scenarios of 2500 ha of irrigated production were explored. The first scenario is based on horticultural production from the entire area, with a focus on export markets via Darwin. The second scenario is based on a mix of broadacre cropping, with the establishment of a peanut drying and shelling plant in Katherine and horticultural production aimed at domestic markets. Scenario 1 generated a regional gross value of production of approximately $100 million/year, while Scenario 2, which has a smaller area of high-value horticultural production resulted in a gross value of production of approximately $50 million/year. Scenario 1 had a strong focus on export of horticulture to Asia and highlights the benefits that can be gained if cost-effective supply chains can be established. This is not just important in terms of supply chain costs but also in the context of new markets, particularly for horticulture because of easily saturated demand in domestic markets.

- Scenario 1 required a modest investment in additional powered refrigerated sites at Darwin port, and Scenario 2 required a relatively modest investment in peanut processing facilities in Katherine ($3 to $4 million).
- Both scenarios had significant implications for the infrastructure required to transport goods either to southern and eastern markets/processors or to the port in Darwin. While Scenario 1 had 50% more total tonnage of product to freight than Scenario 2, it required fewer vehicles because all of the transport was going to Darwin rather than to southern markets.
- Darwin port is well serviced by the road network into Darwin, and the port presently has the berthing capacity and footprint to easily accommodate expansion in agricultural production for export. Refrigerated slot capacity at the port would need to be increased to provide adequate storage while awaiting loading on to ships.
- Existing demand for refrigerated freight of horticultural products to southern markets is close to the capacity of the available supply of vehicles through backloading arrangements during peak harvest periods. Additional production under Scenario 2 would likely result in a need for additional refrigerated transport beyond the present backloading availability, with implications for costs.
- While some investment in hard infrastructure associated with processing and road transport is necessary, the most pressing need in this region is soft infrastructure investment for:
  - developing export markets and addressing the associated market access
  - developing reliable and regular shipping routes from Darwin to Asia and the Middle East that can cost-effectively freight refrigerated containers
  - increasing yields and reducing year-to-year variability in production and quality of fruit.
- The proposed investments are projected to generate moderate increases in GRP of around 6% with larger increases in regional exports.

6.2 Description of region: existing agriculture, scale of irrigation and development

Agriculture in the Katherine–Mataranka region historically dates from the 1870s. Pastoral leases were initially taken up around Katherine, with sheep and cattle being first stocked on Springvale Station in 1879. Limited cropping was undertaken at around that time in the Daly River region, with sugarcane being the first crop trialled. The pastoral industry rapidly expanded in the region over the ensuing six decades and agricultural crops continued to be tested but without significant commercial success.

During World War II, the Katherine region was viewed as having good agricultural potential, based on the reliable wet seasons and apparently well-structured soils. In 1946, a small area of land was taken up by the CSIRO on the levee soils of the Katherine River, which had its origins as an army experimental farm (Basinski and Wood, 1985). As these levee soils are fairly restricted in extent, a much larger experimental farm was established in 1948 on Tippera red earths, because it was felt that dryland agriculture could be established on these soils. This resulted in various crops being tested over the next few decades, including guar, cowpea, mungbean, millet, grain sorghum and kenaf.

The Douglas Daly Research Station was established in the 1960s about 220 km to the north-west of Katherine to support research on a range of crops and improved pasture species. The short growing season made it difficult to reliably grow summer annual crops in Katherine or at Douglas Daly, and in 1996 effort was directed to irrigated crops, especially peanuts (Shotton, 2011). At the Katherine Research Station research was initiated on horticultural crops, particularly mango and citrus, in response to increasing commercial interest. A commercial dairy farm near Katherine also invested in irrigation but for high-quality forage crops for dairy cattle.

Large-scale investment in irrigated horticulture commenced in the Katherine region in 1982 with the establishment of 300 ha of mangoes on Manbulloo Station. This development triggered increased investment by government and the private sector in the region, with the horticultural sector gradually expanding in subsequent decades.

More recent agricultural investments in the region included the Peanut Company of Australia trialling irrigated peanuts in 2002, with a planned major expansion in 2007–08 to have 4000 ha of broadacre peanut production, 3200 ha of which was to be irrigated. This development did not proceed to full scale, and in 2012 the land was acquired for sandalwood production.

Irrigated agriculture in Mataranka (Figure 6-1) was initially focused on watermelon and pumpkin and now includes areas of mango. Irrigation water in this area is drawn from the Tindall aquifer. The present water allocation plans provide for 36 GL of water being available for irrigation per year, although high reliability can only be achieved with approximately 20 GL/year.

The Northern Territory Government and the horticultural industry recognise the potential for this region to expand its irrigated horticultural and agricultural production. The region is well positioned in terms of transport links to Adelaide and, for crops such as mango, it provides a slightly later production window compared with mango production around Darwin.

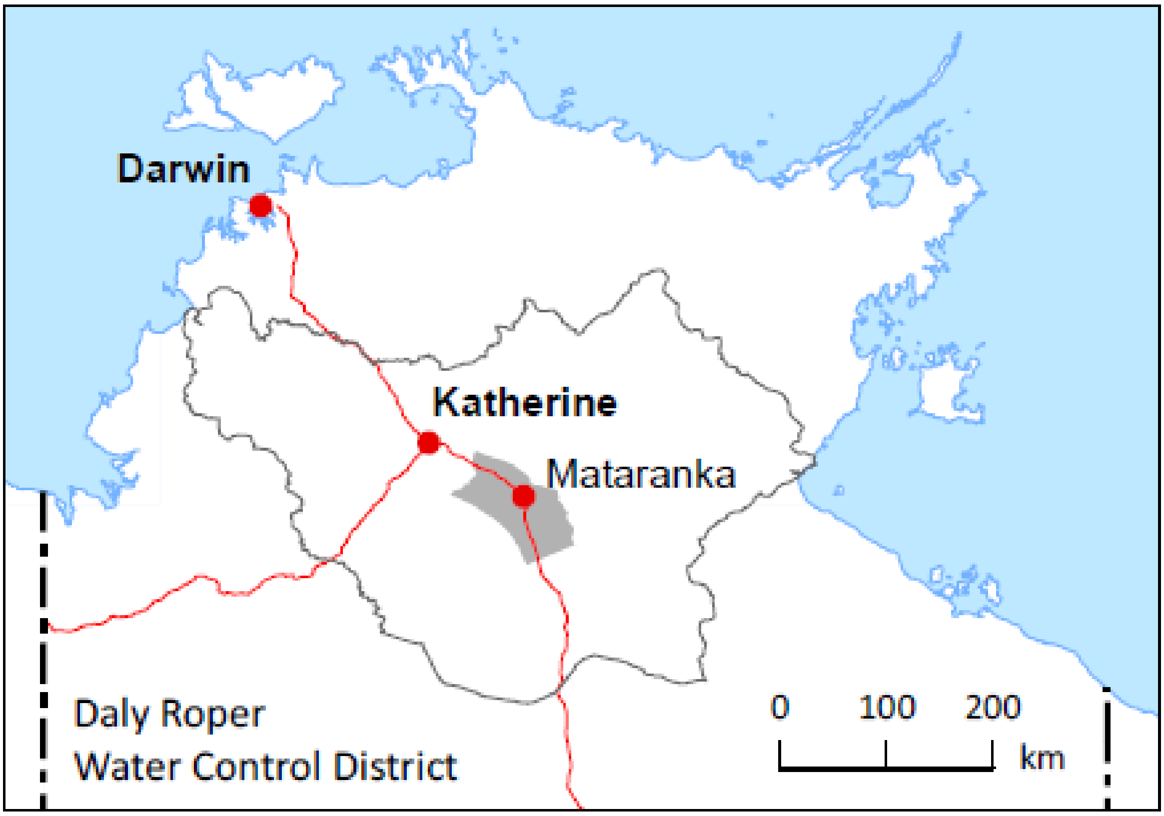

Figure 6.1 Map of the Mataranka Water Allocation Planning Area
Source: DNRETAS (2011b)

6.3 Climate: existing and future trends

6.3.1 CURRENT CLIMATE

The Katherine–Mataranka region experiences a semi-arid climate that is strongly influenced by the tropical monsoon, with an average rainfall (1963 to 2013) of 1090 mm, 90% of which occurs from December to April (Figure 6.2). The short growing season, while quite reliable, is effectively too risky to support regular dryland cropping. The lack of rainfall in the dry season means that crops grown in this period will rely entirely on irrigation, whether from surface storages, permanent streams or groundwater. Potential evaporation rates are high (pan evaporation >2350 mm/year), with a strong seasonal cycle, which has implications for crop water demand in irrigation schemes, particularly in the late dry season.

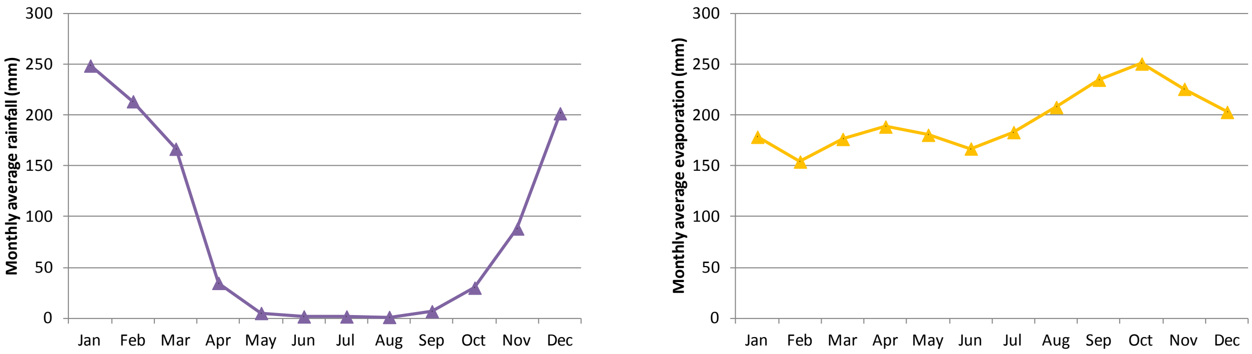

Figure 6.2 Monthly average rainfall (left) and pan evaporation (right) at Katherine

In contrast to many other agricultural regions in northern Australia, the Katherine–Mataranka region experiences low year-to-year variability in annual rainfall. A good measure of annual rainfall variability is the coefficient of variation (CV), calculated as the standard deviation of mean annual rainfall divided by the mean annual rainfall. The higher the CV, the more variable is the annual rainfall. The CV for Katherine is 0.23, while for other areas of Australia with a similar mean annual rainfall total the CV is generally in the range of 0.25 to 0.30. It is, however, considerably lower than in northern Queensland, where the CV of annual rainfall is approximately 0.4.

The lower annual rainfall variability is a result of the tropical monsoon, which is relatively reliable in these low latitudes. The region also experiences sequences of wet and dry years, which are highlighted in Figure 6.3. There can be sequences of years where the annual rainfall is below average, but this is usually not as dramatic as for areas in eastern Australia that are more strongly influenced by the El Niño Southern Oscillation (ENSO). However, the ENSO still has an influence on rainfall patterns, with rainfall below average in El Niño years and above average in La Niña years.

The rainfall sequence (Figure 6-3) also reveals a trend in recent decades of higher rainfall as a result of a greater frequency of above-average years and a decreased frequency of dry years. It is unclear whether this trend of increased rainfall will persist (see Section 6.3.2).

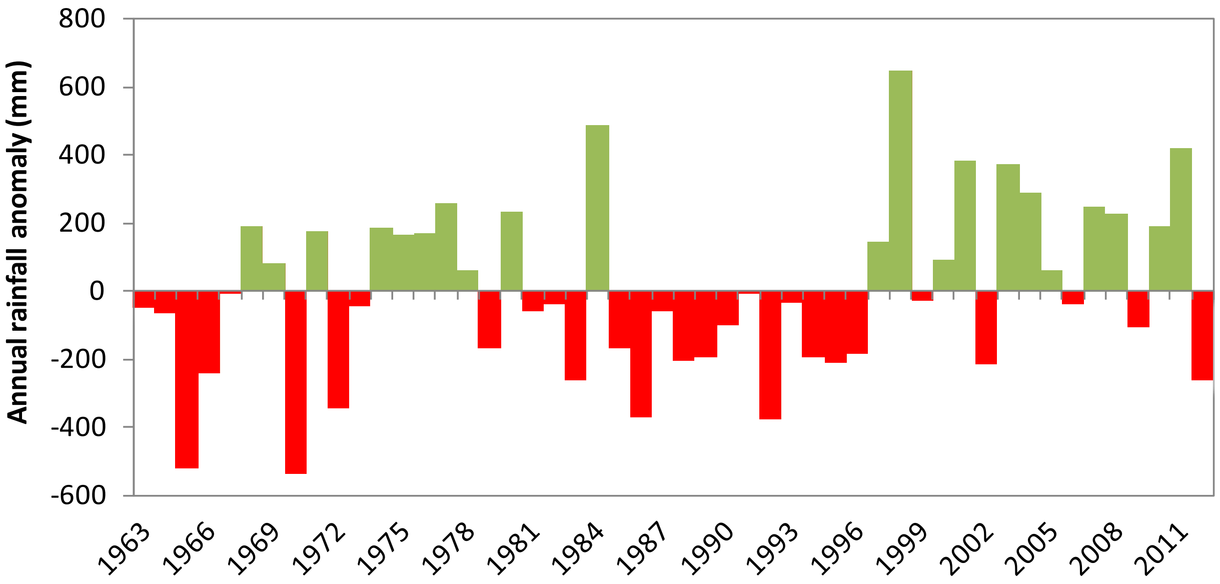

Figure 6.3 Runs of wet and dry years at Katherine, measured by the difference in mean annual rainfall from the long-term average (1963 to 2012)

Wet years are denoted by the green bars and dry years by the red bars.

6.3.2 FUTURE CLIMATE

Climate projections for 2030 were assessed using four global climate models: ECHAM5, GFDL-21, HADCM3 and MIROC. Global climate models are physical representations of the main drivers of the climate system. Future climate is modelled by perturbing the carbon dioxide concentrations in the model, which then has implications for temperature and rainfall. In this study, two future emission scenarios of carbon dioxide were used, based on the Intergovernmental Panel on Climate Change – one was a high-emissions scenario (A1FI) and the second a moderate emissions scenario (A2). The results from the models, which provide results at a regional scale, were then used to transform the historical station records for Kununurra (see Section 2.3.1).

Rainfall projections for 2030 under two emission scenarios (A1FI – high emissions, A2 – moderate emissions) show no distinct rainfall trend, based on the four climate change models used in this study (Figure 6.4). Two models show a small increase in rainfall (2%), while two suggest a small decrease (1 – 10%). Based on this analysis, projected changes in mean annual rainfall are small and uncertain and would not appear to be a major factor in planning for crop production out to 2030.

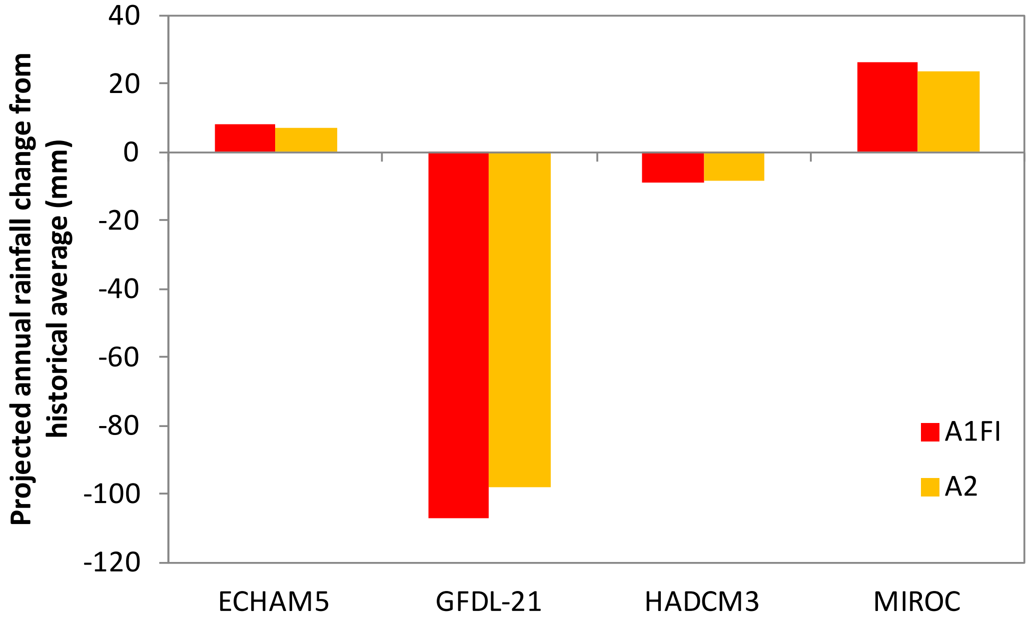

Figure 6.4 Rainfall projections for 2030, based on two emission scenarios (A1FI – high, A2 – moderate), using four global climate models
The rainfall projection is the difference in millimetres from the recent historical average annual rainfall (1970 to 2010)

Unlike rainfall, the projected trend in temperature is much more certain, with a projected increase in temperature of 0.7 to 1.3°C to 2030. Given the overall high temperatures in the tropics, a small increase in mean temperature levels can have a significant impact on the frequency of extreme temperature events. This impact on extreme event frequency is highlighted in Figure 6-5, which shows that the projected number of days in excess of 40°C will increase from 5 days/year to between 17 and 25 days/year by 2030. This shift will impact on crops that are sensitive to high temperatures (e.g. some horticultural crops such as melon towards the end of the dry season). High temperatures may also affect seedling survival of broadacre crops such as maize. An increase in minimum temperatures may also have some effect on flowering in crops such as mango.

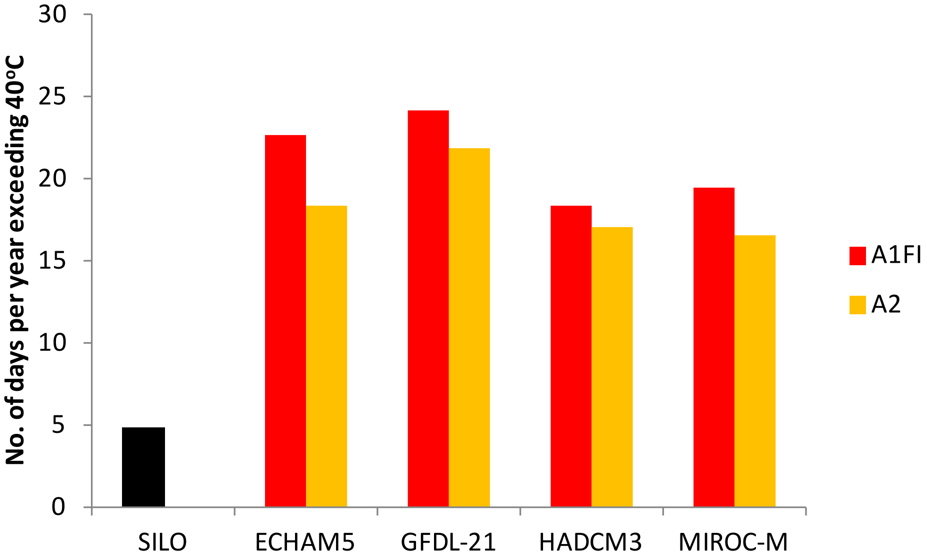

Figure 6.5 Number of days per year in Katherine projected to exceed 40°C in 2030 for two emission scenarios (A1FI – high emissions, A2 – moderate emissions), using four global climate models, compared with historical climate (SILO data for 1970 to 2010, black column)

6.4 Water resources

The Katherine–Mataranka region lies across the Daly and Roper River catchments (Figure 6-6). Sited underneath these surface catchments is the Daly Basin, which is a collection of geological formations that are important for groundwater resources. For the Katherine–Mataranka region the most important of these geological formations is the Tindall limestone aquifer, which is a karstic formation that underlies about one-third of the Northern Territory.

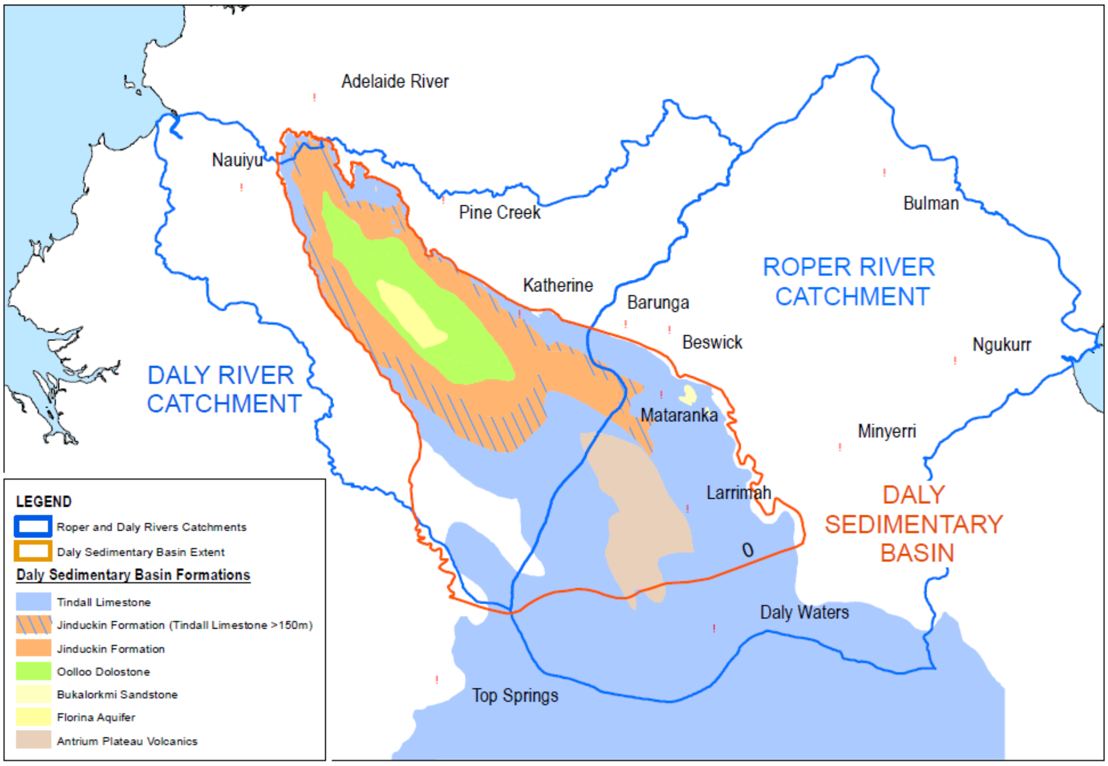

Figure 6.6 Tindall Limestone Aquifer in the context of the Daly Sedimentary Basin and the Daly and Roper River catchments

Source: DNRETAS (2011b)

The limestone geological formation contains many cracks, fissures and caves that can hold large volumes of water that are readily accessible in some places, such as in the Mataranka region. Much of the Tindall limestone aquifer is overlaid by other geological formations that confine it and make access difficult, whereas in the Mataranka region it is shallow and unconfined, making it suitable for consumptive uses such as irrigation.

The Tindall limestone aquifer is recharged on a regular basis, especially in wet seasons of average or above-average rainfall. Recharge occurs after significant rainfall via diffuse percolation through the surface soil, point recharge via sink holes or directly through riverbeds. The amount of recharge is dependent on the timing and intensity of rainfall (Figure 6-7), with the average annual modelled recharge (1900 to 2008) being 129 GL/year (DNRETAS, 2011b). Over the relatively wetter period of the last 40 years (1970 to 2010), average annual recharge was modelled to be 180 GL/year.

The aquifer discharges into a number of river systems, including the Katherine, Roper, Flora and Douglas rivers. In the Mataranka region it discharges into the Roper River and various swamps and springs, the most well known of these springs being the Rainbow Thermal Springs and Bitter Thermal Springs. During the dry season the discharge from the Tindall limestone aquifer provides base flows for the Roper River and is important for water-dependent ecosystems along the river.

Water quality across the Mataranka region varies depending on its location within the aquifer. Examination of water-quality data from a number of drill holes (Karp, 2008) show that the Mataranka groundwater resources can be classified into three broad groups:

- groundwater with low total dissolved solids (TDS), low sodium, chloride and sulfate (typical of the Tindall Limestone aquifers from the Daly Basin)
- groundwater in the mixing zone (shows mixing between typical Tindall Limestone Daly Basin aquifers and the Georgina Basin – Anthony Lagoon Beds aquifers)
- groundwater with elevated TDS, elevated sodium, chloride and sulfate (representing water under the influence of salt from the unsaturated zone that formed during seasonal evaporation and evapotranspiration).

The main Mataranka aquifer is groundwater from the second group. The high mineral content (calcium) that has resulted from the limestone dissolving causes the water to be hard and can cause scale build up in water and irrigation lines. TDS, sodium and chloride can be high enough to affect taste, but the water generally meets acceptable limits for human consumption.

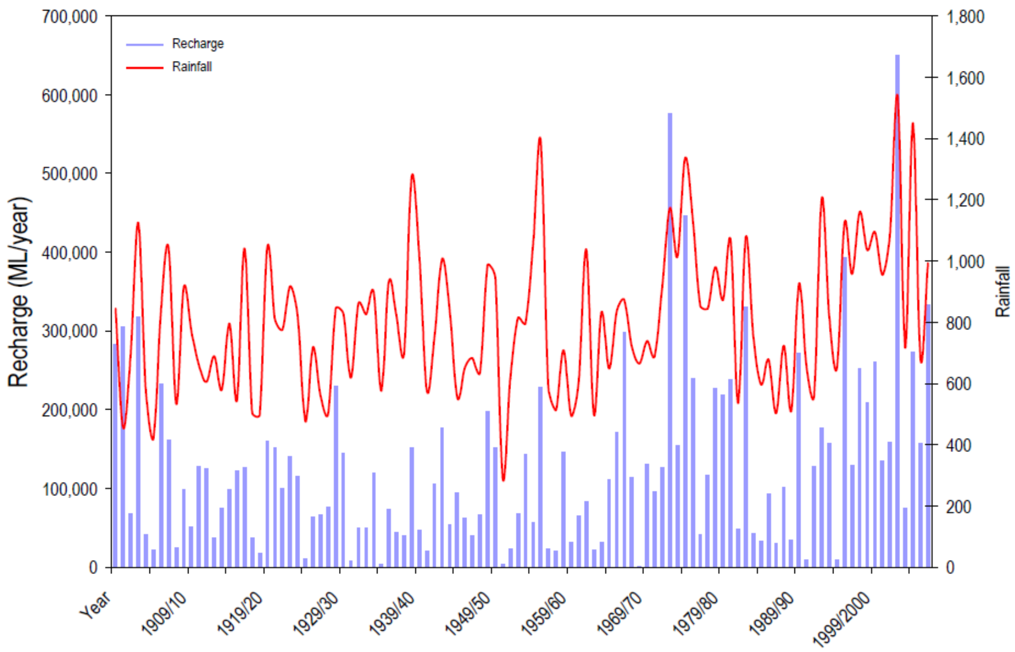

Figure 6.7 Annual rainfall and modelled recharge for the Tindall Limestone Aquifer
Source: DNRETAS (2011b)

6.4.1 EXISTING WATER USE AND REGULATION

Based on the understanding of surface and groundwater hydrology and the interactions between the two, a draft water allocation plan was developed for the Tindall limestone aquifer (DNRETAS, 2011a), with allocations revised in 2013. Current allocations are based on the annual recharge levels of the last 40 years (180 GL/year) and an upper consumptive limit of 20% of annual recharge, to give a maximum allocation of 36 GL/year. Based on annual recharge figures for the last 40 years (DNRETAS, 2011b) this maximum amount of 36 GL would be achieved in only 40% of years (Figure 6-7). Given this level of reliability, allocations are priority based, with a high-priority allocation of around 5 GL (90% reliability) and a general priority allocation of around 13 GL (70% reliability). Any remaining allocations would be low priority. Currently, there are about 19 GL of approved or pending allocations.

6.5 Land suitability for cropping

Soils of the Mataranka case study area are predominantly red, brown and yellow Kandosols (structureless soils) and Tenosols (weakly developed soils) on flat to low, sloping land, with minor areas of Dermosols (structured soils), particularly along the upper reaches of Elsey Creek (Figure 6-8). These soils generally have sandy topsoils, are deep with moderate-to-good plant-available water-holding capacity, although they may be imperfectly drained, and have high gravel contents. They mostly have moderately acid to neutral pH. Some moderately to strongly alkaline soils (pH >7.0) occur to the east of Mataranka, particularly in the Red Lily Lagoon area and along Elsey Creek.

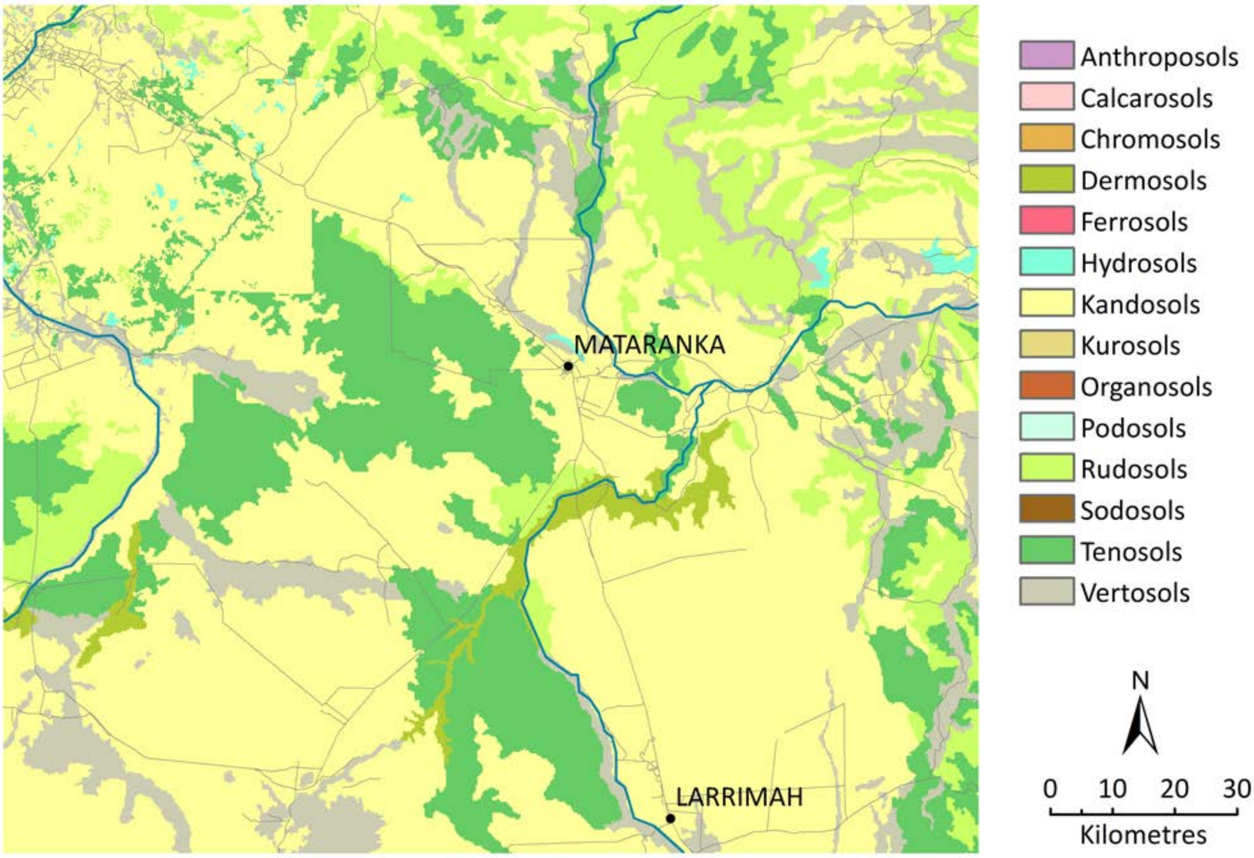

Figure 6.8 Dominant mapped Australian Soil Classification orders, Mataranka study area
Source: ASRIS (2014)

Agricultural suitability for irrigated annual and perennial crops is moderate (Figure 6.9a), with the lighter textured sandy topsoils likely to require well-considered application of irrigation water. High gravel contents and poor nutrient status also require significant management inputs, and these nutrient limitations are effectively managed under existing intensive cropping (melon, mango). The erosion potential of the soils may be considerable, particularly on long, low slopes, if adequate ground cover is not maintained. Suitability for forestry and tree crops may be higher, although similar management considerations to those described above would be required during crop establishment phases.

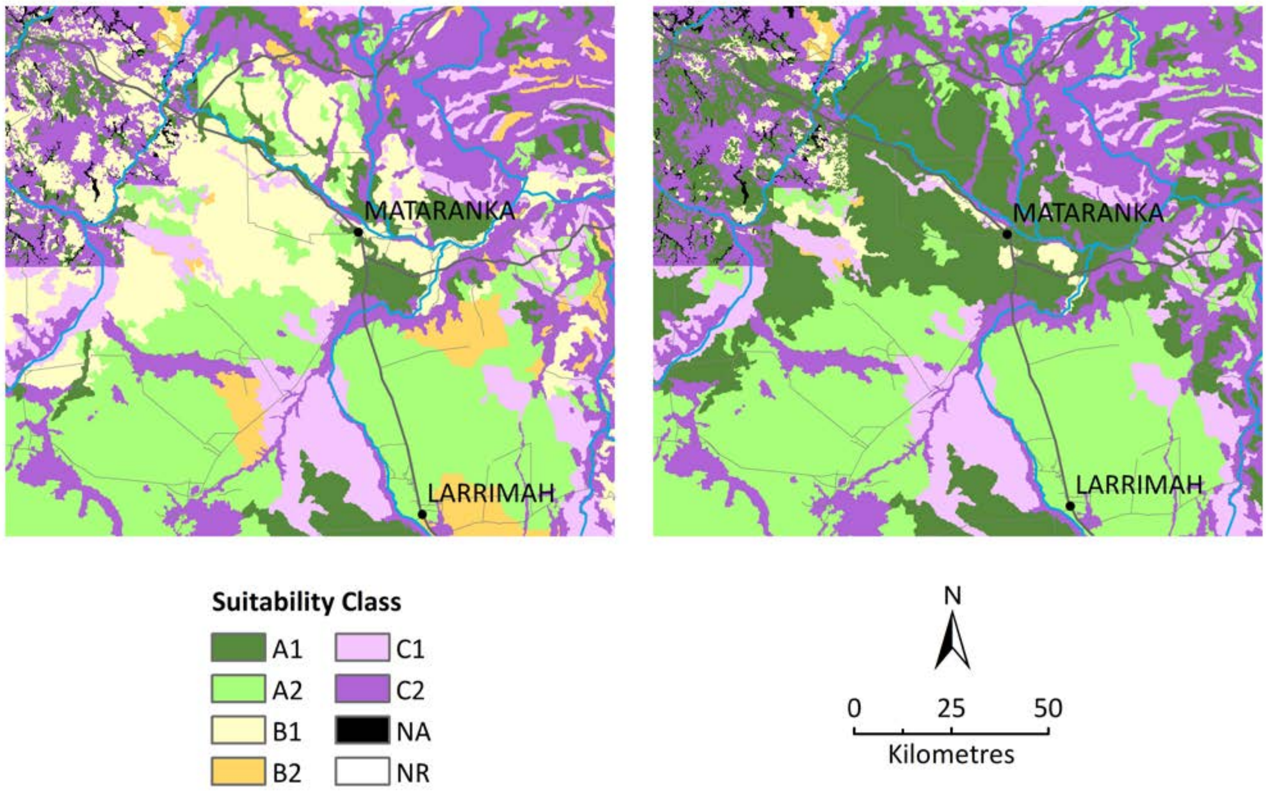

Figure 6.9 Suitability for (a) irrigated annual crops (left) and (b) irrigated forestry (right) in the Mataranka study area
A1 >70% of the area is Class 1 or 2; A2 50 to 70% of the area is Class 1 or 2; B1 > 0% of the area is Class 1,2 or 3; B2 >50 to 70% of the area is Class 1, 2 or 3; C1 > 50 to 70% of the area is Class 4 or 5; C2 >70% of the area is Class 4 or 5, where Class 1 is suitable land with negligible limitations and Class 5 is unsuitable land.
Source: Wilson et al. (2009)

6.6 Pest and disease risk

A total of 267 species were identified as potential pests or pathogens of any of the 11 crops evaluated for the Mataranka region; many of these were pests or pathogens of multiple crops (Appendix 6.1, separate document). For most crops, the likelihood of at least one of these pests or pathogens invading the region is 1 (100% likelihood) (Table 6.1), because, many are already present in Australia and at least one is present within Western Australia (with the exception of sandalwood, which has no pest known to be present). Despite the large numbers of pests and pathogens assessed, only a small proportion of species have been identified as major or significant pests of each crop (CABI, 2011) (Appendix 6.1, separate document). However, for many of these crops (mungbean, peanut, mango, watermelon, rockmelon, pumpkin, potato and cotton), at least one of the major pests is already found in the Northern Territory and therefore represents a significant threat, with a potentially high impact.

Table 6.1 Invasion likelihoods, most likely impact and overall biosecurity risk from insect pest and fungal pathogens to proposed crops of the Mataranka region, Northern Territory

Values of 1 denote almost certain likelihood, very high impact and very high risk, while values of 0 reflect no likelihood, impact or risk.

CROP	INVASION LIKELIHOOD	IMPACT	RISK
Broadacre food			
Chickpea	1	0.1	0.1
Mungbean	1	0.4	0.4
Peanut	1	0.4	0.4
Intensive food			
Mango	1	0.1	0.1
Watermelon	1	0.4	0.4
Melon (rock)	1	0.4	0.4
Pumpkin	1	0.4	0.4
Potato	1	0.4	0.4
Fibre/other			
Cotton	1	0.4	0.4
Sandalwood	0.06068	0.1	0.061
Poppy	1	0.1	0.1

6.7 Crop production

6.7.1 BROAD OVERVIEW OF CROP TYPES AND AGRONOMY

The potential productivity of a number of broadacre, high-value and industrial crops was investigated for the Mataranka regional case study analysis. This broad analysis includes high-volume products such as pulses, high-value products such as horticulture, and industrial products that require further processing, often nearby, such as cotton.

Broadacre cropping is generally characterised by large-scale (area), relatively low input and high-volume production of a commodity with a relatively low value (in per-tonne terms). Cereal and pulse production are the two most common forms of broadacre production in Australia, and a number of cereal and pulse crops have previously been grown to the north of the Mataranka region.

Pulses are legume crops that are grown for the grain they produce. Being legumes, they are able to ‘fix’ atmospheric nitrogen, meaning fertilisation with inorganic nitrogen fertiliser of pulses is minimised. As this fixed nitrogen is also available to subsequent crops, pulses are often grown in rotation with high nitrogen-demanding crops such as cereals.

Pulse production is well established in Australia, with approximately 2 million hectares of pulse crops grown annually. Many pulse crops have a relatively short growing season, and are well suited to opportunistic production when there is sufficient available water (either stored in soil or available from irrigation). A range of pulse crops is suitable for the growing conditions of the Mataranka region and for this analysis mungbean was selected as one example for further analysis.

Peanut is a tropical and subtropical annual legume that can be grown as a wet-season crop (either rainfed or with supplementary irrigation) or a dry-season crop under full irrigation. Peanuts are usually processed for human consumption, and the foliage can be used for stockfeed. The peanut is produced underground, and specialist equipment is used to 'pull' the crop from the soil before harvest. Peanuts are not suited to heavy soils because of high losses that result from breakage when the crop is being pulled. Peanuts can be grown at any time of year in northern Australia, but to produce a consistently high-quality crop, should be harvested during dry conditions. Peanuts take approximately 160 to 180 days to mature. The Peanut Company of Australia grew peanut crops at Katherine from 2003 to 2010.

High-value cropping includes horticultural crops that are generally produced on much smaller areas than broadacre crops, with higher input costs per hectare and a product that is of much higher value than broadacre crops. Horticulture crops are often perishable, require a high labour force for 'picking and packing' and specialised postharvest conditions such as refrigeration or controlled atmosphere storage. Horticulture crops are either perennial, such as tree crops, where a planting lasts many years, or annual, such as rockmelon, where the crop is destroyed after harvest.

Horticulture is an important industry, occurring in every state, and accounting for approximately 20% of the total farm-gate value of Australian agriculture. Production is highly seasonal, and annual crops will often include staggered planting on a single farm during the growing season to extend harvest time.

Market prices for horticulture products can be highly volatile, and subject to multiple supply, demand and substitution forces. The importance of freshness for many horticultural products means that seasonality of supply is important in the market, with the Mataranka region potentially having advantages of being able to supply southern markets with 'out of season' produce. High-value crops for the region include mango (both the established Kensington Pride [KP] and newer, higher producing varieties developed under Plant Breeder's Rights [PBR]), watermelon and rockmelon.

For the purpose of this case study, industrial crops are defined as crops that require a major processing step in their production soon after harvest. The nature of industrial crops is generally such that the crop is high volume, and processing facilities are usually located near the point of production, to reduce transport costs between where they are grown and where they are processed. The industrial crops that have been considered in the case study analysis of the Mataranka region include cotton, sandalwood and poppies.

Dryland and irrigated cotton production is already well established in Australia, with the annual area grown generally changing in response to water availability. Commercial cotton production has been tried a number of times in northern Australia and the early attempts encountered major challenges due to capital limitations, climatic adaptability and pest control. Since the introduction of genetically modified (GM) cotton in 1996, yields and incomes from cotton crops have increased in most regions of Australia, with the key benefits of GM cotton (compared with conventional cotton) being savings in insecticide and herbicide use, and improved tillage management. Recent work has been published on cotton potential for northern Australia (Yeates et al., 2013), and based on GM cotton varieties and growing it in the dry season, yields in excess of 9 bales/ha could be achieved in an environment like Mataranka. Cotton processing locally has additional benefits in producing cottonseed, a valuable high-protein meal for cattle, fed either as whole cottonseed or as cottonseed meal. There would also be export potential for cottonseed meal.

An Indian sandalwood industry is currently emerging, with a strong focus in the Ord River Irrigation Area around Kununurra in Western Australia and parts of the Northern Territory. TFS Corporation Ltd has planted significant areas of sandalwood at Taylors Park – land west of Katherine formerly owned by the Peanut Company of Australia. Initial crop yields in the Ord region are expected to be low because early plantings had a low survival rate (approximately 20%) compared with current survival rates (more than 80%). Heartwood yields can vary enormously between individual trees. For example, in a trial involving 32 trees harvested in Kununurra, the average heartwood yield was only 1.5 t/ha, with a range from zero to about 8 t/ha (Brand et al., 2012). However, in that study the tree densities were much lower than current commercial plantings and, as it was an early planting (1994), it is not certain that the leguminous host trees chosen at that time were performing effectively. The oil extracted from sandalwood can be of high value, and consistent oil yields across an entire plantation require good management over the entire growing period (often more than 15 years).

Opium poppy is an annual broadacre herb crop that is currently grown under legislatively restricted conditions in Tasmania for the production of opiates. The crop is grown under contract to a limited number of processing companies that plant and harvest the crop, with farmers providing land preparation, crop protection and irrigation services. At maturity, the crop is dessicated and the upper stem and capsule are harvested and transported direct to processing plants. Here the seed is separated from the poppy straw and alkaloids are extracted from the straw to produce a concentrate of poppy straw (CPS). The CPS is either sold as a narcotic raw material or used in the manufacture of codeine-based painkillers in Europe and the United States. Poppy seed contains almost no alkaloids and is used in the food industry; the United States is a strong export market for poppy seed. Poppy quality is dependent on the alkaloid content of the dried straw. The Tasmanian industry is highly vertically integrated, with extremely strict regulatory controls from growing through to harvest, particularly to protect market access to the United States. Approximately 20,000 hectares of poppies are grown in Tasmania, producing roughly half of the world's morphine.

6.7.2 MARKET ANALYSIS OF CROPS

A range of market opportunities exist for the crops that are currently grown in the Mataranka region and also for those that potentially could be grown under an expansion of irrigation. This section highlights some of these opportunities for the range of broadacre, high-value and industrial crops that are analysed in the cropping scenarios for the Mataranka region. A more detailed market analysis of each commodity is given in Appendix 4.1.

Broadacre food crops

Maize

Within Australia, livestock feeding of maize accounts for around 54% of total domestic consumption, while food and industrial consumption accounts for the remaining 46%. Maize is a minor component of the feed complex, but over 90% of feed maize is consumed by poultry or pigs; only a small amount is consumed by feedlot cattle.

Australia's most important export markets for maize are Japan and the Republic of Korea, but Australian maize comprises less than 1% of these countries' imports. The dominance of Japan and Korea as import markets has been falling in recent years and growth in world maize imports have been driven by Latin America and member states of the Association of Southeast Asian Nations (ASEAN).

Asia is expected to be a driver of world maize consumption, largely as a result of growing demand for maize as a feed gain. This may present export opportunities, but Australia does not yet have access to China's market for maize. Australia's status as a non-GM producer provides marketing opportunities to access high-value niche markets. Main competitors in Japan and Korea are the United States, Argentina and Brazil. Increasing demand for non-GM maize in Asian markets means Australian exporters can command a premium above the world price.

Domestic marketing opportunities will depend largely on poultry and pig numbers. Over the medium term, pig and poultry numbers are projected to rise, supporting domestic demand for maize.

Mungbean

Australian production of mungbeans has almost doubled in the two decades to 2012–13. Currently, Australian mungbean production is largely destined for export. In 2011–12, Australia shipped 50% of mungbean exports to India with another 22% sent to the ASEAN member states. Within the ASEAN region, Indonesia was the largest importer of Australian mungbeans. India and ASEAN will continue to be growing markets for Australian mungbeans.

Domestically, and internationally, opportunities exist to market mungbeans as a functional food to domestic food manufacturers and consumers. Mungbeans have a range of potential applications such as starch, flour and paste, and can also be used as an additive to other foods.

Peanut

Australian peanuts are mostly used on the domestic market, with food consumption the primary use. Australia is usually a net importer of peanuts, except in years of large production, and imports both processed and unprocessed peanuts. Argentina is the source of almost 80% of unprocessed peanut imports, followed by China and Nicaragua. China and Nicaragua are the main suppliers of processed peanuts. Australia exports unprocessed peanuts – 1100 t in 2011–12 – mainly to New Zealand, Japan, Fiji and China. Processed peanuts – 1700 t in 2011–12 – were exported mainly to New Zealand, the Republic of Korea and Japan.

China and India together produce more than half of the world's peanuts. China is also the largest consumer of peanuts for food, followed by Indonesia, the United States and Nigeria. China and India are the largest crushers of peanuts and consumers of peanuts meal and oil. While China was once the primary supplier in international markets, growing domestic consumption has reduced exports.

Should local production expand, there is potential for some import substitution of peanuts for food use and also peanut meal for intensive livestock production. Any expansion in production could also be shipped to current export markets, particularly Japan and the Republic of Korea. The major supplier to these markets is China but, with its own domestic consumption increasing, there may be opportunity for Australian exports to expand in these markets. Likewise, net exports from the United States, the second-largest supplier to Japan, are projected by the United States Department of Agriculture to fall over the medium term, providing opportunity for Australian exports in Japan. Opportunity also lies in supplying high oleic peanut oil to the world market, but capitalising on this opportunity would require a large-scale stable supply of high oleic peanuts and export market development.

High-value crops

Cucurbits

The cucurbit industry's exposure to international markets is limited, with most production sold into the domestic retail and foodservice markets. In 2012–13, Australia exported 1500 t of pumpkin, with the largest markets being Singapore (62%), Papua New Guinea, Indonesia and the United Arab Emirates. Only around 5 to 6% of melon production is exported, with New Zealand – the largest market – taking 38% of total melon exports in 2012–13. Imports of both pumpkins and melons are negligible.

China is the world's largest pumpkin producer, accounting for 28% of global production in 2011, followed by India (19%) and the Russian Federation (5%). Exporters include Spain, accounting for 45% of exports in 2011, followed by New Zealand, Mexico and Morocco. The United States and the European Union are some of the largest consumers of pumpkins in the world and together account for around 80% of imports.

World melon production has almost trebled over the past two decades, with two-thirds of global watermelon and just over half of all other melons now produced by China. China is also one of the world's largest melon-consuming countries – second to the United States and ahead of the European Union. The United States and China are also the world's largest importers of watermelons, together accounting for over one-third of world imports in 2011. For other melons, the largest import markets are the United States and the European Union.

Rising nutritional awareness is expected to have an impact on demand for cucurbits in the domestic market. Northern Australian production is counter-seasonal to southern Australian production and therefore extends their availability to consumers. However, any specific effects on the consumption of pumpkins and melons will depend on consumer preference towards them compared with other fruits and vegetables and their relative prices against other fruits and vegetable. There are perhaps greater opportunities for producers to export -quality fresh produce to Northern Hemisphere countries, particularly to ASEAN memebr states and the Middle East, which are already important markets for Australian exports of pumpkins and melons. Although China is a major producer of melons, it is also one of the largest importers and so offers market opportunities for Australian exporters of high-quality melons.

Mango

Mangoes grown in the Northern Territory, the Ord region and other parts of northern Western Australia are among the earliest harvested, with the harvest beginning in September. This is followed by harvest in Queensland's dry tropical regions (Townsville, Burdekin and Bowen) in mid-November, other regions of Queensland in December and northern New South Wales in January.

The Australian mango industry is domestically focused, with 80% sold as fresh produce and the remaining 20% processed. Of the fresh fruit, around 90% is sold on the Australian domestic market. The Australian domestic market is well supplied in season and, with increased mango production in the Northern Territory over the past five years, the availability of early season mangoes has increased for domestic consumers.

Imports are low but have been growing steadily over the past decade. Supply from imports is counter-seasonal to Australian production. However, as the Australian season extends with growing production of early season mangoes, it is likely there will be increasing overlap in supply to the market. Key export markets for mangoes are Hong Kong (42% of export volumes in 2012–13), the ASEAN member states (21%), the Middle East (18%) and New Zealand (13%). Important ASEAN markets are Singapore, Vietnam and Malaysia. However, Australia is a small producer of mangoes on a global scale at only 0.1% of world production.

The highest mango consumption is in Asia. In Asia, unripe mangoes are especially popular, while in western countries ripe mangoes are mainly eaten. Increased production of mangoes in Australian would provide export opportunities for unripe and ripe mangoes to countries in Asia. Thailand offers strong competition in this region because it is the main supplier of mangoes to Malaysia, China and Singapore. Japan sources mangoes from Mexico, the Philippines and Thailand.

Industrial crops

Cotton

Australia has been a relatively minor cotton producer on a global scale but in recent years became the world's sixth-largest producer. In 2012–13, Australia produced 1 million tonnes of cotton lint and 1.4 million tonnes of cottonseed. The level of Australian cotton production depends largely on the availability of irrigation water. Currently, about 95% of Australian cotton production takes place in the Murray–Darling Basin (MDB) region and usually more than 90% is irrigated. Increased diversions of irrigation water away from farms to environmental uses in the MDB are expected to have a minor effect on Australian cotton production over the medium term, but the prospects of significant expansion in irrigated plantings in the MDB are limited by water availability.

Around 95% of Australian cotton lint is exported to international markets, mainly in Asia, while a large proportion of cottonseed is consumed in Australia. In the 10 years to 2012–13, Asian markets accounted for 98% of total Australian lint exports, with the remainder exported to Europe. China has now emerged as the largest importer of Australian cotton, taking around 70% of Australia's exports in 2012–13. Other important markets are Indonesia, Thailand and the Republic of Korea.

Given Australia's small textile manufacturing sector, domestic textile mills only consume around 3% of the cotton industry's output. It is unlikely that additional demand for ginned cotton will be created domestically because labour costs in textile manufacturing are much cheaper overseas. Demand from other ASEAN countries such as Cambodia and Vietnam is expected to grow as wage inflation in China has led to Chinese manufacturers and global textile companies moving their manufacturing to other low-cost nations. Other potential markets for Australia that could be further developed include Bangladesh and Pakistan.

Poppies

The poppy industry covers the growing, harvesting and processing of opium poppy material (poppy straw and CPS) into the global narcotic manufacturing sector. The alkaloids extracted from the poppy plant include morphine, thebaine, codeine and oripavine, all of which are under strict international control to balance the supply of licit narcotic products with demand.

Currently, Tasmania is the only state licensed to grow poppies for the commercial production of alkaloid-based pharmaceuticals, but the Northern Territory and Victoria have shown interest in growing opium poppies. TPI Enterprises successfully trialled poppies near Katherine in 2013 and has plans for a larger commercial trial of around 500 ha on the Tipperary cattle station once Northern Territory legislation – introduced into the parliament in May 2014 – is passed. Tasmanian plantings estimated for 2014 are around 27,000 ha.

Australia (Tasmania) dominates global production of opiate raw materials, accounting for 31% of morphine-rich raw materials and 77% of thebaine-rich raw materials in 2013. Other major producer countries are France, Spain, India and Turkey. Global consumption by narcotics manufacturers has been increasing in recent years. The United States, France and Australia are the main users of both anhydrous morphine alkaloids from concentrate of poppy straw and anhydrous thebaine alkaloids. The United Kingdom is also a major user of anhydrous morphine alkaloids from concentrate of poppy straw. Australia accounted for 30% of world exports of anhydrous morphine alkaloid in 2012 and 93% of anhydrous thebaine alkaloid exports.

Demand for opiates will increase into the future, driven by ageing populations and increasing use of painkilling and anti-addiction medications. The market is currently concentrated in the United States but growth in the developing world is expected. As developing countries increase in affluence and their spending on health care increases, world demand for opiate-based pain management will rise. Production of poppies in the Northern Territory offers potential productivity growth, with the warmer climate shortening the growing period, potentially allowing two crops a season compared with Tasmania’s single crop as part of a mixed farming rotation.

Sandalwood

Culturally significant in India, China and the Middle East, sandalwood heartwood is widely used for religious worship and ceremonies and in a range of wood-based consumer products. Heartwood is also distilled into premium quality oil for use as a fixative in fine fragrances, beauty products, medicines and incense, and as flavouring agents for chewing-tobacco products. In recent years Australian sandalwood oil has been incorporated into many high-end perfumes and other cosmetic products. Expansion of Indian sandalwood plantations into the Northern Territory and Queensland, adding to large-scale production in the Ord region, is designed to take advantage of this demand.

Australian sandalwood currently supplies well over half of all sandalwood traded around the world annually. Indonesia, East Timor and India are the other main exporters. Global supplies of sandalwood have been depleted by overharvesting of wild plantations. The Indian Government has placed restrictions on exports of Indian sandalwood in response to depletion of natural resources as a result of illegal harvesting.

Australian sandalwood has historically been used in the agabati and incense markets in China, Taiwan, Hong Kong and most other Asian countries. The main importers of sandalwood are Taiwan, China and India. The United States and France are the main importers of sandalwood oil, but there is also demand from North Asia and the Middle East for oil.

Internationally, the key market drivers are the decline in the supplies of sandalwood from India and other traditional sources in Indonesia and the Pacific, and growing populations and affluence in developing nations, particularly in India and China. Provided a steady supply of high-quality sandalwood can be maintained, the preference in Europe and North America for natural products in cosmetics will assure the future market for the oil and perhaps also for the nuts. There are also opportunities for sandalwood products in pharmaceutical uses. At the same time, lower-grade powdered sandalwood products will have a ready market in Asia for incense.

6.7.3 CROP PRODUCTION ESTIMATES

The APSIM (Agricultural Production Systems sIMulator) model (Keating et al., 2003) has been used to provide suitability and yield estimates for a range of broadacre, high-value and industrial crops. These crops include maize, mungbean, peanut and cotton (Table 6.2). For horticultural crops, sandalwood and poppy, yield estimates were based on benchmarking studies, expert opinion and ‘heat sum’ approaches.

Two soils parameterised to represent a Blaine sand and a lighter Clarevale soil were used in the APSIM simulations. The Blaine sand holds 79 mm of water to a depth of 1.5 m, and the lighter Clarevale sand holds 52 mm to 0.8 m. Results for the Blaine sand are presented in the tables below. Historical meteorological data for Mataranka between 1900 and 2010 were used to generate simulations of the variation in crop yield and irrigation water required.

APSIM assumes that best practice has been applied for managing a crop, and that the crop has been grown in the absence of any pest and disease-related stress. Simulations were undertaken to achieve crop growth in non-limiting soil water and nutrient environments. Applied irrigation was triggered in the model using soil water deficit and the potential root zone of each crop. Natural reset points were selected at the end of winter (September), when the soil profile is normally dry, to initialise the soil water, soil nitrogen and surface cover each year so as to only capture the effect of seasonal climate and applied irrigation on crop production. Irrigation management is assumed to give 100% efficiency in applying irrigation to the crop, regardless of the actual availability of supply.

The values presented for water applied to a crop do not equal the total water use to produce the crop (Table 6.3). APSIM assumes 100% efficiency of irrigation water supply, and the reported productivity figures are 'on crop', not accounting for any inefficiencies involved with storage, delivery from the water storage and on-farm application of the water. The outputs from simulation modelling and those estimated for non-modelled crops are the potential productivity and irrigation water use on a per-hectare basis.

Table 6.2 Crop yields simulated using APSIM (represented by those crops with 20th, 50th and 80th percentile values) or estimated based on production in the region (for other crops except poppy, which is based on published estimates)

APSIM yields for broadacre crops are based on 110 years of simulations (1900 to 2010) and are expressed in tonnes of dry matter per hectare. For the economic assessment these were converted to fresh yields, based on moisture contents of 12 to 14%.

CROP	YIELD PERCENTILE		
	20th	**50th**	**80th**
Broadacre (t/ha)			
Maize	10.7	10.0	9.0
Mungbean	2.0	1.8	1.5
Peanut	4.6	4.1	3.7
High value			
Mango – Plant Breeder's Rights varieties		3100 trays	
Watermelon		52	
Rockmelon		1706 trays	
Industrial			
Cotton	8.7 bales	8.1 bales	6.0 bales
Cotton (dry season)	9.3 bales	9.2 bales	9.0 bales
Sandalwood[a]		8.0 t/ha heartwood	
Poppy		1.8 t/ha	

a Sandalwood is grown on a 15-year cycle, so yields harvested per hectare will be 1/15th of 8 t/ha.

Table 6.3 Irrigation water use (mm per crop) for the broadacre and industrial crops simulated in APSIM for 110 years (1900 to 2010)

Assumes perfect timing of irrigation (i.e. no field application losses)

CROP	IRRIGATION WATER USE (mm) PERCENTILE		
	20th	**50th**	**80th**
Broadacre			
Maize	568	523	478
Mungbean	196	152	111
Peanut	269	211	165
Industrial			
Cotton	733	544	369
Cotton (dry season)	597	557	528

Maize

Maize was sown in the simulations on 15 March. Although maize can be planted during a wide sowing window, management of heat stress during flowering, grain fill and seedling development is required to reduce the risk of yield penalties. The maize yields simulated for Mataranka show that maize is very well adapted to the region. Maize can also be grown as a forage crop for livestock.

Mungbean

Mungbean was sown in the simulations on 15 March. Mungbean matures relatively quickly and, like chickpea, can be opportunistically sown but is often part of planned crop rotations. Mungbean prices can vary greatly with seed quality when sold for human consumption (which generates the highest prices). Rainfall during the later stages of pod fill can have a detrimental effect on grain quality and, consequently, the average price received. Therefore, planting is usually timed to ensure a low risk of receiving rainfall at this crucial time.

Peanut

In the simulations peanuts were sown in early December, to ensure planting operations could be completed before the onset of the wet season and to have the peanuts maturing in March–April. Yields were simulated to be around 4.1 t/ha on a dry-weight basis or 4.7 t/ha on a sale-weight basis (around 12% moisture).

Mango

Stands of KP mangoes are still widespread in the Katherine–Mataranka region. However, for this study, focus has been placed on newer varieties (e.g. Calypso and Honey Gold), which are grown under licence through PBR. Yields of KP mangoes are typically around 5 to 10 t/ha in the Katherine region, but the newer varieties can yield 20 to 25 t/ha. Yields of 22 t/ha were assumed in the assessments undertaken for Mataranka.

Mango trees flower from May to August and, from time of flowering to harvest (October to December), water management is crucial for optimum mango development and yields. While water stress before flowering can boost floral initiation (Lu and Chacko, 2000), applying sufficient water post-flowering and through to harvest is essential in achieving high yields (Bithell et al., 2010). Cold spells after flowering can have a detrimental effect on mango yield and is often the cause of seasonal variation. However, there is also anecdotal evidence that unusually warm dry seasons can also affect flowering (e.g. 2013 in the Ord). Individual mango trees often exhibit a biennial yield variation.

A wide range of pests and diseases affect mangoes, which can generally be managed with vigilant treatment. In the last two years in the Northern Territory, mangoes have been affected by resin canal disorder, resulting in skin discolouration that makes the fruit aesthetically unappealing at point of sale. The disorder is usually not visible at harvest but develops during ripening; little is presently known of the cause. The problem appears to be confined to KP mangoes and is an added reason for the focus on PBR varieties for this regional case study.

Melons

Cucurbits (watermelon and rockmelon) are well suited to the Katherine–Mataranka region. Planting of melons is usually staggered, and harvest occurs over an extended period (May until October) to reduce the peak work load and extend market access. The planting season commences when the daytime air temperature reduces enough so that young plants do not suffer from heat stress (late February to mid-March) and continues until July. Based on production data in the region, baseline yields are assumed to be 52 t/ha for watermelon and 26 t/ha for rockmelon. Trickle tape and plastic mulch are used to grow curcurbits in the Katherine–Mataranka region. Pests and diseases can significantly affect yields if they are not closely monitored and managed.

Cotton

In the simulations, wet-season cotton was sown on 1 January. Rainfall during late crop development can downgrade cotton quality and price, so planting in the Katherine region needs to be timed to avoid rainfall at this time. Dry-season sowing of cotton was on 31 March. The Katherine and Ord regions are unusual in that cotton can be grown over the dry season because the minimum daily temperatures are high enough and there are advantages to doing so in this environment. Yields were 9.2 bales/ha for the dry-season cotton and 8.1 bales/ha for wet-season cotton (sowing in December/January). Dry-season cotton is also easier to manage in terms of farm operations, especially the planting window, and integrated pest management.

Sandalwood

Sandalwood is grown for around 15 years before the main harvest, and requires good irrigation management during the entire time to ensure optimum oil yields. Results from the Ord region suggest that the crop will not do as well on heavier clays and is likely to be well suited to the lighter soils of the Mataranka region. Estimates of commercial yields of heartwood in the Ord region are around 10 t/ha. A more conservative yield of 8 t/ha of heartwood has been used for Mataranka, and an oil content of 3.5%. Agronomic techniques and management of host species have improved greatly since the early plantings in the Ord in the 1990s, which gives rise to some confidence that yields of 8 t/ha can be realistically achieved.

Poppies

In Australia, poppy production has been concentrated in Tasmania, but experimental and commercial poppy trials have commenced in the Northern Territory and Victoria in response to growing world demand for pain killers. Northern Australia could have advantages for poppy production in the dry season, when wet weather at harvest and issues with rain washing alkaloids from the seed capsules can be avoided. Poppy production was assumed to be 1.8 t/ha of harvested stem and capsules.

6.7.4 CROPPING CALENDAR

Cropping calendars identify the sowing times and the growing season for different crops. The time during which a crop can be reliably and profitably sown is called the sowing window. Sowing windows vary in both timing and length among crops. The cropping calendar (Table 6.4) identifies the sowing and growth windows for the crops that are analysed for the Mataranka region. Perennial crops are grown throughout the year and consequently have a less well-defined growing season or planting window; they are not shown in Table 6.4. The calendar was developed on the basis of expert knowledge of these crops in the Katherine–Mataranka region or from elsewhere in the tropics, and combined with an understanding of plant physiology to estimate responses to differences in local climate. The identified sowing and crop growth windows correspond with the times that are likely to maximise potential crop yield in the Mataranka region. Crops can sometimes be successfully sown outside the identified sowing and growth windows, with only a small yield penalty.

In this analysis, sowing dates between August and November were generally avoided so that crops did not reach maturity during the wet season. Note that sowing to achieve maximum potential crop yield may not always be possible. Wet-season difficulties in access and trafficability may prevent sowing at optimum times.

Table 6.4 Calendar of sowing for annual crops in the Mataranka region

CROP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Broadacre												
Maize				X	X	X	X	X	X			
Mungbean			X	X	X	X	X	X	X			
Peanut	X	X	X	X							X	X
High value												
Watermelon			X	X	X	X	X	X	X			
Rockmelon			X	X	X	X	X	X	X			
Industrial												
Cotton		X	X	X	X							X
Cotton (dry season)			X	X	X	X	X	X				
Poppy					X	X	X	X	X	X		

6.8 Gross margin analysis: sensitivity to price, production and supply chain costs

The crop gross margin is the difference between the gross income and variable cost of growing a crop.

Variable costs include those associated with crop management, harvesting, transport and marketing. For regions such as Katherine–Mataranka, which are distant from major infrastructure and support services, the costs of production have been historically high relative to other agricultural regions in southern or eastern Australia. These higher costs can be attributed to both higher costs for inputs such as fertiliser, as well as the costs associated with transport to markets and processing facilities.

Gross margins for a range of crops specific to the Mataranka region are summarised in Table 6.5. For the crops that were modelled using APSIM, gross incomes were calculated for the median yield over the historical period. For crops that could not be modelled, estimated yields are provided based on production data in the region, or in other regions if that crop is currently not grown. The variable costs of production were based on gross margins developed by local agricultural economists and agronomists with experience of the region, and local agribusiness sources.

The gross margin analyses are indicative and should be used with care because they are highly sensitive to assumptions concerning prices, yields, transport costs and input costs, all of which can vary not just within the region but also between individual farms. The projections in Table 6.4 are based on existing supply chains and processing facility locations.

For horticultural crops, which mostly supply domestic markets that can be easily oversupplied, there can be rapid price movements over days and weeks. This is highlighted in Figure 6.10, which shows movements in the wholesale price of mangoes at the Sydney markets in 2013. This example is particularly relevant to production in Mataranka because the high prices at the start of the season (September–November) each year provide a niche opportunity for Northern Territory mango production. In contrast, significant price movements in broadacre crops more typically play out over months and years (Figure 6.11).

Table 6.5 Gross margin analysis for existing and potential crops in the Mataranka region
Yields of crops simulated by APSIM on a dry-matter basis have been adjusted upwards to account for moisture content of marketed product.

CROP	LOCATION FOR MARKET OR PROCESSING	YIELD UNIT/ha	MEDIAN YIELD (per ha)	PRICE PER UNIT YIELD ($)	VARIABLE COSTS LESS FREIGHT ($/ha)	FREIGHT COSTS ($/ha)	TOTAL VARIABLE COSTS ($/ha)	GROSS MARGIN ($/ha)
Broadacre								
Maize	Adelaide	tonnes	11.5	280	1679	1196	2875	345
Mungbean	Adelaide	tonnes	2.0	900	1084	208	1292	348
Peanut	Kingaroy	tonnes	4.7	900	2506	1,786	4,292	–101
High value								
Mangoes – Plant Breeder's Rights varieties	Adelaide	trays (7 kg)	3,100	21	39,676	5,022	44,698	11,102
Watermelon	Adelaide	tonnes	52	900	25,252	11,440	36,692	10,108
Rockmelon	Adelaide	tray (17 kg)	1,706	18	19,078	6,704	25,782	4,924
Industrial								
Cotton	Emerald	bales	9.2	500	3,389	2,208	5,687	–467
Sandalwood[a]	Albany	kg	315	3500	4,204	73	4,277	37,253
Poppy	Melbourne	tonnes	1.8	2610	2,464	594	3,058	2,234

a Sandalwood is a 15-year crop. These gross margins assume 1/15 of a hectare is harvested each year but ongoing variable costs are required across the full 1 ha.

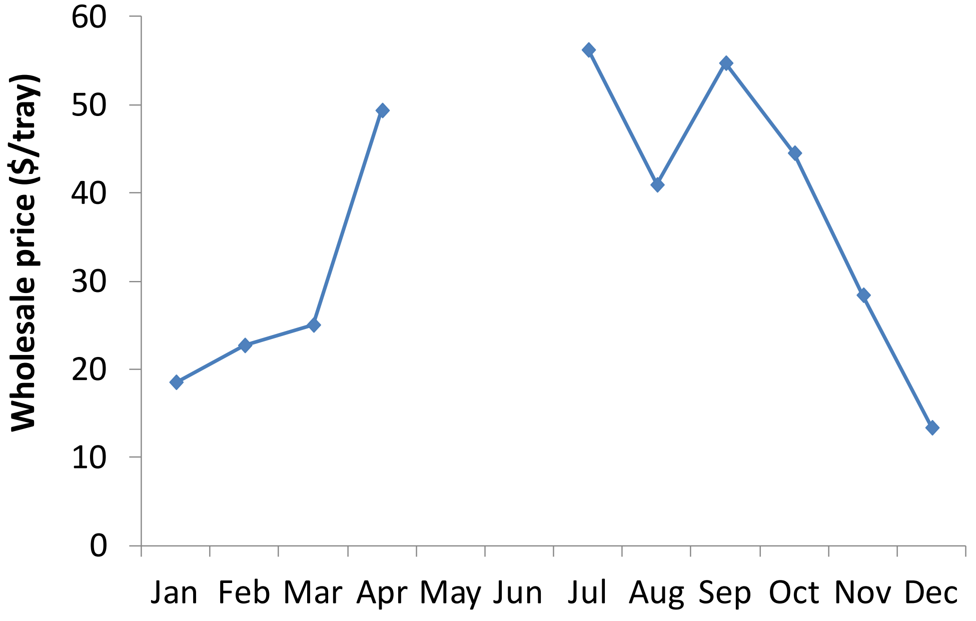

Figure 6.10 Wholesale prices for Kensington Pride mangoes at the Sydney markets during 2013
Source: Data provided by Ausmarket Consultants, Brisbane.

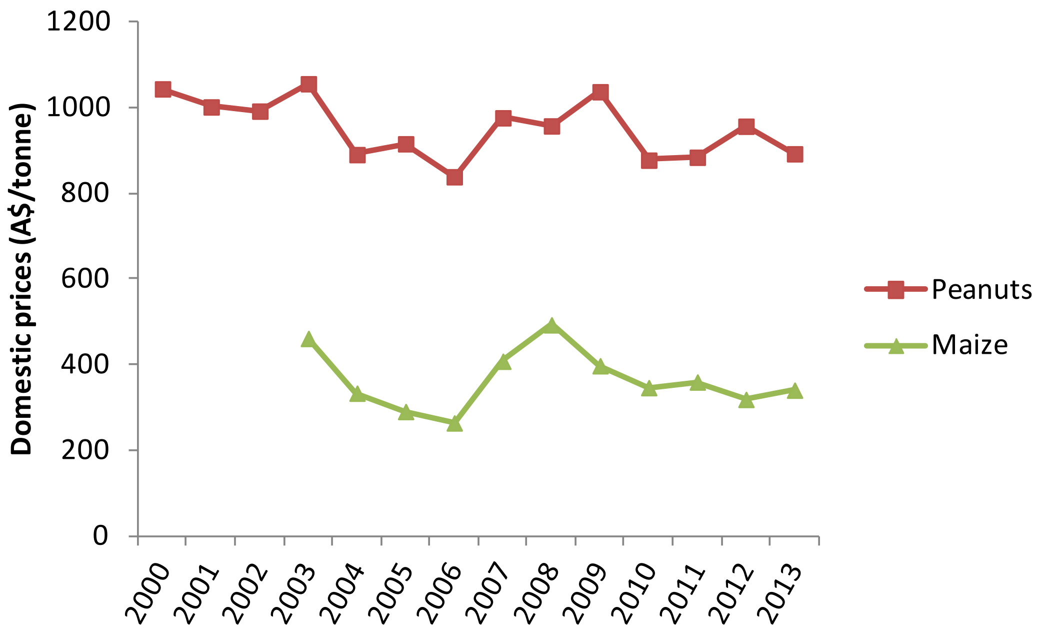

Figure 6.11 Prices received for peanuts and maize in Australia
Source: Data supplied by ABARES

6.8.1 **BROADACRE CROPS**

In general, broadacre crops produce gross margins that are either negative or less than $500/ha. Under the existing supply chain arrangements, all of the broadacre crops are transported significant distances to markets from Mataranka (e.g. Adelaide). Table 6.6 highlights the high freight costs as a percentage of the total costs of production for high-yielding grains such as maize, even though favourable backloading freight costs can be negotiated for empty trailers returning to Adelaide. Mungbeans are relatively low yielding and freight costs are a manageable component of overall costs. However, gross margins are still modest because the revenue for a 2 t/ha crop is low. Although peanuts are relatively high value, the projected gross margin is negative. This is due to the high cost of transport to Kingaroy in south-eastern Queensland for shelling and processing, resulting from a combination of lower tonnes per vehicle for peanuts in shells and the limited availability of backloading on the route. For the coarse grain and pulse crops to be grown more profitably, a local market for grain consumption in beef production systems would need to be developed.

Table 6.6 Freight costs as a percentage of total value of production and total production costs for a range of crops in the Mataranka region

Location represents the point of wholesale or processing.

CROP	LOCATION FOR MARKET OR PROCESSING	FREIGHT COSTS AS A PERCENTAGE OF TOTAL VALUE OF PRODUCTION	FREIGHT COSTS AS A PERCENTAGE OF TOTAL COSTS OF PRODUCTION
Broadacre			
Maize	Adelaide	37.1	41.6
Mungbean	Adelaide	11.6	16.1
Peanut	Kingaroy	42.2	41.6
High value			
Mangoes – Plant Breeder's Rights varieties	Adelaide	7.7	11.2
Watermelon	Adelaide	24.4	31.2
Rockmelon	Adelaide	21.8	26.0
Industrial			
Cotton	Emerald	48.0	39.5
Sandalwood	Albany	0.0	1.7
Poppy	Melbourne	12.6	19.4

6.8.2 HIGH-VALUE CROPS

The gross margins for intensive horticultural products are all highly positive, based on the assumptions that have been used in this analysis. All horticultural crops have high input costs and, as indicated in Figure 6.10, price movements can occur rapidly in response to supplies put on the market at a national scale. The sensitivity of gross margins to the price of horticultural products grown in Mataranka is highlighted in Table 6.7, which demonstrates that while gross margins per hectare can be high, large losses can also occur when product is oversupplied and prices fall.

Table 6.7 Gross margin sensitivity ($/ha) to price of horticultural crops in the Mataranka region

Baseline gross margins are the same as reported in Table 6.4, and the price sensitivities are in steps of +/–15%.

PRICE SENSITIVITY	MANGO – PLANT BREEDER'S RIGHTS VARIETIES	WATERMELON	ROCKMELON
–45%	–$11,747.79	–$5,803.82	–$8,893.74
–30%	–$4,131.09	–$499.82	–$4,287.86
–15%	$3,485.61	$4,804.19	$318.03
Baseline	$11,102.31	$10,108.19	$4,923.91
+15%	$18,719.01	$15,412.19	$9,529.79
+30%	$26,335.71	$20,716.19	$14,135.67
+45%	$33,952.41	$26,020.19	$18,741.56

For the scenario of new crop development opportunities, it has been assumed that new PBR varieties of mangoes are grown and yield considerably more (20–25 t/ha) than the KP mangoes that currently dominate production in the Katherine region, and that this is a key driver of the high gross margins compared with KP mangoes. Benchmarking suggests that these PBR varieties are currently yielding about 16 t/ha across northern Australia, but in many orchards the trees of these newer varieties are still maturing.

Intensive horticultural production involves high labour costs, especially those associated with picking, grading and packing operations in the shed. Labour costs for these harvest and postharvest activities typically represent 20 to 30% of total production costs and, therefore, have a significant influence on net returns from horticulture. Labour supply is sourced largely from backpackers who can obtain a second-year holiday visa if they work for 3 months in a regional area of Australia.

The majority of horticultural production from northern Australia is currently directed to supplying domestic markets, and the Katherine–Mataranka region is no exception. Consequently, transport costs per hectare of production are high (Table 6.5) for all crops and are a significant percentage of the total costs of production for watermelons and rockmelons, although they are not as high for mangoes (Table 6.6).

The flow of refrigerated produce from southern Australia to northern Australia into supermarkets and other food outlets allows horticultural producers to take advantage of otherwise empty refrigerated containers returning to major centres in southern and eastern Australia. In the supply chain model developed for this project, backloading was set at 100% (one-way transport costs only) to realistically represent costs incurred by farmers. On an individual case-by-case basis, freight rates for backloading can be negotiated, which are at times even less than the calculated 100% backloading rates. Without this supply of empty refrigerated containers returning to southern capitals, it is likely that transport costs would be prohibitive.

Given the sensitivity of prices to supply in the domestic market and the freight costs incurred in transporting produce to southern Australia, an opportunity potentially exists to develop export markets with the produce being shipped from a well-developed port such as Darwin. Currently, this is generally not feasible due to a combination of factors, including:

- the limited number of markets with export protocols already developed
- for some crops, the high costs associated with treatments for pests or disease before export (e.g. vapour heat treatment costs of approximately $14/tray for mangoes)
- a limited number of refrigerated container slots at Darwin port and the absence of refrigerated containers arriving to provide a cost-effective supply of empty containers for shipment
- insufficient volumes of supply to generate the shipping trade at regular enough frequency for perishable fruit or vegetables, hence the cost structure is currently prohibitive.

In the supply chain scenarios that are considered below, some alternative supply chain costs are assessed assuming that these current constraining factors have been addressed. Darwin port has the underpinning infrastructure to easily support significant growth in horticultural exports if the logistical and cost challenges can be overcome.

6.8.3 **INDUSTRIAL CROPS**

Gross margins for the industrial crops that were reviewed provide a distinct contrast in terms of prospective financial returns. Cotton is projected to generate a large negative gross margin, which is entirely due to the high costs of transport of raw cotton bales to a cotton gin for processing at Emerald in central Queensland. Transport costs for raw cotton are exacerbated by the high volume per unit weight of cotton bales, which means a Type 2 vehicle can only load 25.8 t of raw cotton, of which only between 35 and 40% is lint. For cotton to be grown successfully at a commercial scale, a gin would need to be much closer to Katherine. The impact of this on reducing supply chain costs is addressed below.

Commercial yields of sandalwood are yet to be proven, so the gross margins provided for this plantation crop are estimates that are based on investment analysis reports and other information provided by TFS

Corporation Ltd to the Australian Securities Exchange. The sandalwood gross margin that was derived for the Ord regional case study has also been applied to the Mataranka case study, with adjustments in variable costs to allow for differences in local management and irrigation costs. The main crop is assumed to be harvested at the end of a 15-year growth cycle, and the gross margin per hectare projection is based on an assumption that $1/15^{th}$ ha of crop is harvested and planted each year once the plantings have stabilised.

The price for sandalwood oil is currently approximately $4500/kg and is projected to further increase. However, a more conservative price of $3500/kg has been used in the present gross margin analysis. India has closed its sandalwood market and Australian production will dominate the supply of oil entering the world market because of the large areas planted. Projected yields of sandalwood are yet to be proven, but based on estimates of 8 t of heartwood per hectare after 15 years (assumes 80% survival rates of seedlings and 20 kg heartwood per tree), a gross margin of $65,000/ha was generated. This far exceeds the value for any other crop likely to be grown in northern Australia. Because of the exceptionally high value of the crop, and despite the distance involved, transport costs of heartwood to a processing plant at Albany are a very small proportion of total value of production or total plantation costs.

As for sandalwood, opium poppies have not yet been commercially proven in the Northern Territory. Commercial trials have been undertaken and it is believed that both yields and alkaloid content were similar to those achieved from crops grown in Tasmania, where the industry is well established. The gross margin analysis indicated higher returns (>$2200/ha) than for any other broadacre field crop. The freight costs per tonne are high because the poppy straw would have to be transported to a processing plant near Melbourne. Poppy straw has a low weight per unit volume and as such incurs relatively high costs per tonne shipped. Nevertheless, while the projected yields are quite low, the unit value per tonne of poppies is high and transport costs represent a modest percentage of overall production costs and of the total value of product. These attributes produce a similar outcome for poppies as that for growing chia in the Ord region.

6.8.4 DIFFERENT SUPPLY CHAIN OPTIONS AND GROSS MARGINS

In an effort to explore how gross margins might be improved, a range of different supply chain options were assessed, assuming different market options or the existence of local processing facilities. Table 6.8 summarises these different options using the same revenue and on-farm variable costs as shown in Table 6.5.

The altered supply chain scenario for maize is based on the assumption that the grain could be integrated into more intensive beef production systems associated with a new abattoir that has been established near Darwin. Associated with this assumption was a reduction in returns from maize grain for livestock feeding from $280/t to $250/t. This is based on the costs per unit of feed needed to generate a profit in intensive or feedlot situations. With transport costs reduced to $30/t, the projected gross margins increased to $863/ha.

In the peanut scenario, it was assumed that in addition to the existing drying facility, a new shelling plant and cold-storage facility were established in Katherine. This additional processing and handling infrastructure has the effect of significantly reducing transport costs of raw peanuts to Kingaroy. For the cotton scenario, it was assumed that a cotton gin was constructed in Kununurra to service the Ord region and that raw cotton from Mataranka was also transported there for processing rather than going to Emerald. This resulted in the projected cotton gross margins moving from being highly negative to positive (> $1000/ha).

For the horticulture scenarios, where refrigerated containers are shipped to Singapore fortnightly, freight costs are reduced significantly compared with the present road transport arrangement to Adelaide and, consequently, there is a modest increase in the projected gross margins. Much of the savings in freight costs are, however, offset by additional costs incurred for quarantine and inspection. The shipping freight costs assume that the refrigerated containers are cycled from Darwin to Singapore/Asia and that sufficient refrigerated slots have been established at Darwin port to store and power refrigerated containers. The interest in exploring this particular scenario was essentially not the impact of a potential reduction in freight costs per se, but to explore the feasibility of developing alternative markets where transport costs are more competitive with the costs of current supply chains. This is particularly relevant for regional scenarios of expanded horticultural production, where a key objective must be to avoid oversupplying the already highly volume-sensitive domestic markets (see Section 6.9).

Table 6.8 Change in gross margin for a range of selected crops in response to altered location of processing facilities or market destination

CROP	LOCATION FOR MARKET OR PROCESSING BASELINE	GROSS MARGIN ($/HA)	LOCATION FOR MARKET OR PROCESSING SCENARIO	GROSS MARGIN ($/HA)	ASSUMPTIONS FOR SUPPLY CHAIN SCENARIOS
Broadacre					
Maize	Adelaide	345	Darwin	863	Beef-feeding systems associated with abattoir
Peanut	Kingaroy	–101	Katherine	488	Shelling plant in Katherine
High value					
Mango – Plant Breeder's Rights varieties	Adelaide	11,102	Singapore	11,148	Regular Darwin to Singapore ship, cycling of refrigerated containers, additional quarantine costs
Watermelon	Adelaide	10,108	Singapore	12,528	Regular Darwin to Singapore ship, cycling of refrigerated containers, additional quarantine costs
Industrial					
Cotton	Emerald	–467	Kununurra	1,115	Cotton gin in Kununurra

6.9 Integrated scenario analysis: investment and supply chain options

The analyses in the previous sections have focused on individual crops, their production characteristics in the Mataranka region, farm gross margins and some supply chain options for those crops. In this section, two scenarios for agricultural production are examined at a regional scale, with implications drawn for the regional value of production, supply chain logistics and investment in infrastructure.

The regional-scale analysis assumed 2500 ha is available for irrigation, with 80% irrigation reliability. This scale of development is based on water allocations of 36 GL for the Tindall aquifer, of which 5 GL is high priority (90% reliability) and 13 GL is medium priority (70% reliability) (DNRETAS, 2011a). The remaining 18 GL is low priority and its reliability is such that its use is likely to only be opportunistic. Eighteen gigalitres of relatively high reliability water has the potential to irrigate around 2500 ha on the assumption that significant areas are used for horticulture, which typically uses 3 to 5 ML/ha. This assumes water is applied with about 85% efficiency (i.e. around 6 ML/ha available for crop use).

6.9.1 INVESTMENT AND SUPPLY CHAIN OPTIONS

Two scenarios were chosen to explore potential development of crop production systems for the Mataranka case study (Table 6.9).

Scenario 1

The first scenario assumes that existing horticultural crop production in the Mataranka region is scaled up to occupy the entire 2500 ha. The market orientation for this expanded horticultural production is for export out of Darwin rather than augmenting domestic consumption. The rationale for this scenario is twofold.

Firstly, domestic markets for the horticultural crops under study are already serviced at near full capacity for much of the year (the early season supply of mangoes from the Northern Territory being an exception), and export markets for key produce such as mangoes, watermelons and rockmelons will need to be established if supply from northern Australia is to significantly increase. Only around 5% of the total Australian production of cucurbits is presently exported, most of which is made up of rockmelons. Exports of watermelons only account for approximately 1.5% of the total annual production. Extremely small volumes (i.e. hundreds of tonnes) of rockmelon and watermelon are presently exported from the Northern Territory (HAL, 2012). About 8% of mangoes grown in Australia are exported. The vast bulk of mangoes that are exported from the Northern Territory are first transported to Brisbane or Sydney and then exported by air or sea freight, and mostly to Asian markets.

Secondly, there may be opportunities to reduce the total costs of production of horticultural crops by achieving lower freight rates, if this produce could be directly shipped to Asian markets from Darwin. The present arrangement for transporting horticultural produce from Katherine–Mataranka to southern capitals is reasonably cost-effective because of the competitive backloading rates that can be negotiated with transport companies for refrigerated trucks that would otherwise return empty on their southward journey. However, even with current production volumes there can be challenges in sourcing refrigerated transport during peak production periods. As current shipping volumes out of Darwin are below critical mass for economies of scale, freight costs to Asia are relatively high and these costs are exacerbated by the need to re-position empty refrigerated containers to Darwin. Discussions with shipping lines suggest that if volumes can be substantially increased, the current high costs will significantly decrease. Treatment requirements for pests associated with meeting protocols of importing countries can add significantly to costs of production (e.g. vapour heat treatment of mangoes are estimated to be $14/tray). Either more favourable export protocols will need to be negotiated or different, cost-effective approaches to postharvest treatment need to be developed.

Scenario 2

The second scenario comprises 1000 ha of horticultural production continuing to supply domestic markets, and 1500 ha devoted to broadacre crop production. Although there are a number of possible options for expanded broadacre crop production, the 1500-ha broadacre cropping component of the scenario is based on peanuts and maize grown in rotation. This permits two crops to be grown each year, which would increase overall returns with peanuts achieving relatively high gross receipts (c. $900/t at ~ 5 t/ha). The peanuts are grown in the wet season and maize is grown in the dry season. Simulations of this cropping sequence in Katherine have shown that this rotation can achieve combined yields that are 28% higher than the reverse rotation of wet-season maize and dry-season peanuts due to better maize production in the dry season (Chauhan, 2010).

Investment in processing infrastructure is required in the form of a drying plant, a shelling plant and a cold room for storage. This investment would allow peanuts to be shelled and stored before being shipped for final grading and value-adding in Kingaroy, with raw peanuts being able to be transported at a lower cost than peanuts in shells. Capital investment in a dryer, shelling plant capable of primary grading, and a cold room is likely to be around $3 million to $4 million. Rather than trucking maize to Adelaide at a cost of around $100/t, thereby eroding most of the profitability, it is assumed maize is incorporated as a stockfeed into intensive beef production systems located in the region. The opportunity for realising this possibility has been enhanced with the construction of an abattoir near Darwin by the Australian Agriculture Company.

Table 6.9 Scenarios used to explore implications of scaled-up production at the regional scale

CROP	AREA OF LAND (ha)	CROP YIELD/HA (t)	LOCATION FOR MARKET OR PROCESSING	ASSUMPTIONS FOR REGIONAL SCENARIO
Scenario 1 – export horticulture				
Mango	1250	22	Asia	Refrigerated transport to Darwin and then ship to Asia, assumes some additional costs associated with meeting quarantine requirements
Watermelon	1250	52	Asia/Middle East	Export to Asia and the Middle East, assumes some additional costs associated with meeting quarantine requirements
Scenario 2 – domestic horticulture and broadacre rotation cropping system				
Peanut	1500	4.7	Katherine and Kingaroy	Peanuts dried and shelled in Katherine and final processing in Kingaroy
Maize (rotation with peanuts)	1500	11.5	Darwin	Integrated as high-energy source in beef production systems associated with abattoir
Mango	500	22	Adelaide	Supplying southern domestic markets
Watermelon	500	52	Adelaide	Supplying southern domestic markets

Results

The regional-scale implications of the two scenarios operating at 2500 ha in the Mataranka region are presented in Table 6.10. Scenario 1, which focuses on intensive horticultural production, generated a gross value of production of nearly $130 million/year, while Scenario 2, which incorporates a larger area of lower-value broadacre crops produced $62 million/year in gross value of production. The intensive horticulture focus of Scenario 1 results in high regional costs of production when aggregated over 2500 ha. A significant component of this cost is attributed to labour issues, which provide both challenges and opportunities at a regional scale. A larger seasonal labour force in the region will have flow-on benefits for the local economy, but sourcing the additional labour could be challenging, especially if other regions in northern Australia are also looking to expand horticultural production.

Successfully expanding horticultural production will require the development of new export markets, both in Asia and beyond, given the price sensitivity of existing domestic markets to oversupply. Establishing a reliable and regular refrigerated container service from Darwin has the potential to significantly reduce freight costs compared with land transport costs to existing southern-based markets, assuming that increased volumes of supply can reduce the current high costs of shipping agricultural commodities to Asia (Table 6.11). A major challenge would appear to be developing a wider range of export markets and overcoming the various regulatory and quarantine barriers. These barriers include both the time that might be taken up to negotiate new export protocols (more than 10 years) and the potentially high costs of meeting quarantine requirements for the new markets (e.g. vapour heat treatment of mangoes).

In Scenario 2, a combination of establishing peanut processing and storage facilities in Katherine and being able to grow two crops in a single year in a cereal–legume rotation generated aggregate gross margins of more than $1300/ha and a total value of regional production in excess of $10 million from the 1500 ha of broadacre development. This scenario requires modest infrastructure investment in peanut processing and storage facilities and provides a diversity of enterprises beyond intensive horticulture. Integrating maize grain into regional beef production systems is not without its challenges (e.g. costs of feed inputs versus value of additional beef produced). However, if implemented in combination with accessing the new abattoir near Darwin, it has the potential to provide an alternative market for cattle to the current heavy reliance on the live cattle export trade.

Table 6.10 Influence of the two regional scenarios on total flows of product and value of production per year

CROP	TOTAL PRODUCTION (t)	TOTAL VALUE OF PRODUCTION ($)	TOTAL VARIABLE COSTS ($)
Scenario 1 – export horticulture			
Mango	27,500	70,675,000	55,815,000
Watermelon	65,000	58,500,000	42,840,000
Total	92,500	129,175,000	98,655,000
Scenario 2 – domestic horticulture and broadacre rotation cropping system			
Peanut	7,050	6,345,000	5,550,000
Maize	17,250	4,312,500	3,019,500
Mango	11,000	28,270,000	22,326,000
Watermelon	26,000	23,400,000	17,136,000
Total	61,300	62,327,500	48,031,500

Table 6.11 Effect of regular, cost-effective shipping routes to Asia on freight costs of the crops assessed in Scenario 1

CROP	BASELINE DESTINATION	BASELINE FREIGHT COSTS ($/t)	SCENARIO DESTINATION	SCENARIO FREIGHT COSTS ($/t)
Mango	Adelaide	235	Singapore/Asia	151
Watermelon	Adelaide	215	Singapore/Asia	146

Transport implications

Both development scenarios carry significant implications for the infrastructure required to transport goods either to southern and eastern markets/processors or to the port in Darwin. A major infrastructure requirement is for suitable transport vehicles (prime movers and trailers), along with refrigerated container storage at the port. From the supply chain analysis information presented in Appendixes 6.2 and 6.3 for each of the two scenarios, minimum fleet requirements were estimated for both refrigerated and non-refrigerated vehicles for each month, to accommodate the harvest and transport requirements of each crop. Vehicle requirements for all crops within a region were then aggregated into those requiring refrigerated and non-refrigerated transport. Vehicle requirements account for minor rest breaks en route to the destination and time required for loading/unloading, but do not account for major down time or maintenance. Figures 6.12 and 6.13 show the monthly gross vehicle requirements for Scenarios 1 and 2, respectively. Backloading currently plays an important role in meeting refrigerated freight demands for horticultural produce to southern and eastern markets and it will make up some of the vehicle requirements in Scenario 2. Backloading would be unlikely to be available for transport of peanuts to Kingaroy because the reverse trip is an uncommon freight route for the grain trailers. Note that the numbers in Figures 6.12 and 6.13 are based on the actual number of prime movers, and a Type 2 road train is classed as one vehicle. Therefore, the number of prime movers were multiplied by three (or by two for Type 1 vehicles) to give the projected number of trailers.

Vehicle requirements (both standard and refrigerated) were considerably less for Scenario 1 than for Scenario 2 due to the shorter average freight distance to Darwin compared with Adelaide, despite the lower production of mangoes and rockmelons in Scenario 2. Mangoes and rockmelons have adjacent harvest seasons, which spread the demand for refrigerated transport to six or seven months of the year and increases the use of expensive refrigerated trailers. For Scenario 2, there is backloading capacity from general freight trips from Adelaide to Darwin to service many of the 12 vehicle trips per day for mangoes and rockmelons. There would be some significant logistical challenges in the timing of available vehicles and refrigerated trailers to actually match the transport demand for mangoes and rockmelons, and this logistical challenge already causes some issues from the current levels of total production from the Katherine–Mataranka region.

In considering the results, it is important to note that the percentage of trips that could be serviced by backloading would drop substantially if other regional scenarios are taken into account. For example, if the scenario of expanded rockmelon production in the Ord (Scenario 2, Ord regional analysis Section 5.9.1) were to occur simultaneously with increased melon production in Mataranka, then 63 Type 2 refrigerated vehicles would be required, and this far exceeds the existing backloading capacity from the region. This is likely to lead to increased transport costs under future scenarios of increased horticultural supply because of a requirement for an expanded fleet of dedicated vehicles above that comprising the existing backloading capacity. Clearly, the flow-on supply chain consequences of increasing production to supply distant domestic markets needs to be considered in any decisions on expansion. This suggests that for expanded horticultural production, substantial attention should be focused on Scenario 1 – that is, on developing export markets and direct shipping routes from the north that reduce costs of production and avoid oversupply issues in domestic markets. Investment needs that are associated with this option are discussed below.

Transport of shelled peanuts to Kingaroy would require a fleet size of nearly six Type 2 vehicles to provide two trips per day from Mataranka (3-day turnaround time). This trailer and vehicle fleet requirements represent much less of a constraint for expanding production of peanuts and maize, compared with produce requiring refrigerated transport, due to lower costs and the ability of the transport assets to migrate between regions and crops to take advantage of different harvest seasons.

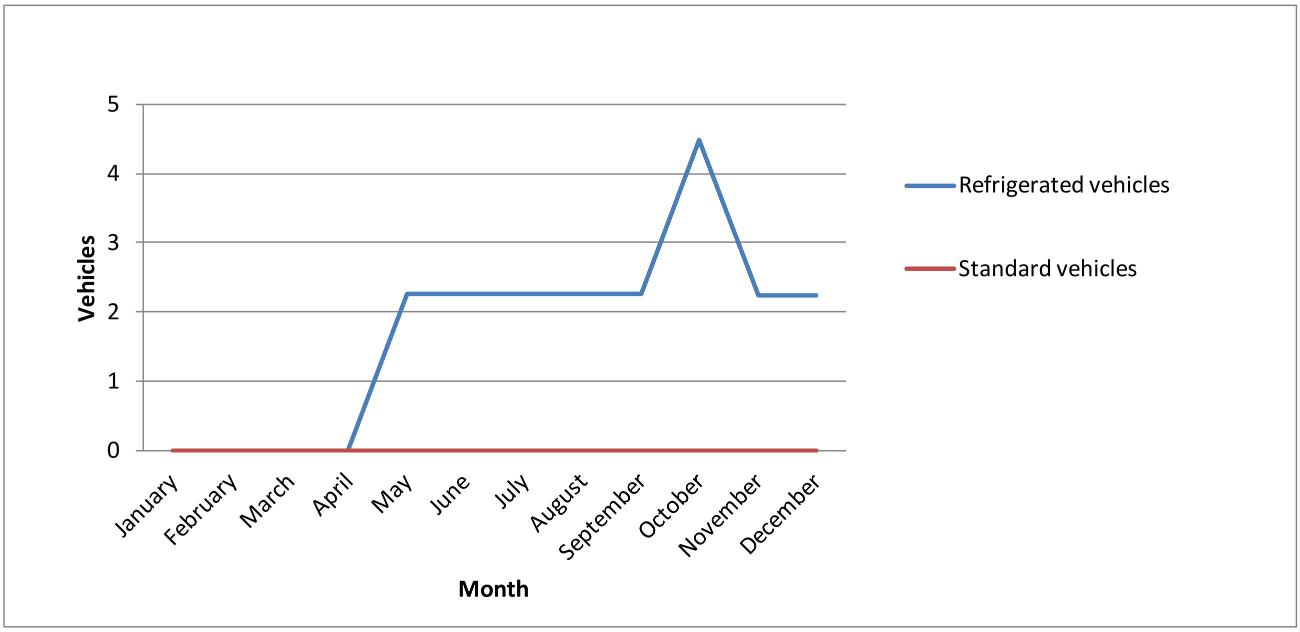

Figure 6.12 Vehicle requirements for 2500 ha of cropping in Scenario 1

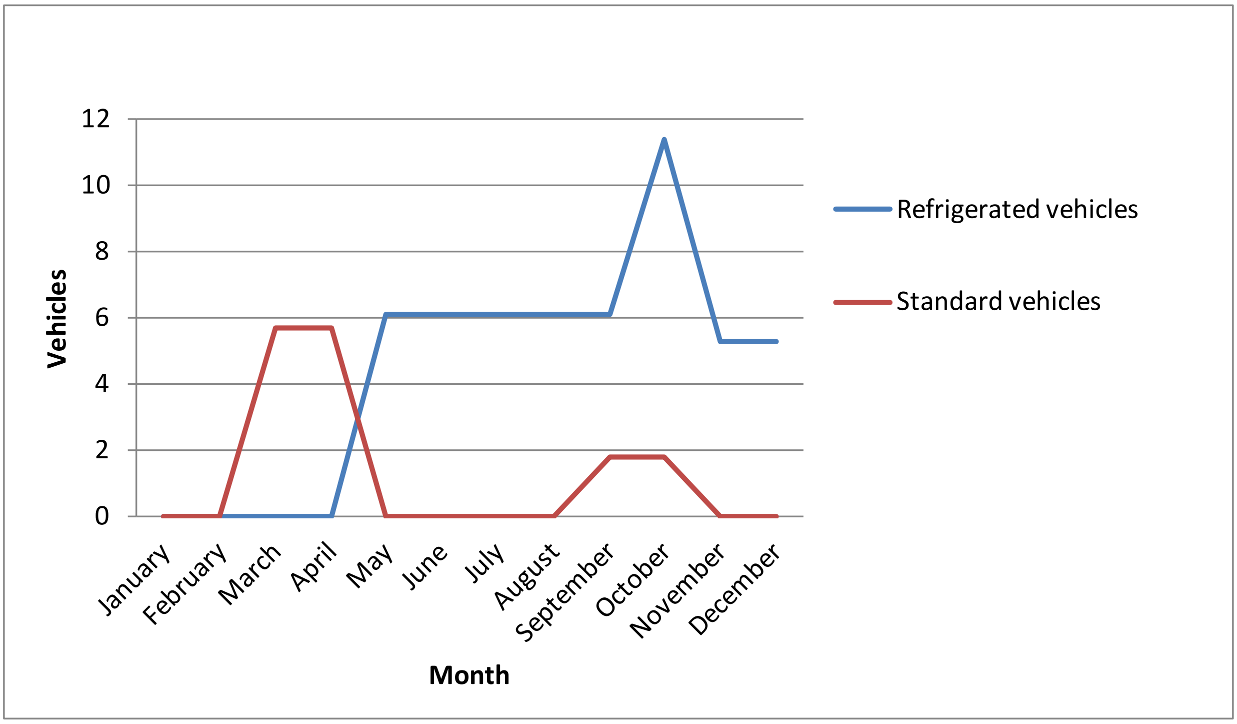

Figure 6.13 Vehicle requirements for 2500 ha of cropping in Scenario 2

Infrastructure

The two scenarios of modest agricultural expansion (2500 ha) in the Mataranka region suggest that the present level of hard infrastructure is not a major constraint, especially in the context of expanded horticultural production. The water supply is in place and, because it is entirely based on extracting groundwater, the infrastructure costs occur at the farm scale in the form of bores and pumps. There is no requirement for large-scale and capital-demanding water storages and distribution networks.

There are good-quality roads between Mataranka and Darwin, and Mataranka is well located for transport of refrigerated horticultural goods to Adelaide and Melbourne. Horticultural production occurs during the dry season so there are usually few interruptions to the road network during harvest, except for occasional extreme rainfall events in southern Australia during winter and spring. The road network to the east through Queensland is in a much poorer condition and, in addition to the costs this can impose through inefficiencies and increased vehicle maintenance, there can be issues with damaged fruit. Clearly, improving the road network and its condition would provide benefits, but there is no single stand-out piece of the road network that specifically constrains the supply chain from Mataranka.

As production expands to take up any potential growth opportunities in domestic capacity, there will need to be investment in vehicle infrastructure as existing backloading capacity for refrigerated transport reaches capacity during periods of peak production. There is still considerable backload capacity in the dry-transport vehicle fleet.

Darwin port is well serviced by the road network into Darwin and has the berthing capacity and footprint to easily accommodate expansion in agricultural production for export. Refrigerated slot capacity at the port would need to be increased to provide adequate storage while produce awaits loading on to ships.

The biggest need to support expanded horticultural production in this region is for soft infrastructure investment in:

- developing export markets and addressing the associated market access requirements. As there are only limited growth opportunities in domestic consumption of horticultural produce, expanded production on any significant scale will need to be considered in the context of exploiting export markets. However, developing export markets (excluding various informal and unregulated 'grey channel' markets) requires considerable long-term investment in areas such as trade protocols,

technical support for the development of cost-effective quarantine treatment procedures or products that minimise the need for such treatment (e.g. green mangoes). Given the costs of production in Australia, any plans to exploit export market opportunities will best be addressed to higher-value markets
- developing reliable and regular shipping routes from Darwin to Asia and the Middle East that can cost-effectively freight refrigerated containers. The current supply chain of refrigerated goods into Darwin is not compatible with outbound shipments (i.e. few refrigerated containers presently come into Darwin via ship and the repositioning costs for containers is high). Analysis and exploration of opportunities for supply chains that involve return freight is required (e.g. use of refrigerated containers for dry goods on return journeys)
- increasing yields and reducing year-to-year variability in production and quality of produce. Horticulture is particularly exposed to high variability in production due to pests, diseases, extreme weather events at times of flowering and harvest. Developing new varieties and agronomic management approaches to minimise this variability will be important in guaranteeing supply, particularly to export markets. In the case of mangoes, PBR varieties provide two to threefold the yield of traditional varieties such as KP, and continued investment in increasing productivity of product is required for the industry to remain competitive.

Although not possible to formally address them in this study, some other infrastructure investment possibilities that are relevant to the horticulture industry relate to increased mechanisation in harvest and shed operations to reduce labour costs. These affect a significant component of the costs of production, and their address may overcome challenges in sourcing labour at critical times (e.g. harvest).

As with other regional case studies examined in this project, this analysis has highlighted the benefits from having access to local processing facilities for broadacre crops. Transport costs of raw product to distant destinations can seriously erode profitability. For the Mataranka case study, a relatively modest investment of $3 million can provide the necessary processing facilities to service a 1500-ha peanut crop. The other form of local ‘processing’ considered in this study is the use of grain in intensive regional beef production systems, with finished stock slaughtered in the new abattoir in Darwin. This development would provide a piggyback opportunity for regional grain production, and will require some investment in feedlot type facilities as part of an integrated crop–livestock system or be operated independently by specialised beef enterprises.

An alternative option is to avoid infrastructure costs of processing facilities by developing broadacre crops that are relatively high value and low volume, which means the product can be transported cost-effectively. Opium poppy is an emerging example of a crop that essentially meets these criteria.

6.9.2 **RISK ANALYSIS**

The analysis for the two regional development scenarios has used averages of yields and prices, and is based on historical data and simulated crop yields. Future investment also needs to be based on a good understanding of risk. Price risk is one variable that needs to be considered when making investments. ABARES produces market outlooks for a range of commodities, which are shown in Table 6.12 for the crops that were considered for the two scenarios. These market outlooks are based on medium-term drivers and as such do not capture shorter-term year-to-year variability. This is highlighted in Figure 6.14, which illustrates the market outlook for mangoes over the next 10 years with the previous 10-years price data also superimposed to illustrate the pattern of interannual variability that might be expected beyond the longer-term price trend.

Table 6.12 Ten-year forward price projections for the crops used in the two regional scenarios
Numbers represent real domestic prices (in 2012–13 dollars).

CROP	UNIT	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Maize	$/t	354	310	324	326	313	301	360	359	357	356
Peanut	$/t	1006	1068	1069	1070	1096	1095	1093	1092	1090	1089
Mango	$/kg	3.1	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Watermelon	$/kg	1.17	1.24	1.24	1.24	1.27	1.27	1.27	1.27	1.27	1.26

Source: Data provided by ABARES

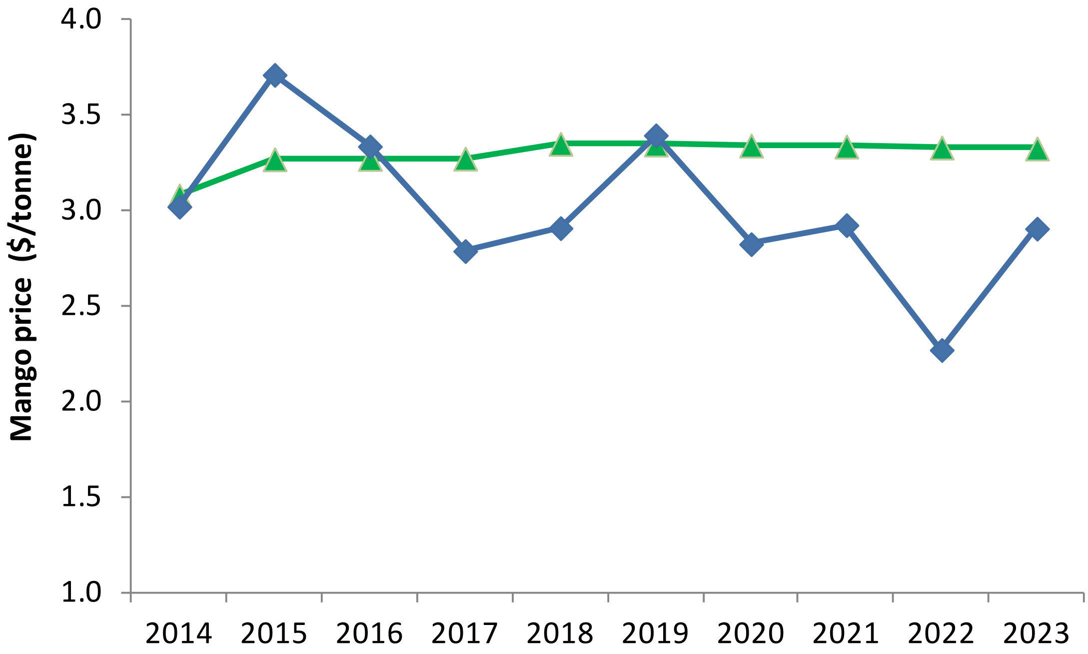

Figure 6.14 Ten-year forward projection for the price of mangoes (green line) with previous 10 years (2004 to 2013) of prices (blue line) superimposed to highlight historical year-to-year price variability

As indicated earlier in the gross margins section (Section 6.7), price variation can combine with yield variation to produce gross margins that can vary significantly between years. In terms of future risk, it is useful to understand how these two primary drivers of economic returns might influence risk. Figure 6.15 shows a distribution of gross margins for high-yielding PBR variety mangoes in the Mataranka region that is based on simulated yield variation and historical price variation, based on 10 years of ABARES data. For this analysis, a scenario has been used involving export of produce via Darwin port. The yield distribution was based on a most likely yield of 22 t/ha and a low (20th percentile) and high (80th percentile) of 14 and 26 t/ha, respectively. The 20th percentile is the low performance that would be expected every 1 in 5 years. The price and yield variability results in a large spread for the distribution of gross margins for mangoes. The median gross margin is approximately $10,000/ha. However, there is a 30% chance of observing a yield or price combination that would generate a negative gross margin. The large losses that are predicted to occur as a result of low prices would be avoided to some extent by growers making decisions to not harvest the crop and thus avoiding the large costs associated with harvest, packing and freight. This scenario is not unusual in the horticultural sector when market prices are depressed.

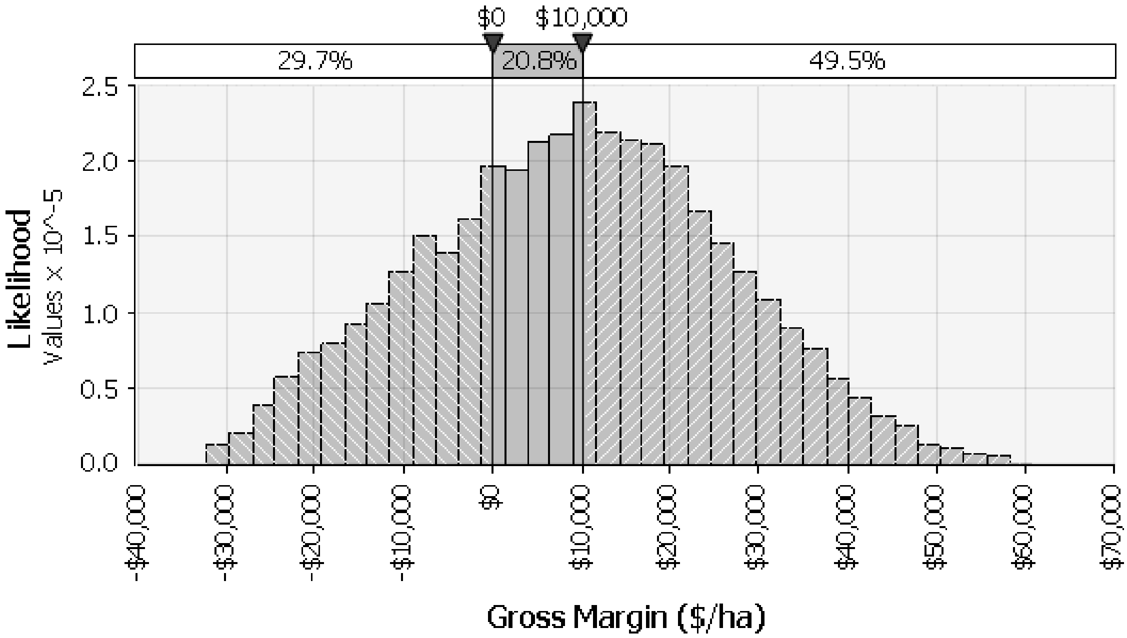

Figure 6.15 Variability in gross margins for mangoes (Plant Breeder's Rights varieties) in Mataranka due to yield and price variability

The historical analysis of agricultural developments in northern Australia (Appendix 3.1) identified several factors that have inhibited the success of some attempts to become commercially sustainable. One of these was to have access to sufficient capital reserves to allow new developments to get through the first few years of establishment and scaling-up to reap advantages of economies of size and throughput. In the start-up phase it is essential to provide time to learn and adapt agronomic management to suit local conditions without the pressure of striving to achieve the unrealistic yield projections that often underpin pre-development cash flow and investment analysis. Also, there is no guarantee that the climate will be kind or that prices will be average or above average. An additional consideration for plantation and some industrial crops is the effect of delayed income while trees mature and begin to yield produce.

The following analysis builds on the variability presented in the gross margin analysis to consider the business vulnerability to a sequence of better and poorer years and the level of debt. Similar to the gross margin analysis, this risk analysis does not specifically cover farm profit because it does not include fixed or overhead expenses such as depreciation for equipment and buildings. However, the risk being assessed will directly impact on prices and yields, which are adequately captured by changes to the gross margin projections.

Figure 6.16 illustrates the effect of different starting conditions for debt and sequences of good or bad years with a 7% interest rate. The two opening debt levels of $20,000/ha and $30,000/ha assumed that the land had to be purchased, cleared and developed, and that associated irrigation and machinery had to be purchased. The actual number of better and poorer years that were experienced during the 15-year period were the same for the 'better years early' and 'poorer years early' sequences, but the sequence in which they occurred were altered to create the contrasting runs of years. A random sequence was also generated; this included the shock of 2 'failed' years of yield. A failed year was defined as 20% of the median yield and is simulated to represent an extreme weather, pest or disease event. In all cases the tree crops were assumed to reach maturity in the seventh year from planting. Years 4, 5 and 6 were assumed to begin producing saleable fruit with yields of 45%, 68% and 91% of the yield in the seventh year, respectively.

In all scenarios the level of debt more than doubled before the planting began to produce a yield in the fourth year. The accumulation of debt before any income was produced exacerbated the effect of interest payments and the importance of paying down the debt as quickly as possible. The most favourable sequence represented by the 'good years early' scenario greatly reduced the debt and ongoing level of interest payments. The ability to reduce the principal as early as possible reduces the ongoing cost of interest for later years when yields are assumed to be lower. 'Low debt, better years early' reduced the debt to zero by the end of year 8. In contrast, the most unfavourable 'poorer years early' scenario led to further debt for another 4 years after maturity of the planting. This means that although yields increased, more of the income from later years went towards meeting greater interest payments. The effect of different levels of starting debt can be seen in these scenarios in the level of outstanding debt at the end of the period of analysis. The 'low starting debt, poorer years early' scenario had paid off all debt by year 15. In comparison, the 'medium starting debt poorer years early' scenario began with a debt of $30,000/ha and had a terminal debt of approximately $24,000/ha at the end of year 15.

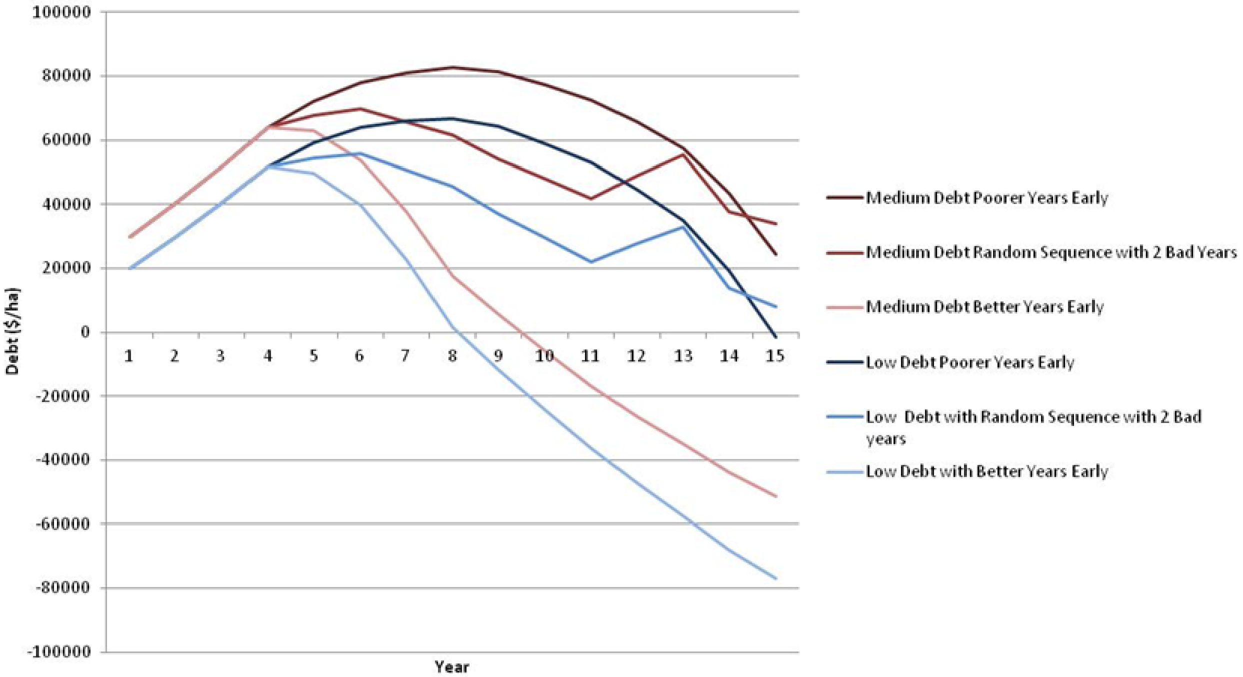

Figure 6.16 Effect of starting conditions of debt and the run of poorer or better years on the level of debt for mangoes in Mataranka

The level of debt was also sensitive to any shocks in the crop yield. The random sequence of yields and prices shows that debt was repaid at a steady rate until the shock of two bad years in years 12 and 13. This pushed the debt onto a similar trajectory as 'poor years early' in the investment cycle and meant that the debt was still not fully repaid at the end of the 15-year period of analysis.

This simple analysis highlights that in addition to good planning and management, a certain element of good fortune is needed in the run of years that are experienced in the start-up phase of any capital-intensive agricultural development.

6.10 Regional economic analysis

6.10.1 **MATARANKA ECONOMY**

The Katherine-Mataranka region lies in the Northern Territory, and is defined as the Statistical Local Areas of Victoria, Katherine, Elsey and Mataranka. Under the reference case, economic activity in Katherine-Mataranka is projected to grow at 4.6% a year, which compares favourably with the Northern Territory GSP growth rate of 3.5% and the projected GDP growth rate of 2.7%. Agriculture, mainly livestock, is the largest industry in the region although mining is also important.

6.10.2 **SCENARIO DESCRIPTION**

Each scenario is modelled in two phases—construction and production. Table 6.13 reflects a stylised version of the scenarios for Mataranka described earlier as modelled in AusRegion. The benefits of the government investment in ports and roads benefits various agricultural industries with transport costs assumed to fall by 20% in both scenarios. The investment in local peanut processing facilities benefits these producers through reduced transport costs.

Table 6.13 AusRegion stylised scenario description for Mataranka

Development parameter	Unit	Crop	Scenario 1	Scenario 2
Government investment	$m		4	4
Private Investment	$m	Grains		20
	$m	Horticulture	40	16
	$m	Total private	40	36
Total Investment	$m		44	40
Land supply	’000ha		2.5	2.5
Transport costs	%	Grains		-30
	%	Horticulture	-20	-20
Yield (%)	%	Horticulture	30	30

a Assumed change in transport costs arising from investment. **b** Assumed increase in sectoral land productivity arising from private investment**.**

6.10.3 **REGIONAL ECONOMIC OUTCOMES**

The proposed investments will affect economic activity, employment and exports in the Mataranka region and have consequences for the Northern Territory and Australian economies. Table 6.14 shows the regional economic impacts of Scenarios 1 and 2 at 2029-30.

Table 6.14 Economic impacts for Mataranka at 2029–30, % deviation from the reference case

	Unit	Scenario 1	Scenario 2
GRP	%	5.4	6.7
Employment	%	3.7	5.4
Real wages	%	0.6	0.6
Exports	%	11.3	9.2
Sectoral output			
Agriculture	%	37.3	28.0
Mining	%	-1.3	-1.8
Other	%	0.6	0.6
Northern Territory GSP	%	0.4	0.4
GDP	%	0.0	0.0

The results for Mataranka are very similar for Scenario s 1 and 2. In both scenarios agricultural output is projected to be around 10% higher than the reference case at 2029-30 leading to GRP and employment to be around 2.7% higher than the reference case at 2029-30. Exports from the region are 6.7% and 5.4% higher than reference case levels in Scenarios 1 and 2, respectively. The relatively large growth in exports derives from the large share of the economic activity in Mataranka that is devoted to agriculture and the export orientated nature of agricultural investment.

Economic activity in the Northern Territory is projected to be marginally higher than reference case levels in both scenarios.

6.11 References

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7 FLINDERS AND GILBERT REGIONAL ANALYSIS

7.1 Summary and key messages

- The Flinders and Gilbert region has the capacity to supply water to irrigate around 45,000 ha through a combination of large-scale in-stream water storages (Gilbert) and on-farm storage in ring tanks (Flinders).
- The water infrastructure required to undertake irrigation on this scale is not yet available and this is a fundamental constraint on further development.
- A tropical, semi-arid climate with a rainfall pattern that is highly variable from year to year will constrain the reliability of water available for irrigated agriculture. Wet-season rainfall may in some years limit farm operations and the ability to grow summer crops, especially on clay soils in the Flinders region. Most summer crops can be grown, however, during the relatively mild dry season. Tropical perennial crops, such as sugarcane and mangoes, are well suited to the Gilbert region.
- Using existing domestic supply chains and infrastructure, gross margins were assessed for 13 different crops. With the exception of cassava, all crops generated positive gross margins, although these varied from marginally positive to more than $10,000/ha for high-value crops such as bananas and sandalwood.
- Horticultural crops can generate high returns but gross margins are very price sensitive and, when coupled with high input costs, gross margins can fluctuate from highly positive to highly negative over periods of weeks. Freight costs represent 13 to 22% of the total costs of production and labour costs associated with harvesting and packing represent a further 20 to 30% of the total cost of production.
- Gross margins for relatively low-value broadacre crops, with the exception of chia, were less than $1000/ha, although this is higher than for the same crops grown in other regions in northern Australia, primarily due to the closer proximity of markets. This meant that transport costs were relatively lower, representing 6 to 20% of the gross value of production. Chia, a high-value and low-volume crop, produced higher gross margins even though it requires transporting to Melbourne for processing.
- For industrial crops, sugarcane generated gross margins of around $1400/ha, based on the presence of a local sugar mill. The gross margin for cotton was around $1200/ha in the Flinders region but it was less than half that in the Gilbert region because of the freight costs associated with transporting raw cotton to Emerald in central Queensland where the nearest gin is located. Hemp and guar generated modest gross margins on the assumption that processing facilities were located in Townsville or Ayr. Cassava generated highly negative gross margins because of the very high transport costs to the nearest (existing) processing facility in Dalby. Sandalwood generated extremely high gross margins ($65,000/ha) but because it is a long-lived plantation crop the projected returns are not realised for many years (~15) after planting.
- Using supply chain scenarios of (a) local processing mills/gins, (b) locally developed supply chains (e.g. maize grain integrated into intensive beef production systems) or (c) export horticultural markets developed via Cairns, gross margins for most crops significantly increased. This was especially the case for developments for which processing facilities could be established within or close to the Flinders and Gilbert region – that is, a cotton gin in Charters Towers and a bioenergy refinery to process cassava in Ingham.
- Two regional development scenarios of 45,000 ha of irrigated production were explored. Scenario 1 involved the siting of a cotton gin at Charters Towers, with significant areas of cotton grown in both the Gilbert and Flinders regions. A major expansion in mango production and a range of other broadacre crops were explored in the Gilbert region. Scenario 2 was based on the

entire 30,000 ha available in the Gilbert region going into sugarcane production, with a mill established in Georgetown, while various broadacre crops were considered for the Flinders region. No horticulture was included in this second scenario.

- Both scenarios generated high gross values of production at the regional scale: Scenario 1 $0.31 billion/year and Scenario 2 $0.2 billion/year. The significant value generated from mangoes in the Gilbert region was the main reason for the higher production value in Scenario 1, although that was dependent on developing new export markets with product being shipped via Cairns.
- Both scenarios required significant investment in infrastructure in the form of processing facilities. A sugar mill capable of producing 300,000 t/year of sugar with co-generation and potential to produce ethanol would require a capital investment of $400 million, a cotton gin capable of processing upwards of 200,000 bales/year would require an investment of $40 million and expanded capacity of rice milling and pulse-processing facilities and associated grain/pulse storage would require a $25 million investment. Expanded horticulture in the Gilbert region with shipping via Cairns would need additional refrigerated container slots established at Cairns port. Additional bulk storage capacity (155,000 t) at Townsville port would be required to store an additional 300,000 t of sugar produced in Scenario 2.
- Both development scenarios require an additional supply of transport vehicles in the region. Scenario 1 requires around 40 vehicles/day for a few months of the year, while Scenario 2 requires over 70 vehicles/day when sugar is being transported from Georgetown to Townsville and when rice is being transported at the same time from Richmond to Ayr. This will require significant new investment in vehicle infrastructure, whether by expansion of existing capacity and hubs or via establishment of new hubs. The existing road network should be able to cope with these additional vehicles, but is likely to require some ongoing upgrades and increased maintenance.
- Before any investment is made in supporting infrastructure of processing facilities, storage, vehicles or road/port upgrades, there will be a need for capital investment in the underpinning water infrastructure. The Flinders and Gilbert Agricultural Resource Assessment has made some estimates of the capital costs required for the water infrastructure that is necessary to provide the volumes of water to irrigate 30,000 ha in the Gilbert region and 15,000 ha in the Flinders region. In the Gilbert region, construction of the Green Hills and Dagworth dams, associated storages, main irrigation channels, access roads and pumping capital costs were estimated to be around $1 billion. In the Flinders region, off-stream ring tanks are more suitable, which means that the capital costs would occur at the farm scale and be geographically dispersed across the region. This is estimated to cost in the range of $90 million to $180 million, depending on the types of crops planted and their water demands.
- The investments proposed for the Flinders-Gilbert region are projected to increase regional economic welfare by between 11 and 16 per cent relative to the reference case.

7.2 Description of region: existing agriculture, scale of irrigation and development

The first colonial expeditions in the Flinders and Gilbert regions took place in the 1850s and 1860s. The early explorers recognised the agricultural potential for grazing, particularly on the grassy plains of the Flinders catchment. Pastoralists quickly followed these early expeditions, taking up leases in the 1860s and 1870s.

Mining also played an important part in the early history of European colonisation in both regions. Gold was discovered in the Gilbert River region in the late 1860s and copper deposits were found in the Mt Isa and Cloncurry regions in 1867. This mining activity brought with it further settlement and development for agriculture.

Agriculture in the form of livestock grazing remains the dominant land use in both regions, although mining makes a higher contribution to the total value of economic activity. Table 7.1 shows the economic contribution from agriculture in the two regions and also highlights the small role that cropping plays. However, the prospects for irrigated cropping have been raised at various times in the history of both regions. In the Flinders region the treeless, fertile black soils have been identified as suitable for cropping, but the lack of a reliable water source has hampered development of large-scale irrigation. Small-scale irrigation is practiced mainly for hay production, and a range of other food and industrial crops have either been trialled or suggested as being potentially suitable for the region.

Irrigation development opportunities have been raised more frequently over the years for the Gilbert region because of the large and somewhat more reliable flows that occur in the region's rivers during the annual wet season. Market gardens along the Gilbert River were established early in the region's history to provide fresh produce to the mining population in the late 1800s and early 1900s. At the end of the 20th century, the possibility for irrigated agriculture was more formally assessed and resulted in a proposal to develop Green Hills Dam. However, prospects of developing this dam were ruled out in the Gulf Water Resources Plan, which was implemented in 2007, on the basis that an economically and ecologically sustainable use could not be identified. In 2009, a scoping report identified the economic opportunity for irrigated agriculture, based on a scenario of a water storage providing 300 GL with an annual yield of 100 GL (Mason, 2009). Over recent decades, horticulture – mostly mangoes – and hay production have been developing along the Gilbert River at a modest scale.

Table 7.1 Economic contribution from agriculture in shires in the Flinders and Gilbert catchments
Data is from the (ABS, 2012) and is categorised by local government areas within the catchments.

AGRICULTURAL ACTIVITY	ANNUAL VALUE ($million)						
	Etheridge	Carpentaria	Flinders	Richmond	McKinlay	Cloncurry	Total
Livestock (cattle)	$117.1	$116.2	$87.1	$69.8	$151.6	$72.4	$614.2
Hay production	$0.4	$0.7	$2.1	$4.0	$0.9	$0.0	$8.1
Horticulture (mangoes)	$0.5						$0.5

A detailed resource assessment of the Flinders and Gilbert catchments was released in December 2013 (Petheram et al., 2013c). Key findings from this assessment of soil and water resources, agricultural potential, social and economic implications and ecology include the following:

- Despite their close proximity, the Flinders and Gilbert catchments differ significantly in their physical characteristics and, as a consequence, the extent to and methods by which agricultural development might occur.
- In the Flinders catchment, farm dams could support 10,000 to 20,000 ha of irrigation in 70 to 80% of years; although irrigation may not be possible in very dry years. The precise area under irrigation in any year will vary depending on factors such as irrigation efficiency, water availability, crop choice and landholders' appetite for taking risk.
- In the Gilbert catchment, large in-stream dams could support 20,000 to 30,000 ha of irrigation in 85% of years. Again, the precise area under irrigation in any year will vary depending on factors such as irrigation efficiency, water availability, crop choice and local appetite for risk.
- In-stream dams enable more reliable irrigated production than farm dams, because they can more easily carry over captured water from one year to the next.
- Significant water extraction would, in the downstream environment, amplify the environmental and social challenges associated with dry years and would have impacts on commercial and recreational fishing catches that have not been quantified.

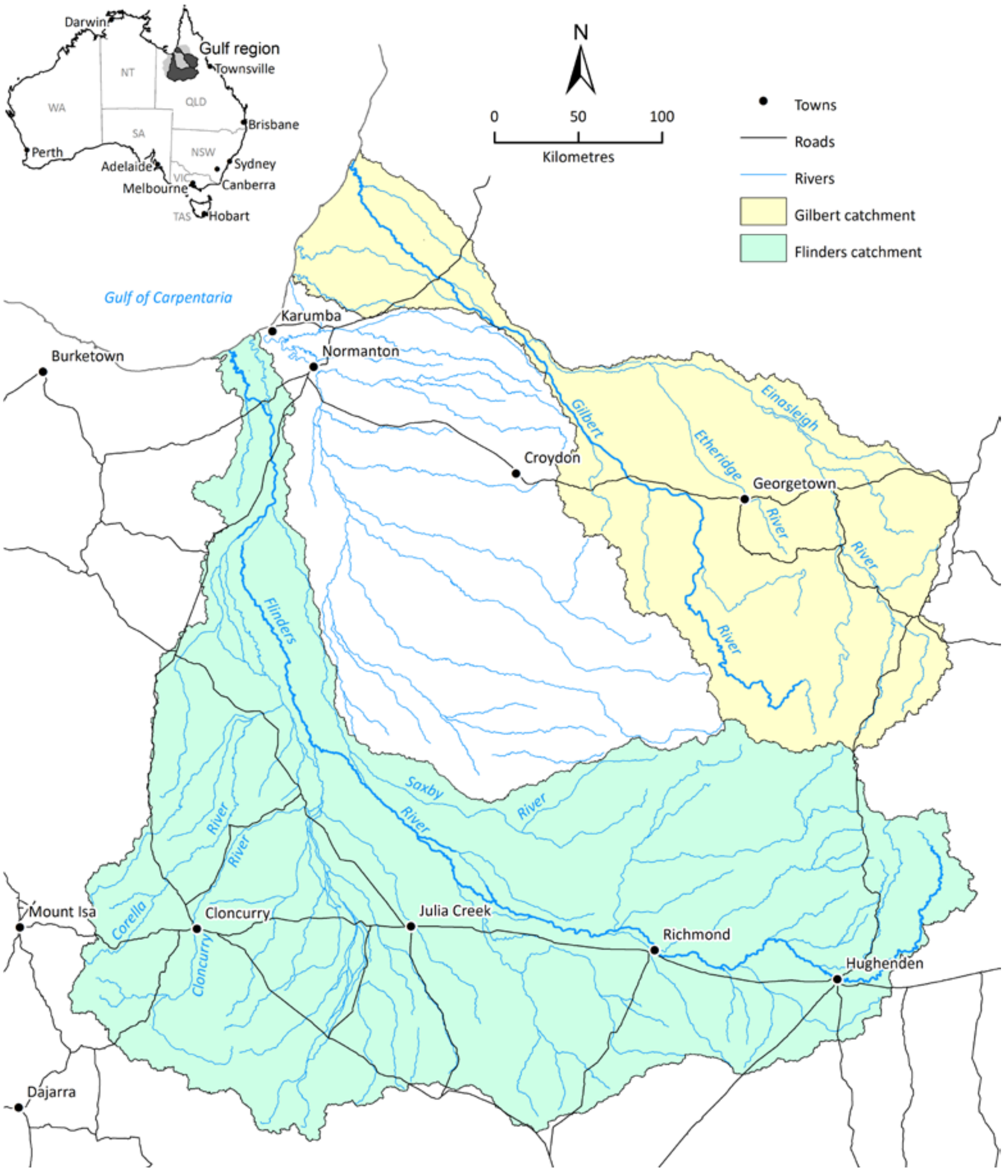


Figure 7.1 Map of the Flinders and Gilbert catchments
Source: Petheram et al. (2013c)

As identified in Chapter 3, development in northern Australia is constrained by infrastructure and labour availability. New, irrigated agricultural developments will need to carefully consider supporting infrastructure, and the associated requirements for labour and services. Both the Flinders and Gilbert regions have experienced a significant fall in their local population over the last decade (Table 7.2), and labour availability for agricultural development is likely to pose a particular challenge without the appropriate incentives.

Table 7.2 Major demographic indicators for the shires in the Flinders catchment in 2011

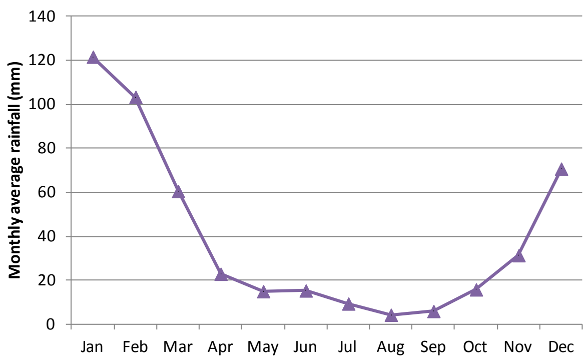
INDICATOR	UNIT	ETHERIDGE	CARPENTARIA	FLINDERS	RICHMOND	MCKINLAY	CLONCURRY	QLD
Total population in 2011		894	2,054	1,792	827	1,050	3,229	4.3M
Total population in 2001		1,474	4,844	2,191	1,050	1,387	4,828	3.4M
Percentage change in population, from 2001 to 2011	%	–39.3	–57.6	–18.2	–21.2	–24.3	–33.1	28.5
Indigenous population, as percentage of total	%	3.5	36.8	6.2	5.7	4.0	21.8	3.6
Median age	y	43	37	40	37	33	34	36
Change in median age, from 2006 to 2011	y	4.0	2.9	5.4	4.7	–2.8	2.4	0.6
Unemployment rate, percentage	%	3.6	5.7	2.9	2.3	1.2	4.8	6.1
Median weekly household income	$	$724	$997	$935	$961	$1152	$1463	$1235

Source: ABS (2011)

7.3 Climate: existing and future trends

7.3.1 CURRENT CLIMATE

The Flinders and Gilbert regions experience a tropical semi-arid climate, with 90% of rainfall occurring from December to April (left parts of Figures 7.2 and 7.3). Average annual rainfall is 494 mm/year for Richmond (Flinders region) and 780 mm/year for Croydon (Gilbert region), so even though the two regions are geographically quite close to each other the annual average rainfalls are quite different. The short growing season combined with unreliable dry-season rainfall means that dryland cropping is too risky to be considered as a regular activity in the Flinders region. In the Gilbert region, even though wet-season rainfall is considerably higher, dryland cropping options will be mostly opportunistic. The lack of rainfall in the dry season means that crops grown in this period will necessarily rely entirely on irrigation, sourced from surface storages, permanent streams or groundwater. Potential evaporation rates are also high (2500–2800 mm/year – Figures 7.2 and 7.3), with a strong seasonal cycle that has implications for crop water demand under irrigation, particularly in the late dry season.



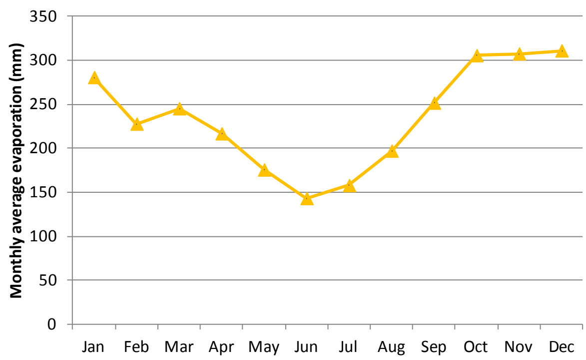
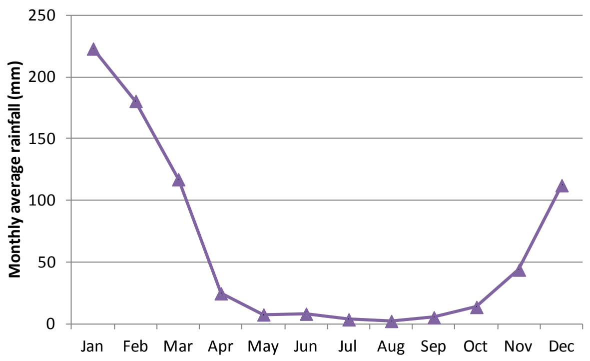


Figure 7.2 Monthly average rainfall (left) and pan evaporation (right) at Richmond



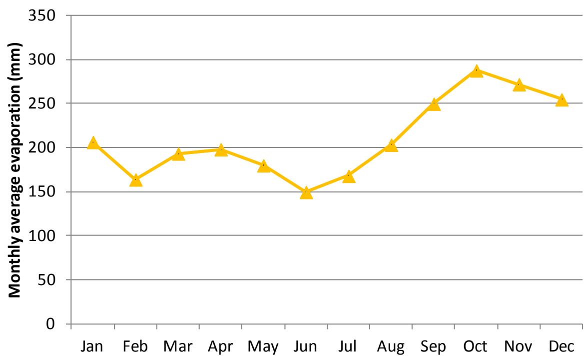


Figure 7.3 Monthly average rainfall (left) and pan evaporation (right) at Croydon

The Flinders and Gilbert regions both experience high year-to-year variability in rainfall, as measured by the coefficient of variation (CV) for annual rainfall. This is calculated as the standard deviation of mean annual rainfall divided by the mean annual rainfall. The higher the CV, the more variable is the mean annual rainfall. For both Richmond and Croydon this value is 0.39, which is high in relation to the total amount of rain received compared with agricultural regions in southern Australia.

In addition to high year-to-year variability, both Richmond and Croydon experience distinct sequences of wet and dry years (Figures 7.4 and 7.5). This rainfall pattern is strongly influenced by the El Niño Southern Oscillation (ENSO), with rainfall being well below average in El Niño years and well above average in La Niña years. The pattern of runs of wet and dry years will impact on the reliability of water storages for irrigation unless those storages have a capacity that is many times more than the annual usage of water.

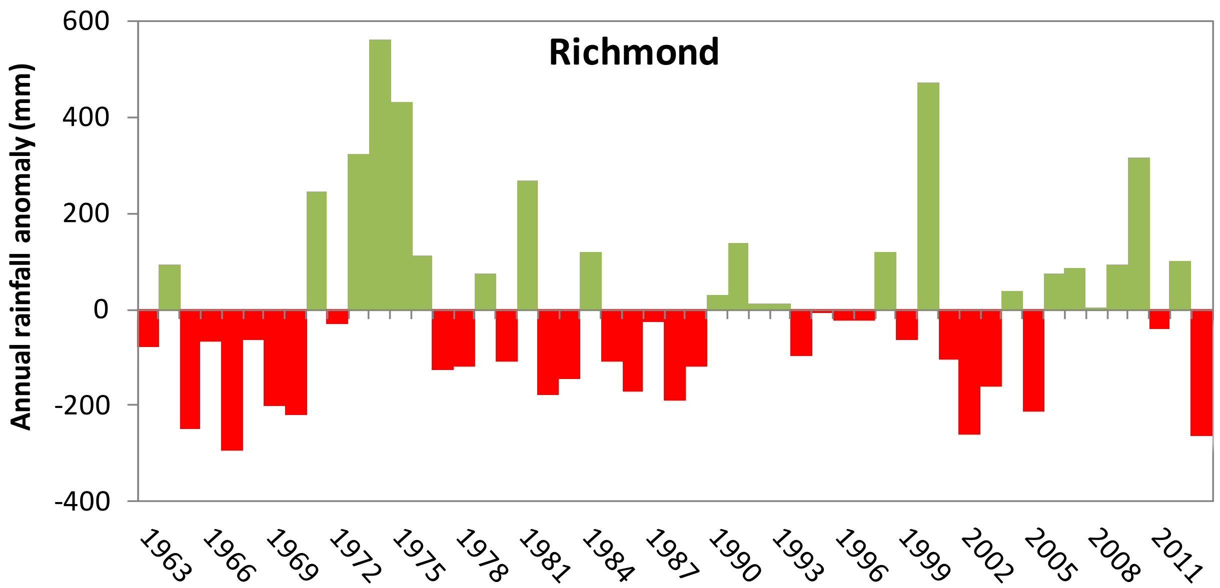


Figure 7.4 Runs of wet and dry years at Richmond, measured by the difference in mean annual rainfall from the long-term average (1963 to 2013)

Wet years are denoted by the green bars and dry years by the red bars.

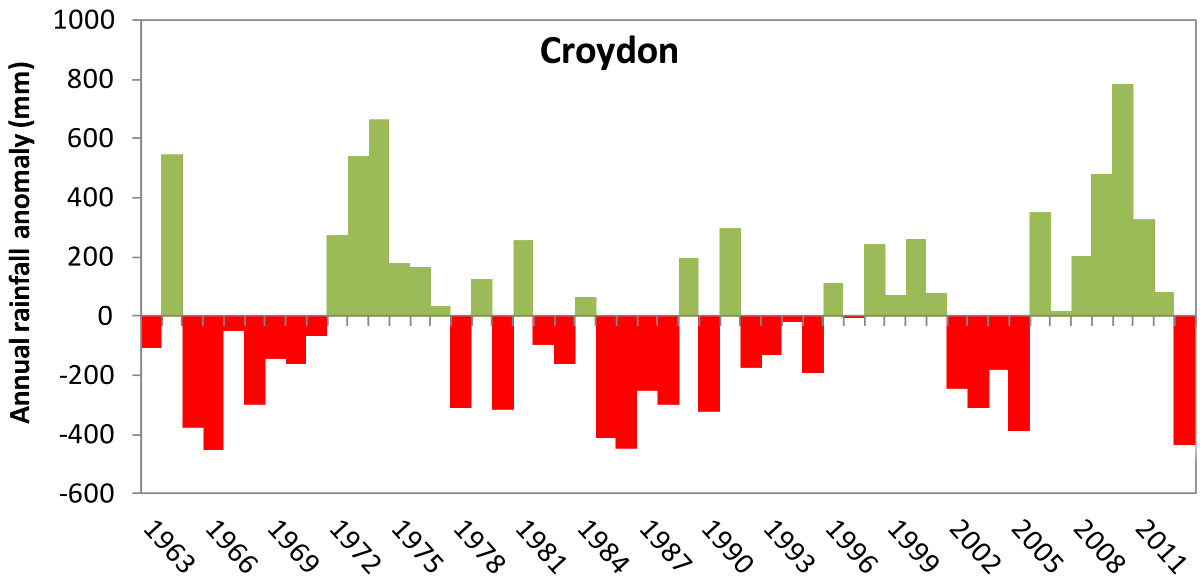


Figure 7.5 Runs of wet and dry years at Croydon, measured by the difference in mean annual rainfall from the long-term average (1963 to 2013)
Wet years are denoted by the green bars and dry years by the red bars.

7.3.2 FUTURE CLIMATE

Climate projections for 2030 were assessed using four global climate models: ECHAM5, GFDL-21, HADCM3 and MIROC. Global climate models are physical representations of the main drivers of the climate system. Future climate is modelled by perturbing the carbon dioxide concentrations in the model, which has implications for temperature and rainfall. In this study, two future emission scenarios of carbon dioxide were used, based on scenarios from the Intergovernmental Panel on Climate Change – one was a high-emissions scenario (A1FI) and the other a moderate-emissions scenario (A2). The results from the global climate models, which provide results at a regional scale, were then used to transform the historical station records for Kununurra (see Section 2.3.1).

Rainfall projections for 2030 under the two emission scenarios (A1FI – high emissions, A2 – moderate emissions) showed no distinct rainfall trend under the four climate change models used in this study (Figures 7.6 and 7.7). For both regions, two of the climate change models showed a small increase in annual rainfall (2 to 5%), while two models showed a modest decrease in annual rainfall (2 to 10%). Based on this analysis, projected changes in mean annual rainfall are small and uncertain and would not appear to be a major factor in planning for crop production out to 2030.

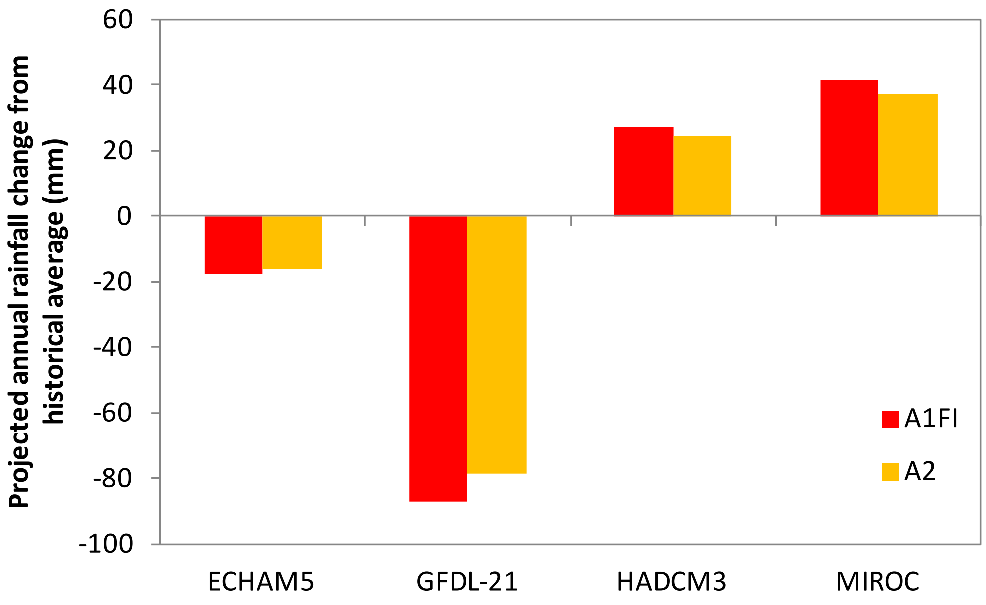


Figure 7.6 Rainfall projections for 2030 for Richmond based on two emission scenarios (A1FI – high, A2 – moderate), using four global climate models
The rainfall projection is the difference in millimetres from the recent historical average annual rainfall (1970 to 2010)

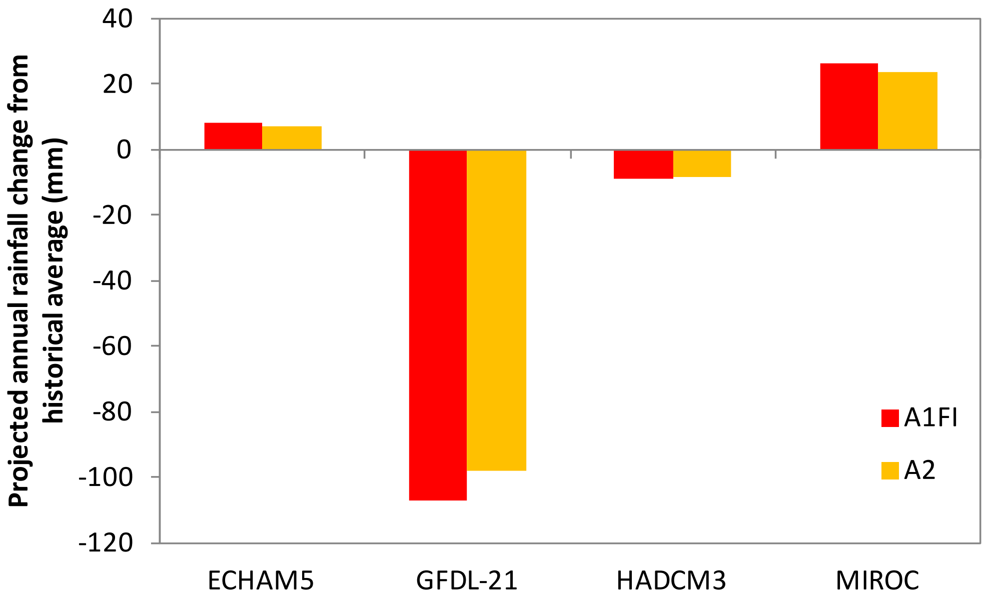


Figure 7.7 Rainfall projections for 2030 for Croydon based on two emission scenarios (A1FI – high, A2 – moderate), using four global climate models
The rainfall projection is the difference in millimetres from the recent historical average annual rainfall (1970 to 2010)

Unlike rainfall, the projected trend in temperature is much more certain, with a projected increase in mean daily temperature of 0.7 to 1.3°C. Given that the mean daily temperature is already high in the tropics, a small increase can have a significant impact on the occurrence of extreme temperature events. This is highlighted in Figures 7.8 and 7.9, which show that the projected number of days with temperatures above 40°C may increase from 25 days/year to between 42 and 58 days/year for Richmond and from 10 days/year to between 24 and 34 days/year for Croydon. This would have an impact on some crops that are sensitive to high temperatures — for example, some horticultural crops towards the end of the dry season when temperatures are getting high. An increase in mean daily minimum temperatures may also have some effect on flowering in crops such as mangoes.

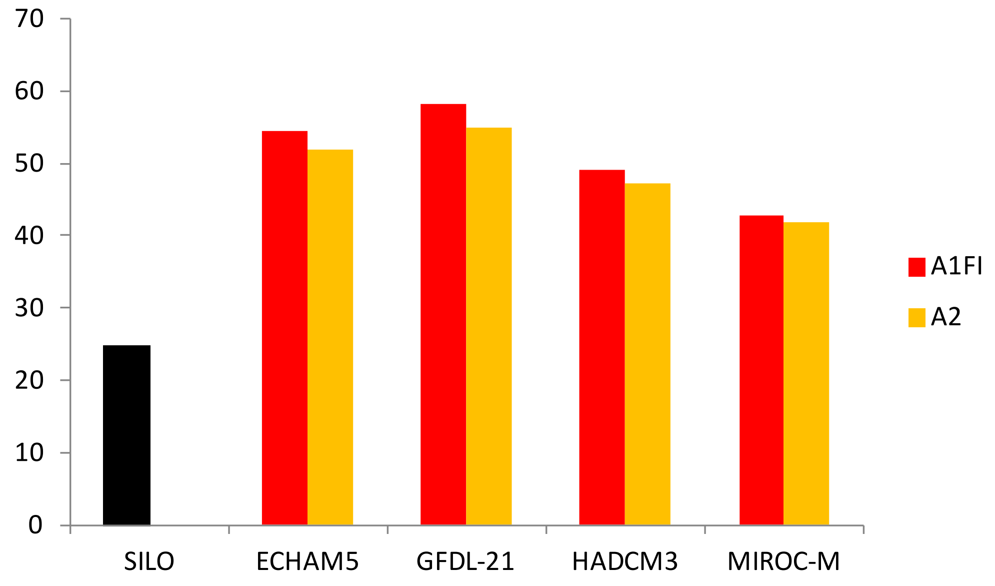


Figure 7.8 Number of days per year in Richmond projected to exceed 40°C in 2030 for two emission scenarios (A1FI – high emissions, A2 – moderate emissions), using four global climate models, compared with historical climate (SILO data from 1970 to 2010, black column)

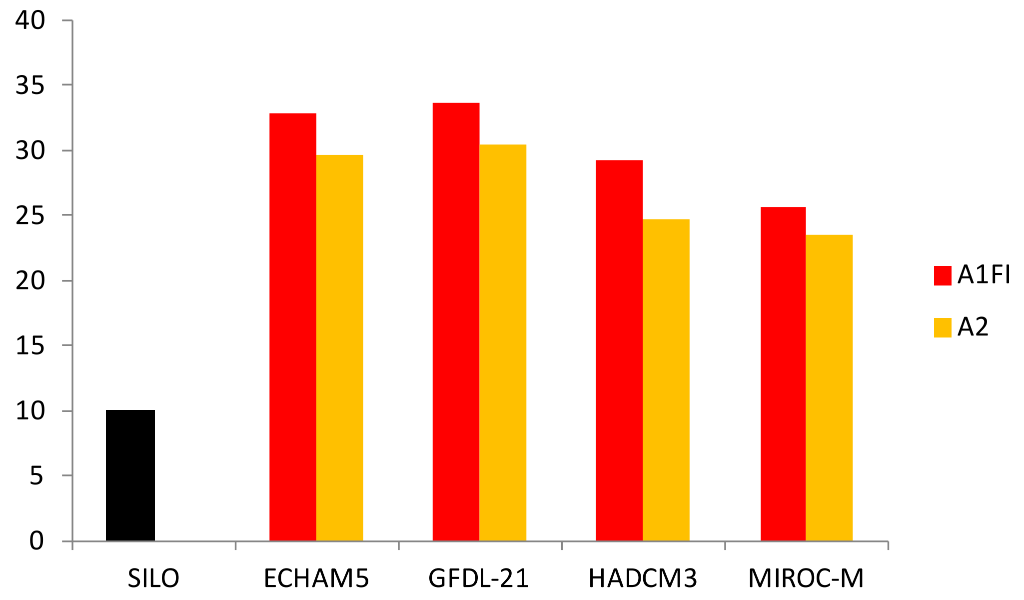


Figure 7.9 Number of days per year in Croydon projected to exceed 40°C in 2030 for two emission scenarios (A1FI – high emissions, A2 – moderate emissions), using four global climate models. compared with historical climate (SILO data from 1970 to 2010, black column)

7.4 Water resources

7.4.1 FLINDERS CATCHMENT

The Flinders catchment is located in the Gulf region of north-western Queensland. Its major river is the Flinders River, which is also the longest river in Queensland. The Flinders River rises in the Great Dividing Range, 100 km north-east of Hughenden, and flows north to south until it reaches Hughenden where it tracks west across flat and naturally treeless Mitchell grass plains. After flowing through the town of Richmond, it continues towards the north-west before flowing north and draining into the Gulf of Carpentaria. The Flinders River has five major tributaries: Dutton River, Stawell River, Alick Creek, Cloncurry River and Saxby River. In terms of catchment area, the largest tributary of the Flinders River is the Cloncurry River (Lerat et al., 2013). One of the key characteristics of the Flinders catchment is that it is particularly susceptible to flooding, because a number of rivers draining large areas of land are funnelled into an area about 50 to 100 km wide. Furthermore, the mid- to lower reaches of the Flinders catchment are very flat, meaning that flood water drains slowly (Dutta et al., 2013). A characteristic of streamflow in the Flinders catchment is that it is highly seasonal and variable from one year to the next. Table 7.3 presents data on streamflow for selected streamflow gauging stations in the Flinders catchment.

Table 7.3 Simulated streamflow at selected gauging stations in the Flinders catchment between 1890 and 2011
The 20th, 50th and 80th refer to the 20th, 50th and 80th percentile exceedance, respectively, and indicate the percentage of time that no streamflow was observed at each of the streamflow gauging stations in the catchment.

STATION ID	STATION NAME	CATCH-MENT AREA (km^2)	STREAMFLOW (GL)				CEASE TO FLOW (%)
			20th	**50th (median)**	**80th**	**Mean**	
915003A	Flinders River at Walkers Bend	106,263	3,857	1,241	150	2,543	63
915008A	Flinders River at Richmond	17,382	505	143	8	405	79
915203A	Cloncurry River at Cloncurry	5,975	545	162	26	308	80

The major groundwater systems in the Flinders catchment are found in the geological Carpentaria Basin, one of the four sub-basins of the Great Artesian Basin (GAB). The Carpentaria Basin is a regional-scale groundwater system, where the distance between the recharge zones and discharge zones is hundreds of kilometres or more and the time taken for groundwater to discharge following recharge is in the order of centuries. A consequence is that the Carpentaria Basin extends well beyond the catchment boundaries of the Flinders catchment. Although a comprehensive assessment of the GAB has recently been done, there are insufficient data on which to assess the ‘sustainable’ water yield of the Carpentaria Basin. Overlying the Carpentaria Basin are unconsolidated alluvial sediments adjacent to the Flinders River and its major tributaries, within which local-scale groundwater systems can form. Local-scale groundwater systems are 1 to 10 km in size and are not well characterised in the Flinders catchment. Water quality in the alluvial aquifers appears to be highly variable and the saturated thickness (total water-bearing thickness of an aquifer) is small (Jolly et al., 2013) and in consequence is considered unlikely to support large-scale irrigation developments. Where hydrogeological conditions are favourable, however, these local-scale systems could support small-scale irrigation (e.g. less than 200 ha) on individual properties.

Groundwater recharge rates are likely to be very low (less than 5 mm/year) across the Flinders catchment, with some small areas of higher recharge (5 to 50 mm/year) in the uplands and in the lower reaches of the Flinders River. A recent assessment of groundwater chemistry and airborne electromagnetic data indicate that Sturgeon Basalt Provinces in the headwaters of the Flinders River are likely to be areas of preferential recharge (Petheram et al., 2013b).

There is little evidence that groundwater from alluvial and fractured rock systems is discharged into rivers and waterholes in the Flinders catchment. Consequently, the majority of waterholes in the Flinders catchment are due to residual streamflow from the previous wet season, and the majority of rivers in the Flinders catchment do not flow for at least 60% of the time.

Existing water use and regulation

Current water use and regulation in the Flinders catchment are low compared with the median annual flow. Before 2013, surface water entitlements in the Flinders catchment totalled about 24 GL/year (approximately 2% of the median annual flow), although the actual water use was estimated to be considerably less than this. In 2013 an additional 80 GL/year of surface water entitlements were released, the majority being allocated for irrigation. In addition to these surface water entitlements there are 0.9 GL/year of groundwater volumetric licences for irrigation and 2.49 GL/year of groundwater volumetric licences for mining and industrial uses.

Two large dams have been constructed in the Flinders catchment: Chinaman Creek Dam near Cloncurry and Corella Dam on the Corella River (Table 7.4). Yields from both dams are small and neither dam has the potential to support irrigation (Petheram et al., 2013a).

Table 7.4 Summary of constructed dams in the Flinders catchment
See Petheram et al. (2013a) for more detail.

DAM	NEAREST TOWN	TYPE OF DAM	ORIGINAL PURPOSE	YEAR CONSTRUCTED	HEIGHT ABOVE BED LEVEL (m)	STORAGE CAPACITY AT FULL SUPPLY LEVEL (GL)	YIELD (GL)
Chinaman Creek Dam	Cloncurry	Concrete gravity – conventional concrete	Town water	1993	13.7	2.75	na
Corella Dam	Mount Isa	Embankment – concrete faced rock fill	Mining	1959	22.9	10.5	4.6

na = not available

7.4.2 GILBERT CATCHMENT

The Gilbert catchment is located in the Gulf region of north-western Queensland. The catchment is comprised of two major rivers, the Gilbert and the Einasleigh. Although the Gilbert catchment is named for the Gilbert River, the median annual streamflow in the Einasleigh River is about 2.5 times that of the Gilbert River (Lerat et al., 2013). The streamflow characteristics of the Gilbert and Einasleigh rivers are quite different, with the Einasleigh River and some of its upper tributaries draining the basalt landscapes in the eastern parts of the catchment. This results in extended flows during the dry season in some reaches of the Einasleigh River and its tributaries. In contrast, the Gilbert and Etheridge rivers (a major tributary of the Einasleigh River) are highly ephemeral and do not flow for more than half the year, on average. At Strathmore Station the Gilbert and Einasleigh rivers converge before forming a river delta and coastal floodplains 100-km wide and then flowing into the Gulf of Carpentaria. These coastal floodplains are particularly susceptible to flooding. Above the confluence of the Gilbert and Einasleigh rivers, however, these major rivers rarely break their banks (Dutta et al., 2013). Table 7.5 presents data on streamflow for selected streamflow gauging stations in the Gilbert catchment.

The major aquifer systems in the Gilbert catchment are similar to those described in the Flinders catchment (above), with the geological Carpentaria Basin being prominent, but in addition the basalt aquifers associated with the Chudleigh and McBride Provinces influence the Gilbert. Local-scale groundwater systems are about 1 to 10 km in size and are not well characterised in the Gilbert catchment, except for the Gilbert River bedsands, which have been developed for local irrigated agriculture and for which the total saturated volume has been estimated as being between 17 and 20 GL (see QDNR, 1998; AGE Consultants Pty Ltd, 1999).

Table 7.5 Simulated streamflow at selected gauging stations in the Gilbert catchment between 1890 and 2011
The 20th, 50th and 80th refer to the 20th, 50th and 80th percentile exceedance, respectively, and indicate the percentage of time that no streamflow was observed at each of the streamflow gauging stations in the catchment.

STATION ID	STATION NAME	CATCH-MENT AREA (km^2)	STREAMFLOW (GL)				CEASE TO FLOW (%)
			20th	50th (median)	80th	Mean	
917009A	Gilbert River at Miranda Downs	38,619	5,279	2,585	1,071	3,706	na
917001D	Gilbert River at Rockfields	10,987	1,519	697	344	1,072	48
917109A	Einasleigh River at Cowana Lake	12,146	1,359	660	213	1,000	32

na = not available

Groundwater recharge rates are likely to be very low (less than 5 mm/year) across most of the catchment, with some areas of higher recharge (5 to 80 mm/year) beneath the coastal deposits of the lower reaches of the Gilbert catchment, and in the recharge areas of the GAB (Petheram et al., 2013b).

Given little evidence that 'persistent' waterholes in the catchment of the Gilbert River receive water from groundwater discharge, they are likely to be filled by streamflow during the previous wet season. Within the catchment of the Einasleigh River, waterholes located downstream and within rivers draining the Chudleigh and McBride Basalt Provinces may be sustained during the dry season by groundwater inflow. Consequently, pumping groundwater from the basalts will reduce the persistence of a number of waterholes in the catchment of the Einasleigh River.

Existing water use and regulation

Current water use and regulation in the Gilbert catchment are low compared with the median annual flow. Before 2013, surface water entitlements in the Gilbert catchment totalled about 20 GL/year (less than 1% of the median annual flow), although the actual water use was estimated to be considerably less than this. In 2013 an additional 14.2 GL/year of surface water entitlements were released, the majority of which is allocated for irrigation. According to the Queensland Department of Natural Resources and Mines' groundwater database (DNRM, 2013), there are more than 400 registered groundwater bores in the Gilbert catchment, the majority of which are accessing water contained in the aquifers of the GAB for stock and domestic purposes.

Kidston Dam, officially known as the Copperfield River Gorge Dam, is the only large dam in the Gilbert catchment (Table 7.6. Yield from the dam is modest (15 GL in 85% of years), and the dam is a long distance upstream of the nearest large area of contiguous soil that is moderately suitable for irrigation.

Table7.6 Summary of constructed dam in the Gilbert catchment
See Petheram et al. (2013a) for more detail.

NAME OF DAM	NEAREST TOWN	TYPE OF DAM	ORIGINAL PURPOSE	YEAR CONSTRUCTED	HEIGHT ABOVE BED LEVEL (m)	STORAGE CAPACITY AT FULL SUPPLY LEVEL (GL)	ANNUAL WATER YIELD[a] (GL)
Kidston Dam (officially known as Copperfield River Gorge Dam)	Kidston	Concrete gravity – roller compacted concrete	Mining	1984	38	20.6	15

a Yield at 85% annual reliability (does not take into account transmission losses).

7.5 Land suitability for cropping

The Flinders-Gilbert study area covers an extensive region of far north Queensland. The Flinders catchment is dominated by large, flat areas of deep, cracking grey and brown Vertosols (cracking clays). Soils in the Gilbert catchment are much more variable, with the steeper upland headwater region dominated by shallow, rocky Rudosols (minimally developed soils) and areas of Chromosols (soils with abrupt increase in clay); the undulating central reaches dominated by Tenosols (weakly developed soils), with areas of deeper, sandy Kandosols (structureless soils) along the river; and the flatter lower reaches dominated by Sodosols (high sodium and abrupt increase in clay), with minor alluvial Dermosols (structured soils) and saline Hydrosols (seasonally or permanently wet soils) in the coastal zone (Figure 7.10).

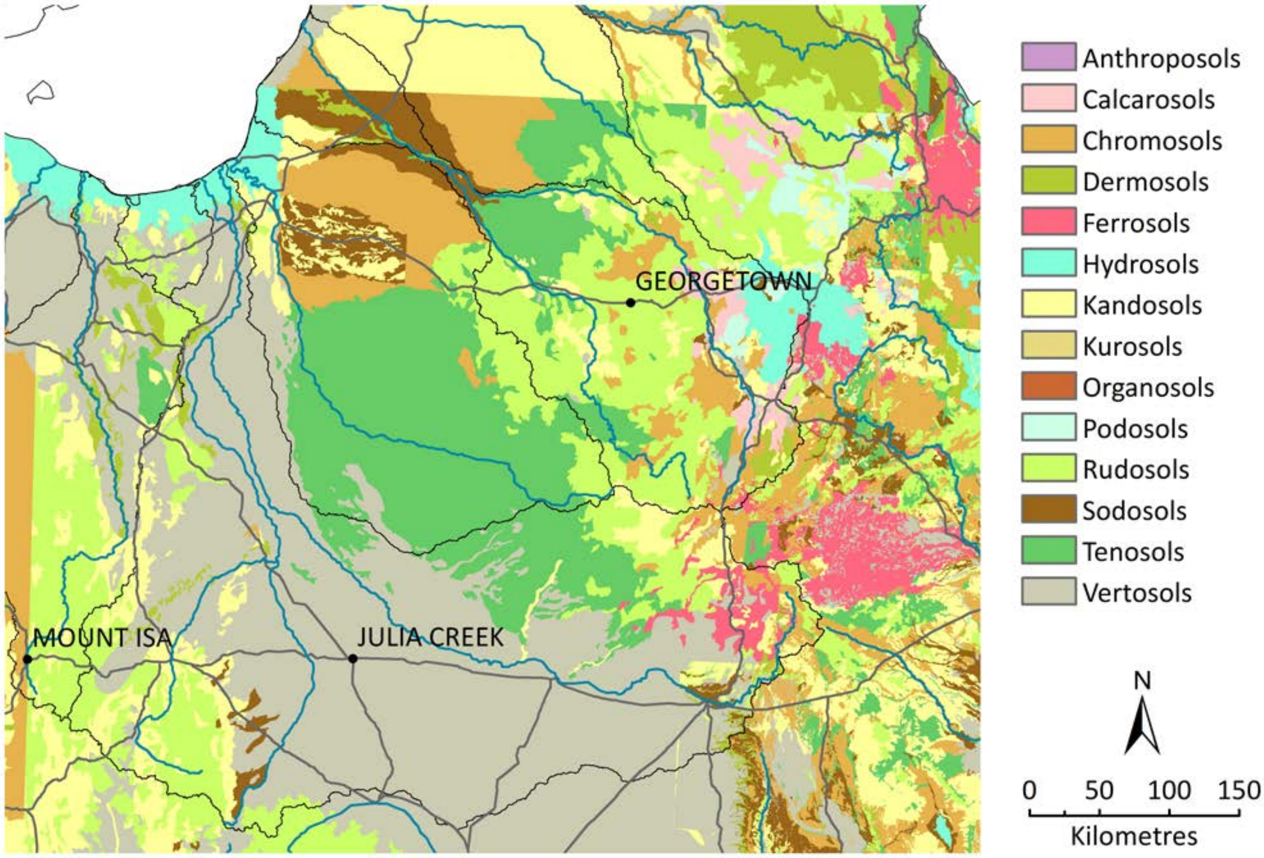


Figure 7.10 Dominant mapped Australian Soil Classification orders, Flinders-Gilbert study area
Source: ASRIS (2014)

Both catchments have recently been the subject of a more intensive soils and agricultural suitability assessment (Bartley et al., 2013) as part of the North Queensland Irrigated Agriculture Strategy. This study used innovative soil sampling, rapid analysis techniques and soil attribute prediction across the catchments, using a spatial correlation approach (digital soil mapping). Importantly, the reliability of the data varies in space, with mapping uncertainty generally declining away from the major river systems where most of the soils data were collected. Therefore, estimates of suitable land areas are considered to have high uncertainties, particularly in areas where no soil data were collected.

In the Flinders catchment, no land was classified as agricultural suitability Class 1 and very little was classified as Class 2 (Figure 7.11). Based on the results (with moderate to high confidence), around 60% of the Flinders catchment is moderately suitable for agriculture but with considerable limitations (Class 3) for cotton, soybean, sorghum, sugar, capsicum/chilli, mangoes, rice, peanuts and Rhodes grass.

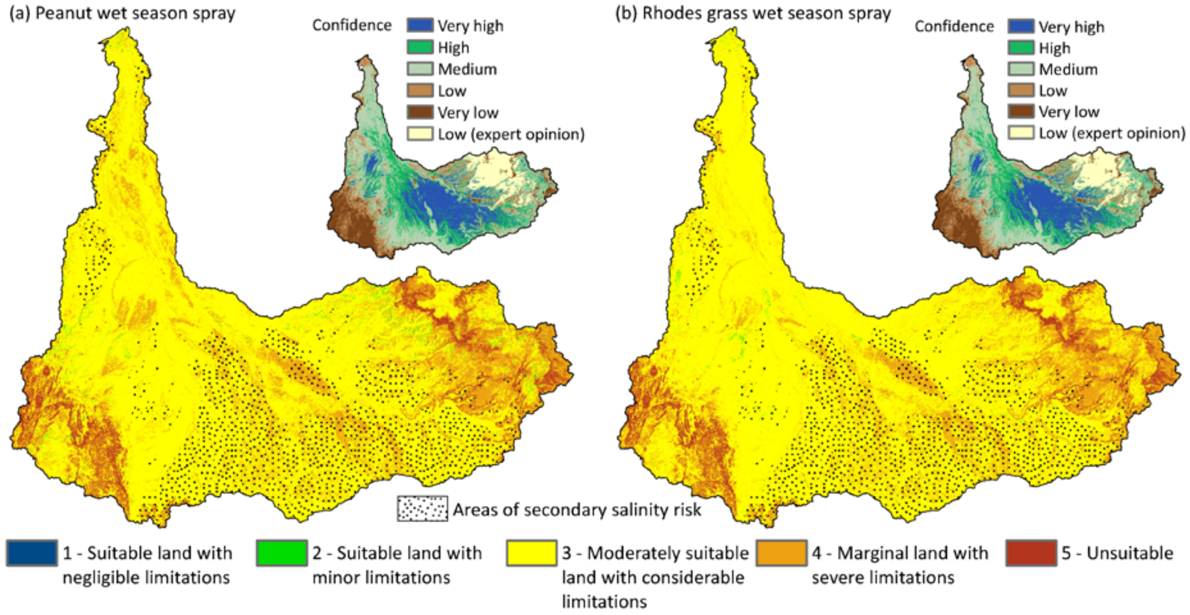


Figure 7.11 Predicted suitability for growing (a) peanuts and (b) Rhodes grass in the Flinders catchment using wet-season spray
Source: Bartley et al. (2013)

The Gilbert catchment generally had less soil suitable for agriculture (Figure 7.12) due to its dissected topography and geology. The main crops shown as moderately suitable (with considerable limitations) in the Gilbert catchment (~20% of area) were capsicum/chilli under trickle irrigation; spray irrigation on cotton, Rhodes grass, forage sorghum, soybean and sugarcane; and furrow irrigation for peanuts.

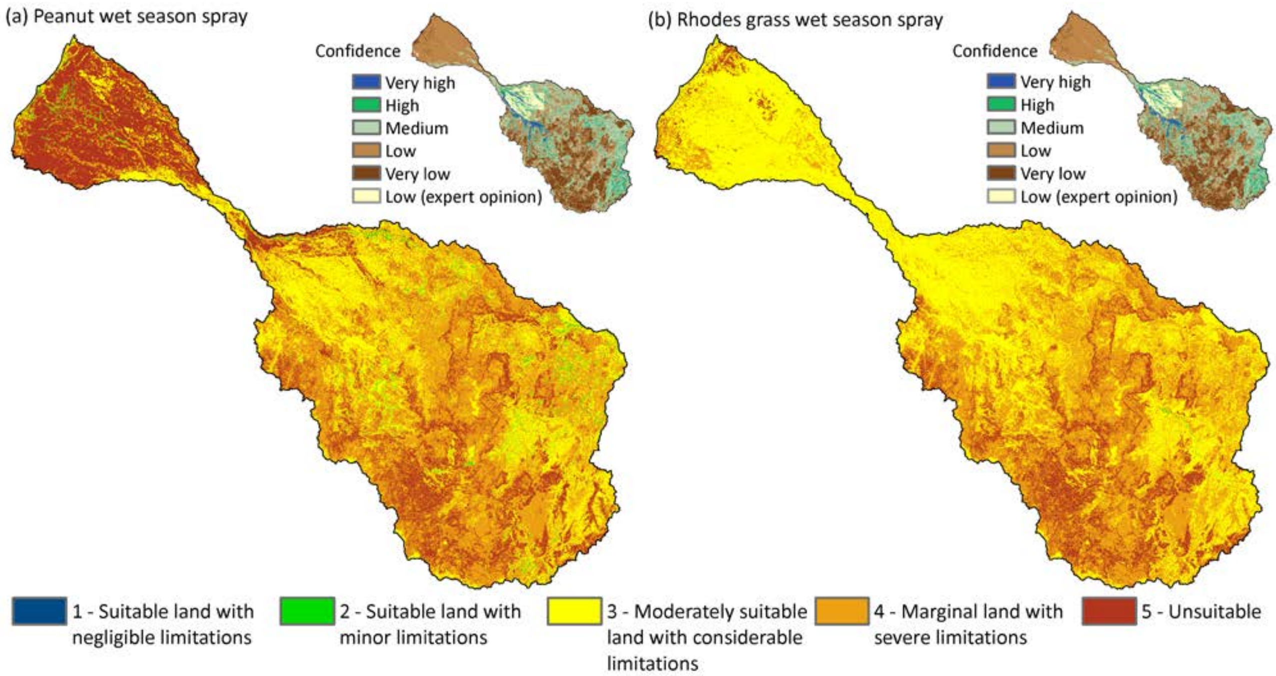


Figure 7.12 Predicted suitability for growing (a) peanuts and (b) Rhodes grass in the Gilbert catchment using wet-season spray irrigation
Source: Bartley et al. (2013)

Bartley et al. (2013) evaluated only climate, soil and local landscape drivers of agricultural suitability. Extreme caution should, therefore, be employed when using their mapping outputs for agricultural development planning purposes. These outputs can be used for gaining a soil-centred, strategic overview of the irrigated agricultural potential in the two catchments. Additional considerations such as water access, flooding risk, salinisation potential and economic factors are available in companion reports (Brennan McKellar et al., 2013, Dutta et al., 2013, Jolly et al., 2013, Lerat et al., 2013, Webster et al., 2013).

7.6 Pest and disease risk

A total of 432 species were identified as potential pests or pathogens of any of the 16 crops evaluated for the Flinders and Gilbert region; many of these were pests or pathogens on multiple crops (Appendix 7.1, separate document). For most crops, many of these pests and pathogens are already present in Australia and at least one is present in Queensland (with the exception of sandalwood). Consequently, the likelihood of at least one of these pests or pathogens invading the region is 1 (100% likelihood) (Table 7.7). Despite the large numbers of pests and pathogens assessed, only a small proportion of species have been identified as major or significant pests of each crop (CABI, 2011) (Appendix 7.1). However, for many of these crops (sugarcane, rice, sorghum, maize, chickpea, mungbean, peanut, mango, cotton, hemp, kenaf and guar), at least one of these major pest is already found in Queensland and therefore represents a significant threat, with a potentially high impact.

Table 7.7 Invasion likelihood, most likely impact and overall biosecurity risk from insect pest and fungal pathogens to proposed crops of the Flinders and Gilbert regions, Queensland

Values of 1 denote almost certain likelihood, very high impact and very high risk, while values of 0 reflect no likelihood, impact or risk.

CROP	INVASION LIKELIHOOD	IMPACT	RISK
Broadacre food			
Rice	1	0.4	0.4
Sorghum	1	0.1	0.1
Maize	1	0.4	0.4
Chickpea	1	0.1	0.1
Mungbean	1	0.4	0.4
Peanut	1	0.4	0.4
Chia[a]			
Intensive food			
Mango	1	0.1	0.1
Banana	0.94738	0.4	0.379
Industrial/other			
Sugarcane	1	0.4	0.4
Cotton	1	0.4	0.4
Hemp	1	0.1	0.1
Kenaf	0.99988	0.1	0.099
Sandalwood	0.060685	0.1	0.061
Guar	0.99928	0.4	0.399
Cassava (biofuel)	1	0.1	0.1
Forage sorghum (biofuel/forage)	1	0.1	0.1

a Chia is a relatively new commercial crop and currently has no known insect pests or fungal pathogens.

7.7 Crop production

7.7.1 **BROAD OVERVIEW OF CROP TYPES AND AGRONOMY**

The potential productivity of a range of broadacre crops, high-value horticulture and plantation crops and industrial crops was investigated for the Flinders and Gilbert regions. This broad analysis includes high-volume products such as cereals and pulses, high-value products such as horticulture, and industrial products that require further processing, often nearby, such as sugarcane.

Broadacre cropping generally involves production using large-scale (area), relatively low-input, high-volume production of a commodity with a relatively low value (in per-tonne terms). Cereals and pulses are the two most common forms of broadacre crop production in Australia but, with the exception of the Ord region where a number of cereal and pulse crops have been grown, broadacre cropping has not featured as a major land use in northern Australia.

Dryland and irrigated cereal production are well established in Australia, with around 20 million hectares grown annually. Cereal crops are either winter or summer grown. Winter-grown dryland wheat is the predominant cereal crop grown in Australia, but summer crops dominate the more northern parts of the traditional cereal-cropping area. Summer-grown cereal crops included in this analysis for the Flinders–Gilbert region included rice, sorghum and maize.

Pulses are legume crops that, like cereals, are grown for the grain. Being legumes, pulses ‘fix’ atmospheric nitrogen and minimise the need to apply inorganic nitrogen. Because this ‘fixed’ nitrogen is also available to subsequent crops, pulses are commonly grown in rotation with high-nitrogen-demanding crops such as cereals. Pulse production is well established in Australia, with approximately 2 million hectares grown annually. Many pulse crops have a relatively short growing season, and are well suited to opportunistic production when there is sufficient available water (either stored in soil or available from irrigation). The pulse crops considered in this analysis for the Flinders and Gilbert regions were chickpea, soybean and mungbean.

Peanuts are a tropical and subtropical annual legume that can be grown as a wet-season crop (either rainfed or with supplementary irrigation) or a dry-season crop under full irrigation. Peanuts are usually processed for human consumption, and the remaining foliage can be used for stockfeed or a green manure. The peanut is produced underground, and specialist equipment is used to ‘pull’ the crop from the soil before harvest, which makes peanuts unsuited to heavy soils where losses from breaking off can be very high. Although peanuts can be grown at any time of year in northern Australia, to produce a consistently high-quality crop requires that peanuts be harvested during dry conditions. Peanuts take approximately 160 to 180 days to mature.

Chia is a ‘niche’ crop that fits into the broadacre category considered in this analysis. Chia is neither a cereal nor a pulse, but is grown on a large scale and is harvested for its seed. There is a small established chia industry in the Ord region but it is difficult to obtain financial data because it is grown commercial in confidence and costs of production and returns are not in the public domain. Consequently, the yield and gross margin values that are presented for the analysis for chia should be regarded as broad estimates.

High-value cropping includes horticultural crops that are generally produced on much smaller areas than broadacre crops, with higher input costs per hectare and a product that is of much higher value than broadacre crops. Horticulture crops are often perishable, require a high labour force for ‘picking and packing’ and specialised postharvest conditions such as refrigeration and controlled atmosphere storage. Horticulture crops are either perennial (e.g. tree crops), where a planting lasts many years, or annual (e.g. cucurbits), where the crop is destroyed after harvest.

Horticulture production is an important industry for Australia, occurring in every state and accounting for approximately 20% of the total farm-gate value of agricultural production. Production is highly seasonal, and annual crops will often include staggered planting on a single farm during the growing season to extend the harvest time.

The market price of horticulture products is subject to multiple supply, demand and substitution forces, and can be highly volatile. The importance of freshness in many horticultural products means that seasonality of supply is important in the market. The Gilbert region has a potential advantage of being able to supply southern markets with crops such as mango a few weeks before the main production season in north Queensland. In horticultural crops, the Gilbert region competes in timing with the Katherine–Mataranka region, but it can more easily establish vertically integrated operations with other growing areas on the Atherton Tableland and along the north Queensland coast. The high-value crops considered in this analysis for the Gilbert region were mango and banana. Given the prevailing soils types and other agricultural activities (predominantly livestock grazing), the Flinders region is considered to be more likely to support a significant broadacre cropping industry in the future and horticultural crops are not considered for this region.

For the purpose of this study, industrial crops are defined as those that require a major processing step in their production soon after harvest. Most industrial crops involve high-volume production, with processing facilities located nearby to reduce costs of transport from where they are grown to where they are processed. The industrial crops considered in analysis of the Flinders and Gilbert regions include cotton, sugarcane, guar, sandalwood, hemp and cassava for biofuel.

Dryland and irrigated cotton production are well established in Australia, with the area grown generally changing each year in response to irrigation water availability. Commercial cotton production has been attempted a number of times in northern Australia, including in the Ord River Irrigation Area. Limited capital, climatic adaptability and pest control were major issues confounding the early commercial cotton production. Since the introduction of genetically modified (GM) cotton in 1996, yields and incomes from cotton crops have increased in most regions of Australia, with the key benefits of GM cotton (compared with conventional cotton) being savings in insecticide and herbicide use, and improved tillage management. Agronomic work on cotton is being conducted in the Burdekin region and based on findings to date it would seem possible that wet-season cotton could produce yields in excess of 9 bales/ha (Yeates et al., 2013).

Sugarcane is a tropical grass, with a well-established industry along Queensland's east coast. Although sugarcane is a perennial crop, it is commercially grown as an annual under a system known as ratoon cropping. The cane is planted and grown for between 12 and 16 months before the entire biomass is harvested. The plant then reshoots (called ratooning) and grows for a further 12 months before being harvested again. Sugarcane can ratoon many times, but is generally only allowed to ratoon between 3 and 5 times because yield declines with each ratoon crop. Sugarcane is usually harvested between June and December; however, in the Gilbert region harvest could begin in May because May is cool and dry.

An Indian sandalwood industry is currently established in the Ord region, with initial commercial harvesting commencing in 2014. Initial yields are expected to be low because early plantings had a low survival rate (approximately 20%) compared with current survival rates (more than 80%). Heartwood yields can vary enormously between individual trees. In a small group of 32 trees harvested in Kununurra, average heartwood yield was only 1.5 t/ha, ranging from zero to about 8 t/ha (Brand et al., 2012). However, in that study tree densities were much lower than current commercial plantings. Sandalwood is an unusual commercial crop in that it is a hemi-parasite requiring macronutrients from the roots of the host leguminous trees. It has taken some time to develop the appropriate cultural techniques to ensure good survival and growth of sandalwood, and the early plantings assessed by Brand et al. (2012) were likely affected by suboptimal host-sandalwood relationships. The oil from sandalwood can be of high value, and consistent oil yields across an entire plantation requires good management over the entire (often more than 15 years) growing period.

There are now plantings of sandalwood in north Queensland, with 500 ha established in the upper part of the Burdekin River Irrigation Area. The crops have been planted as far inland as possible in the irrigation area to lessen the risk from cyclones. Cyclones are also common in the Gilbert region, although the location of likely irrigation areas is approximately 300 km from the coast, which means that cyclone strength is usually low by the time it has travelled that distance over land. Figure 7.13 shows a track of cyclones in north Queensland for the 30-year period from 1976 to 2006 for which about six cyclones affected the Gilbert region.

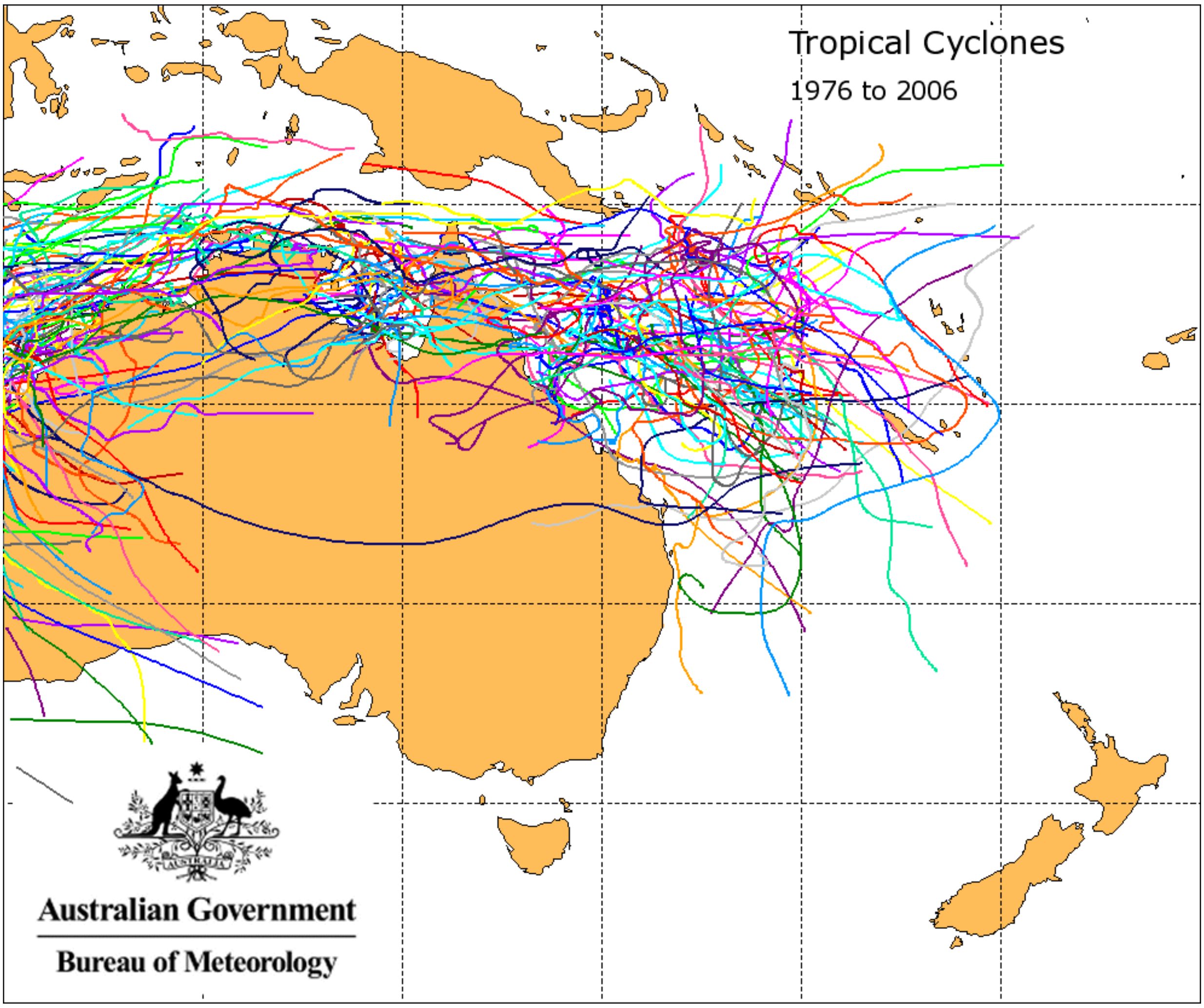


Figure 7.123 Tracks of tropical cyclones in north Queensland from 1976 to 2006
Source: BOM (2014)

Industrial hemp, also known as Indian hemp, is a fibre crop that can be used to produce textiles, composite building materials, insulation and paper, or it can be used as a biomass source to produce ethanol. Hemp is grown on a small commercial scale, mostly in southern Australia. Most varieties of industrial hemp are sensitive to daylength and produce best in areas with long summer daylengths. Industrial hemp varieties grown commercially need to have concentrations of tetrahydrocannabinol (THC) that do not exceed 1%. Although the seed from industrial hemp is valued as a food product and contains no THC, it cannot be legally grown in Australia as a food crop. A reasonable amount of research on industrial hemp took place in the 1980s and 1990s, but there is a lack of high-producing varieties that are suited to low latitude, tropical climates.

Cassava is a tropical root crop that is grown widely in Africa, Asia and the Pacific as a staple food crop and for starch in industrial uses such as ethanol production. Thailand exports over 4 million tonnes of dried cassava and nearly 2 million tonnes of cassava starch each year. Its main potential use in Australia is for biofuel production, and crops have been grown commercially at a pilot scale in north Queensland. A significant amount of agronomic research was undertaken on cassava in the 1970s and 1980s, with one modelling study suggesting a production potential at Normanton (close to the Gilbert region) of 23 t/ha on a dry-weight basis, which equates to about 50 to 55 t/ha on a fresh-weight basis (Fukai and Hammer, 1987). Commercial test production using newer varieties of cassava in north Queensland has reported claimed yields of at least 70 t/ha as a minimum, with yields of 80 to 100 t/ha/year (CassTech Limited, 2010).

Cassava has a high-starch and fermentable content and cassava chips can provide a less expensive form of feedstock for ethanol than other high-energy crops such as corn (Table 7.8).

Table 7.8 Costs of cassava for ethanol production

	UNIT	CASSAVA STARCH	CASSAVA CHIPS	CORN
World price	US$/t	273	139	160
Starch content	%	85	70	60
Ethanol yield	L/t	680	560	385
Feedstock cost	$/L	0.53	0.37	0.67

Source: Cuevas-Cubria (2012)

Guar is an annual legume species that is grown widely in the semi-arid tropics of South Asia, particularly in India and Pakistan. The crop is highly tolerant of hot, dry conditions and is well suited to northern Australia. Its adaptability to dry conditions is a result of its deep taproot, and it is well suited as a rotation crop. Guar's main value is the gum content of its grain, which is up to 30% galactomannan. Once extracted from the seed the gum is useful in a range of food and industrial products, including as a thickener in food and in the gas and oil industry as a suspending component of fracking fluids.

CSIRO and the NTDPI&F did some research on guar in the 1970s and 1980s. Apart from low and variable trial yields, it was found not to be suitable for clay soils. There was some renewed interest in examining guar in the early 2000s, and an evaluation of a large number of cultivars identified varieties that could produce up to 1400 kg/ha of grain under dryland conditions (Douglas, 2005). Under irrigated conditions the crop can produce around 2.5 t/ha of grain (Ahmed, 2011). Increased demand for guar by the oil and gas industry has seen renewed interest in its viability in more recent years.

With the significance of the beef industry in the region, there is potentially strong local demand for forage hay. This hay is used to feed animals in yards, especially weaners and animals being held for transport to live export shipping points or to the abattoirs in Townsville. With the prospect of larger-scale regional irrigation precincts, there is the opportunity to grow both forage hay and grains for use in more intensive feeding systems in the region. Forage hays could either be grown as an annual crop (e.g. forage sorghum) or as a perennial grass (e.g. Bambatsi panic or Rhodes grass). An alternative option would be to grow irrigated forages for grazing with the aim of using the forage to meet particular finishing markets, trade markets or even for boosting the reproductive performance of heifers and breeding cows. The financial outcome for grazing irrigated forages is highly dependent on the amount and quality of forage that can be grown (Grice et al., 2013, Hunt et al., 2014), given the high costs of establishing the irrigation systems. This regional analysis is focused on hay production because it can be used to integrate with grain in intensive feeding systems.

7.7.2 MARKET ANALYSIS OF CROPS

This section highlights some of the market opportunities for the range of broadacre, high-value and industrial crops analysed in the cropping scenarios for potential irrigation in the Flinders and Gilbert region. A more detailed market analysis of each commodity is given in Appendix 4.1.

Broadacre food crops

Chia

Chia was first established commercially in the Ord River Irrigation Area in 2005 as a dry-season crop. Currently nearly all Australian production of chia is contracted to The Chia Company. In Australia, The Chia Company produces whole chia seeds, chia bran, ground chia seed and chia oil for wholesale and retail sale, and exports these products to 36 countries. The company also sells bulk ingredients to a number of food manufacturers, including Kellog's, Baker's Delight, PepsiCo and Allied Bakeries.

Chia consumption is growing across the world. In Australia, health concerns and nutritional awareness are providing opportunities for producers, manufacturers and marketers to develop and promote healthier food alternatives. Therefore, there are opportunities for the domestic market to further market chia to interested consumers.

Internationally, the United States and Asia are the largest markets for Australian chia. Central and South American chia production poses the greatest competition to Australian chia in North America because of the geographic proximity of these regions, therefore, greater opportunity lies in expanding chia sales in the growth markets of Asia.

Chickpea

Most of Australia's chickpea production is exported. Australia is the world's largest chickpea exporter, accounting for 44% of global chickpea trade in 2011. In 2011–12, Australia exported 581,000 t of chickpeas from the 673,400 t produced. More than 80% of Australia's chickpea exports are destined for South Asia (India, Pakistan and Bangladesh).

Continuing growth in demand from South Asia for pulses is likely, given projections of population growth and the largely vegetarian Hindu diet. Ongoing shortfalls in South Asian production will provide opportunities for Australian chickpea exporters. Opportunity also exists to provide the large South Asian and Middle Eastern migrant communities in Australia with domestically produced chickpeas.

Grain sorghum

Grain sorghum is largely consumed in intensive livestock industries, such as feedlot cattle, pigs and poultry. Feedlot cattle consume around half of all grain sorghum used for feed. Domestic marketing opportunities will depend largely on livestock numbers in intensive feed industries. Over the medium term, the lot-fed cattle industry is likely to continue to feel pressure from United States competition in the important grain-fed beef markets of Japan and the Republic of Korea. Poultry numbers are projected to rise, supporting the demand for grain sorghum. Reduced tariffs under the Korea–Australia Free Trade Agreement and the Japan–Australia Economic Partnership Agreement improve those prospects.

Australia exported around half of its grain sorghum production in 2010–11 and 2011–12. Japan historically has been the major trading partner, but China has recently become an important export destination, taking 25% of exports in 2012–13. The China market is forecast to grow substantially. Australia's main competitors in overseas markets are the United States and Argentina, both generally lower-cost suppliers than Australia. United States grain sorghum exports are projected to be maintained over the medium term, while Argentina's are forecast to increase slightly.

In addition to livestock feed demand, sorghum can be processed into ethanol. For example, an ethanol plant in Dalby, Queensland, has the capacity to process around 200,000 t of sorghum to produce 80 million litres of ethanol annually. Production statistics are not available for the Dalby biorefinery, but in 2010-11, Australian production of ethanol was 90% of capacity. In 2011–12 biofuels represented around 1% of Australia's petrol and diesel production. The latest long-term projection of Australian energy supply and demand to 2050 by the Bureau of Resources and Energy Economics is for bioenergy production in Australia to grow by 3.9% per year.

Maize

In Australia, livestock feeding of maize accounts for around 54% of total domestic consumption, and food and industrial consumption accounts for the remaining 46%. Maize is a minor component of the feed complex, but more than 90% of feed maize is consumed by poultry or pigs; only a small amount is consumed by feedlot cattle.

The most important export markets for maize are Japan and the Republic of Korea, but Australian maize comprises less than 1% of these countries' imports. The dominance of Japan and Korea as import markets has been falling in recent years, and growth in world maize imports have been driven by Latin America and member states of the Association of Southeast Asian Nations (ASEAN). Asia is expected to be a driver of world maize consumption, largely as a result of growing demand for maize as a feed gain. This may present export opportunities. However, Australia does not yet have access to China's market for maize. Main competitors in Japan and Korea are the United States, Argentina and Brazil.

Domestic marketing opportunities will depend largely on poultry and pig numbers. Over the medium term, pig and poultry numbers are projected to rise, supporting domestic demand for maize.

Mungbean

Australian production of mungbeans has almost doubled in the two decades to 2012–13. Currently, Australian mungbean production is largely destined for export. In 2011–12, Australia shipped 50% of mungbean exports to India and 22% sent to the ASEAN member states. Within the ASEAN region, Indonesia was the largest importer of Australian mungbeans. India and ASEAN will continue to be growing markets for Australian mungbeans.

Domestically and internationally, opportunities exist to market mungbeans as a functional food to domestic food manufacturers and consumers. Mungbeans have a range of potential applications, such as starch, flour or paste, and can also be used as an additive to other foods.

Peanut

Australian peanuts are mostly consumed on the domestic market, with food consumption the primary use. Australia is usually a net importer of peanuts, except in years of large production, importing both processed and unprocessed peanuts mostly from Argentina, China and Nicaragua. Australia exports unprocessed peanuts — 1100 t in 2011–12 – mainly to New Zealand, Japan, Fiji and China. Processed peanuts – 1700 t in 2011-12 – were exported mainly to New Zealand, the Republic of Korea and Japan.

China and India together produce more than half of the world's peanuts. China is also the largest consumer of peanuts for food, followed by Indonesia, the United States and Nigeria. China and India are the largest crushers of peanuts and consumers of peanuts meal and oil. Although China was once the primary supplier in international markets, growing domestic consumption has reduced exports.

Should local production expand, there is potential for some import substitution of peanuts for food use and also peanut meal for intensive livestock production. Any expansion in production could be shipped to current export markets, particularly Japan and the Republic of Korea. The major supplier to these markets is China, but, with its own domestic consumption increasing, there may be opportunity for Australian exports to expand in these markets. Likewise, net exports from the United States, the second-largest supplier to Japan, are projected by the United States Department of Agriculture to fall over the medium term, providing opportunity for Australian exports in Japan.

Opportunity also lies in supplying high oleic peanut oil to the world market, but capitalising on this opportunity would require a large-scale, stable supply of high oleic peanuts and export market development. However, unless significant price premiums can be achieved, production would need to be at such a scale as to reduce production costs to increase grower profitability. Given the small peanut oil market in Australia, expansion requires export market development.

Rice

An advantage of rice production in northern Australia is the ability to grow tropical rice varieties. This also includes brown rice, which receives a premium in health food markets. Domestic use of rice in Australia has increased over the past decade. Australia, a small exporter of rice on a global scale, exported 585,000 t of rice and imported 145,000 t in 2012–13, with around 34% of domestic demand fulfilled by imports. There is potential for increased production of Australian rice, particularly of tropical varieties, to replace imports and service growing domestic demand if it can be profitably and competitively produced relative to the price of imports.

Growth in international demand for Australian rice is expected from Japan, Taiwan and the Middle East as incomes rise and trade liberalisation increases. However, in each of these markets, Australian rice exports would need to be competitively priced compared with supplies from other major exporting countries. Exports to Japan and Taiwan are likely to continue to be limited by trade barriers.

High-value food crops

Banana

In terms of production value, the banana-growing industry is one of Australia's largest fresh fruit crops and the largest horticulture industry in Queensland. Almost all of Australia's banana production is consumed domestically as fresh produce. More bananas are sold than any other fruit on the domestic market and they are purchased by over 90% of Australian households. A key advantage for the industry has been the ongoing popularity of bananas. The industry has also benefited from rising health consciousness and an associated trend towards increased fruit consumption. For this reason, there is scope for some continuing growth of demand on the domestic market. However, because Australian banana production is mainly consumed domestically, any significant increase in production that exceeds growth in demand would place downward pressure on prices and hence growers' returns.

Only minimal amounts of Australian bananas are exported, in most recent years being directed to New Zealand and Nauru. Australia does not import fresh bananas or plantains. So far no country has met Australia's strict biosecurity requirements for fresh banana imports, so international markets exert very little influence on the Australian banana industry.

Although exports are currently minimal, the industry has been striving to develop new export markets, particularly in Asia where population and income growth rates are high. The industry's opportunity lies in its counter-seasonal supply advantage into the Northern Hemisphere markets. Japan provides a potential market because it is a high-income country and a major world importer of bananas. China also, with its growing urban population and growing incomes, provides a potential market as a large importer of bananas.

Mango

Mangoes in the Ord region and other parts of northern Western Australia, along with those grown in the Northern Territory are among the earliest harvested, with the harvest beginning in September. This is followed by harvest in Queensland's dry tropical regions (Townsville, Burdekin and Bowen) in mid-November, other regions of Queensland in December and northern New South Wales in January.

The Australian mango industry is domestically focused, with 80% sold as fresh produce and the remaining 20% processed. Of the fresh fruit, around 90% is sold on the Australian domestic market. The Australian domestic market is well supplied in season and, with increased mango production in the Northern Territory over the past 5 years, the availability of early season mangoes has increased for domestic consumers.

Imports are low but have been growing steadily over the past decade. Supply from imports is counter-seasonal to Australian production. However, as the Australian season extends with growing production of early season mangoes, it is likely there will be increasing overlap in supply to the market. Key export markets for mangoes are Hong Kong (42% of export volumes in 2012–13), the ASEAN member states (21%), the Middle East (18%) and New Zealand (13%). Important ASEAN markets are Singapore, Vietnam and Malaysia. However, Australia is a small producer of mangoes on a global scale, at only 0.1% of world production.

The highest mango consumption is in Asia where unripe mangoes are especially popular. Ripe mangoes are mainly eaten in western countries. Increased production in Australian mangoes would provide export opportunities for unripe and ripe mangoes to countries in Asia; however, Thailand offers strong competition in this region as the main supplier of mangoes to Malaysia, China and Singapore. Japan sources mangoes from Mexico, the Philippines and Thailand.

Industrial crops

Sugarcane

Australia is a relatively small sugar producer on a global scale, but is currently the world's third-largest exporter of sugar. Queensland accounts for 95% of Australian production and New South Wales accounts for the remaining 5%. Sugarcane production commenced in the Ord River Irrigation Area in 1995 but ceased with the closure of the mill in 2007 because of low world prices at the time.

Around 20% of Australian sugar is consumed domestically and the remaining 80% is exported. Although high compared with other developed countries, consumption of sugar in Australia has stagnated because demand for sugar is adversely affected by increased health awareness, which is driving Australian consumers to increasingly substitute sugar with alternatives such as artificial sweeteners. Future growth in the domestic market will likely be limited, driven largely by population growth. Also, Australia's ageing population could potentially affect domestic sugar demand in the future as children and teenagers take the largest components of the final-user market. This limited opportunity in the domestic market will increase the industry's reliance on international markets.

Demand overseas is growing and should support exports. Australia exports raw and refined sugar mainly to Asian markets, particularly the Republic of Korea, Japan, Malaysia and Indonesia. In the longer term, growing sugar consumption in developing countries, largely across Asia, will be in response to rising incomes and strong population growth in these countries, which should offset lower demand for sugar in developed countries. Indonesia, particularly, has emerged as one of the largest importers of Australian sugar and is now our second-largest market after the Republic of Korea. The main competing countries with Australia in the Asian sugar markets are Thailand and Brazil, both of which have capacity to expand exports of either raw or refined sugar.

Cassava

Cassava is not grown commercially in Australia, but CassTech Limited has commenced commercial cassava trials in the Burdekin region of Queensland to produce high-yielding cassava on a broadacre basis. Australia imports a small amount of mostly frozen cassava from Fiji, Vietnam, Tonga, Thailand and Indonesia. Imports of cassava starch are more significant, totalling 11,800 t in 2011–12 and nearly all from Thailand. Other smaller suppliers of starch are Vietnam, China, Malaysia and Indonesia. In 2012–13, cassava starch imports doubled to 22,700 t, again mostly from Thailand.

Africa contributes more than half of global cassava production. As it is an important food staple in Africa, the continent consumes almost all of its production. Unlike Africa, much of Asian production is directed to industrial purposes (starch) and energy (biofuels). Asia contributes around one-third of world production and 60% of this is shared by Thailand and Indonesia, with Indonesia growing in strength. Thailand is the leading global exporter of cassava starch, which is used in food processing, pharmaceutical chemistry, foundries, textiles, paper and adhesives. Thailand exports more than 80% of its cassava production, mostly to China. Latin America and the Caribbean represent 13% of world supply, with Brazil the major producer. Around half of Latin American production is used for livestock feed.

Opportunities for Australian production of cassava also lie in production of bioethanol rather than for food purposes. Global production of bioethanol is expected to grow by 50% between 2011 and 2020. One tonne of cassava can produce around 280 L of 96% pure ethanol. Although cassava is still a small player in the biofuel arena relative to maize and sugarcane, China is increasing production of ethanol from cassava. The likelihood of Australia developing a domestic market for fresh cassava consumption is low.

Interest in clean energy investment in Australia is continuing to grow, supported by technology advancements and improving commercial viability. Biofuels in 2011–12 represented around 1% of Australia's petrol and diesel production. The latest long-term projections of Australian energy supply and demand by the Bureau of Resources and Energy Economics (BREE) reflect these changes. BREE projects primary energy consumption of all renewables to grow at around 3.6% per year from 2012-13 to 2049-50. Bioenergy is forecast to grow faster than this, by 3.9% per year. Australia's imports of petroleum products are expected to continue to rise. Increasing the use of alternative fuels, such as biofuels, and diversifying the fuel mix in the transport market can help mitigate some of the risks of fuel insecurity in the conventional fuel market.

Cotton

Australia is a relatively minor cotton producer on a global scale, but in recent years became the world's sixth-largest producer. In 2012–13, Australia produced 1 million tonnes of cotton lint and 1.4 million tonnes of cottonseed. About one-third of production is in Queensland, with most of the remainder in northern New South Wales. A small area is planted to cotton in the Banana Shire of central Queensland where, in 2010–12, production of cotton lint was around 5600 t.

The level of Australian cotton production depends largely on the availability of irrigation water. Currently, about 95% of Australian cotton production takes place in the Murray–Darling Basin (MDB) region, and usually more than 90% is irrigated. Increased diversions of irrigation water away from farms to environmental uses in the MDB are expected to have a minor effect on Australian cotton production over the medium term, but the prospects for significant expansion in irrigated plantings in the MDB are slight.

Around 95% of Australian cotton lint is exported to international markets, mainly in Asia, while a large proportion of cottonseed is consumed in Australia. In the 10 years to 2012–13, Asian markets accounted for 98% of total Australian lint exports, with the remainder exported to Europe. China has now emerged as the largest importer of Australian cotton, taking around 70% of Australia's exports in 2012–13. Other important markets are Indonesia, Thailand and the Republic of Korea.

Given Australia's small textile manufacturing sector, domestic textile mills consume only around 3% of the cotton industry's output. It is unlikely that additional demand for ginned cotton will be created domestically because labour costs in textile manufacturing are much lower overseas. Demand from other ASEAN countries, such as Cambodia and Vietnam, is expected to grow as wage inflation in China has led to Chinese manufacturers and global textile companies moving their manufacturing to other low-cost nations. Other potential markets for Australia that could be further developed include Bangladesh and Pakistan.

Guar

Guar gum, a product of the guar bean, is traditionally used as a thickening agent in food processing but has more recently been used in the oil and gas industry as a hydraulic fracturing ('fracking') agent. Growing guar is in the early stages of being established into a viable industry in Australia.

Currently, guar gum is imported into Australia from India and Pakistan. Strong demand from the oil and gas extraction industries resulted in a sharp upturn in world prices in 2011–12. In Australia, import values rose from under $2/kg to an average of $6.48/kg in 2011–12 and $7.88/kg in 2012–13. World guar production is currently dominated by India, at 80% of global production, with Pakistan and the United States the other significant producers. In Asia, guar beans are used as a vegetable for human consumption and the meal is used as a high-protein livestock feed. Now, over half of the world's guar gum is used for oil and gas mining.

The United States is the world's largest importer of guar gum. Germany is the second-largest importer, servicing its large food processing industry. In Australia, the emergence of fracking in the oil and gas extraction industry has led to the creation of a new market for guar gum, providing greater incentive for guar gum processing to start in Australia and for farmers to plant guar crops. Record prices in 2012–13 saw demand in the mining industry shift to cheaper alternatives, but demand is expected to remain strong in coming years, albeit constrained by the availability of alternatives.

Industrial hemp

Industrial hemp production is either not permitted or is strictly regulated in many countries to guard against the illegal production of marijuana. In Australia, the state and territory governments control the legalisation and licensing of industrial hemp production. At present, industrial hemp can be legally grown in Victoria, Queensland, Western Australia and New South Wales. The industry is dominated by a few large companies that contract the growing of industrial hemp to farmers.

In Australia, human consumption of hemp seed is prohibited in the Australia New Zealand Food Standards Code, but this prohibition is currently under review. If hemp seed is legalised for human consumption in Australia, it is expected that demand would increase although the impact may be small.

Australia is a net importer of hemp fibre. As such, with increased production of industrial hemp and associated production capacity, Australian producers could potentially supply the domestic market. This will depend on quality and price competitiveness against available imports. Increased production of industrial hemp in Australia could lead to export opportunities to other countries such as the United States where there is growing demand for hempseed and hempseed products. However, Australian exports would have to compete with exports from Canada, the largest supplier to the United States market.

Sandalwood

Culturally significant in India, China and the Middle East, sandalwood heartwood is widely used for religious worship and ceremonies, and in a range of wood-based consumer products. Heartwood is also distilled into premium quality oil for use as a fixative in fine fragrances, beauty products, medicines and incense, and as a flavouring agent for chewing-tobacco products. In recent years, Australian sandalwood oil has been incorporated into many high-end perfumes and other cosmetic products. Expansion of Indian sandalwood plantations into the Northern Territory and Queensland, adding to large-scale production in the Ord region, is designed to take advantage of this demand.

Australian sandalwood currently supplies well over half of all sandalwood traded around the world annually. Indonesia, East Timor and India are the other main exporters.

Global supplies of sandalwood have been depleted by overharvesting of wild plantations. The Indian Government has placed restrictions on exports of Indian sandalwood in response to depletion of natural resources as a result of illegal harvesting.

Australian sandalwood has historically been used in the agabati and incense markets in China, Taiwan, Hong Kong and most other Asian countries. The main importers of sandalwood are Taiwan, China and India. The United States and France are the main importers of sandalwood oil, but there is also demand from North Asia and the Middle East for oil.

Internationally, the key market drivers are the decline in the supplies of sandalwood from India and other traditional sources in Indonesia and the Pacific, and growing populations and affluence in developing nations, particularly in India and China. Provided a steady supply of high-quality sandalwood can be maintained, the preference in Europe and North America for natural products in cosmetics will assure the future market for the oil and perhaps also for the nuts. There are also opportunities for sandalwood products in pharmaceutical uses. At the same time, lower-grade powdered sandalwood products will have a ready market in Asia for incense.

Hay/forage

Hay plays a crucial role in livestock production, particularly during times of drought conditions when grass is not readily available. The majority of Australia's hay production is in southern Australia and is used domestically by livestock sectors in southern Australia. However, export markets have developed over the past two decades, principally to Japan (64% of exports in 2012–13), the Republic of Korea, Taiwan and China. Other smaller markets include the Middle East (particularly the United Arab Emirates, Saudi Arabia and Qatar), Indonesia and Malaysia. Livestock export ships are also a significant destination for Australian hay exports, although this outlet has diminished since 2008–09, with falling live sheep exports to the Middle East and a live cattle trade affected by Indonesia's import restrictions.

Recent reinvigoration of the live export trade – with Indonesia lifting its cattle import restrictions and cattle demand increasing from other markets such as Vietnam and Malaysia – should result in an increasing amount of hay being used by livestock-holding depots and aboard livestock transport ships. Increasing demand for meat protein and growing commercial feedlots in developing countries also provide opportunities for expanding exports of hay to markets such as China, Indonesia, Malaysia, Vietnam and a range of markets in the Middle East.

Domestically, the development of meat processing in northern Australia, with both Yeeda Pastoral's abattoir near Broome and the Australian Agricultural Company's abattoir near Darwin close to completion, provides opportunity for increased use of hay and forage crops for finishing cattle for slaughter in northern Australia. The immediate throughput of these plants will be mostly lower-value cull cows and slaughter cattle that do not meet live export specifications. However, development of meat processing in northern Australia, combined with increased availability of fodder crops, could result in increased cattle fattening, either in feedlots on cattle stations or commercial feedlots close to the abattoirs, and the opportunity for pastoralists to diversify their production away from live export.

7.7.3 **CROP PRODUCTION ESTIMATES**

Estimates of crop yields and water needs for identified broadacre, high-value and industrial crops were made using the APSIM (Agricultural Production Systems sIMulator) simulation model (Keating et al., 2003) for the crops that ASPIM has appropriate modules (rice, sorghum, maize, chickpea, mungbean, peanut, sugarcane and cotton) (Tables 7.9 and 7.10). Various 'heat sum' approaches and expert-based techniques have been used to analyse historical yields in northern Australia for the remaining crops for which there presently is no APSIM module.

Two soil types were paramaterised for use in the APSIM simulations: a grey Vertosol for the Richmond region and a sandy loam for the Georgetown region. The grey Vertosol soil holds 204 mm of water to a depth of 1.7 m and the sandy loam holds 150 mm to 1.8 m. Historical meteorological data from Richmond and Georgetown between 1900 and 2010 was used in the simulations for the Flinders and Gilbert regions, respectively. This time period was used to generate variation in crop yield and irrigation water required.

APSIM assumes best practice for managing a crop, and the absence of any pest- and disease-related stress. Simulations were undertaken to achieve crop growth in non-limiting soil water and nutrient environments. Applied irrigation was triggered in the model using soil water deficit and the potential root zone of each crop. Natural reset points were selected at the end of winter (September), when the soil profile is normally dry to initialise the soil water, soil nitrogen and surface cover each year, so that only the effect of seasonal climate and applied irrigation on crop production were captured. Irrigation management assumed 100% efficiency in applying irrigation to the crop, regardless of availability of supply.

The values presented for water applied to a crop do not actually equal the total water used to produce the crop (Tables 7.11 and 7.12). APSIM assumes 100% efficiency of irrigation water supply, and reported figures are 'on crop', not accounting for delivery losses from storage, transport and on-farm application of the water. The outputs from modelling (and estimates for non-modelled crops) are potential productivity and irrigation water use on a per-hectare basis.

Table 7.9 Gilbert region simulated crop yields

Crop yields were simulated using APSIM (for those crops with 20**th**, 50**th** and 80**th** percentile values); for other crops, estimates were based on production data (except for hemp, guar and cassava, which are based on published estimates). APSIM yields for broadacre crops are based on 110 years of simulations (1900 to 2010) and are expressed in tonnes of dry matter per hectare. For the economic assessment, these were converted to fresh yields, based on moisture contents of 12 to 14%.

CROP	YIELD PERCENTILE		
	20th	**50th**	**80th**
Broadacre (t/ha)			
Chia		1.1	
Maize	9.6	8.6	7.7
Peanut	5.1	4.7	4.3
Soybean	3.4	3.1	2.8
High value			
Banana (cartons/ha)		3300 cartons/ha	
Mango — Kensington Pride (trays/ha)		1,540 trays/ha	
Industrial/other			
Cassava (dried chips) (t/ha)		40 t/ha	
Cotton (bales/ha)	9.2	8.7	8.2
Guar (t/ha)		2.0	
Hemp[a] (t/ha)		10	
Sandalwood[b] (t/ha heartwood)		8	
Sugarcane[c] (t/ha)	133	116	102
Forage sorghum hay (t/ha)	30.2	27.9	25.4

a 35% of the total yield (t/ha) is used.
b Sandalwood is grown on a 15-year cycle, so yields harvested per ha will be 1/15th of 8 t/ha.
c Yield is averaged to include a fallow crop after the last ratoon.

Table 7.10 Flinders region simulated crop yields

Crop yields were simulated using APSIM (for those crops with 20**th**, 50**th** and 80**th** percentile values). APSIM yields for broadacre crops are based on 110 years of simulations (1900 to 2010) and are expressed in tonnes of dry matter per hectare. For the economic assessment, these were converted to fresh yields, based on moisture contents of 12 to 14%.

CROP	YIELD PERCENTILE		
	20th	**50th**	**80th**
Broadacre (t/ha)			
Chickpea	2.9	2.5	2.4
Mungbean	2.2	1.9	1.6
Rice	10.0	9.4	8.7
Sorghum	8.2	7.4	2.9
Industrial/other			
Cotton (bales/ha)	10.8	8.8	7.6
Forage sorghum hay (t/ha)	35.4	32.7	30.7

Table 7.11 Irrigation water use for the broadacre and industrial crops simulated in APSIM for the Gilbert region, 1900 to 2010

Assumes perfect timing of irrigation (i.e. no field application losses).

CROP	IRRIGATION WATER USE (mm) PERCENTILE		
	20th	**50th**	**80th**
Broadacre			
Maize	483	415	358
Peanut	526	479	421
Soybean	441	352	276
Industrial/other			
Cotton	566	499	417
Guar	441	352	276
Sugarcane	1,467	1,172	1,033
Forage sorghum	841	748	657

Table 7.12 Irrigation water use for the broadacre and industrial crops simulated in APSIM for the Flinders region, 1900 to 2010

Assumes perfect timing of irrigation (i.e. no field application losses).

CROP	IRRIGATION WATER USE (mm) PERCENTILE		
	20th	50th	80th
Broadacre			
Chickpea	332	297	242
Mungbean	303	219	154
Rice	615	563	449
Sorghum	483	345	216
Industrial/other			
Cotton	631	558	445
Forage sorghum	973	854	670

Rice

Rice was grown in summer in the Richmond simulations. The crop can be grown from December to February, although there is a much greater chance of wet weather impeding getting machinery on to the cracking clay soils in late January and February. In the simulations, planting occurred in mid-January to reduce the heat stress that could occur from earlier planting, while also permitting a longer growing season to maximise yield. Autumn planting of rice can encounter limitations from low night-time temperatures during grain fill. The rice crop from panicle initiation onwards needs careful water management, which is practically easier to achieve using wet-season rainfall to supplement irrigation in summer-planted crops.

Sorghum

Dryland sorghum is grown over summer, but with irrigation available it was sown in the simulation on 15 March. When sorghum is sown later than March, heat stress later in the year during flowering and grain fill can depress yields. Planting before December results in the developing seedling growing in the hottest part of the year, increasing the risk of yield loss through heat stress. In the simulations grain sorghum yields averaged around 7 t/ha, which is comparable with sorghum grown in established cropping regions elsewhere in northern Australia. Non-grain (forage) varieties of sorghum can also been grown as forage crops for direct feeding of livestock.

Maize

Maize is also a summer crop, but was sown in the simulations on 15 March. Much like grain sorghum, maize can be planted during a wide sowing window, but management of heat stress during flowering, grain fill and seedling development is required to reduce the risk of yield penalties. The maize yields simulated for the Gilbert region showed that it is very well adapted to the region. Maize can also be grown as a forage crop for livestock.

Chickpea

Chickpea was sown in the simulations on the 1 May. Chickpea develops in a relatively short time, and is deep rooted and well suited to opportunistic cropping. There is some merit in planting chickpea after a summer-grown rice crop has been harvested, to take advantage of water stored in the soil that is needed by rice during grain fill. Yields of chickpea were simulated to be around 2.5 t/ha.

Mungbean

Mungbean was sown in the simulations on 15 March. Mungbean matures relatively quickly, and like chickpea, can be opportunistically sown, although it is often planted as a part of a planned rotation. Mungbean prices can vary greatly with seed quality when sold for human consumption (which generates the highest prices). Rainfall during the later stages of pod fill can have a detrimental effect on grain quality, and consequently the price received, so planting is usually timed to ensure a low risk of receiving rainfall at this crucial time. Yield was simulated to be around 2 t/ha, which is consistent with commercial yields obtained in northern Australia.

Soybean

Soybean was simulated in the Gilbert region only on the basis that it would be used as a rotation crop with sugarcane, and planted after the last ratoon crop of cane. This practice has been shown to increase the yield of sugarcane in the subsequent plant and early ratoon crops (Garside and Bell, 2011). It was simulated to produce 3.1 t/ha (dry-matter basis).

Peanut

Peanuts were simulated only in the Gilbert region, with sowing on 15 March. The dominant grey cracking Vertosol soils that dominate the Flinders catchment are considered unsuitable for peanut production. Peanut production needs to be timed so that crop pulling and harvest is not interrupted by rain, which can lead to a downgrading of nut quality. Yield was simulated to be around 5 t/ha.

Chia

No information is available on chia production in the Flinders or Gilbert catchments because the crop has not been grown commercially or experimentally in the region. For this analysis, yields of 1.1 t/ha were assumed, based on the published literature and imputed yields based on production in the Ord region.

Mango

Kensington Pride mangoes are the most common type of mango grown in Australia, and this variety dominates production in the Gilbert River Irrigation Area. The yields of Kensington Pride mangoes average around 8.0 t/ha across the Australian tropics and subtropics. Newer varieties such as Honey Gold and Calypso have become the new standard for mango production yield, with relatively high yields of 20 to 25 t/ha. However, for this regional analysis, it is assumed that Kensington Pride will continue to dominate production, although with favourable growing conditions in this part of the tropics the yield is assumed to be around 11 t/ha.

Mangoes flower from May to August, and from time of flowering to harvest (November to March) water management is crucial for optimum mango development. Cold spells after flowering can have a detrimental effect on mango yield and is often the cause of seasonal variation. However, anecdotal evidence suggests that unusually warm, dry seasons can also affect flowering. Individual mango trees often exhibit a biennial yield variation.

Banana

Banana production is suited to the climate of the Gilbert region. Although bananas can be planted during most of the year, planting is generally undertaken to avoid young plants developing in the very hottest months. Banana growth will be slower with cooler weather, and damage can occur through frosts that can occur in the Gilbert region. Banana plants ratoon via suckers and do not require annual planting, but they are generally removed and replanted after three or four ratoons (depending on disease presence). Fruiting in older banana blocks becomes asynchronous, with harvesting windows extending for much of the year. As discussed before, although the inland locations for growth in the Gilbert region provide some protection against severe cyclone intensity, cyclones can still affect production. In this analysis, production is assumed to be around 3300 cartons/year (approximately 40 t/ha).

Sugarcane

Sugarcane was sown in the simulations on 15 May, with harvest for the plant, first, second and third ratoon crops being 15 September and for the fourth ratoon, 15 June. Sugarcane is a biomass crop, with the yields in the simulations (118 t/ha across the five crops) comparing favourably with yields for the Burdekin River region, which has a similar climate and is recognised to be the best sugarcane producing region in Australia. Water use in sugarcane is substantially higher than for most crops because it is a perennial crop, with irrigation only ceasing in the months leading up to harvest, and heavy water use being required in the highest evaporative demand months in the Gilbert region from October to December.

Cotton

In the simulations, cotton was sown as a wet-season crop on 1 January. Unlike the Ord and Katherine–Mataranka regions, winter night-time temperatures are too low to permit high-yielding dry-season cotton production, so it needs to be grown over summer. Cotton is susceptible to rainfall during late crop development, which can downgrade cotton quality and price, so planting needs to occur as late as possible before the onset of the wet season to avoid rainfall at later stages of crop development. Cotton yields were simulated to be just below 9 bales/ha, which is consistent with results published by Yeates et al. (2013) for northern tropical regions. If cotton can be processed locally, there is the additional benefit from producing cottonseed, which is a valuable high-protein meal for cattle, fed either as whole cottonseed or as cottonseed meal.

Sandalwood

Sandalwood is grown for 15 years, and requires good irrigation management during the life of a stand to ensure optimum oil yields. Projected estimates of commercial production of sandalwood in the Ord are around 10 t/ha of heartwood. In this analysis, a somewhat more conservative yield estimate has been applied of 8 t/ha of heartwood and an oil content of 3.5%. Agronomic techniques and management of host species have improved greatly since the early plantings in the Ord region in the 1990s, which supports the likelihood that yields of at least 8 t/ha can be achieved.

Guar

There is an emerging interest in growing guar for gum in the Flinders and Gilbert catchments, possibly as a rotation crop with sugarcane in the Gilbert catchment. Guar is a legume crop with only limited trial data available from areas in northern Australia. The crop has similar growth characteristics to soybean and, based on past published research from Australia and overseas, a yield of 2.5 t/ha has been assumed under irrigation.

Hemp

Although there has been little work on industrial hemp varieties that might be suited to tropical Australia, for this analysis a yield of 10 t/ha has been assumed, with a recovery rate of 30% of bast fibre following the retting process.

Cassava

Cassava yields were simulated to be around 70 t/ha (fresh weight) or 40 t/ha as dried chips. This yield was based on past research and yields obtained in commercial plantings in other regions of north Queensland.

Forage hay

Forage grass yields for hay production can vary from 15 to 20 t/ha/year of dry matter for forage sorghum planted at commonly used seeding rates, and between 30 and 40 t/ha for very high-density planted forage sorghum or for perennial grasses such as Rhodes grass. These high yields are dependent on significant fertiliser inputs and up to four harvests per year to achieve high biomass production, while maintaining forage quality above 1% nitrogen (7% protein). For the yield simulation, a high-density forage sorghum hybrid is used that receives four cuts over the 10-month growing period, giving simulated yields of 25 t/ha of dry matter in the Gilbert region and 29 t/ha of dry matter in the Flinders region.

7.7.4 **CROPPING CALENDAR**

Cropping calendars identify sowing times and the growing season for different crops. The time during which a crop can be reliably sown is called the sowing window. The cropping calendar presented in Table 7.13 identifies sowing windows for the crops that have been analysed for the Flinders and Gilbert catchments. Perennial crops are grown throughout the year, and consequently have a less well-defined growing season or planting window. Generally, perennial tree crops are transplanted as small plants (not seeds), and in the Flinders and Gilbert region this is usually timed towards the beginning of the wet season to take advantage of wet-season rainfall.

The cropping calendar was developed based on direct knowledge of the performance of these crops in the Flinders and Gilbert region. This was supplemented by knowledge of crops from elsewhere in the tropics. Combined with an understanding of plant physiology, this enabled the crop response to differences in local climate to be anticipated. The sowing and growth windows that have been identified correspond to the times that are likely to maximise potential crop yield in the Flinders and Gilbert region (Table 7.13). Crops can at times be successfully sown outside the identified sowing windows with only a small yield penalty. In this analysis, sowing dates between August and November are generally avoided because high evaporative demand and low water availability are not conducive to seedling establishment. It is, however, possible to sow many crops at this time. It should be noted that sowing to achieve maximum potential crop yield may not always be possible as, for example, difficulties in wet-season access and trafficability may prevent sowing at optimum times.

Table 2.13 Calendar of sowing for annual crops in the Flinders and Gilbert regions

CROP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Broadacre												
Chia				X	X	X	X	X	X	x		
Chickpea					X	X	X	X	X			
Maize			X	X	X	X	X	X	X			
Mungbean			X	X	X	X	X					
Peanut			X	X	X	X	X	X	X			
Rice	X	X	X	X	X	X						X
Sorghum			X	X	X	X	X	X				
Soybean	X	X	X	X	X							X
Industrial												
Cassava	X	X	X	X	X	X	X	X	X	X	X	X
Cotton	X	X	X	X	X	X						X
Guar	X	X	X	X							X	X
Hemp	X	X	X						X	X	X	X

7.8 Gross margin analysis: sensitivity to price, production and supply chain costs

The crop gross margin is the difference between the gross income and variable cost of growing a crop and is commonly used to assess the impact of changes in crop activity mixes and intensities of production.

Variable costs include those associated with crop management, harvesting, transport and marketing. For cropping activities in regions such as the Flinders and Gilbert, which are distant from major infrastructure and support services, the costs of production will be relatively high compared with other agricultural regions in southern or eastern Australia. These higher costs can be attributed to both higher costs for inputs as well as the costs associated with transport to markets and processing facilities.

Estimates of the gross margins for a range of crops specific to the Flinders and Gilbert regions are presented in Tables 7.14 and 7.15. The gross margins do not include overhead costs (e.g. business administration, insurance) or debt and depreciation on capital costs (e.g. farm equipment, irrigation infrastructure) that must be met even if a crop is not grown. Estimates for the crops that were simulated using APSIM are based on 100 years of historical climate data and use the 50th percentile exceedance crop yields. For crops that could not be modelled with APSIM, the estimated yields underpinning the gross margins are based on production data in the region or in other regions if that crop is currently not grown. For crops that have not been grown commercially in any of the case study regions of this report (e.g. hemp, guar, cassava), published estimates were used. Costs of production were based on gross margins developed by local agricultural economists and agronomists, various published gross margins such as on Queensland Government website,[5] and various published reports. The same baseline costings were used in both the Flinders and Gilbert regions before being modified to account for the different water delivery systems that were assumed to apply in each region (i.e. bulk water storage and channel delivery system in the Gilbert and initial pumping into ring tanks and then further pumping to the paddock for the Flinders) and different freight costs. Estimated crop yields differed slightly between the regions and these differences are reflected in the revenue component of the gross margin estimates.

Gross margin analyses are indicative and should be used with care because they are highly sensitive to the assumed values of price, yield and transport costs, and the input costs, not just within a particular region but between individual farms. The analyses in Tables 7.14 and 7.15 have been based on existing supply chains and processing facility locations.

Rapid price movements can occur over days and weeks in horticultural crops, which largely supply domestic markets that have a finite demand capacity and can be easily oversupplied. This market pattern is highlighted in Figure 7.14, which shows movements in the wholesale price of bananas at the Sydney markets in 2013. The price varies 25% or more either side of the year-long average, and this can have a huge impact on profitability for the crop. Indeed, it is not unusual with a commodity like bananas for growers to be just breaking even for much of the year and relying on good returns over periods of weeks to generate the major part of their annual profits. In contrast, significant price movements for broadacre crops generally, play out over a longer timescale of months and years (Figure 7.15).

[5] www.agbiz.daff.qld.gov.au/plants/field-crops-pastures.html

Table 7.14 Gross margin analysis for existing and potential crops in the Gilbert region

CROP	LOCATION FOR MARKET OR PROCESSING	YIELD UNIT/ha	MEDIAN YIELD (per ha)	PRICE PER UNIT YIELD ($)	VARIABLE COSTS LESS FREIGHT ($/ha)	FREIGHT COSTS ($/ha)	TOTAL VARIABLE COSTS ($/ha)	GROSS MARGIN ($/ha)
Broadacre								
Chia	Melbourne	tonnes	1.1	3,300	1,806	305	2,111	1,189
Maize	Townsville	tonnes	9.9	280	1,342	703	2,045	713
Peanut	Tolga	tonnes	5.3	850	2,908	286	3,194	992
Soybean	Townsville	tonnes	3.5	500	912	249	1,161	589
High value								
Banana	Brisbane	carton (13 kg)	3,300	18	30,818	8,910	39,728	13,732
Mango — Kensington Pride	Brisbane	tray (7 kg)	1,540	20	18,213	2,712	20,985	6,944
Industrial/other								
Cassava	Dalby	tonnes (dried)	40	135	1,897	5,400	7,297	–1,955
Cotton	Emerald	bales	8.7	500	2,980	1,383	4,363	574
Guar	Townsville	tonnes	2.0	625	663	142	805	445
Hemp	Townsville	tonnes	10	650	1,033	448	1,481	469
Sandalwood[a]	Albany	tonnes	8	122,500	7,337	302	7,639	64,960
Sugarcane	Georgetown	tonnes	118	39	2,530	709	3,239	1,370
Forage hay	Georgetown	tonnes	25	130	2,335	560	2,895	689

a Ony 1/15 ha is harvested each year due to the 15-year rotation.

Table 7.15 Gross margin analysis for existing and potential crops in the Flinders region

CROP	LOCATION FOR MARKET OR PROCESSING	YIELD UNIT/ha	MEDIAN YIELD (per ha)	PRICE PER UNIT YIELD ($)	VARIABLE COSTS LESS FREIGHT ($/ha)	FREIGHT COSTS ($/ha)	TOTAL VARIABLE COSTS ($/ha)	GROSS MARGIN ($/ha)
Broadacre								
Chickpeas	Townsville	tonnes	2.8	500	691	146	837	551
Mungbean	Townsville	tonnes	2.2	850	1,044	114	1,158	536
Rice	Townsville	tonnes	10.7	320	1,611	631	2,242	1,149
Sorghum	Emerald	tonnes	8.4	240	1,588	403	1,991	25
Industrial/other								
Cotton	Emerald	bales	8.8	500	3,131	642	3,773	1,221
Forage hay	Richmond	tonnes	29	130	2,525	290	2,825	945

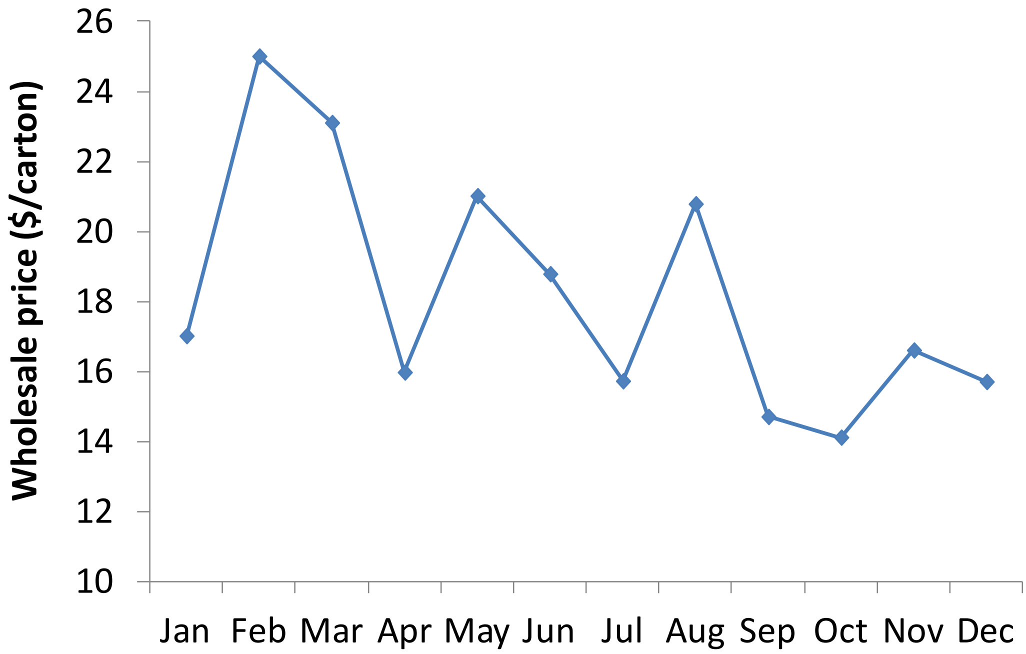


Figure 7.134 Wholesale prices for bananas at the Sydney markets during 2013
Source: Data provided by Ausmarket Consultants, Brisbane

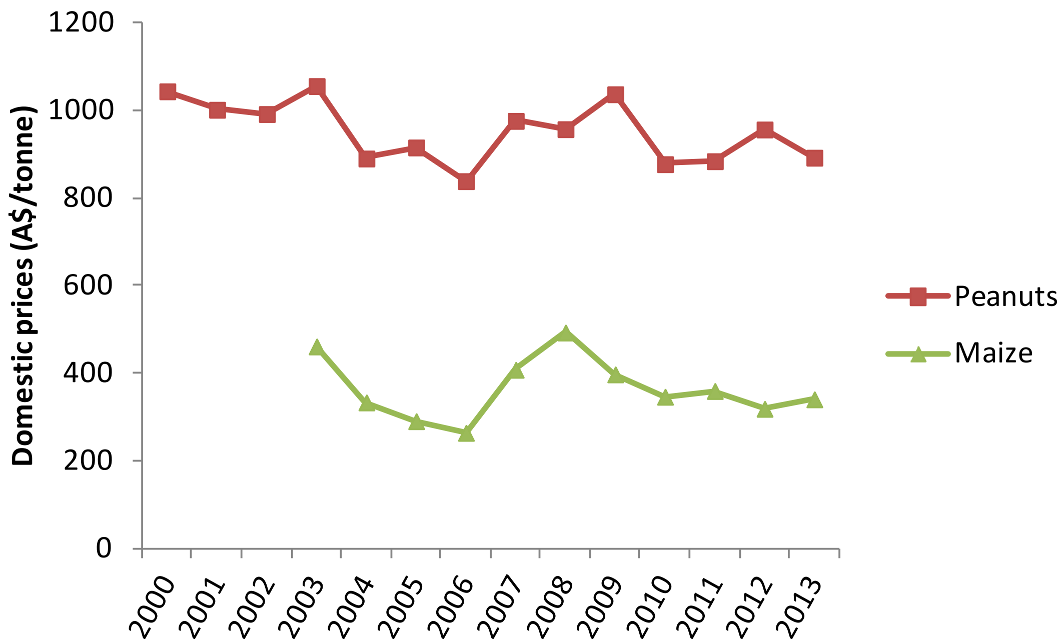


Figure 7.145 Prices received for peanuts and maize in Australia
Source: Data supplied by ABARES

7.8.1 BROADACRE CROPS

The estimated gross margins for the broadacre crops were in the range of $500 to $1000/ha, although there were exceptions. For example, rice and chia generated gross margins of more than $1000/ha, while sorghum grown at Richmond produced an estimated gross margin of only $25/ha. Most of these broadacre crops need to be transported significant distances (300 to 500 km), which added to the costs of production. The estimates presented in Tables 7.16 and 7.17 show that freight costs made up between about 10 and

35% of the total costs of production. The production costs were relatively higher for high-yielding crops such as rice and maize, and lower for small-seeded, lower-yielding crops such as mungbean and chia. In making these calculations, some backloading allowance (20 to 50%) was assumed for transport costs, with the higher backloading percentages applied for produce transported along the Flinders Highway because of the volume of freight going from Townsville to the mining regions west of the Flinders catchment.

The processing facilities that are available near Ayr in Queensland for rice, other grains and pulses provides a market for these products and, even though freight costs are a significant component of total costs, gross margins are still positive. An exception was sorghum grown in Richmond, which was transported to Emerald for use in feedlots. The relatively low value of this grain relative to the costs of shipping it any significant distance reduced the gross margin to almost zero. Gross margins for peanuts grown in the Gilbert were close to $1000/ha, based on shipping to a primary processing facility in Tolga, which kept freight costs to less than 10% of the total costs of production.

Table 7.16 Freight costs as a percentage of total value of production and total production costs for a range of crops in the Gilbert region
Location represents the point of wholesale or processing.

CROP	LOCATION FOR MARKET OR PROCESSING	FREIGHT COSTS AS A PERCENTAGE OF TOTAL VALUE OF PRODUCTION (%)	FREIGHT COSTS AS A PERCENTAGE OF TOTAL COSTS OF PRODUCTION (%)
Broadacre			
Chia	Melbourne	9.2	14.4
Maize	Townsville/Ayr	25.4	34.4
Peanut	Tolga	6.3	9.0
Soybean	Townsville/Ayr	14.2	21.5
High value			
Banana	Brisbane	16.7	22.4
Mango – Kensington Pride	Brisbane	9.8	13.0
Industrial/other			
Cassava	Dalby	100	74.0
Cotton	Emerald	31.8	31.7
Guar	Townsville	11.4	17.6
Hemp	Townsville	23.0	30.3
Sandalwood[a]	Albany	0.4	8.3
Sugarcane	Georgetown	15.4	21.9
Forage hay	Georgetown	7.7	9.7

a Ony 1/15th ha is harvested each year due to the 15-year rotation.

Table 7.17 Freight costs as a percentage of total value of production and total production costs for a range of crops in the Flinders region

Location represents the point of wholesale or processing.

CROP	LOCATION FOR MARKET OR PROCESSING	FREIGHT COSTS AS A PERCENTAGE OF TOTAL VALUE OF PRODUCTION	FREIGHT COSTS AS A PERCENTAGE OF TOTAL COSTS OF PRODUCTION
Broadacre			
Chickpea	Townsville/Ayr	10.4	17.9
Mungbean	Townsville/Ayr	6.1	10.0
Rice	Townsville/Ayr	18.4	28.1
Sorghum	Emerald	20.0	20.2
Industrial/other			
Cotton	Emerald	14.6	17.0
Forage hay	Richmond	7.7	10.3

7.8.2 HIGH-VALUE CROPS

The gross margins for intensive horticultural production in the Gilbert region were strongly positive, based on the assumptions used in this analysis. All horticultural crops have high input costs and, as indicated in Figure 7.14, price movements can occur rapidly in response to supplies at a national scale. The sensitivity of gross margins to price of horticultural products grown in the Gilbert region is highlighted in Table 7.18, which demonstrates that, although gross margins per hectare can be high, large losses can also occur when product is oversupplied and prices fall.

Table 7.18 Gross margin sensitivity ($/ha) to price or horticultural crops in the Gilbert region

Baseline gross margins are the same as reported in Table 7.15 and the price sensitivities are in steps of +/–15%.

PRICE SENSITIVITY	BANANA	MANGO – KENSINGTON PRIDE
–45%	–$6,315.48	–$4,525.70
–30%	$367.02	–$702.65
–15%	$7,049.52	$3,120.40
Baseline	$13,732.02	$6,943.45
+15%	$20,414.52	$10,766.50
+30%	$27,097.02	$14,589.55
+45%	$33,779.52	$18,412.60

Labour costs for harvest and postharvest activities typically represent 20 to 30% of total production costs for horticultural crops and, therefore, have a significant influence on net returns. Labour supply is sourced largely from backpackers who can obtain a second-year holiday visa if they work for 3 months in a regional area of Australia. Accordingly, accessing labour is likely to be easier in regions with high tourism appeal for backpackers (e.g. Katherine, Kimberley). This, when combined with a rapid decline in the local population of the Flinders and Gilbert regions, means that labour supply as well as its overall contribution to costs will be a challenge for expanded horticultural production in the Gilbert region.

The vast majority of horticultural production from northern Australia is presently directed to domestic markets, and the small amount of production sourced from the Gilbert region is no exception. Consequently, transport costs per hectare of production were high in absolute terms (Table 7.14) for both bananas and mangoes and represented 22% of the costs of production for bananas (Table 7.16).

The flow of refrigerated produce to supermarkets in northern Australia provides an opportunity for horticultural producers to take advantage of attractive backloading rates for otherwise empty refrigerated containers returning to capital cities in southern and eastern Australia. In the supply chain model developed for this project, backloading capacity was set at 80% for horticultural produce in the Gilbert region. This provided some non-backloading freight for refrigerated vehicles that would need to travel empty from the Atherton Tableland to the Georgetown district to collect fruit. Without this supply of empty refrigerated containers returning to southern capitals, it is likely that transport costs for northern produce to southern markets would be prohibitive.

Given the sensitivity of prices to supply and market capacity in the domestic market and the freight costs incurred in transporting the produce to southern Australia, an opportunity exists to develop export markets, with the produce moving out of a well-developed port such as Cairns. This is currently not generally feasible due to a combination of factors, including:

- the high costs of production for Australian tropical fruit when taken into an Asian market, unless it is a specialised niche market
- the limited number of markets with appropriate export protocols already developed
- for some crops, the high costs associated with treatment for pests or disease before export (e.g. vapour heat treatment costs of approximately $14/tray for mangoes)
- insufficient port capacity to accommodate storage and electricity supply to refrigerated containers and volumes of supply too low to generate a shipping demand for perishable fruit at sufficient frequency to be cost-effective

In the supply chain scenarios that are considered below, some alternative supply chain costs are assessed assuming that some of these constraining factors are removed. Cairns port has the underpinning infrastructure to accommodate a growth in horticultural exports if the logistical and cost challenges can be addressed.

7.8.3 INDUSTRIAL CROPS

Gross margins for the industrial crops provided a distinct contrast in terms of financial returns. Many of the differences were heavily influenced by the location of existing processing facilities. Industrial crops are usually characterised by high raw produce volumes and bulk relative to that of semi-processed or highly processed produce, with implications for transport costs. As a result, processing facilities are often located in or near the main production area; this analysis highlights the economic impacts of relying on more distant processing facilities. In the case of sugarcane, the option of sending raw sugarcane to the existing sugar mill at Mareeba was discounted because the freight costs greatly exceeded the value of the cane.

Cassava is not commercially grown at any scale in north Queensland, and the nearest ethanol plant capable of taking cassava chips is located at Dalby on the Darling Downs. There is an ethanol plant at Sarina but it is presently set up to process molasses as a by-product from locally sourced sugarcane. Given the relatively low value of dried cassava chips ($135/t), the revenue from the crop was entirely consumed by freight costs to Dalby, leaving a negative gross margin. In the supply chain scenarios below, it was assumed that a new ethanol plant is located at Ingham, which is based on actual plans to establish one there in the next few years.

For the cotton development scenario, it was assumed that the raw cotton was processed in Emerald, some 1000 km away from the irrigation areas west of Georgetown. As a consequence, freight costs comprised a large percentage of the costs of production and the gross margin, which although still positive at $574/ha, was low by comparison with cotton grown in other regions of southern Australia. For cotton grown at

Richmond in the Flinders region, the Emerald gin was much closer and so gross margins were more than $1200/ha.

As commercial harvests of sandalwood from the Ord region only commenced in 2014, commercial returns are yet to be proven. The gross margin estimates for sandalwood were based on investment analysis and information provided by Tropical Forest Services (TFS Pty Ltd) to the Australian Securities Exchange. The Ord region gross margin analysis was adopted for the Gilbert region, although variable costs for some of the management and irrigation costs were different. The crop was assumed to be harvested after 15 years, so for this analysis a steady state 15-year rotation was employed in which 1/15th of the area was planted and 1/15th was harvested to generate a per-hectare gross margin.

Current prices for sandalwood oil are around $4500/kg and are projected by the promoting interests to increase into the future. However, in the gross margin analysis, a more conservative price of $3500/kg was used. India has closed its sandalwood market and Australia will dominate oil entering the world market because of the large areas that have been planted, especially in the Ord River Irrigation Area. Projected yields of sandalwood are yet to be proven, but based on estimates of 8 t/ha of heartwood after 15 years (assumes 80% survival rates of seedlings and 20 kg/tree of heartwood), a gross margin of $65,000/ha was generated. This far exceeds the value for any other crop. Because of the high value of the crop, transport costs of heartwood to a processing plant at Albany from northern Queensland comprised only a small proportion of the total value of production or total production costs.

Because industrial hemp has not been grown commercially or experimentally in the Australian tropics, it was hard to provide an estimate of either production costs or gross margins with any degree of confidence. For the present study, it was assumed that the crop can be processed in Townsville following on-farm harvest and retting, a process whereby microorganisms and water rot away the cellular tissues and pectin surrounding the bast fibres. About 30% of the harvested yield is bast fibres and a return of $645/t was assumed for this fibre. After costs of production and freight costs to Townsville were accounted for, a gross margin of under $500/ha was projected. Similarly, a gross margin of around $700/ha was generated for guar, although confidence in this estimate is also necessarily low.

7.8.4 **FORAGES**

Forage sorghum returned a gross margin of between $650 and $950/ha, based on the assumption that it could be used locally in the beef industry, either as hay for feeding animals in yards or as part of a feedlot ration in intensive feeding systems. Higher gross margins were obtained in the Flinders region, mostly because of the lower freight charges assumed in providing hay to the local industry compared with the Georgetown region

7.8.5 **DIFFERENT SUPPLY CHAIN OPTIONS AND GROSS MARGINS**

Gross margins are presented in Table 7.19 for a range of crops, assuming different supply chain options to those that were used in the baseline analysis in Tables 7.14 and 7.15. Assumptions for the new supply chain options are also provided.

Incorporating coarse grains such as maize and sorghum into local intensive beef-feeding systems rather than trucking the grain significant distances produced increases in gross margin, particularly for sorghum. Development of this localised supply chain is dependent on the ability of local beef enterprises to profitably intensify their production. In addition to the grain component, forages that are grown for hay can also provide the high-quality roughage component of these intensive feeding systems. Such integrated systems may work most effectively with the corporate pastoral companies that operate multiple properties in the Flinders and Gilbert regions and can coordinate supply chains of young growing animals from specialised breeding properties to intensive finishing systems. A number of these companies already operate such systems, but the finishing components tend to occur on properties located in major grain-producing regions in central or southern Queensland.

For the horticulture scenario where mangoes are transported to Cairns and then shipped to Asia, there was a modest increase in gross margins. This assumes that regular shipping routes for refrigerated containers can be established and that the requisite empty refrigerated containers are available at Cairns port. As indicated above, there can be significant quarantine treatment costs associated with export protocols, which have not been included in this analysis. However, the rationale for investigating this scenario was not so much on the basis of significant savings in freight but rather the opportunity to establish export markets, given the limited growth capacity in domestic markets for tropical produce. This is particularly relevant for regional scenarios of expanded horticultural production where the objective is to avoid oversupplying domestic markets (see Section 7.9).

For both the Flinders and Gilbert regions, the baseline cotton scenarios involved raw cotton being transported to Emerald in central Queensland for ginning. Under the development scenarios, a cotton gin was assumed to be available in Charters Towers. Such a development would not only be available to process cotton grown in the Richmond and Georgetown districts, but also that grown in the Burdekin region where commercial scale trials are presently being undertaken. At present, the product sourced from the Burdekin region only has the option of being processed at Emerald. A cotton gin in Charters Towers resulted in gross margins increasing to around $1500/ha based on a cotton price of $500/bale.

The other industrial crop that significantly benefited from an improved supply chain was cassava for ethanol. North Queensland Bioenergy Corporation Limited[6] is proposing to construct a $425 million multifunction refinery near Ingham that will produce sugar, ethanol and electricity via co-generation (North Queensland Bio-Energy, 2014). Although it is planned that sugar will be the primary feedstock, it is anticipated that a wide range of other feedstocks could be accommodated, including cassava. Transporting cassava dried chips to Ingham greatly reduced transport costs and turned a highly negative gross margin to a positive return ($894/ha).

Table 7.19 Change in gross margin for a range of selected crops in the Flinders and Gilbert regions in response to altered location of processing facilities or market destination

CROP	LOCATION FOR MARKET OR PROCESSING-BASELINE	GROSS MARGIN ($/ha)	LOCATION FOR MARKET OR PROCESSING – SCENARIO	GROSS MARGIN ($/ha)	ASSUMPTIONS FOR SUPPLY CHAIN SCENARIOS
Broadacre					
Maize	Townsville	713	Mareeba	990	Incorporated into livestock feeding systems
Sorghum	Emerald	25	Richmond	386	Sorghum used in on-farm and commercial feedlots
High value					
Mango – Kensington Pride	Brisbane	6,944	Cairns/Asia	8,022	Road transport to Cairns and then export by ship to Asia – excludes additional costs of export protocol requirements
Industrial					
Cotton (Flinders)	Emerald	1,221	Charters Towers	1,547	Cotton gin in Charters Towers
Cotton (Gilbert)	Emerald	574	Charters Towers	1,357	Cotton gin in Charters Towers
Cassava	Dalby	–1,955	Ingham	845	Ethanol plant in Ingham

[6] www.nqbioenergy.com.au/index.php

7.9 Integrated scenario analysis: investment and supply chain options

The scenario analyses in the previous sections have focused on individual crops, their production characteristics in the Flinders and Gilbert regions, farm gross margins and supply chain options for the individual crops. In this section, development scenarios are examined for agricultural production at a regional scale, with implications for regional value of production, logistics and investment in supporting infrastructure.

The regional-scale analysis assumes that 30,000 ha is available for irrigation development in the Gilbert region and 15,000 ha in the Flinders region. For this analysis the two regions are combined. Unlike the other tropical regions that have been considered in this report, the water supply is not yet available at the scale required to meet the scenarios (45,000 ha in total). Therefore, an assumption has been made that the necessary water supply is available, based on ring tanks on farm in the Flinders catchment and on major river storages in the Gilbert catchment. These assumptions are consistent with resource assessments provided by the recent Flinders and Gilbert Agricultural Resource Assessment (Petheram et al., 2013c). The areas of irrigable land assume supply reliabilities of 85% in the Gilbert catchment and 80% in the Flinders catchment. For this analysis, the reliability of water supply availability is considered in the context of risk rather than assuming, for example, that for 1 year in 5 there is no water available for allocation or that for 2 years in 5 there may be half the required water available.

7.9.1 INVESTMENT AND SUPPLY CHAIN OPTIONS

Two scenarios were chosen to explore development of irrigated crop production systems and supporting infrastructure (Table 7.20).

Scenario 1

The first development scenario provides an integrated focus for the Flinders and Gilbert districts with the establishment of a cotton gin at Charters Towers and both regions growing significant areas of irrigated cotton. In the Gilbert region, a diversified mix of crops are grown in addition to cotton, including maize, peanuts, forage for hay and mangoes. It is assumed that the maize and hay are incorporated into regionally based beef-feeding systems. There is also an opportunity to use maize in pig and poultry feeding systems on the Atherton Tableland. Given the significant area of mangoes (5,000 ha), this scenario took an export market approach, with the mangoes being transported to Cairns and then shipped to Asia. The export focus has been applied to avoid potential oversupply problems in the domestic market, although it is recognised that developing new export markets and associated protocols has significant challenges.

Scenario 2

The second scenario assumes a major investment in sugarcane in the Gilbert region, including the establishment of a mill and a diversified mix of broadacre crops in the Flinders region. To ensure sufficient scale to justify a mill, the entire 30,000 ha of development in the Gilbert region under this scenario is devoted to a sugarcane system. Associated with this is a fallow crop of soybean of 5000 ha each year, with the remaining 25,000 ha of development under sugarcane (i.e. a plant crop followed by four ratoon crops). Soybean is a legume and the fallow crop is used to avoid declining yields of sugarcane (Garside and Bell, 2011). This development scenario is based on construction of a sugar mill in Georgetown with a capacity to produce between 300,000 and 350,000 t/year of sugar. Broadacre crops to be grown in the Flinders catchment as part of this scenario included rice, sorghum, high-quality forage for hay, mungbean and chickpea. Rice is the major crop and it is grown in a rotation with chickpeas (i.e. two crops in a year). Both the sorghum grain and the hay are assumed to be used locally as part of integrated beef production systems.

In both scenarios, the processing location for rice and pulse grains is assumed to be at Brandon, near Ayr, using the existing Blue Ribbon facilities that can mill rice, and grade and process pulses. Those facilities presently have the capacity to mill 20,000 t/year of rice, so in the scenario where 5000 ha of rice is grown at Richmond, additional milling capacity would be required to handle the 50,000 t/year. Rice mills are relatively inexpensive and can effectively be purchased off the shelf. Additional storage capacity would also be required to service the increased volume of produce.

Table 7.20 Scenarios used to explore implications of scaled-up production at the regional scale

CROP	LOCATION	AREA OF LAND (ha)	CROP YIELD/ha (t)	LOCATION FOR MARKET OR PROCESSING	ASSUMPTIONS FOR REGIONAL SCENARIO
Scenario 1 – regional processing infrastructure + horticulture and mixed cropping					
Maize	Gilbert	5,000	9.9	Georgetown/ Mareeba	Maize used in beef-feeding systems and other livestock (e.g. poultry)
Peanut	Gilbert	5,000	5.3	Tolga	Processed at plant in Tolga
Mango	Gilbert	5,000	11	Asia	Refrigerated transport to Cairns and then ship to Asia, assumes some additional costs associated with quarantine
Cotton	Gilbert	15,000	8.7	Charters Towers	Cotton gin servicing Gilbert and Flinders in Charters Towers
Forage hay	Gilbert	2,500	25	Georgetown	Hay for beef enterprises and intensive feeding systems
Sorghum	Flinders	5,000	8.4	Richmond	Integrated into intensive beef systems
Cotton	Flinders	10,000	8.8	Charters Towers	Cotton gin servicing Gilbert and Flinders in Charters Towers
Scenario 2 – Gilbert infrastructure investment (sugar mill) + Richmond mixed cropping processed in Ayr					
Soybean	Gilbert	5,000	3.5	Ayr	Rotation for sugarcane after last ratoon
Sugarcane	Gilbert	25,000	118[a]	Georgetown	Sugar mill established in Georgetown
Chickpea	Flinders	5,000	2.8	Ayr	A rotation crop after rice in the same year (i.e. double cropped) using stored water
Mungbean	Flinders	2,500	2.2	Ayr	Useful crop in years when water availability is limited
Rice	Flinders	5,000	10.7	Ayr	Used in rotation with chickpeas to achieve two crops per year
Sorghum	Flinders	5,000	8.4	Richmond	Integration into local intensive beef-feeding systems
Forage hay	Flinders	2,500	29	Richmond	Extensive beef enterprises and integration into intensive beef-feeding systems

a Yield is average per year over 30,000 ha, including the 5000 ha that is fallow cropped with soybean following the last ratoon

Results

The regional-scale implications of the two scenarios operating at a scale of 45,000 ha in the Flinders and Gilbert regions are presented in Table 7.21.

Scenario 1, which focuses on regional infrastructure in the form of a cotton gin to service both the Flinders and Gilbert as well as a significant area of horticulture for export markets, generated a projected gross value of around $300 million.

Horticulture has a high gross value and high costs, and the 5000 ha of mangoes in this scenario contributed half of the gross value for the region. Successfully expanding horticultural production will require development of new export markets in Asia and beyond, given the sensitivity of domestic markets to oversupply. Establishing a reliable and regular refrigerated container service from Cairns has the potential to reduce freight costs compared with freighting produce to the existing southern-based markets. An alternative option for export is air freight out of Cairns. Under current arrangements it is cheaper to truck mangoes to Brisbane or Sydney and air freight them to Asia from there at a cost of about $6/tray than it is to fly them out of Cairns. This is because of the relatively small number of wide-bodied aircraft capable of handling freight that arrive in Cairns and are then either returning northwards or are en route northwards from southern capitals. There is potential for this situation to change with the proposed Aquis tourism development in Cairns, which will involve a mega-scale integrated resort containing around 5000 rooms and apartments. It is anticipated that most tourists will arrive from Asia in wide-bodied aircraft, which will be capable of taking cargo on the return journey at freight rates that are likely to be competitive with current rates out of Sydney.

The much bigger challenge would appear to be developing a wider range of export markets and overcoming the various regulatory and quarantine barriers. These barriers include both time to negotiate new export protocols (10 years +) and the potentially high costs of meeting quarantine requirements (e.g. vapour heat treatment of mangoes). Growcom, the peak industry body representing fruit and vegetable growers in Queensland, has clearly outlined the challenges of developing profitable new markets in a recent submission to the Northern Australia white paper process (Growcom, 2014):

> 'Growcom sees the development of strong trade ties with the Asia-Pacific region as absolutely critical for the development of the horticultural industry in Northern Australia and in fact Australia as a whole. The domestic market for fresh fruit and vegetables has limited capacity for growth ...'.

The horticulture scenario resulted in high production costs when aggregated over 5000 ha. A significant component of this cost is comprised of labour, which provides both challenges and opportunities at a regional scale. A larger seasonal labour force in the region would have flow-on benefits for the local economy, but sourcing the additional labour could be challenging, particularly if other regions in northern Australia are also seeking to expand horticultural production. An added challenge in this region is the declining local population, which adds further pressure on the ability to source labour within the region.

A key feature of this scenario is the establishment of a cotton gin at Charters Towers. Although this site is not immediately adjacent to either region where the crop is grown, it provides a central location for processing cotton, being 440 km from Georgetown and 370 km from Richmond. In addition, it is about 100 km from the Burdekin River Irrigation Area, which potentially offers an additional source of raw cotton for the gin. In the analysis, cotton from the 25,000 ha of production contributed over $110 million/year in gross value, and it would provide additional regional employment in both production and processing.

For the remaining crops grown in the Gilbert region in Scenario 1, processing facilities are assumed to be located within the immediate region. Peanuts can be processed through the drying and shelling facility of the Peanut Company of Australia that is located at Tolga on the Atherton Tableland. Maize and forage hay are intended to be used in local or regional livestock feeding systems, intensive beef feeding and/or for small livestock feeds (e.g. poultry on the Atherton Tableland). Together, these crops provide about $40 million/year in gross production, but would have multiplier effects within the region because of their integration.

Scenario 2 assumes that the Gilbert region has its entire focus on sugarcane, with the entire 30,000 ha devoted to production of this industrial crop. Based on the analysis, sugarcane alone would provide $138 million in gross value of production, with additional revenue being generated from the 5000 ha/year used as a break crop after the last sugarcane ratoon has been harvested. This scenario would require major investment in a sugar mill, about $400 million, in addition to the investment in developing the land for irrigation, which is likely to be about $300 million. For the supply chain analysis (below) it is assumed that the sugar, once processed at the mill, is transported to Townsville port for bulk storage and export loading.

For the Richmond area in Scenario 2, the focus is placed on producing commodities that can be either used locally or processed close to Townsville port. In the transport cost analysis for the gross margins, it was clear that the costs of trucking bulk grains and pulses to Townsville or Ayr (where milling and processing facilities are presently located) is not a significant impediment to viable production. Grain and pulse crops grown at Richmond and the soybean grown at Georgetown, together would add about $40 million in production. Together, these grains and pulses total nearly 90,000 t in production, which greatly exceeds the current milling/processing capacity in Ayr. The infrastructure investment requirements are discussed further below.

Both development scenarios include a similar amount of maize/sorghum and forage hay production, based on the assumption that these commodities can underpin the development of more intensive beef-feeding systems in the Gilbert and Flinders regions. Producing 25,000 to 40,000 t of grain in the region has the potential to support a significant number of animals in intensive finishing systems. Assuming each animal is in the feeding system for 100 days (i.e. three cohorts per year) and consumes 10 kg/head/day of grain, this level of grain production could support 30,000 animals. Given the present size of the regional beef herd, sourcing the necessary animals to place on feed is not a constraint. The biggest challenge facing the intensification of local livestock feeding systems is more likely to be in growing out animals in a cost-effective way, given the tight margins that are typically associated with feedlot finishing. Daily liveweight gains would need to be in excess of 1.5 kg/animal fed and the value of the gain around $2.00/kg liveweight to be profitable. There would also need to be significant upfront investment in feeding pens, water, shade, effluent disposal, etc., but there would also be opportunities for on-farm feedlots to be developed in addition to larger commercial-scale units.

Table 7.21 Influence of the two regional scenarios on total flows of product and value of production per year

CROP	TOTAL PRODUCTION (t)	TOTAL VALUE OF PRODUCTION ($)	TOTAL VARIABLE COSTS ($)
Scenario 1 – regional processing infrastructure + mixed cropping			
Maize	24,750	6,930,000	4,420,000
Peanuts	26,500	22,525,000	15,970,000
Mangoes	55,000	157,135,000	101,190,000
Cotton (Gilbert)	130,500 bales	65,250,000	53,700,000
Forage hay	62,500	8,125,000	7,237,500
Sorghum	42,000	10,080,000	8,150,000
Cotton (Richmond)	88,000 bales	44,000,000	34,480,000
Total	429,250	314,04,5000	225,147,500
Scenario 2 – Gilbert infrastructure investment (sugar mill) + Richmond mixed cropping processed in Ayr			
Soybean	17,500	8,750,000	5,805,000
Sugarcane	3,540,000	138,060,000	97,170,000
Chickpea	14,000	7,000,000	4,185,000
Mungbean	5,500	4,675,000	2,895,000
Rice	53,500	17,120,000	11,210,000
Sorghum	42,000	10,080,000	8,150,000
Forage hay	72,500	9,425,000	7,062,500
Total	3,745,000	195,110,000	136,477,500

Transport implications

Both development scenarios have significant implications for the infrastructure required to transport produce to either new processing facilities or to existing markets/facilities towards Cairns and Townsville. Major infrastructure requirements are a gin at Charters Towers (Scenario 1) or a sugar mill at Georgetown

(Scenario 2), both of which would require a large vehicle fleet during the harvest season and specialised dry-weight containers.

From the supply chain analysis information shown in Appendixes 7.2 and 7.3 for each of the two regional development scenarios, vehicle requirements for all crops within a region were aggregated into those requiring refrigerated and nonrefrigerated transport. Vehicle requirements account for minor rest breaks en route to the destination, and time required for loading and unloading. They do not account for major downtime or maintenance. Figures 7.16 and 7.17 show the vehicle requirements by time of year for Scenarios 1 and 2. These requirements do not include any allowance for vehicle reductions that may be achieved by backloading opportunities on some routes.

Backloading opportunites would not be available for the cotton and sugar transport due to the specialised trailers used and high usage rates during the harvest season. Some limited backloading would likely be available for refrigerated transport to Cairns in Scenario 1, because refrigerated trucks would be delivering produce to supermarkets on the Atherton Tableland and, to a lesser extent, Georgetown. Minimal non-refrigerated backloading would be available from the Tableland and the east coast to Georgetown and Richmond because there is no need for grain trailers on the return trip. The numbers in Figures 7.16 and 7.17 are based on the number of prime movers, and a Type 2 road train is classed as one vehicle. Therefore, the numbers in Figures 7.16 and 7.17 are multiplied by 3 (or by 2 for Type 1 vehicles or 1.5 for B-doubles) to give the actual number of trailers that are required. Transport to Cairns and the Tableland is restricted to B-double vehicles.

The high vehicle requirement between May and July in Scenario 1 is mostly due to the transport of cotton, which requires a fleet of 41 vehicles (or 123 trailers). Similarly, in Scenario 2, the high vehicle requirement between June and November is mostly due to the transport of sugar to the mill (fleet size of 35.6 vehicles) plus the transport of raw sugar to Townsville (fleet size of 18 vehicles). Transport of Rice in May and June created the additional peak of more than 70 vehicles/day for Scenario 2. The transport advantage for Scenario 2 over Scenario 1 is the longer timeframe (5 to 6 months) of vehicle usage per year.

In Scenario 2, sugar is transported to Townsville (487 km) despite Cairns being closer (381 km away). This is because the trip to Cairns is limited to B-double vehicles in and around Atherton, which leads to a substantial increase in transport costs versus the road train option. For the Cairns trip, a Type 2 road train will need to break down into a B-double at Mt Garnet, which is 110 km from Cairns. This logistical requirement would make the total transport costs similar to those for the Townsville option, not accounting for the additional handling costs of breaking down to B-doubles. A Georgetown mill would produce about 300,000 t/year of sugar and would require additional storage at Townsville of about 151,000 t, assuming sugar is exported 12 months of the year. The Townsville sugar storage facility has a capacity of 755,000 t (Sugar Terminals Limited) and, during the high production year of 2011, the Burdekin produced 1,306,000 t of sugar and required most of this capacity. During a high production year, the Townsville facility would reach capacity when Georgetown supplies sugar, and would require sugar to be transported to the Cairns sugar storage facility. The Cairns facility has a capacity of 234,000 t and would have a spare capacity of about 110,000 t at the end of the harvest season of supply from Mulgrave and Mossman. The combined spare capacity of Townsville and Cairns storage facilities would be sufficient to accommodate supply from a Georgetown mill, unless production levels at existing mills also increase. If the road between Mt Garnet and Cairns was upgraded to allow Type 2 road trains, which would be a very expensive upgrade, it would reduce the sugar transport costs by at least 10%, or $5/t.

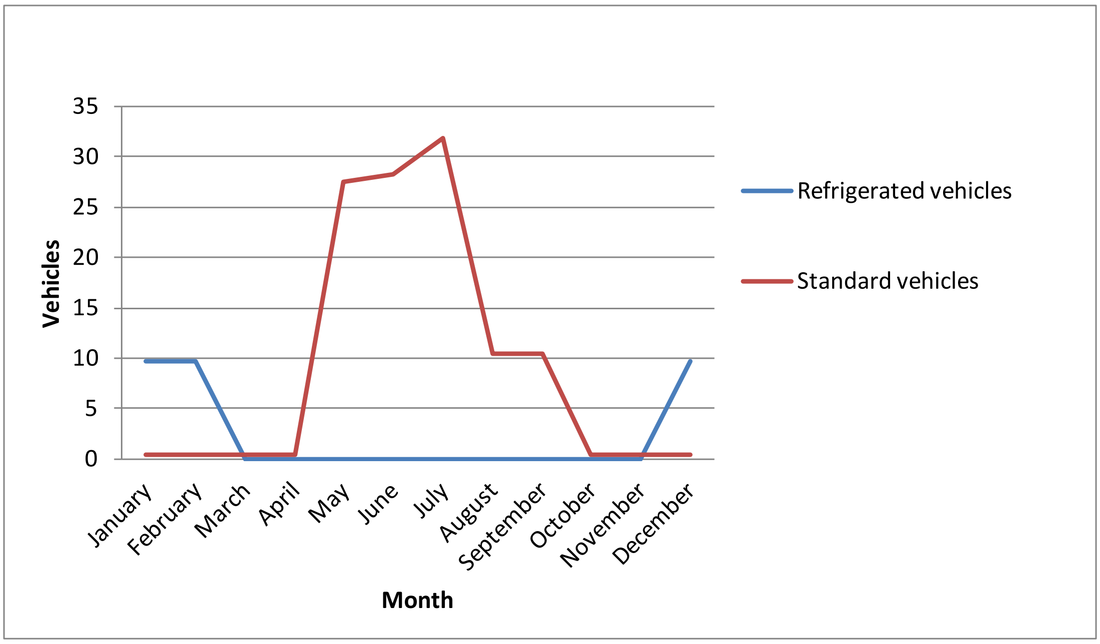


Figure 7.16 Vehicle requirements for 45,000 ha of cropping in Scenario 1

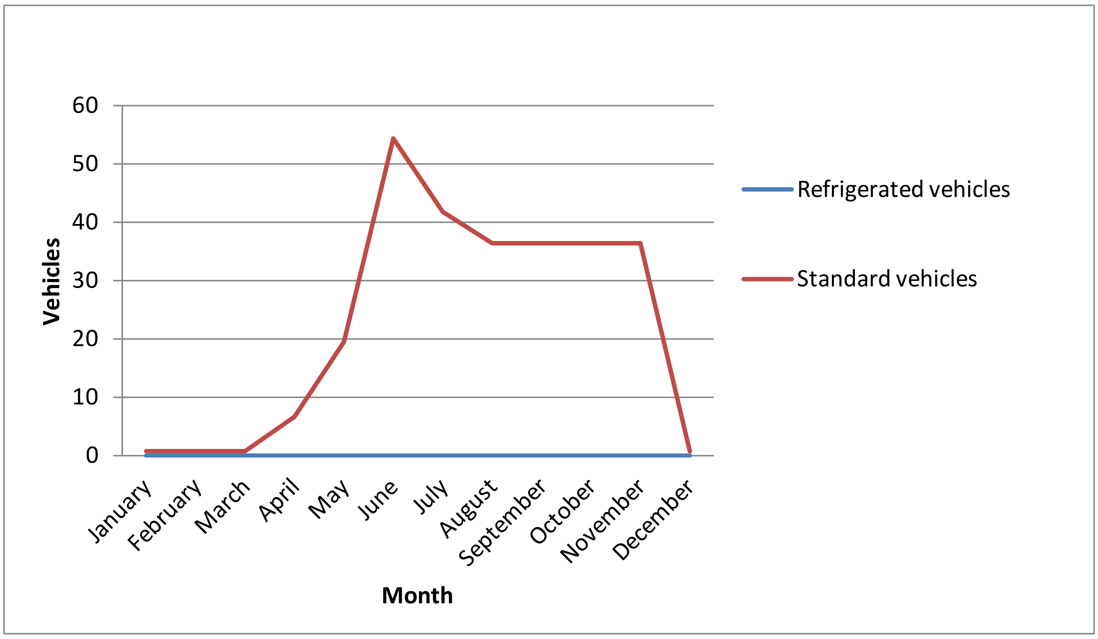


Figure 7.17 Vehicle requirements for 45,000 ha of cropping in Scenario 2

Infrastructure

There are significant infrastructure needs in both scenarios of expanded agricultural production in the Flinders and Gilbert regions. Unlike the other regions examined in this study, where the water is either presently available or there are firm plans in place to make it available, the water for irrigation in the Flinders and Gilbert regions is not currently available via existing infrastructure. This is the major infrastructure requirement for these regions that underpins the two scenarios examined for this case study. The Flinders and Gilbert Agricultural Resource Assessment (Petheram et al., 2013c) made some estimates of the capital costs that would be required to provide the necessary water infrastructure to supply the volumes of water to irrigate 30,000 ha in the Gilbert region and 15,000 ha in the Flinders region. In the Gilbert region, construction of the Green Hills and Dagworth dams, associated storages, main irrigation channels, access roads and pumping capital costs were estimated to be around $1 billion. This excludes on-farm costs of land development and supporting capital equipment (e.g. machinery, irrigation plant). In the

Flinders region, off-stream ring tanks are more suitable for supplying the necessary irrigation water, which means capital costs would be incurred at the farm scale and be geographically dispersed across the region. As ring tanks cost about $1000/ML to construct (Holz et al., 2013), for a total development of 15,000 ha where a crop such as cotton requires 6 ML/ha, the capital costs of installation would be about $90 million. For crops such as rice that are flood irrigated and require 10 to 12 ML/ha, capital costs could be $180 million. As with the Gilbert region, these costs represent the water storage capital costs, and exclude the operating costs to pump water from the river to the ring tank and the costs of clearing and developing the land and providing the water to the crop.

Assuming that the water is available for irrigation at the scales that have been identified in the two development scenarios, significant levels of investment in other infrastructure are also required. This includes:

- *Processing facilities*. Both development scenarios include industrial agriculture and, as was highlighted with the supply chain baseline for cotton, processing facilities need to be sited within a reasonable distance of the production area. This is especially true for sugar because the value of raw sugarcane is approximately $30/t and transporting it over distances of more than 30 to 50 km quickly erodes the profitability of the crop. The scenarios require a sugar mill to be established in Georgetown, a cotton gin in Charters Towers and an expansion of existing grain and pulse-milling facilities near Ayr. As indicated above, the likely capital investments required are around $400 million for a sugar mill, $30 to $40 million for a cotton gin and $20 million for expansion of grain and pulse-milling and processing facilities.

  Given the large capital sums involved, there is the challenge of which comes first, the land coming into production to drive the infrastructure investment or the investment in processing facilities to provide confidence to growers to invest in developing land. It is likely that for developments of this scale to proceed, both scaling-up of production and investment in processing facilities would have to be closely integrated.

- *Storage facilities*. For the scenarios involving bulk grains, pulses or sugar, consideration needs to be given to having adequate storage facilities before processing or export. As indicated in the section above on vehicle requirements, producing 300,000 t/year of raw sugar at Georgetown will require 155,000 t of additional storage at Townsville, assuming the bulk sugar is transported there. Similarly, producing 50,000 t/year of rice would require additional grain storage capacity. Current storage capacity at Ayr can handle 7500 t, which would need to be expanded. At a cost of about $80/t to construct bunker storage, the necessary investment would be around $3 to $5 million.
- *Transport infrastructure*. Both development scenarios require a significant investment in vehicle infrastructure. Scenario 1 requires around 40 vehicles/day for a few months of the year, while Scenario 2 requires more than 70 vehicles/day when sugar is being transported from Georgetown to Townsville and when rice is being transported at the same time from Richmond to Ayr. As production develops, it is envisaged that existing transport companies would be able to provide the necessary investment to increase capacity to service this additional demand.

  The existing road network should be able to cope with these additional vehicles, but it is likely some ongoing upgrades and increased maintenance would be required. Townsville is now well serviced by a dedicated port access road from the south-western side of the city, servicing both the Flinders Highway from the west and the Bruce Highway from the south. It allows Type 2 triple road trains to access the port of Townsville. This is important for Scenario 2, where sugar is transported from Georgetown to Townsville via Charters Towers.

  An alternative scenario is to transport the sugar to Cairns. The distance between Georgetown and Cairns is 381 km, while the distance between Georgetown and Townsville is 487 km. However, for the Cairns trip, a Type 2 road train would need to break down to a B-double at Mt Garnet, which is 110 km from Cairns, whereas this vehicle type can complete the entire trip to Townsville. The cost of transporting raw sugar to Townsville would be $49/t, while the cost of transport to Cairns was calculated to be $44/t, including the breakdown to B-doubles at Mount Garnet. If the road to Cairns could allow Type 2 road trains, the cost would be $39/t. If all the sugar from Georgetown was transported to Cairns, this would be a saving of about $1.4 million/year. However, the cost of upgrading the road and/or constructing various bypasses to allow Type 2 vehicles would cost many billions of dollars and may not be feasible through Cairns central district. This would involve an upgrade or a bypass road over the Atherton Tableland and down the range from Kuranda to Cairns.

For the horticulture development scenario (Scenario 1), export shipping of product was assumed to occur via Cairns port. Transport to Cairns from Georgetown is not a major constraint but there would need to be additional investment in storage and associated electricity slots for refrigerated containers. The more significant investment is in developing the reliable shipping routes if markets can be established in Asia, or beyond.

A different transport alternative that would require significant infrastructure investment is exporting sugar and other agricultural products out of the port of Karumba. The development of the port at Karumba has been the subject of proposals such as that put forward by Carpentaria Rail (2012), which includes a railway line from the minerals-rich areas in north-west Queensland to Karumba and the construction of a 40-km jetty into the Gulf of Carpentaria to facilitate large ships to berth. The port of Karumba was not considered in this study, based on the following rationale:

(a) The road distance from Georgetown to Karumba is 370 km, from Georgetown to Cairns it is 380 km, and from Georgetown to Townsville it is 470 km, so there is not much saving in road transport in taking goods to Karumba. The road to Karumba would need significant upgrading to cope with regular heavy transport and to provide better all-year access.

(b) The ports in Townsville and Cairns are well established and contain facilities such as bulk sugar storage (though no bulk grains storage) and bulk loading facilities, as well as hard stand capacity for containers. The port of Karumba would require significant upgrading, especially in providing deeper water access for larger ships. Zinc concentrate is currently shipped out of Karumba but this is done by loading on to 5000-t barges that transfer the concentrate to larger ships anchored about 40 km offshore.

(c) The distance from the port of Karumba to Indonesia, Singapore and China is about 1000 km less than that from Townsville, so there would be savings in time and operational costs out of Karumba. In addition, ships do not have to navigate the Great Barrier Reef. However, with little prospect for much inward cargo, ships would be arriving empty into Karumba, and for refrigerated cargo such as mangoes refrigerated containers would need to be re-positioned, which is costly. In contrast, shipping on the east coast is returning to Asia under-capacity, often with empty containers and bulk cargo space and, as a consequence, competitive freight rates can be obtained, which are likely to result in the overall costs being lower out of Townsville. This comparison has some parallels to that between Townsville and Brisbane, where containerised cargo to Asia is less expensive out of Brisbane than Townsville, even though the journey is 1000 km further.

7.9.2 **RISK ANALYSIS**

The analysis for the two development scenarios has been undertaken using averages of yields and prices, based on historical data and simulated crop yields. Future investment needs to be based on a good understanding of risk, particularly price risk. ABARES produces market outlooks for a range of commodities. These are shown in Table 7.22 for the crops used in the two regional development scenarios. These market outlooks are based on medium-term drivers and, as such, do not capture shorter-term year-to-year variability. This is highlighted in Figure 7.18, which shows the market outlook for sugar over the next 10 years; the previous 10 years of price data are superimposed to illustrate the pattern of interannual variability that might be expected on top of the longer-term price trend.

Table 7.22 Ten-year forward price projections for the crops used in the two regional scenarios
Numbers represent real domestic prices (in 2012–13 dollars).

CROP	UNIT	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Maize	$/t	354	310	324	326	313	301	360	359	357	356
Mungbean	$/t	1001	1063	1064	1065	1091	1090	1088	1087	1085	1084
Peanut	$/t	1006	1068	1069	1070	1096	1095	1093	1092	1090	1089
Rice	$/t	306	324	322	317	317	311	311	311	311	311
Soybean	$/t	509	466	447	445	440	435	434	433	432	431
Mango	$/kg	3.08	3.27	3.27	3.27	3.35	3.35	3.34	3.34	3.33	3.32
Cotton	$/bale	504	498	509	510	518	531	530	528	527	526
Sugarcane	$/t	38.0	34.0	40.3	41.2	41.3	42.3	42.3	42.2	42.2	42.1

Source: Data provided by ABARES

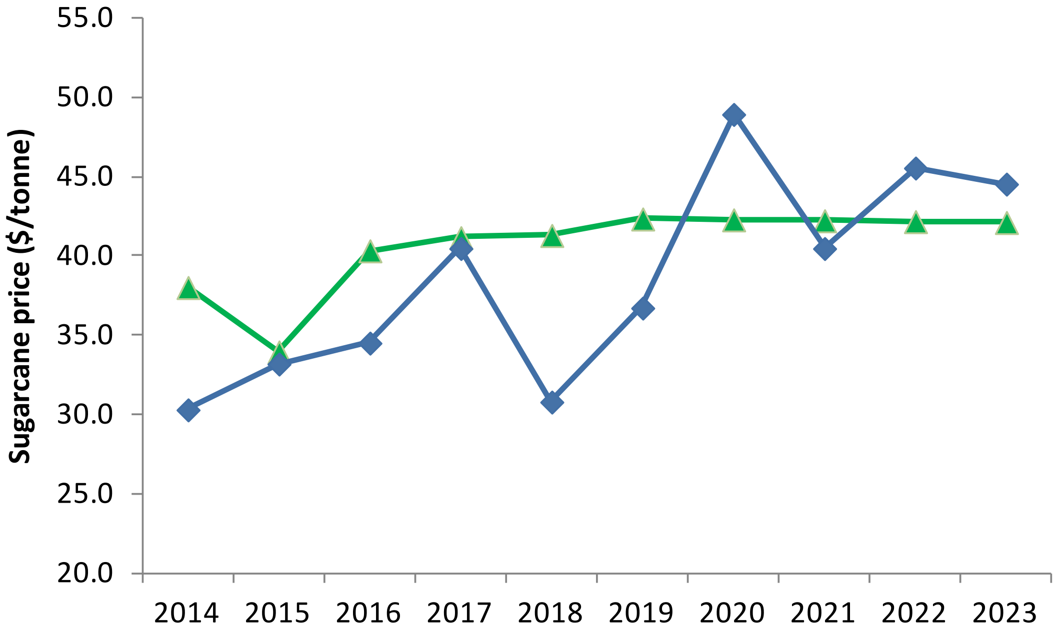


Figure 7.15 Ten-year forward price projection for sugarcane (green line) with previous 10 years (2004 to 2013) of prices (blue line) superimposed to highlight historical year-to-year price variability

As indicated in Section 7.7, price variation combines with yield variation to produce gross margins that can vary significantly between years. In terms of future risk it, is useful to understand how these two primary drivers of price and yield might influence risk. Figure 7.19 shows the variability in gross margins for sugar due to variability in past prices and the modelled variability in yield. The yield distribution was based on a most likely yield of 124 t/ha and a low (20th percentile) and high (80th percentile) of 103 and 133 t/ha, respectively. The 20th percentile is the low performance that would be expected every 1 in 5 years. The price and yield variability results in a large spread for the distribution of gross margins for sugar. The median gross margin is approximately $1250/ha, and there is a small chance (about 1 in 20) of generating a negative gross margin.

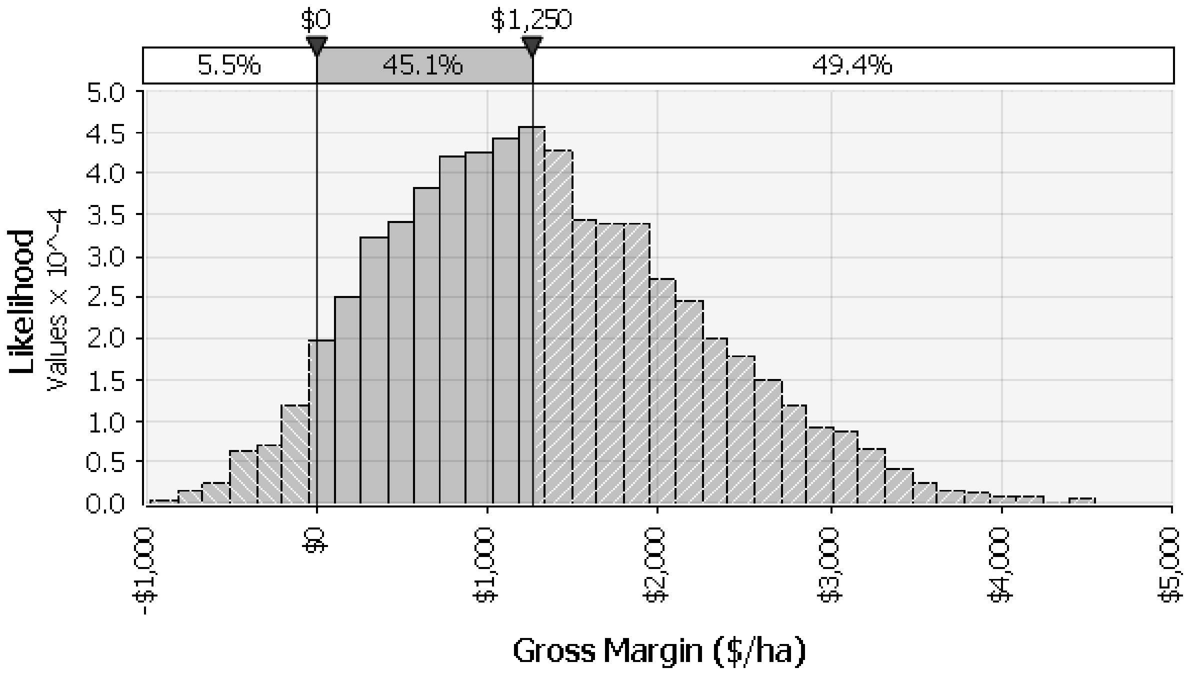


Figure 7.16 Variability in gross margins for sugar in Gilbert due to yield and price variability

The historical analysis of agricultural developments in northern Australia (Appendix 3.1) suggested that a major determinant of success or failure of such development is the ability to get through the first few years of establishment and scaling-up. In the start-up phase, it is essential to provide time to learn and adapt agronomic management to suit local conditions, without the pressure of unrealistic yields that often underpin cash flow and investment analysis. Also, there is no guarantee that the climate will be kind or that prices will be average or above average.

The following analysis builds on the variability presented for gross margins to consider the business vulnerability to a sequence of good and bad years and the importance of the level of debt. Similar to the gross margin, the analysis does not show farm profit because it does not include fixed or overhead expenses such as depreciation for equipment and buildings.

Figure 7.20 illustrates the effect of different starting conditions for debt and runs of better or poorer years with a 7% interest rate. Two starting debts were used in the analysis; $8000/ha and $12,000 ha were assumed to represent the capital investment required in clearing and developing new land for irrigated development, but this does not include the capital costs associated with the dams and channels or other non-farm-based water infrastructure.

The actual number of better and poorer years experienced during the 10-year period were the same in the ‘better years early’ and ‘poorer years early’ runs, and differences were generated by altering the sequence of the year types. A random sequence was also generated that included the shock of two ‘failed’ years of yield. A ‘failed’ year was defined as 20% of the median yield and is simulated to represent an extreme weather, pest or disease event. The ‘better years early’ scenario reduced the debt from the onset. The ‘lower’ starting debt at the start resulted in all debt being paid off by the end of year 5. By comparison, the ‘medium’ starting debt was still about $5000/ha at the end of year 5. This debt was then repaid at a slower rate over the remainder of the period because the second half of the scenario contains the poorer yields and prices. Conversely, the ‘poorer years early scenarios’ had increasing debt for the first 4 years, which was then repaid at an increasing rate in the second half of the scenario.

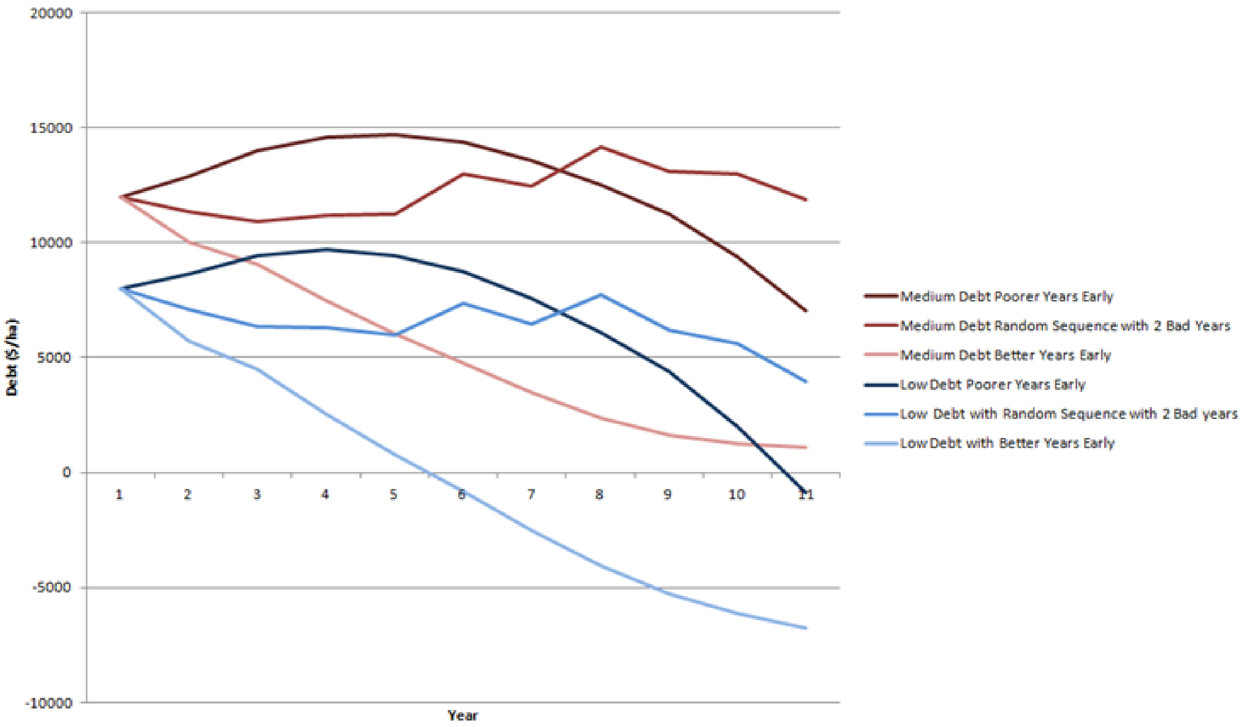


Figure 7.20 Effect of starting conditions of debt and runs of better or poorer on the level of debt for sugarcane in the Gilbert region

The level of debt was sensitive to shocks in the yield, particularly for higher levels of starting debt. The shocks had the effect of delaying the point where debt is repaid and results in the higher starting debt being at much the same level after 10 years.

7.10 Regional economic analysis

7.10.1 FLINDERS-GILBERT ECONOMY

The northern Queensland region of Flinders–Gilbert is described in AusRegion as the towns of Carpentaria, Croydon, Etheridge, Cloncurry and McKinlay. Under the reference case, economic activity in the Flinders–Gilbert is projected to grow at 3.6% annually, which compares favourably with the Queensland GSP growth rate of 2.5% and the projected GDP growth rate of 2.7%. Together agriculture and mining dominate the regional economy.

7.10.2 SCENARIO DESCRIPTION

Each scenario is modelled in two phases—construction and production. Table 7.23 reflects a stylised version of the scenarios for the Flinders and Gilbert regions described earlier as modelled in AusRegion. Public investment in local infrastructure totals $1.1 billion in both scenarios. In Scenario 1, private investment occurs in the cotton, grains and beef industries. In Scenario 2, the sugar industry receives most of the private investment.

Government investment benefits various agricultural industries with transport costs assumed to fall by between 20% and 40%. The private investment in both scenarios also leads to 20% increase in land productivity for beef production. In Scenario 2, land productivity does not increase but transport costs decline for the cotton and grains sectors by 30% and 10%, respectively, because of investment in processing facilities.

Table 7.23 AusRegion stylised scenario description for Flinders–Gilbert

Development parameter	Unit	Commodity	Scenario 1	Scenario 2
Government investment	$m		1 120	1 120
Private Investment	$m	Beef Cattle	65	65
	$m	Cotton	310	
	$m	Grains	180	189
	$m	Horticulture	100	
	$m	Sugar		735
	$m	Total private	655	989
Total Investment	$m		1 775	2 109
Land supply	'000ha		45	45
Transport costs	%	Beef Cattle	-20	-20
	%	Cotton	-40	
	%	Grains	-30	-30
	%	Horticulture	-30	
	%	Sugar		-10
Yield	%	Beef Cattle	20	20

a Assumed change in transport costs arising from investment. **b** Assumed increase in sectoral land productivity arising from private investment.

7.10.3 **REGIONAL ECONOMIC OUTCOMES**

The proposed investments will affect economic activity, employment and exports in the Flinders–Gilbert region and have consequences for the Queensland and Australian economies (Table 7.24).

Table 7.24 Economic impacts for Flinders–Gilbert at 2029–30, % deviation from the reference case

	Unit	Scenario 1	Scenario 2
GRP	%	15.7	11.0
Employment	%	21.1	13.9
Real wages	%	2.0	2.3
Exports	%	46.6	26.7
Sectoral output			
Agriculture	%	46.3	25.7
Mining	%	-3.3	-2.7
Other	%	-2.6	22.7
Queensland GSP	%	0.02	0.04
GDP	%	0.0	0.0

Regional economic welfare (GRP) is projected to be 15.7% higher than the reference under Scenario 1 and 11% higher in Scenario 2 despite the higher investment. This is the second-largest growth projected in any of the case studies and reflects the scale of investment relative to size of the economy in what is a small region. Employment growth is projected to be over 20% higher than the reference case growth driven by: the GRP growth; the high share of labour costs in the agricultural production costs relative to other sectors in the regional economy; and the higher wages in Flinders–Gilbert relative to other regions.

The projected GRP growth is comprised of expansion in the agriculture and associated sectors, balanced by some contraction in other sectors resulting from higher wages and capital costs. For example, during the production phase of Scenario 1, mining output is projected to be 3.3% below the reference case. In Scenario 2, the substantial growth in other sectors in Scenario 2 reflects the output from the proposed sugar mill.

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8 PILBARA REGIONAL ANALYSIS

8.1 Summary and key messages

- The Pilbara region now has the capacity to develop significant areas for irrigated agricultural production by accessing surplus water from mining operations. There may potentially be 200 to 300 GL/year of water available for irrigation from dewatering operations. In this regional case study, it was assumed that 125 GL/year would be available for 30 years to irrigate 8000 ha. The 8000 ha that are actually cropped may change throughout the 30-year period as mining operations come to an end in one location and extraction of new ore deposits come online in nearby areas.
- Surplus mine water has to be used year-round, and this was achieved by irrigating forage crops or by double cropping (e.g. maize immediately followed by peanuts).
- A tropical, arid to semi-arid climate allows most summer crops to be grown year-round. The region experiences very high temperatures in summer, which affects the ability to grow some crops.
- Using existing domestic supply chains and infrastructure, gross margins across eight crops varied from being negative to highly positive. Most crop gross margins were affected by high input costs (e.g. labour, fertiliser) and, for those that were transported out of the region, high freight costs greatly reduced gross margins because of the large distances involved.
- Horticultural crops such as watermelons can generate high gross margins (more than $8000/ha), but these margins are highly price sensitive and, when coupled with high input costs, gross margins can fluctuate from highly positive to negative in weeks. Freight costs of watermelons represent more than 35% of the total costs of production, and labour costs associated with harvesting and packing represent another 20 to 30% of the production costs. The freight costs are particularly high for refrigerated transport because of the limited scope for obtaining backloading discounts from the central Pilbara region.
- Gross margins for broadacre, annual crops were generally less than $500/ha. Commodities such as peanuts generated negative gross margins when transported in shells to Kingaroy along a transport route with limited backloading potential. Transport costs in general for high volume, low value crops represented a significant percentage of the gross value of the product.
- Cotton and guar were assessed as two industrial crops potentially suitable for the Pilbara region. Guar generated a gross margin of around $500/ha, based on being processed in Perth, but cotton returned a negative gross margin because the nearest cotton gin is currently in Menindee, New South Wales.
- Forage sorghum and lablab grown as hay crops both generated gross margins of around $500/ha on the assumption they were used locally in the beef industry. Transporting hay long distances would not be feasible unless high returns per tonne could be achieved.
- Using supply chain scenarios of local or regional processing mills such as a peanut shelling plant and a cotton gin located at Newman; or locally developed supply chains (e.g. maize grain and hay integrated into intensive beef production systems) both resulted in improved gross margins for crops that were previously transported long distances. An exception to this was the scenario of exporting maize to Asia via Port Hedland, which resulted in reduced returns because of the high combined costs of road transport and shipping. The gross margins for both peanuts and cotton were highly positive with a scenario of local processing.
- Two regional development scenarios of 8000 ha of irrigated production were explored. The first scenario involved local processing of peanuts, and a focus on producing grain and forage crops for use in intensive beef-feeding systems in the region. The second scenario centred on using the entire 8000 ha for cotton production with a legume rotation crop and access to a gin in Newman.
- Scenario 1 generated a regional gross value of production of more than $40 million/year, whereas Scenario 2 produced a value of about $50 million/year. The gross value of production for Scenario 1 did

not include the value-added to the beef industry through intensively feeding 24,000 head of cattle, but this may be in the order of $5 to $10 million/year.

- Both scenarios required investment in infrastructure for processing peanuts and cotton within the Pilbara region. For peanuts, this requires a dryer and a shelling plant at a cost of approximately $4 million, whereas the costs of establishing a cotton gin would be $20 to S30 million. It is anticipated that these processing facilities would be located next to a mining township such as Newman to benefit from access to grid power and the engineering services.
- Both scenarios had implications for the infrastructure required to transport goods. In both scenarios, this was mostly in the form of local transport, given the emphasis on integration of crops into the beef sector and local processing.
- Infrastructure investment in this region should also consider the possible need to shift the location in which cropping occurs in response to changing supplies of surplus water from mining operations through time, as ore deposits are exhausted and new ones come onstream. This will emphasise irrigation equipment that can be easily shifted, such as pumps and centre pivots, or that has a short lifespan, such as trickle tape.
- A significant infrastructure consideration for the Pilbara region is the soft infrastructure required to support a 'greenfields' agricultural development. Other regions across northern Australia that have irrigated agricultural development potential have an established or developing agriculture/horticulture sector in the region. Appropriate agronomic and farming skills, and supporting agribusiness infrastructure will need to be established in the region, which will face some challenges given the strong competition for labour from the mining sector.
- The proposed investments in the Pilbara are only expected to expand the economy marginally despite large increases in agriculture, because of the dominance of mining in the region.

8.2 Description of region: existing agriculture, scale of irrigation and development

The Pilbara region is a vast and sparsely populated area that stretches from the Northern Territory border in the east to the Indian Ocean in the west, covering more than 500,000 km^2. For the purposes of this regional case, the focus is on the western part of Pilbara region, which contains most of the commercially significant mineral deposits. When mineral deposits are mined, groundwater is extracted, which can then be used for a range of purposes such as mine operations, town water and irrigation for agriculture. The Pilbara region is defined here as encompassing the Ashburton, Onslow Coast, Fortescue, Port Hedland Coast and De Grey River Basins, as well as the West Canning Basin (Figure 8.1).

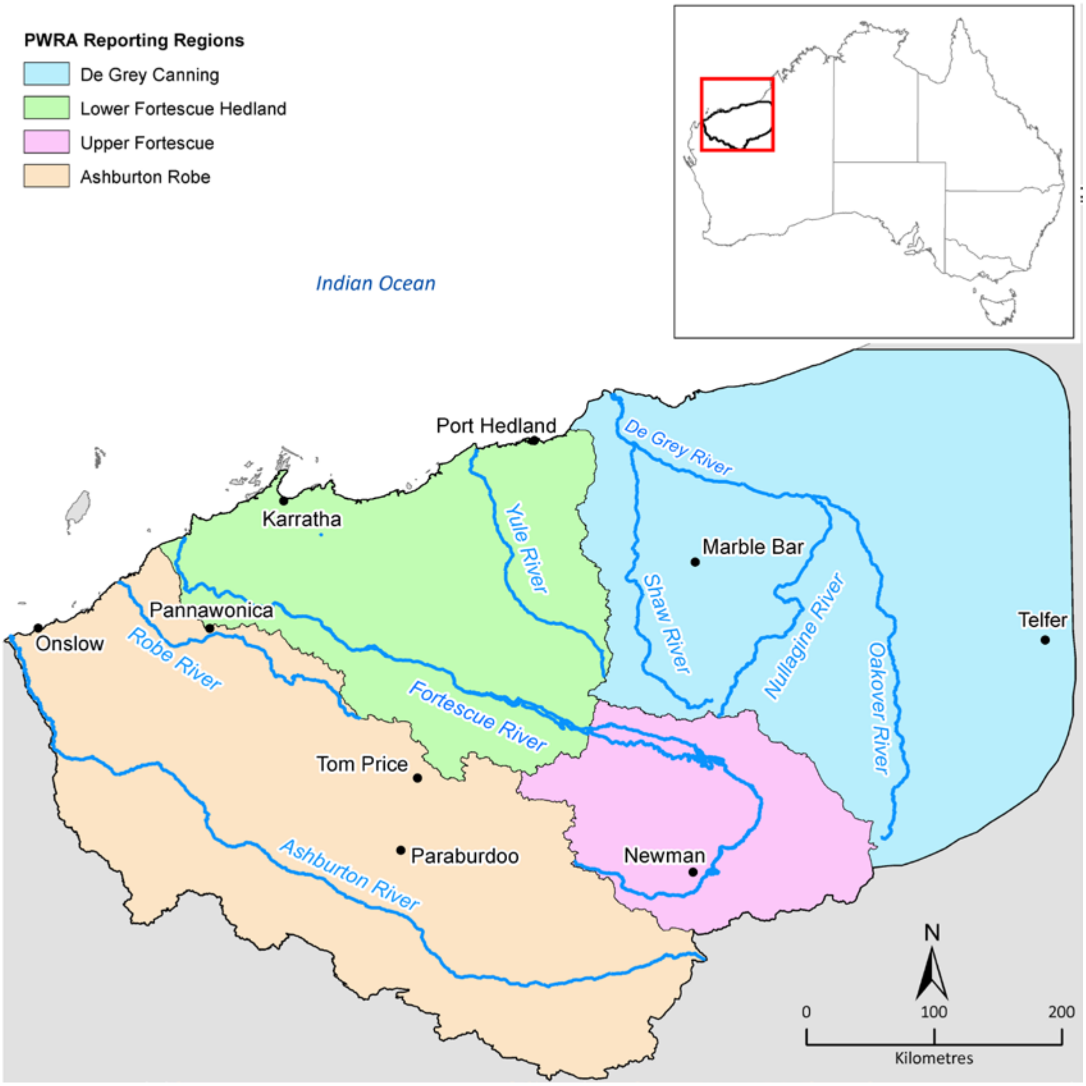

Figure 8.1 The Pilbara region
PWRA = Prescribed Water Resources Area
Source: Charles et al. (2013)

Agriculture in the region has been dominated by pastoralism based on extensive grazing of sheep and cattle since the late 1800s. The rainfall is too low and variable to support any form of dryland cropping and, historically, water resources have been too scarce or inaccessible for irrigated agriculture.

Irrigated agriculture and horticulture around Broome and Carnarvon has demonstrated that commercial production is possible in this environment if reliable and high-quality water can be made available. The Pilbara region now has water being made available from mine dewatering, which has the potential to support significant areas of irrigated agriculture.

Such potential is being explored through a number of initiatives. For example, Rio Tinto has implemented the Hamersley Agricultural Project as a means of managing the surplus water from its mining operations at the Marandoo iron ore mine. Environmental regulations prevent this water from being disposed of in local watercourses, so a productive use for this resource is being explored in the form of irrigated forage.

The HAP scheme involves irrigation of 850 ha of Rhodes grass (*Chloris gayana*), which is cut for hay. This area of land can use the 40 ML/day of surplus water that is extracted from the Marandoo Phase 2 operations during the winter months and up to 120 ML/day during the summer. The development includes a 3 GL buffer dam to store water in winter that is in excess of the needs of the grass hay crop. The system is presently operational using centre pivot irrigators, and an advanced fertigation (fertilisers dosed into the irrigation water) and irrigation management system.

The hay produced by the scheme will be used in Rio Tinto's pastoral operations for use in yard-feeding weaners and young cattle awaiting transport for live export, and as a supplementary fodder resource in times of drought, which will reduce the grazing pressure on the rangelands. It is also possible that this hay can be used within the region by other pastoral operations, because there is currently more hay being produced than required from within Rio Tinto's own pastoral operations.

The Pilbara Hinterland Agricultural Development Initiative (PHADI) has been established under the Royalties to Regions program of the Western Australian Government. This initiative is a partnership between the Western Australian Department of Agriculture and Food, the Pilbara Development Commission, the Department of Regional Development, community groups, the mining industry, agribusiness and industry. There are three projects currently under way:

- Pathways to Pilbara Irrigation Development Project, which is developing the underpinning knowledge to support development of an irrigated agricultural industry in the Pilbara
- Woodie Woodie pilot project, which involves a 38-ha irrigated pilot site to evaluate the fodder production potential for cattle and as a biomass source for biofuel
- Yandicoognia pilot project, which is exploring a range of food and fodder crops.

In terms of developing agricultural opportunities in the region, the Shire of East Pilbara sees the main opportunities applying to larger-scale corporate agriculture rather than family farms (Shire of East Pilbara, 2012). This view stems from the need to scale-up quickly to size of the rapidly expanding mine dewatering resource and, possibly, the medium-term nature of the water resource (i.e. the life of individual mines and their water available for agriculture will be about 20 years).

8.3 Climate: existing and future trends

8.3.1 CURRENT CLIMATE

The Pilbara region experiences an arid to semi-arid climate. Rainfall is strongly summer dominant, with 90% of rainfall occurring in December to April (Figure 8.2) and an average annual rainfall at Wittenoom of 437 mm (1963 to 2013). However, annual rainfall across much of the Pilbara region is only in the 200–300 mm range. This low annual rainfall makes it unsuited to supporting any form of dryland cropping and irrigation is the only means of growing crops. Potential evaporation rates are very high (3150 mm/year pan evaporation), with a strong seasonal cycle. This has implications for crop water demand in irrigation schemes, with very high demand in summer in the absence of any seasonal rainfall.

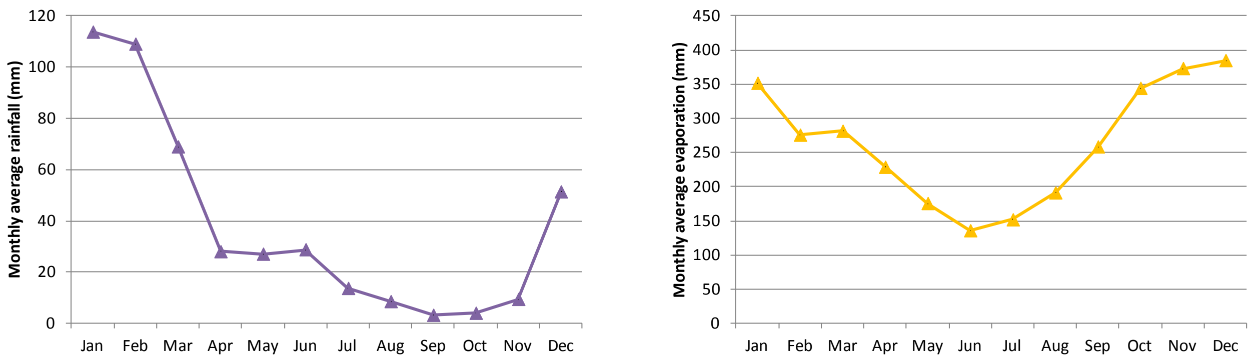

Figure 8.2 Monthly average rainfall (left) and pan evaporation (right) at Wittenoom

In addition to a low average annual rainfall, there is large year-to-year variability. A good measure of rainfall variability is the coefficient of variation (CV), which is calculated as the standard deviation of mean annual rainfall divided by the mean annual rainfall. The higher the CV, the more variable the rainfall. For Wittenoom, CV = 0.50, which is very high even in the context of the highly variable rainfall that is characteristic of the Australian semi-arid tropics.

The high rainfall variability is a result of inconsistent summer rainfall, most of which is generated by tropical lows and cyclones crossing the Western Australian coast and moving across the Pilbara region. In some years, one or more cyclones have occurred, and there are other years where no cyclones have entered the Pilbara region. The length of runs of dry years is not unusual in the Pilbara region (Figure 8.3). However, the magnitude of the deviation in dry years (i.e. negative deviations from the median) is generally larger than the run magnitude of deviation in dry years at most other rainfall stations in south-east and south-west Australia (Petheram and Yang, 2013). In recent decades, there has been a more noticeable trend of runs of wetter years. This has contributed to an overall trend of increasing rainfall in the Pilbara region in the past few decades. It is unclear whether this trend of increased rainfall will persist (see Section 8.3.2).

The Pilbara region also experiences extreme temperatures, with more than 50 days/year in excess of 40 °C. This extreme temperature has implications for cropping over summer and, unless irrigation is well managed, crops are likely to be affected, especially younger seedlings. With high temperatures and high levels of radiation, some crops such as melons can get sunburnt.

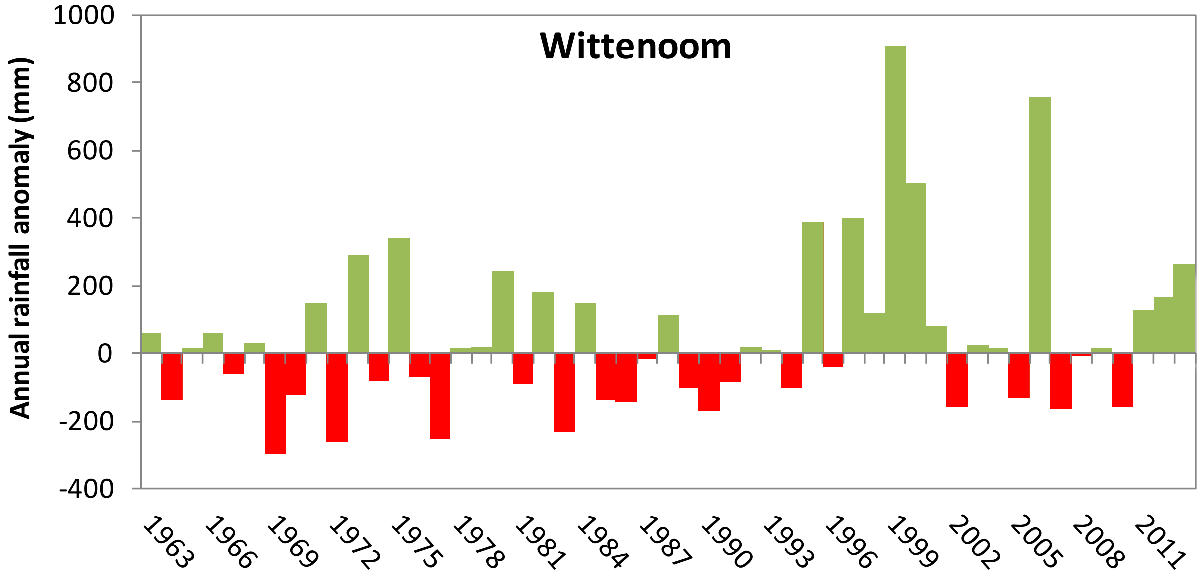

Figure 8.3 Runs of wet and dry years at Wittenoom, measured by the difference in mean annual rainfall from the long-term average (1963 to 2013)
Wet years are denoted by green bars and dry years by red bars.

8.3.2 FUTURE CLIMATE

Climate projections for 2030 were assessed using four global climate models: ECHAM5, GFDL-21, HADCM3 and MIROC. Global climate models are physical representations of the main drivers of the climate system. Future climate is modelled by perturbing the carbon dioxide concentrations in the model, which has implications for temperature and rainfall. In this study, two future emissions scenarios of carbon dioxide were used, based on scenarios from the Intergovernmental Panel on Climate Change (IPCC) – one was a high-emissions scenario (A1FI) and the other a moderate-emissions scenario (A2). The results from the global climate models, which provide results at a regional scale, were then used to transform the historical station records for Kununurra (see Section 2.3.1).

Rainfall projections for 2030 using the four climate models under the two emissions scenarios (A1FI – high emissions, A2 – moderate emissions) show varied responses (Figure 8.4). One model shows an increase in rainfall, one model shows little change and the other two models show a moderate decrease. This trend of an overall decrease in rainfall in response to climate change is consistent with more detailed climate modelling work undertaken for this region (Charles et al., 2013), although the rainfall change was less in that study, which used 15 global climate models. The small decline in projected rainfall by 2030 observed for most global climate models is somewhat uncertain and may not have a major impact on agriculture during that timeframe.

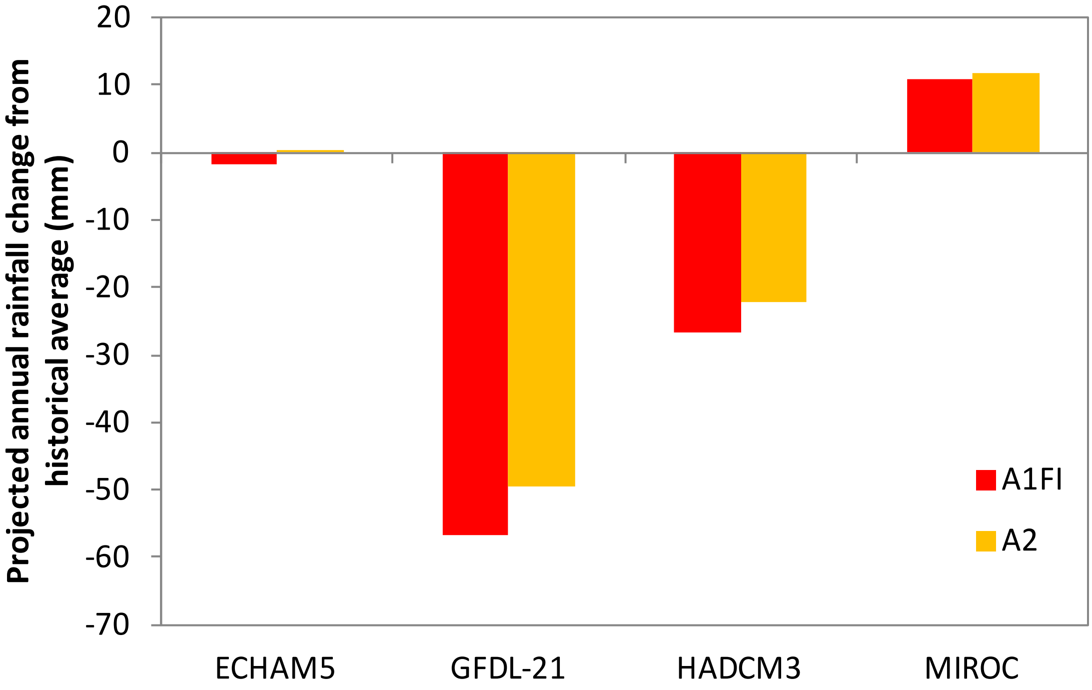

Figure 8.4 Rainfall projections for 2030 based on two emissions scenarios (A1FI – high, A2 – moderate), using four global climate models

The rainfall projection is the difference in millimetres from the recent historical average annual rainfall (1970 to 2010).

Unlike rainfall, the projected trend in temperature is much more certain, with a projected increase in temperature of 0.7 to 1.3°C, depending upon the emissions scenario. Given the overall high temperatures in the tropics, a small increase in overall mean temperature can have a significant impact on extreme temperatures. This is highlighted in Figure 8.5, which shows that the number of days in excess of 40°C will increase from about 50 days/year to more than 80 days/year. This may have an impact on crops that are sensitive to high temperatures – for example, seedlings trying to establish in summer or some horticultural crops, such as melons, towards the end of the dry season.

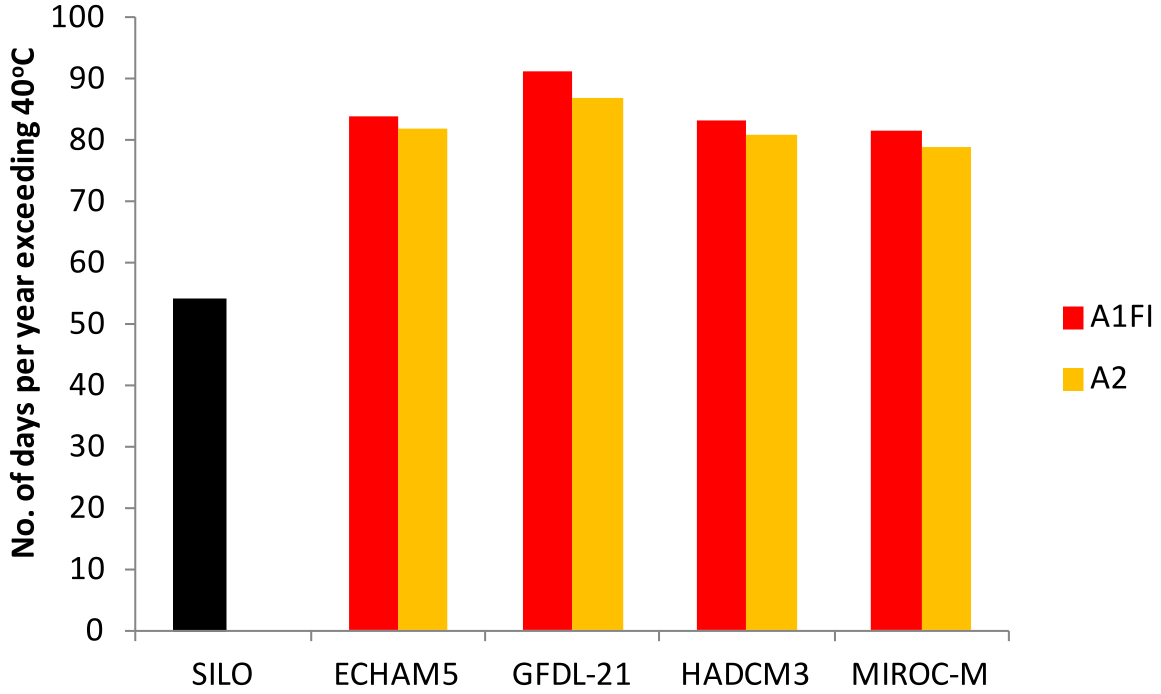

Figure 8.5 Number of days per year in Wittenoom projected to exceed 40°C in 2030 for two emissions scenarios (A1FI – high emissions, A2 – moderate emissions) using four global climate models compared with historical climate data (SILO data for 1970 to 2010, black column)

8.4 Water resources

The major rivers of the Pilbara region are the De Grey, Ashburton, Fortescue, Yule, Sherlock, Robe, Harding, Cane, Turner and Maitland rivers. These rivers drain westwards into the Indian Ocean. The relatively flat landscape west of the Hamersley Range results in rivers that are wide and have braided flow paths. They discharge directly into the Indian Ocean, or via wetlands and marshes. In addition, they provide the major source of recharge to the alluvial aquifers sited closer to the coast.

Given the summer dominant rainfall, most river flow occurs from January to March, with cyclones being the major source of significant river flows. Cyclones often result in rainfall events exceeding 150 mm, and this is the trigger for major river flows. There can be smaller river flows in the middle of the year in response to winter rainfall events. Overall, given the low annual rainfall in the region (200 to 450 mm), average river flows are low, but are highly episodic and show very high interannual variability (Table 8.1). Consequently, they provide limited opportunity to support irrigated agriculture in the Pilbara region.

Table 8.1 River flow statistics for the major rivers in the Pilbara region

RIVER	GAUGING STATION NUMBER	CATCHMENT AREA (km^2)	MEAN ANNUAL RAINFALL (mm)[A]	MEAN ANNUAL FLOW (GL)	MEDIAN ANNUAL FLOW (GL)	CV
Ashburton	706003	71,387	300	922	534	1.32
Cane	707005	2,326	400	88	65	0.80
Robe	707002	7,104	500	87	18	1.70
Fortescue	708002	14,629	450	215	51	1.40
Fortescue	708003	18,371	400	255	97	1.31
Maitland	709004	1,948	375	40	14	2.08
Harding	709001	1,058	400	39	23	1.30
Sherlock	709003	4,581	400	164	40	1.60
Yule	709005	8,427	400	350	136	1.40
Turner	709010	885	400	29	5	1.20
De Grey	710003	50,007	400	1430	1062	1.10
Shaw	710229	6,501	400	328	151	1.60
Coongan	710204	3,736	400	112	68	1.30

CV = coefficient of variation
a Based on mean annual isohyets
Source: Data extracted from Haig (2009)

Groundwater is subsurface water that occurs beneath surface watertables in various soils and rock formations. It originates from both rainfall infiltration and surface water flows.

Within the Pilbara region, there are three main types of groundwater:

- Unconsolidated sedimentary aquifers. These occur in coastal areas in the plains and alluvial systems, and are mostly recharged from surface water flows. They tend to be highly dynamic and recharge episodically in response to major flow events at the surface. Estimates of freshwater yields range from 1 GL/year in the Turner River to 10 GL/year from the lower Fortescue River (WA Department of Water, 2010).
- Sedimentary rock aquifers. These aquifers fill from rainfall infiltration and surface water flows, and have filled during long periods. Their size is often large compared with recharge rates and, as such, are less affected by episodic events. This type of aquifer dominates the Canning Basin. Estimated available extraction for the coastal part of the Canning Basin is 100 GL/year, and 10 to 100 GL/year for the areas more than 100 km from the coast (Turnadge et al., 2013). The La Grange area of the coastal Canning Basin is being examined for its potential to support irrigated agriculture, with around 50 GL/year potentially available for irrigation. It should be noted that these estimates are based on desktop studies rather than geological field studies and, as such, have high uncertainties attached to them.
- Fractured rock aquifers. These are the main aquifer type in the central Pilbara region and take in most of the area with significant iron ore deposits. Aquifers recharge mainly from direct rainfall infiltration in areas of fractured rock, although surface water flows also contribute to recharge. These aquifers tend to be more localised and are highly variable in the quantity and quality of water.
- As mining of iron ore deposits proceeds, it intersects these aquifers and water produced can vary at particular sites from 1 GL/year to 10–40 GL/year. With the expansion of mining in the Pilbara region, the amount of water becoming available through mine dewatering activities has been growing rapidly. An assessment in 2007 (Economics Consulting Services, 2007) indicated that about 150 GL/year might be produced from mine dewatering. More recent estimates put the amount of water potentially available for irrigation from mine dewatering at 200 to 300 GL/year (Shire of East Pilbara, 2012).

Indicative groundwater prospectivity in the Pilbara region in comparison with other regions in northern Australia is shown in Figure 8.6. It should be noted that more reliable estimates of groundwater would require more extensive field data collection. The Canning Basin shows medium levels of prospectivity, in line with the potential extraction yields indicated above. Overall, the central Pilbara shows negligible to low levels of sustainable groundwater yield, although this is highly variable because of the spatially diverse nature of the rock aquifers, which can produce high yields as noted above.

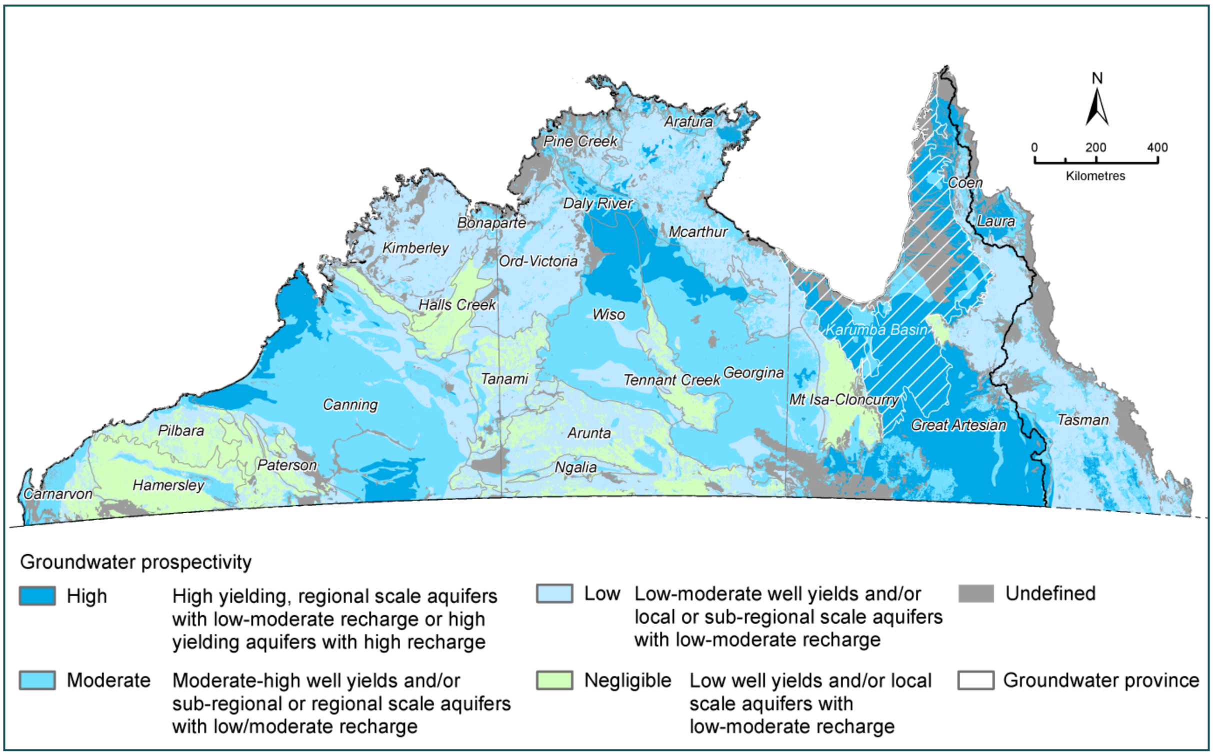

Figure 8.6 Revised map of groundwater prospectivity in northern Australia

White hatching indicates areas where the more developed Karumba Basin overlies the Great Artesian Basin.

Source: Turnadge et al. (2013)

The amount of water that can be made available for irrigated agriculture from mine dewatering will depend on the scale of mining activities, and the approvals under which the extraction and disposal of that water are given. The extraction of water for dewatering purposes in mines is managed under the *Rights in Water and Irrigation Act 1914* (WA) to minimise the adverse impacts of the extraction and release of water.

A challenge for mining companies has been the disposal of this water, which is managed under the *Environmental Protection Act 1986* (WA) to ensure that appropriate measures are taken to prevent degradation of any receiving water body. In some mining operations, this is being addressed by re-injection of the extracted water into aquifers at depth, whereas in other areas the water is being used for irrigation of forage crops, principally as a water disposal mechanism rather than as an agricultural pursuit per se.

However, mine dewatering does offer opportunities for agricultural development in the region. In this case study, it has been assumed that 120 GL/year is available for irrigated agricultural purposes.

8.5 Land suitability for cropping

The Pilbara case study region mostly comprises rocky low hills and mountains, with shallow Rudosols (minimally developed soils) and Kandosols (structureless soils). Apart from localised areas that may be developed for agriculture using water from mining operations, another area of potential interest for agricultural development is the 25 to 50-km-wide Fortescue River corridor, which stretches some 250 km north and east of the township of Newman. Soils in the corridor are mapped as red–brown, non-cracking clayey Dermosols (structured soils), with lesser areas of Vertosols (cracking clays), Calcarosols (soils with calcium carbonate), red Kandosols (structureless soils) and minor Chromosols (soils with an abrupt increase in clay) (Figure 8.7).

The soils are generally deep, clayey textured throughout, and have few course fragments or rock outcrop, neutral to slightly acid pH, and good water-holding capacity. The land is relatively flat to gently undulating with low-erosion hazard, rapid-to-moderate drainage and low levels of salinity. Some wet-season flooding and waterlogging may occur in lower landscape positions.

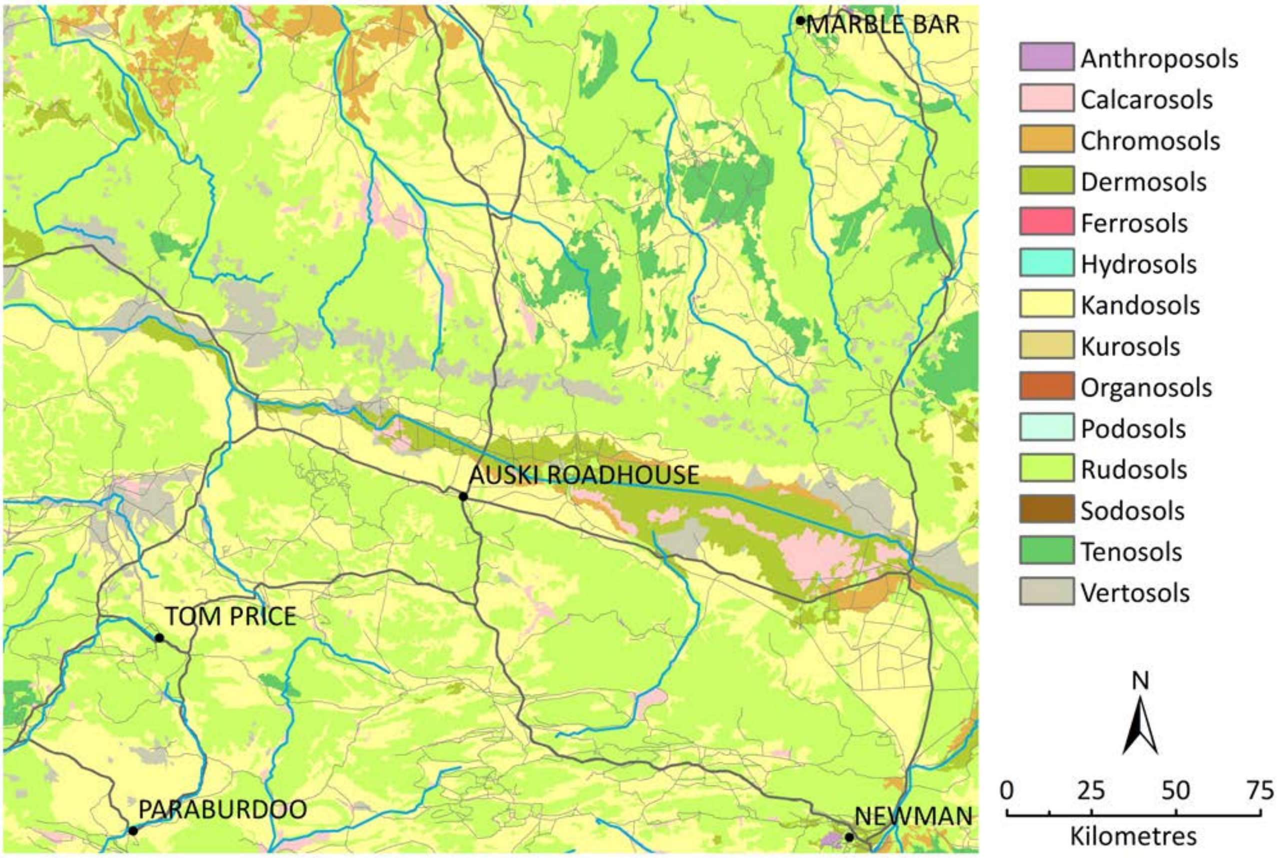

Figure 8.7 Dominant mapped Australian Soil Classification orders, Pilbara study area
Source: ASRIS (2014)

Soil and land resource limitations for agricultural development along the Fortescue River are minimal for irrigated annual and perennial crops, improved pasture or forestry (e.g. Figure 8.8, left). Areas of heavier textured soils have moderate suitability for rice (Figure 8.8, right) and cotton, although they are likely to be subject to increased risks of flooding, erosion and salinity. Maintaining ground cover in all irrigated agriculture management systems should also be considered to reduce the risk of wind erosion, which can be severe in the area.

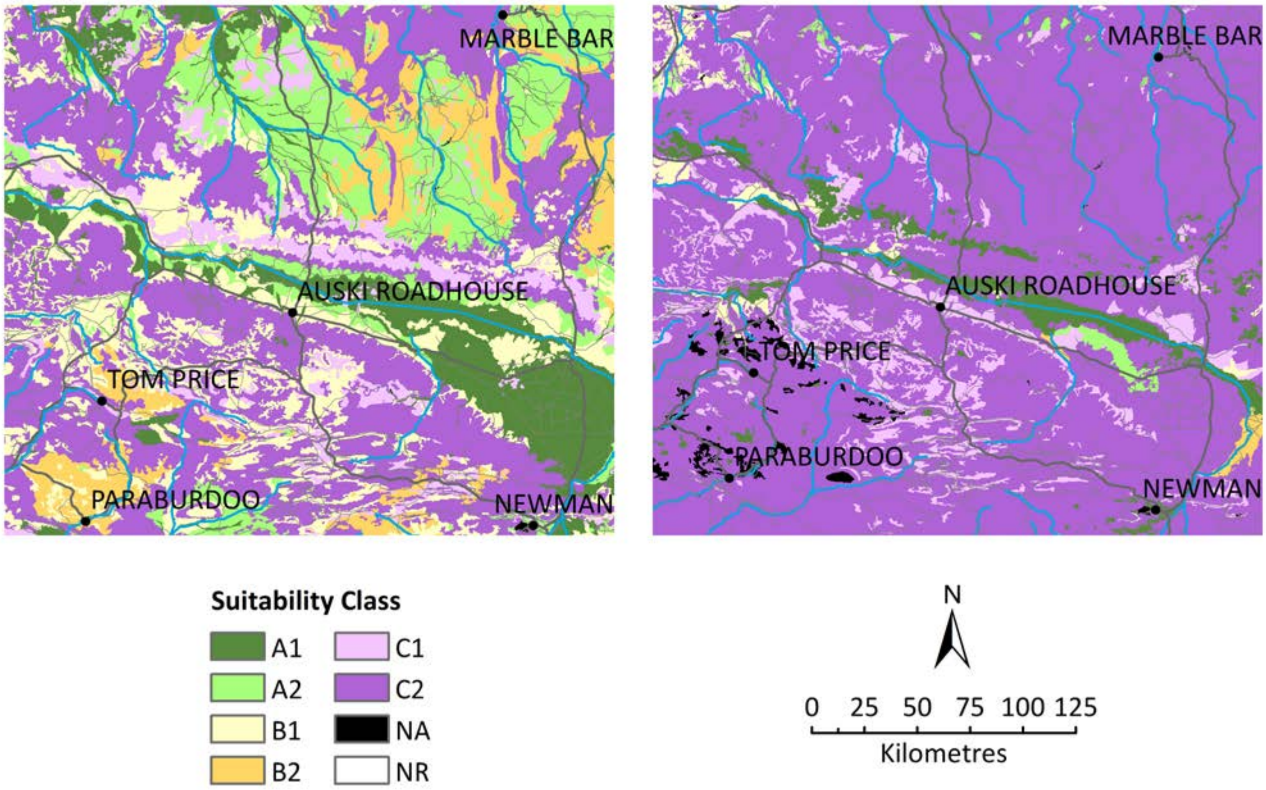

Figure 8.8 Suitability for irrigated annual crops (left) and for irrigated rice (right)

A1 >70% of the area is Class 1 or 2; A2 50 to 70% of the area is Class 1 or 2; B1 > 0% of the area is Class 1,2 or 3; B2 >50 to 70% of the area is Class 1, 2 or 3; C1 > 50 to 70% of the area is Class 4 or 5; C2 >70% of the area is Class 4 or 5, where Class 1 is suitable land with negligible limitations and Class 5 is unsuitable land.

Source: Wilson et al. (2009)

Areas of Kandosols (structureless soils) and Tenosols (weakly developed soils) also occur in the northern half of the case study region, around the tributaries of the Yule and Shaw river systems. These also have a good-to-moderate suitability for agricultural development of annual and perennial crops, improved pastures and forestry. Suitability for rice and cotton is low due to the lighter sandy topsoils.

Further soil and suitability investigations in the Pilbara region are currently being conducted by the Western Australian Department of Agriculture and Food (N Schoknecht 2014, pers. comm.). These more intensive surveys will provide better analysis of limitations and agricultural suitability.

8.6 Pest and disease risk

A total of 394 species were identified as potential pests or pathogens of any of the 12 crops evaluated for the Pilbara region; many of these were pests or pathogens on multiple crops (Appendix 8.1, separate document). For most crops, the likelihood of at least one of these pests or pathogens invading the region is 1 (100% likelihood) (Table 8.2), because for every crop (with the exception of sandalwood), many are already present in Australia and at least one is present within Western Australia. Despite the large numbers of pests and pathogens assessed, only a small proportion of species have been identified as major or significant pests of each crop (CABI, 2011) (Appendix 8.1, separate document). However, for many of these crops (rice, sorghum, mungbeans, peanuts, mangoes, watermelon, rockmelon, pumpkin, cotton and guar), at least one of these major pests is already found in Western Australia and therefore represents a significant threat, with a potentially high impact.

Table 8.2 Invasion likelihood, most likely impact and overall biosecurity risk from insect pest and fungal pathogens to proposed crops of the Pilbara region (Western Australia)
Values of 1 denote almost certain likelihood, very high impact and very high risk, while values of 0 reflect no likelihood, impact or risk.

CROP	INVASION LIKELIHOOD	IMPACT	RISK
Broadacre food			
Rice	1	0.4	0.4
Sorghum	1	0.1	0.1
Maize	1	0.4	0.4
Chickpea	1	0.1	0.1
Mungbean	1	0.4	0.4
Peanut	1	0.4	0.4
Intensive food			
Mango	1	0.1	0.1
Watermelon	1	0.4	0.4
Melon (rock)	1	0.4	0.4
Pumpkin	1	0.4	0.4
Fibre/other crops			
Cotton	1	0.4	0.4
Guar	1	0.4	0.4
Forage sorghum (biofuel/forage)	1	0.1	0.1

8.7 Crop production

8.7.1 BROAD OVERVIEW OF CROP TYPES AND AGRONOMY

The potential productivity of a range of broadacre, high-value and industrial crops were investigated for the Pilbara region. This broad analysis includes high-volume products such as pulses, high-value products such as horticulture, and industrial products that require further processing, often nearby, such as cotton.

Broadacre cropping is characterised by large-scale (area), relatively low input, high-volume production of a commodity with a relatively low value per unit of weight. Cereal and pulse production are the two most common forms of broadacre production in Australia, but, presently, there is little understanding of their agronomic potential in the Pilbara region.

Cereals such as maize and sorghum are widely grown across northern Australia and there would appear to be no particular constraints to their production in the Pilbara region under irrigation. However, there is little direct cropping experience with cereals in the region.

Pulses are legume crops that are primarily grown for grain, but have the added advantage of 'fixing' atmospheric nitrogen, thereby minimising the need for fertilisation with inorganic nitrogen fertiliser. Because the fixed nitrogen is also available to subsequent crops, pulses are often grown in rotation with high-nitrogen-demanding crops such as cereals.

Pulse production is well established in Australia, with approximately 2 million hectares of pulse crops grown each year. Many pulse crops have a relatively short growing season, and are well suited to opportunistic production when there is sufficient available water (either stored in soil or available from irrigation). There is a range of pulse crops potentially suitable to growing conditions in the Pilbara region, including peanuts and mungbeans.

Peanuts are a tropical and subtropical annual legume that can be grown as a wet-season (either rainfed or with supplementary irrigation) or dry-season crop under full irrigation. Peanuts are usually processed for human consumption, whereas the remaining foliage can be used for stockfeed. The peanut is produced underground and specialised equipment is used to pull the crop from the soil before harvest. Therefore, peanuts are not suited to heavy soils due to excessive losses from breakage when the crop is being pulled. Peanuts can be grown at any time of year in northern Australia, but to produce a consistently high-quality crop, peanuts should be harvested during dry conditions. Peanuts take approximately 160 to 180 days to mature. There is no peanut shelling or processing facility in Western Australia, because the vast majority of the crop is grown in Queensland.

High-value cropping includes horticultural crops that are generally produced on much smaller areas than broadacre crops, with higher input costs per hectare and a product that is of much higher value. Horticulture crops are often perishable, require a high labour force for ‘picking and packing’, and specialised postharvest conditions such as refrigeration and controlled atmosphere storage. Horticulture crops are either perennial, such as tree crops, where a planting lasts many years, or annual, such as rockmelon, where the crop is destroyed after harvest.

Horticulture production is an important industry for Australia, occurring in every state and accounting for approximately 20% of the total farm-gate value of Australian agriculture. Production is highly seasonal, and plantings of annual crops are often staggered on a single farm during the growing season to extend harvest time.

Market prices of horticulture produce can be highly volatile, and subject to multiple supply, demand and substitution forces. The importance of freshness in many horticultural products means seasonality of supply is important in the market and this can provide opportunities for tropical locations. Horticultural production is important in the Carnarvon region; there is also some commercial production in the Broome region, where there is a focus on cucurbits and mangoes. As with other crops, there is little commercial horticultural production in the Pilbara region.

Industrial crops typically require a major processing step in their production soon after harvest. These crops generally involve high production volumes, and processing facilities are usually located nearby to reduce transport costs between the fields and the processing sites. The industrial crops that have been considered in the Pilbara region study include cotton and guar.

Dryland and irrigated cotton production is well established in Australia, with the area grown each year changing in response to both water availability and market prices. Various attempts have been made to initiate commercial cotton production in northern Australia, but problems encountered with capital availability, climatic adaptability and pest control have limited the success of these ventures. Since the introduction of genetically modified (GM) cotton in Australia in 1996, yields and incomes from cotton crops have increased in most regions of Australia, with the key benefits of GM cotton (compared to conventional cotton) being savings in insecticide and herbicide use, and improved tillage management. Although cotton has not been grown in the Pilbara region, trials were done in the late 1990s south of Broome in the La Grange Basin (Yeates, 2001).

Guar is an annual legume species that is widely grown in the semi-arid tropics of South Asia, particularly India and Pakistan. It is a crop that is highly tolerant of hot, dry conditions and may be well suited to the Pilbara region. The adaptability of guar to dry conditions is a result of its deep taproot and it is well suited as a rotation crop. The main value of the crop is the gum content of its grain, which is up to 30% galactomannan. Once extracted from the seed, the gum is used in a range of food and industrial products, including use as a thickener in food processing, and in the gas and oil industry as a suspending component of fracking fluids.

Some research was carried out on guar in the Ord region by CSIRO and in the Northern Territory by the Northern Territory Department of Primary Industries and Fisheries in the 1970s and 1980s, and it was found to be unsuited to clay soils, as well as having low and variable yields. There was some renewed interest in examining guar in the early 2000s and an evaluation of a large number of cultivars found varieties that could produce up to 1400 kg/ha of grain under dryland conditions (Douglas, 2005). Under irrigated conditions, the crop can produce about 2.5 t/ha of grain (Ahmed, 2011). Increased demand for guar by the oil and gas industry has seen renewed interest in the viability of the crop in recent years.

Beef cattle production is the dominant agricultural activity in the Pilbara region, which generates a demand for forage hay. This hay is used to feed animals in yards, especially weaners and young animals that are being held for transport before being exported live to South-East Asia or the Middle East. With the prospect of larger-scale irrigation precincts, there is the opportunity to grow forage hay for use by regional pastoral enterprises or for export to other regions following further compression of hay bales to increase the cost-effectiveness of transport. In combination with cereal grains, there are possibilities for using locally produced hay and grain in more intensive livestock feeding systems. There are also options to use an irrigated crop, such as forage sorghum, as a biofuel crop for use in local mine operations.

Within Western Australia, there are strict environmental conditions on which pasture species can be grown because of concerns about weed spread potential. As indicated in Section 8.2, there is now a large irrigated forage system in operation in the Pilbara region, the Hamersley Agricultural Project. In that project, Rhodes grass (*Chloris gayana*) is being grown. Given the need to have year-round cropping to use the surplus mine water, there may also be an opportunity to grow legume forage crops such as lablab (*Lablab purpureus*) in rotation with a broadacre crop such as cotton.

8.7.2 MARKET ANALYSIS OF CROPS

This section highlights some of the market opportunities for the range of broadacre, high-value and industrial crops that are analysed in the cropping scenarios for potential irrigation in the Pilbara region. A more detailed market analysis of each commodity is given in Appendix 4.1.

Broadacre crops

Grain sorghum

Grain sorghum is largely consumed in intensive livestock industries such as feedlot cattle, pigs and poultry, with feedlot cattle consuming around half of all grain sorghum used for feed. Domestic marketing opportunities will depend largely on livestock numbers in intensive feed industries. Poultry numbers are projected to rise, supporting the demand for grain sorghum. During the medium term, the feedlot cattle industry is likely to continue to feel pressure from competition from the United States in the important grain-fed beef markets of Japan and the Republic of Korea. Reduced tariffs under the Korea–Australia Free Trade Agreement and the Japan–Australia Economic Partnership Agreement improve those prospects.

Australia exported around half of its grain sorghum production in 2010–11 and 2011–12. Japan historically has been the major trading partner, but China has recently become an important export destination – taking 25% of exports in 2012–13. The China market is forecast to grow substantially. Australia's main competitors in overseas markets are the United States and Argentina, both generally lower-cost suppliers than Australia. United States grain sorghum exports are projected to be maintained during the medium term, while Argentina's are forecast to increase slightly.

In addition to livestock feed demand, sorghum can be processed into ethanol. For example, an ethanol plant in Dalby, Queensland, has the capacity to process around 200,000 t of sorghum to produce 80 million litres of ethanol each year. In 2011–12, biofuels represented around 1% of Australia's petrol and diesel production. The latest long-term projection of Australian energy supply and demand to 2050 by the Bureau of Resources and Energy Economics is for bioenergy production in Australia to grow by 3.9% each year.

Maize

In Australia, livestock feeding of maize accounts for around 54% of total domestic consumption, whereas food and industrial consumption accounts for the remaining 46%. Maize is a minor component of the feed complex, but more than 90% of feed maize is consumed by poultry or pigs; only a small amount is consumed by feedlot cattle.

The most important export markets for maize are Japan and the Republic of Korea, but Australian maize comprises less than 1% of these countries' imports. The dominance of Japan and the Republic of Korea as import markets has been falling in recent years, and growth in world maize imports have been driven by Latin America and Association of Southeast Asian Nations (ASEAN) member states. Asia is expected to be a driver of world maize consumption, largely as a result of growing demand for maize as a feed grain. This may present export opportunities. But Australia does not yet have access to China's market for maize. Main competitors in Japan and the Republic of Korea are the United States, Argentina and Brazil.

Domestic marketing opportunities will depend largely on poultry and pig numbers. During the medium term, pig and poultry numbers are projected to rise, supporting domestic demand for maize.

Peanut

Australian peanuts are mostly consumed on the domestic market, with food consumption the primary use. Australia is usually a net importer of peanuts except in years of large production, importing both processed and unprocessed peanuts. Argentina is the source of almost 80% of unprocessed peanut imports, followed by China and Nicaragua. China and Nicaragua are the main suppliers of processed peanuts. Australia exports unprocessed peanuts (1100 t in 2011–12) mainly to New Zealand, Japan, Fiji and China. Processed peanuts (1700 t in 2011–12) were exported mainly to New Zealand, the Republic of Korea and Japan.

China and India together produce more than half of the world's peanuts. China is also the largest consumer of peanuts for food, followed by Indonesia, the United States and Nigeria. China and India are the largest crushers of peanuts, and consumers of peanut meal and oil. Although China was once the primary supplier in international markets, growing domestic consumption has reduced exports.

Should local production expand, there is potential for some import substitution of peanuts for food use, as well as peanut meal for intensive livestock production. Any expansion in production could also be shipped to current export markets, particularly Japan and the Republic of Korea. The major supplier to these markets is China but, with its own domestic consumption increasing, there may be opportunity for Australian exports to expand in these markets. Likewise, net exports from the United States, the second-largest supplier to Japan, are projected by the United States Department of Agriculture to fall in the medium term, providing opportunity for Australian exports in Japan. Opportunity also lies in supplying high oleic peanut oil to the world market, but capitalising on this opportunity would require a large-scale stable supply of high oleic peanuts and export market development.

Mungbean

Australian production of mungbeans has almost doubled in the two decades before 2012–13. Currently, Australian mungbean production is largely destined for export. In 2011–12, Australia shipped 50% of mungbean exports to India and another 22% to the ASEAN member states. Within the ASEAN region, Indonesia was the largest importer of Australian mungbeans. India and the ASEAN region will continue to be growing markets for Australian mungbeans.

Domestic and international opportunities exist to market mungbeans as a functional food to food manufacturers and consumers. Mungbeans have a range of potential applications such as starch, flour or paste, and can also be used as an additive to other foods.

High-value crops

Cucurbits

The cucurbit industry's exposure to international markets is limited, with most production sold into the domestic retail and food service markets. In 2012–13, Australia exported 1500 t of pumpkin, with the largest markets being Singapore (62%), Papua New Guinea, Indonesia and the United Arab Emirates. Only around 5 to 6% of melon production is exported, with New Zealand the largest market – taking 38% of total melon exports in 2012–13. Imports of both pumpkins and melons are negligible.

China is the world's largest pumpkin producer, accounting for 28% of global production in 2011, followed by India (19%) and the Russian Federation (5%). Exporters include Spain, accounting for 45% of exports in 2011, followed by New Zealand, Mexico and Morocco. The United States and the European Union are some of the largest consumers of pumpkin in the world and together account for around 80% of imports.

World melon production has almost trebled during the past two decades, with two-thirds of global watermelons and about one-half of all other melons now produced by China. China is also one of the world's largest melon-consuming countries – second to the United States and ahead of the European Union. The United States and China are also the world's largest importers of watermelons, together accounting for more than one-third of the world's imports in 2011. For other melons, the largest import markets are the United States and the European Union.

As for other fruits and vegetables, rising nutritional awareness is expected to have an impact on demand for cucurbits in the domestic market. Northern Australian production is counter-seasonal to southern Australian production, therefore extending their availability to consumers. However, any specific effects on the consumption of pumpkins and melons will depend on consumer preference towards them compared with other fruits and vegetables and their relative prices against other fruits and vegetable. There are perhaps greater opportunities for producers to export high-quality fresh produce to the Northern Hemisphere, particularly to ASEAN and Middle Eastern countries, which are already important markets for Australian exports of pumpkins and melons. For melons, although China is a major producer, being also one of the largest importers offers market opportunities for Australian exporters of high-quality melons.

Industrial crops

Cotton

Australia has historically been a relatively minor cotton producer on a global scale but, in recent years, became the world's sixth-largest producer. In 2012–13, Australia produced 1 million tonnes of cotton lint and 1.4 million tonnes of cotton seed. The level of Australian cotton production depends largely on the availability of irrigation water. Currently, about 95% of Australian cotton production takes place in the Murray–Darling Basin (MDB) region and usually more than 90% is irrigated. Increased diversions of irrigation water away from farms to environmental uses in the MDB are expected to have a minor effect on Australian cotton production during the medium term, but the prospects of significant expansion in irrigated plantings in the MDB are limited by water availability.

Around 95% of Australian cotton lint is exported to international markets, mainly in Asia, and a large proportion of cotton seed is consumed in Australia. In the 10 years before 2012–13, Asian markets accounted for 98% of total Australian lint exports, with the remainder exported to Europe. China has now emerged as the largest importer of Australian cotton, taking around 70% of Australia's exports in 2012–13. Other important markets are Indonesia, Thailand and the Republic of Korea.

Given Australia's small textile manufacturing sector, domestic textile mills only consume around 3% of the cotton industry's output. It is not likely that additional demand for ginned cotton will be created domestically, because labour costs in textile manufacturing are much cheaper overseas. Demand from other ASEAN countries, such as Cambodia and Vietnam, is expected to grow as wage inflation in China has led to Chinese manufacturers and global textile companies moving their manufacturing to other low-cost nations. Other potential markets for Australia that could be further developed include Bangladesh and Pakistan.

Guar

Guar gum, a product of the guar bean, is traditionally used as a thickening agent in food processing, but has more recently been used in the oil and gas industry as a hydraulic fracturing ('fracking') agent. Guar growing is in the early stages of being established into a viable industry in Australia.

Currently, guar gum is imported into Australia from India and Pakistan. Strong demand from the oil and gas extraction industries resulted in a sharp upturn in world prices in 2011–12. In Australia, import values rose from less than $2/kg to an average of $6.48/kg in 2011–12 and $7.88/kg in 2012–13. World guar production is currently dominated by India at 80% of global production, with Pakistan and the United States the other significant producers. In Asia, guar beans are used as a vegetable for human consumption and the meal is used as a high-protein livestock feed. Now more than half of the world's guar gum is used for oil and gas mining.

The United States is the world's largest importer of guar gum. Germany is the second-largest importer, to service its large food processing industry. In Australia, the emergence of fracking in the oil and gas extraction industry has led to the creation of a new market for guar gum, providing greater incentive for guar gum processing to start in Australia and for farmers to plant guar crops. Record prices in 2012–13 saw demand in the mining industry shift to cheaper alternatives, but demand is expected to remain strong in coming years, albeit constrained by the availability of alternatives.

Hay/forage

Hay plays a crucial role in livestock production, particularly during times of poor weather conditions when grass is not readily available. The majority of Australia's hay production is in southern Australia and used domestically by livestock sectors in southern Australia. However, export markets have developed during the past two decades, principally to Japan (64% of exports in 2012–13), the Republic of Korea, Taiwan and China. Other smaller markets include the Middle East (particularly the United Arab Emirates, Saudi Arabia and Qatar), Indonesia and Malaysia. Livestock export ships are also a significant destination for Australian hay exports, although this outlet has diminished since 2008–09 due to decreasing live sheep exports to the Middle East and a live cattle trade affected by Indonesia's import restrictions.

Recent reinvigoration of the live export trade – with Indonesia lifting its cattle import restrictions and cattle demand increasing from other markets such as Vietnam and Malaysia – should result in an increasing amount of hay being used by livestock-holding depots and on-board livestock transport ships. Increasing demand for meat protein and growing commercial feedlots in developing countries also provide opportunity for expanding exports of hay to markets such as China, Indonesia, Malaysia, Vietnam, as well as a range of markets in the Middle East, such as United Arab Emirates and Saudi Arabia.

Domestically, the development of meat processing in northern Australia – with both Yeeda Pastoral's abattoir near Broome and the Australian Agricultural Company's abattoir near Darwin close to completion – provides opportunity for increased use of hay and forage crops for finishing cattle for slaughter in northern Australia. The immediate throughput of these plants will be mostly lower-value cull cows and slaughter cattle that do not meet live export specifications. However, development of meat processing in northern Australia, combined with increased availability of fodder crops, could result in increased cattle fattening, either in feedlots on cattle stations or commercial feedlots close to the abattoirs, and the opportunity for pastoralists to diversify their production away from live export.

8.7.3 CROP PRODUCTION ESTIMATES

Estimates of crop growth, yields and irrigation demands for identified broadacre, high-value and industrial crops have been made using the APSIM (Agricultural Production Systems sIMulator) crop simulation model (Keating et al., 2003) for crops that ASPIM has the potential to simulate (maize, mungbean, peanut and cotton) (Table 8.3). Various 'heat sum' approaches and expert-based techniques for analysing historical yields in northern Australia have been employed for estimating yields and irrigation demands for the remaining crops without APSIM simulation capability.

There were two soils used in the APSIM simulations, parameterised to represent a duplex sandy gravel and a red Kandosol soil. The duplex sandy gravel holds 57 mm (plant-available water capacity) to a 0.6-m depth and 126 mm to a 1.2-m depth. The red Kandosol holds 35 mm to 0.6-m depth, 63 mm to 1.0-m depth and 100 mm to 1.5-m depth. Mungbeans and peanuts can access the shallower soil layers only, whereas forage sorghum can exploit water to more than 1 m in depth. Historical meteorological data from Wittenoom between 1900 and 2010 was used in the simulations to generate variation in crop yield and irrigation water required.

APSIM yield predictions are based on the assumption that best practice has been employed for managing a crop that was also grown in the absence of any pest and disease-related stress. Simulations were used to predict crop growth in non-limiting soil water and nutrient environments. Application of irrigation was triggered in the model using soil water deficit and the potential root zone of each crop. Natural reset points were selected at the end of winter (September) when the soil profile is normally dry to initialise the soil water, soil nitrogen and surface cover each year, so as to only capture the effect of seasonal climate and applied irrigation on crop production. Irrigation management assumed 100% efficiency in applying irrigation to the crop regardless of the actual availability of supply.

The values presented for water applied to a crop does not equal the total amount of water actually used to produce the crop (Table 8.4). APSIM assumes 100% efficiency of irrigation water supply, and reported figures are ‘on crop’, not accounting for inefficiencies that will exist in the storage, delivery and on-farm application of the water. There are likely to be very high irrigation-delivery inefficiencies associated with centre pivot irrigation in an environment such as the Pilbara, where evaporation rates in summer are extremely high. Indeed, the Hamersley Agricultural Project relies on high inefficiencies to fully use the surplus water from mining operations. The outputs from modelling and estimates for the nonmodelled crops are potential productivity and irrigation water use on a per-hectare basis.

Table 8.3 Simulated crop yields under full irrigation

Crop yields were simulated by APSIM (represented by those crops with 20th, 50th, 80th percentile values) or for other crops estimates based on production in nearby regions or published estimates. APSIM yields for broadacre crops are based on 110 years of simulations (1900 to 2010) and are expressed in tonnes of dry matter per hectare and for the economic assessment these were converted to fresh yields, based on moisture contents of 12 to 14%.

CROP	YIELD PERCENTILE		
	20th	**50th**	**80th**
Broadacre (t/ha)			
Maize	11.4	10.5	8.4
Mungbeans	1.9	1.8	1.6
Peanut	4.8	4.6	4.3
High value			
Watermelon		55.0	
Industrial/other crops			
Cotton (bales/ha)	10.1	8.9	6.6
Guar		2.0	
Forage sorghum	30.4	29.9	27.7
Lablab hay	10.4	9.9	8.5

Table 8.4 Irrigation water use (mm per crop) simulated in APSIM
These figures assume perfect timing of irrigation (i.e. no field application losses). The actual amount of water applied will be considerably greater, especially for centre pivot operations in summer where evaporative losses will be high.

CROP	IRRIGATION WATER USE (mm) PERCENTILE		
	20th	**50th**	**80th**
Broadacre			
Maize	443	387	328
Mungbean	206	147	123
Peanut	451	379	338
Industrial			
Cotton	1033	941	841
Forage sorghum	1250	1160	1007
Lablab	455	382	304

Maize

Although maize can be planted during a wide sowing window, management of heat stress during flowering, grain fill and seedling development is required to reduce the risk of yield penalties. For the simulation modelling, maize was sown on 15 March. The simulated maize yields (10.5 t/ha of dry matter) for the Pilbara show that it is well adapted to the region. Maize could also be grown as a summer crop in rotation with other crops grown during winter, as well as a forage crop for livestock.

Mungbean

Mungbean was sown in the simulations on 15 March. Mungbean matures relatively quickly and it can be opportunistically sown, although it is often part of planned rotations. Mungbean price can vary greatly with seed quality when sold for human consumption (the highest value use). Rainfall during the later stages of pod fill can have a detrimental effect on grain quality and, consequently, the price received, so planting is usually timed to ensure a low risk of receiving rainfall at this crucial time.

Peanut

Peanuts were simulated to grow during the dry season, with planting in March. It could also be grown as a summer crop with planting in December or January. The simulated yields were comparable with those of other established peanut-growing regions in Queensland.

Melons

Cucurbits (watermelon and rockmelon) may be well suited to the Pilbara region, although the season length may be restricted by high temperatures from September to March. Cucurbits are generally planted in a staggered manner, so that harvest occurs over a longer time period, from May until October, reducing the time of peak workload and extending the time for market access. The planting season for cucurbits commences when the daytime air temperature reduces sufficiently for young plants to not suffer from heat stress (late February to mid-March) and continues until July. Yields for watermelons were estimated to be 55 t/ha. The drier climate of the Pilbara region and the generally arid environment may result in fewer pest and disease issues, leading to higher yields.

Cotton

Cotton quality is influenced by rainfall during late crop development, which can downgrade the quality and price. Planting in the Pilbara region needs to be timed to avoid rainfall at this time of crop development. For the yield simulations, cotton was planted on 1 January. Night-time temperatures in June and July in the

Pilbara are are about 2 ^{o}C lower than in Kununurra or Katherine, and this is likely to restrict cotton growth. The APSIM simulations showed little difference between wet- and dry-season cotton yields but, in this analysis, only wet-season cotton is considered. Yields were simulated to be about 9 bales/ha.

Guar

Guar production may be well suited to the extreme conditions in the Pilbara region, possibly as a rotation crop with cotton. Guar is a legume crop with only limited trial data available from areas in northern Australia. Guar grows very similarly to soybean and, based on past published Australian and overseas research, a yield of 2 t/ha under irrigation has been used.

Forage hays

Estimated forage sorghum yields of around 30 t/ha of dry matter were obtained using high-density sowing, and four or five harvests during the year. Pilot trials of forage sorghum are being undertaken at Woodie Woodie by AgGrow Energy Resources Pty Ltd, and early results suggest biomass yields can be achieved that are higher than those estimated in the simulations. Similarly, in the Hamersley Agricultural Project, yields are projected to be in the range of 32 to 38 t/ha of dry matter (Ross George 2014, pers. comm.). Lablab was sown in March following a cotton crop and, during its six-month growing period, it was simulated to produce approximately 10 t/ha of dry matter.

8.7.4 CROPPING CALENDAR

Cropping calendars identify sowing times and the growing season for different crops. The sowing window refers to the time during which a crop can be reliably sown. Sowing windows vary in both timing and length among crops. The cropping calendar (Table 8.5) identifies the sowing and growth windows for the crops that have been analysed for the Pilbara region. Perennial crops are grown throughout the year and, consequently, have a less well-defined growing season or planting window, and are not shown in Table 8.5.

The cropping calendar was developed on the basis of knowledge of these crops in the Pilbara region or from data sourced from elsewhere, combined with an understanding of plant physiology. This enables crop response to differences in local climate to be anticipated. The sowing and growth windows that have been identified correspond with the times that are likely to maximise potential crop yield. Crops can sometimes be successfully sown outside the identified sowing and growth windows, and only a small yield penalty would apply. In this analysis, sowing dates between August and November are generally avoided because the high evaporative demand and low water availability are not conducive to seedling establishment; although many crops can be sown at this time. It should be noted that sowing to achieve maximum potential crop yield may not always be possible. Wet-season difficulties in access and trafficability may prevent sowing at optimum times.

Table 8.5 Calendar of sowing for annual crops in the Pilbara region

CROP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Broadacre												
Maize	X	X	X								X	X
Mungbean				X	X	X	X	X	X			
Peanut				X	X	X	X	X	X			
High value												
Watermelon				X	X	X	X	X	X			
Industrial/other crops												
Cotton	X	X	X	X	X							X
Guar	X	X	X	X	X	X	X	X	X	X	X	X
Forage sorghum					X	X	X	X	X	X		
Lablab				X	X	X	X	X	X			

8.8 Gross margin analysis: sensitivity to price, production and supply chain costs

The crop gross margin is the difference between the gross revenue and total variable cost of growing a crop.

Variable costs include those associated with crop management, harvesting, transport and marketing. For regions such as the Pilbara, which are distant from major infrastructure and support services, the costs of production are likely to be high compared with other agricultural regions in south-west Western Australia or eastern Australia. These higher costs can be attributed to both higher costs for inputs, such as fertiliser, as well as the costs associated with transport to markets and/or processing facilities. In addition, given the dominance of mining in the region, costs of both labour and services such as transport are likely to be higher than in regions dominated by agriculture.

The gross margins for a range of crops specific to the Pilbara region are presented in Table 8.6. The gross margins do not include overhead costs (e.g. business administration, insurance), or debt and depreciation on capital costs (e.g. farm equipment, irrigation infrastructure) that must be met even if a crop is not grown. For the crops that were modelled using APSIM and over 100 years of historical climate data, gross incomes were calculated using the 50th percentile (median) exceedance crop yields during the historical period. For crops that could not be modelled with APSIM, the estimated yields are based on production data in the region or in other regions if that crop is currently not grown. Costs of production were based on gross margins developed by local agricultural economists and agronomists (Chris Ham 2014, pers. comm.) and various published gross margins. Given there is no history of commercial-scale crop production in the Pilbara region, there is less confidence in the projected gross margins than for other regions.

Gross margin analyses are indicative and should be used with care because they are highly sensitive to price, yield, transport costs and the input costs – not just within a particular region but between individual farms. The estimates provided in Table 8.6 are based on existing supply chains and processing facility locations.

For horticultural crops, which mostly supply domestic markets that have a finite demand and can be easily oversupplied, there can be rapid price movements during days and weeks. This is highlighted in Figure 8.9, which shows movements in the wholesale price of watermelons at the Sydney markets in 2013. In contrast, significant price movements in broadacre crops play out during longer timescales of months and even years (Figure 8.10).

The broadacre crops are projected to produce gross margins that are either negative or less than $500/ha. Under the existing supply chain arrangements, all of the broadacre crops need to be transported significant distances to markets from the Pilbara (e.g. Perth or, in the case of peanuts, to Kingaroy in Queensland). Table 8.7 highlights the high freight costs as a percentage of the total costs of production for high-yielding grains such as maize, even though favourable backloading freight rates can be negotiated for dry trailers returning otherwise empty from the Pilbara region to Perth. Mungbeans are a relatively low-yielding and high-value-per-tonne crop and, consequently, freight costs comprise a smaller percentage of total production costs. However, the gross margins are still modest because the revenue from a yield of about 2 t/ha is low. Although peanuts are a relatively high-value crop and can generate gross revenue greater than $4000/ha, the transport costs to Kingaroy for shelling and processing are high due to a combination of lower tonnes per vehicle that can be carried with peanuts in shells and the limited availability of backloading opportunities on that route. As a consequence of these high freight costs, the gross margins are negative. For the coarse grain and pulse crops to be grown more profitably, either a local market for feed grain for use in regional beef production systems needs to be developed or local peanut processing facilities (i.e. shelling plants) need to be constructed.

Table 8.6 Gross margin analysis for existing and potential crops in the Pilbara region
Yields of crops simulated by APSIM on a dry-matter basis have been adjusted upwards to account for moisture content of marketed product.

CROP	LOCATION FOR MARKET OR PROCESSING	YIELD UNIT/ha	MEDIAN YIELD (per ha)	PRICE PER UNIT YIELD ($)	VARIABLE COSTS LESS FREIGHT ($/ha)	FREIGHT COSTS ($/ha)	TOTAL VARIABLE COSTS ($/ha)	GROSS MARGIN ($/ha)
Broadacre								
Maize	Perth	tonnes	11.9	280	1,710	1,071	2,781	551
Mungbean	Perth	tonnes	2.0	900	1,124	180	1,304	496
Peanut	Kingaroy	tonnes	5.2	850	2,566	2,168	4,734	-314
High value								
Watermelon	Perth	tonnes	55	900	25,835	14,905	40,740	8,760
Industrial/other crops								
Cotton	Menindee	bales	8.9	500	3,658	1,855	5,513	–458
Guar	Perth	tonnes	2.0	625	573	180	753	497
Forage sorghum	Pilbara	tonnes	30	130	3,031	330	3,361	539
Lablab	Pilbara	tonnes	10	180	1,191	100	1,291	509

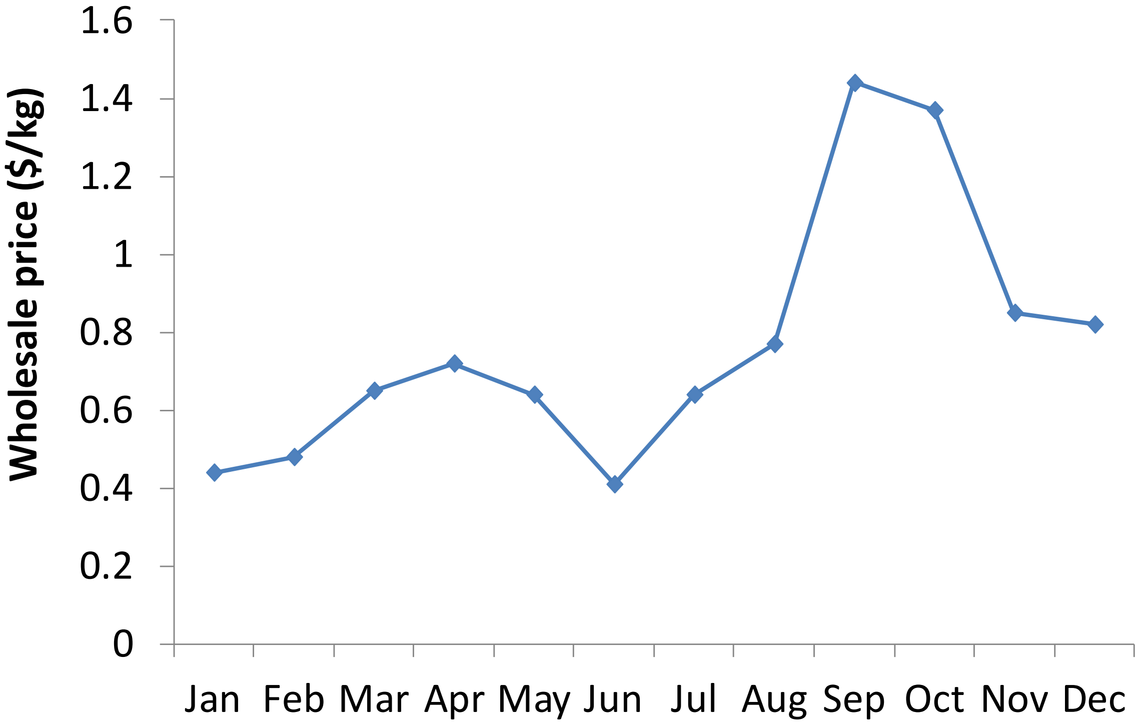

Figure 8.9 Wholesale prices for seedless watermelons at the Sydney markets during 2013
Source: Data from Ausmarket Consultants, 2014

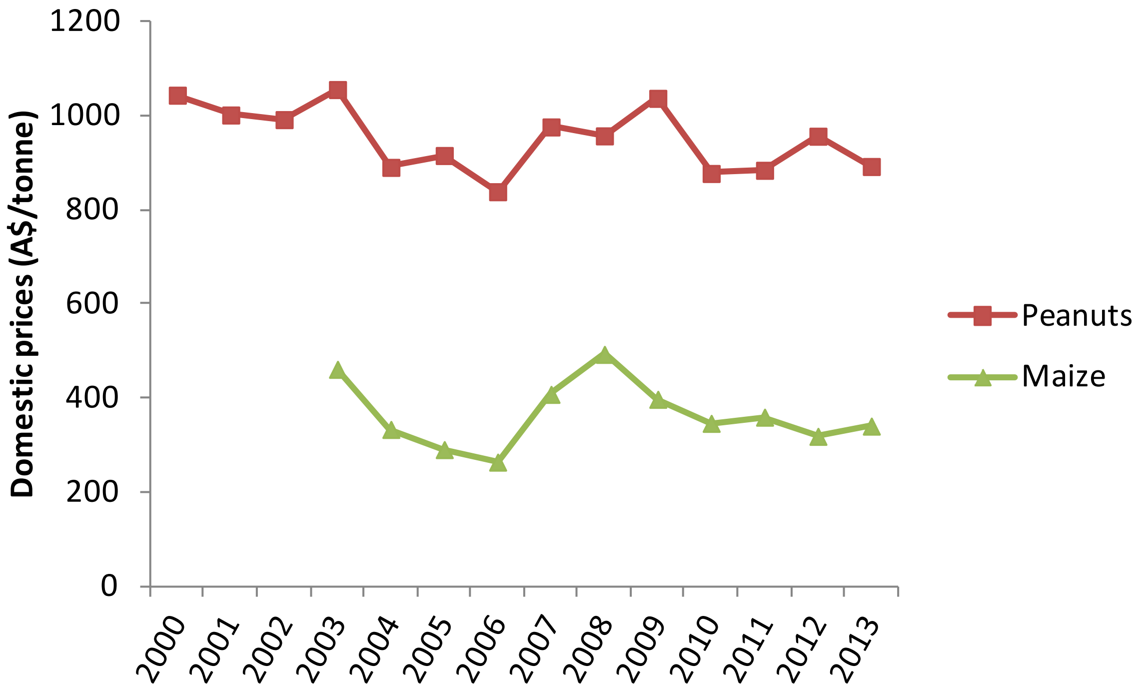

Figure 8.10 Prices received for peanuts and maize in Australia
Source: Data from ABARES, 2014

Table 8.7 Freight costs as a percentage of total value of production and total production costs for a range of crops in the Pilbara region

Location represents the point of wholesale or processing.

CROP	LOCATION FOR MARKET OR PROCESSING	FREIGHT COSTS AS A PERCENTAGE OF TOTAL VALUE OF PRODUCTION (%)	FREIGHT COSTS AS A PERCENTAGE OF TOTAL COSTS OF PRODUCTION (%)
Broadacre			
Maize	Perth	32.1	38.5
Mungbean	Perth	10.0	13.8
Peanut	Kingaroy	49.0	45.5
High value			
Watermelon	Perth	30.1	36.6
Industrial/other crops			
Cotton	Menindee	36.7	33.6
Guar	Perth	14.4	23.9
Forage sorghum	Pilbara	7.7	9.8
Lablab	Pilbara	5.6	7.7

The projected gross margins for watermelons were highly positive based on the yield and cost assumptions that were used in this analysis. All horticultural crops have high input costs and, as indicated in Figure 8.9, price movements can occur rapidly in response to market supplies at a national scale. The sensitivity of gross margins to price of horticultural products that might be grown in the Pilbara is highlighted in Table 8.8, which demonstrates that although gross margins per hectare can be high, large losses can also occur when the market is oversupplied with produce and prices fall. The sensitivity step of –45% in prices translates to about \$500/t (50 c/kg), which was actually the wholesale price for watermelons in Sydney for the first half of 2013.

Table 8.8 Gross margin sensitivity to price for watermelons in the Pilbara region

Baseline gross margins are the same as reported in Table 8.6 and the price sensitivities are in steps of ±15%.

PRICE SENSITIVITY (%)	WATERMELONS (\$/ha)
–45	–6,808.17
–30	–1,618.92
–15	3,570.34
Baseline	8,759.59
15	13,948.84
30	19,138.09
45	24,327.34

Intensive horticultural production commonly involves high labour inputs and costs, especially those associated with picking, grading and packing operations in the shed. Labour costs for these harvest and postharvest activities typically represent 20 to 30% of total production costs and are, therefore, a significant influence on net returns from horticulture. Labour supply for horticultural crops in all regions is now sourced largely from backpackers, who can obtain a second-year holiday visa if they undertake three months of work in a regional area of Australia.

Currently, the vast majority of horticultural production from northern Australia is sold on domestic markets and, with existing markets and supply chains, the Pilbara region would be no exception. Consequently, transport costs per hectare of watermelon production were high in absolute terms and are a significant percentage of the total costs of production (Table 8.6).

The flows of refrigerated produce from southern Australia to major population centres in northern Australia into supermarkets and other food outlets presently allow horticultural producers to exploit backloading opportunities of otherwise empty refrigerated containers returning south. However, for the Pilbara region, there would not be the same availability of refrigerated containers to transport horticultural products to Perth, because there are no major urban centres receiving refrigerated produce from southern Australia. As a result, freight rates were not heavily discounted for backloading and this contributed to the relatively high transport costs.

Given the sensitivity of prices to supply in the domestic market and the freight costs incurred in transporting the produce to southern Australia, there may be opportunities to develop export markets, with the produce moving out of a well-developed port such as Port Hedland. Even under a scenario of commercial-scale horticultural production in the Pilbara region, this is not currently feasible due to a combination of factors, including:

- the limited number of markets with export protocols developed
- for some crops, the high costs associated with treatments for pests or disease before export
- overall high costs of production in Australia, especially for labour-intensive horticultural products, which tend to favour export of niche products rather than bulk horticultural production
- a lack of facilities for refrigerated container storage at Port Hedland and the absence of refrigerated containers arriving to provide a cost-effective supply of empty containers for shipment
- insufficient volumes of supply to generate the shipping trade at regular enough frequency for perishable fruit or vegetables.

Gross margins for the industrial crops provide a contrast in financial returns. Cotton was estimated to yield a large negative gross margin, entirely because of the high costs of transport to a cotton gin at Menindee in New South Wales. Transport costs for raw cotton are exacerbated by the high volume per unit weight, which means a Type 2 vehicle can only carry 25.8 t of raw cotton, of which only 35 to 40% is lint. For cotton to be grown successfully at a commercial scale, there would need to be a gin located in or close to the Pilbara region; the impact of this on reducing supply chain costs is addressed in Section 8.9. Accessing processing facilities that might be developed in neighbouring regions as part of their agricultural expansion plans also needs to be explored, but the large distances involved might still act as a constraint. For example, if cotton was established in the Ord region and a gin constructed there, it would still be about 1800 km to transport the cotton to Kununurra at a cost exceeding $450/t.

The forage sorghum and hay crops both yielded gross margins of about $500/ha on the basis that the hay can be used locally, either in pastoral operations or, in the case of forage sorghum, as a biofuel crop for local liquid fuel needs in mining operations that are off-grid. The costs of growing sorghum are relatively high for a forage crop, which is the result of the large biomass that is produced, and the need to harvest and bale the crop five times per year to maintain good-quality hay.

Table 8.9 shows gross margins for crops, but assuming different supply chain options to those used in the baseline analysis in Table 8.6. Assumptions for the new supply chain options are also provided.

Two different supply chain scenarios were explored for maize. The first scenario involved export out of Port Hedland to Asia, using dry containers that are otherwise returning empty to China or Singapore following import of general cargo for the mining industry. The combined costs of road freight to Port Hedland, wharfage charges and shipping costs resulted in a cost of $135/t to produce maize for export. This is actually more than the estimated $90/t to truck to Perth under present backloading arrangements.

The second supply chain scenario assumed that the maize grain is used in combination with hay to establish intensive beef-feeding systems. Associated with this assumption was a reduction in returns from maize grain directed to local livestock feeding, from $280/t to $240/t. With transport costs reduced to about $10/t, the estimated gross margins increased to more than $1000/ha.

For peanuts, it was assumed that, in addition to the present drying facility, a new shelling plant and cold-storage facility were established in the Pilbara. Processed peanuts were then trucked to Perth and sold either domestically or exported. The revenue for processing peanuts in this way rather than transporting them to Kingaroy for value-adding processing was assumed to be $100/t less at $750/t. Nevertheless, the gross margin shifted from being negative to $866/ha.

For cotton, it was assumed that a cotton gin was constructed in the Pilbara region to process raw cotton rather than to ship it interstate for ginning. This resulted in the cotton gross margin shifting, from being highly negative to $1350/ha.

Table 8.9 Change in gross margin for a range of selected crops in response to altered location of processing facilities or market destination

CROP	LOCATION FOR MARKET OR PROCESSING (BASELINE)	GROSS MARGIN ($/ha)	LOCATION FOR MARKET OR PROCESSING (SCENARIO)	GROSS MARGIN ($/ha)	ASSUMPTIONS FOR SUPPLY CHAIN SCENARIOS
Broadacre					
Maize	Perth	551	Asia	254	Exported via Port Hedland to China
Maize	Perth	551	Pilbara	1028	Maize grain used in local beef-feeding systems
Peanuts	Kingaroy	–314	Katherine	866	Shelling plant in the Pilbara and then trucked to Perth
Industrial					
Cotton	Menindee	–455	Pilbara	1349	Cotton gin in Kununurra

8.9 Integrated scenario analysis: investment and supply chain options

The analyses in the previous sections have focused on individual crops, their production characteristics under growing conditions in the Pilbara region, farm gross margins and supply chain options for the individual crops. In this section, two development scenarios for agricultural production are examined at a regional scale, with implications for regional value of production, logistics and infrastructure investment.

The regional-scale analysis assumes that there are 8000 ha of land suitable for irrigation, with water for irrigation made available through mine dewatering operations at 95% annual time reliability. This level of development is based on being able to use 120 GL at the farm gate of the potentially available 200 to 300 GL of surplus water from mine dewatering operations. This assumes a field application of 15 ML/ha, assuming some losses during application, which is a high rate for irrigation schemes. However, water use in conventional irrigation schemes, where water costs are relatively high, usually has an imperative to achieve efficient water use; for mine dewatering operations, it is important to have year-round water use. Surplus water is generated every day, and it is important to have ongoing crop demand for that water to reduce disposal costs and other bottlenecks involved with removing the water. Alternatively, large and expensive water storages would need to be constructed to hold the water for later use. Even with year-round use of irrigation water, the amount demanded by crops during the cooler months of the year can decline significantly. For example, in the Hamersley Agricultural Project, water use in the summer months can be 120 ML/day, but it can drop to 40 ML/day in the winter months. This has necessitated the construction of a 3-GL buffer dam to accommodate these changes in seasonal demand.

In the following scenarios, the need to have close to year-round water use has been taken into account by either having forage crops that grow for a year (or are perennial), or double-cropping systems where one crop is immediately followed by another crop. In double-cropping systems, there will be small gaps between crops, and a buffer dam would need to be employed on these occasions. In double-cropping systems, where the crop grown throughout the winter is a temperate crop, it is likely that water use can remain high compared with a tropical forage such as Rhodes grass (as used in the Hamersley Agricultural Project). This is because the temperatures in the cooler months are low enough to slow down substantially the growth of tropical forages.

The scenarios are based on the water being made available from mining operations at a low cost. In the economic assessments, it is assumed that the water can be applied in the paddock at a cost of $70/ML (i.e. some pumping costs associated with pumping in the paddock are included, but the cost of getting the water from the mines to the irrigation area is not included).

8.9.1 **INVESTMENT AND SUPPLY CHAIN OPTIONS**

Two scenarios have been chosen to explore the development of crop production systems (Table 8.10).

Scenario 1

The first scenario centres on local processing, and local use of crops and crop products to minimise transport costs and value-add within the region. It comprises 4000 ha of a peanut/maize rotation and 4000 ha of forage sorghum. It is based on establishing a peanut drying, shelling and cold-storage plant in the Pilbara, rather than transporting the peanuts in shell to Kingaroy. It also assumes that the shelled peanuts are trucked to Perth for marketing either locally or for exporting. As previously indicated in the supply chain options, a lower price received for peanuts sold through Perth is assumed ($750/t versus $850/t for product in Kingaroy) on the basis that there is not the value-added grading and processing that occurs in Kingaroy. The peanuts are grown during the dry season (cooler months), with maize as the rotation crop grown during the summer following planting in December.

Rather than being trucked to Perth, the maize is used locally in intensive beef-feeding systems; 4000 ha of maize will produce about 48,000 t of grain. This is sufficient to intensively feed two cohorts of cattle of 12,000 head each, for about 100 days/cohort or 200 days in total. After 100 days of feeding, these animals would either go to slaughter or be further finished in feedlots in south-western Western Australia. Opportunities for slaughter animals are improving, due to the construction of an abattoir 70 km east of Broome, although it is currently focused on processing small-carcase animals in its start-up phase. An operational period of 200 days allows the summer months to be avoided to reduce the challenges of managing heat stress in feedlot cattle. This would have implications for labour requirements.

The 4000 ha of forage sorghum that is produced is assumed to be used in the local pastoral industry as a forage source for weaners and for animals held in yards before being transported southwards or exported live via Port Hedland. Some of the forage would also be used in the intensive feeding systems to provide the required roughage component of a high-grain diet. Although still far from a practical application, there may be an opportunity to use forage sorghum as a biofuel crop to reduce dependency on diesel in mining operations that are off-grid.

Scenario 2

The second development scenario focuses on a single industrial crop (cotton) to use the entire 8000 ha available for irrigation. This scale of cotton production is necessary to justify the construction of a four-stand cotton gin in the Pilbara region. Without a regionally sited cotton gin, this scenario would simply not be feasible. To justify the capital investment in a cotton gin, there would need to be some confidence that surplus water from mine operations would be available for the next 30 years. This may involve shifting the cropping operations some tens of kilometres as some mines are decommissioned and other new ore bodies are brought into production. However, with a centrally located gin, this should be feasible.

Once the cotton crop is harvested at the end of summer, the 8000 ha is used to grow a range of legume rotation crops. This includes 4000 ha of mungbeans, 2000 ha of guar, and 2000 ha of lablab for forage hay and/or as a mulch crop to improve soil condition. The mungbeans and guar would be transported to Perth for processing and sale, and the lablab would be used locally in beef operations as discussed in Scenario 1.

Table 8.10 Scenarios used to explore implications of scaled-up production at the regional scale

CROP	AREA OF LAND (ha)	CROP YIELD (t/ha)	LOCATION FOR MARKET OR PROCESSING	ASSUMPTIONS FOR REGIONAL SCENARIO
Scenario 1 – local processing and use of crops/forages				
Peanut	4000	5.2	Pilbara and Perth	Dried and shelled in the Pilbara region and then trucked to Perth
Maize (rotation with peanuts)	4000	11.9	Pilbara	Integrated into intensive beef-feeding systems within the Pilbara region
Forage sorghum	4000	30.0	Pilbara	Used in pastoral enterprises, intensive beef feeding and, possibly, as a biomass crop for biofuel
Scenario 2 – industrial crop focus: cotton				
Cotton	8000	8.9	Pilbara	Cotton gin built in association with grid power in the region
Lablab (rotation with cotton)	2000	10.0	Pilbara	Used in the beef industry locally and could be compressed and trucked elsewhere
Guar (rotation with cotton)	2000	2.0	Perth	Processed in Perth
Mungbean (rotation with cotton)	4000	52.0	Adelaide	Processed in Perth

Results

The regional-scale implications of the two scenarios operating at 8000 ha in the Pilbara region are shown in Table 8.11. Scenario 1, which focuses on local-scale processing and using products in other regional supply chains such as beef intensification or biofuels, generated a gross value of production of $43 million. This does not include any allowance for the value-added production through increased productivity of the beef sector. Scenario 2 produced a slightly higher value of production at $49 million.

The Pilbara region is different than the other regions examined in this study in that there is virtually no history of commercial agricultural production outside of extensive pastoral activities. Mining also plays a very dominant role in the region, which influences infrastructure, labour costs and supply, and ports. Scaling-up agricultural activities, even up to a relatively modest scale of 8000 ha, needs to take into account these drivers. Scenario 1 places strong emphasis on local use and integration of agricultural production in the beef industry, and value-adding for that sector. To achieve local use of about 50,000 t of grain and more than 120,000 t of hay each year will require significant commitment from beef enterprises in the region. The Pilbara pastoral region is approximately 224,000 km^2 in extent, carrying approximately 300,000 head of cattle on 56 pastoral leases that are considered viable operations (Dray et al., 2011). Currently, about 80,000 head of cattle are turned-off each year – mostly for live export, but about 25% of the cattle are slaughtered or sold domestically. Based on these turn-off numbers, there would appear to be ample supply of young animals within the region to support the scenario of 24,000 head being intensively grown each year under more intensive feeding systems. In practice, this would occur as two cohorts, each with 12,000 head, being fed each year. Presently, Western Australia has a feedlot capacity of 185,000 head, and adding a 12,000-head capacity represents a 6.5% expansion in feedlot capacity.

Scenario 1 also involves establishing 4000 ha of peanuts that are dried and shelled within the region. More than 90% of Australia's current peanut production occurs in Queensland, and establishing a peanut industry in the Pilbara would represent a new industry not just in the region, but for Western Australia, where peanuts have not previously been established at a commercial scale. Knowledge of peanut agronomy and farm management practices would need to be imported, as would market development expertise, given that this scenario does not involve peanuts being processed through the Peanut Company of Australia in Kingaroy.

Scenario 2 generates around 70% of its gross revenue from cotton, with the legume rotation crops of lablab forage, guar and mungbeans providing the balance of the $48 million in gross production. Consistent with all the regional case studies, for cotton production to be profitable, a cotton gin needs to be sited within a reasonable distance from where the cotton is grown. Ideally, it would be as close as possible, but certainly no more than 400 to 500 km away. So, for cotton to be successful in the Pilbara, a cotton gin needs to be constructed in the region. Given the significant scale of the mining industry in the region and its dependence on mechanical infrastructure, establishing a cotton gin in the region is not a major undertaking. Apart from demonstrating that cotton can be grown with competitive yields in the Pilbara, the largest uncertainty is the ongoing supply of water to justify the infrastructure investment in a cotton gin. A viable cotton industry could most likely cope with the areas of production moving around the region in response to specific ore bodies, and the associated surplus water being exhausted and new deposits coming into production. However, there would need to be a degree of confidence that the industry could be supported at the scale of 8000 ha or more during the economic life of a cotton gin.

Table 8.11 Influence of the two regional scenarios on total flows of product and value of production per year

CROP	TOTAL PRODUCTION (t)	TOTAL VALUE OF PRODUCTION ($million)	TOTAL VARIABLE COSTS ($million)
Scenario 1 – local processing and use of crops/forages			
Peanuts	20,800	15.600	12.136
Maize (rotation with peanuts)	47,600	11.424	7.312
Forage sorghum	120,000	15.600	11.124
Total	188,400	42.624	30.572
Scenario 2 – industrial crop focus: cotton			
Cotton	16,162	35.600	29.672
Lablab (rotation with cotton)	20,000	3.600	2.582
Guar (rotation with cotton)	4,000	2.500	1.506
Mungbeans (rotation with cotton)	8,000	7.200	5.216
Total	61,300	48.900	38.976

Transport implications

Both of the regional development scenarios involve only dry-weight transport to local use/processing or the 1450 km road trip to Perth. From the supply chain analysis information shown in Appendixes 8.2 and 8.3 (separate document) for each of the two scenarios, minimum fleet requirements have been calculated by month of the year, accommodating the harvest and transport requirements of each crop. Vehicle requirements account for minor rest breaks en route to the destination, as well as the time required for loading/unloading. They do not account for major downtime or maintenance. Figures 8.11 and 8.12 show the vehicle requirements by time of year for Scenarios 1 and 2. These requirements do not include vehicle reductions that may be achieved by backloading opportunities on some routes. Backloading would likely be available for transport to Perth due to the large amount of general freight presently being moved from Perth to the Pilbara to support the large mining industry. However, the grain trailers will need to be transported back to Wittenoom empty (e.g. attached to a B-double or Type 1 vehicle to form a larger road train) if there is no other freight suited to these trailers. If backloading was available, the transport costs to Perth would reduce from $168/t to about $90/t. Note that the numbers in Figures 8.11 and 8.12 are based on the number of prime movers, and a Type 2 road train is classed as one vehicle. The numbers in Figures 8.11 and 8.12 are multiplied by three (or by two for Type 1 vehicles) to give the number of trailers.

A noticeable result is that the peak vehicle requirements only last for one to two months. The one-month peak in Scenario 2 is due to the overlapping requirement for vehicles in August as a result of cotton being transported locally from the field to the gin and the harvest of pulse/grain crops at the same time. This could make it difficult or more expensive to source vehicles and grain trailers for such a short peak demand, given the isolation of Wittenoom from other agricultural production regions. Alternatively, there may be options to adjust the crop calendar and harvest/processing times to overcome this short peak in vehicle demand.

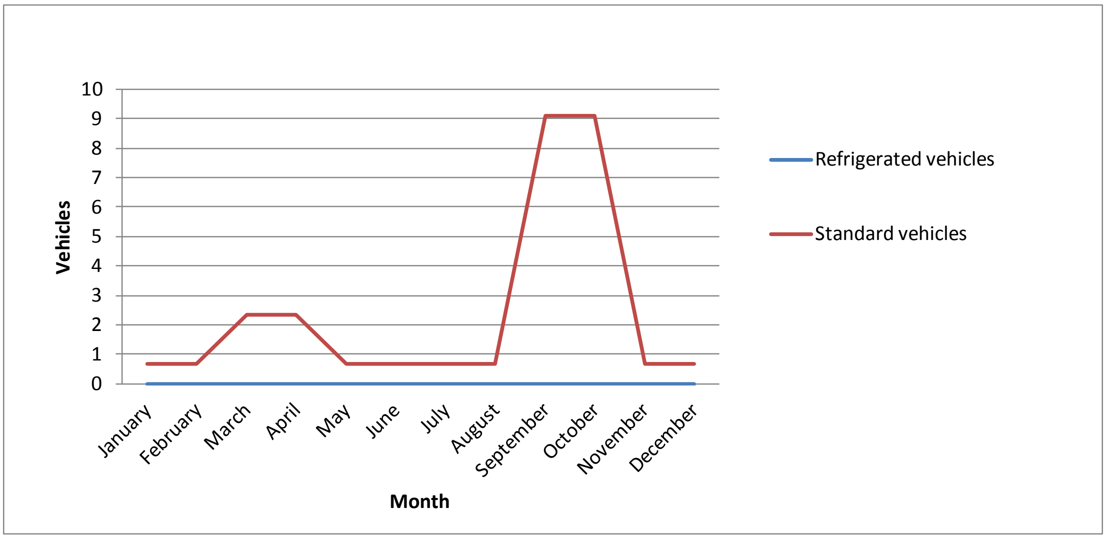

Figure 8.11 Vehicle requirements for 8000 ha of cropping in Scenario 1

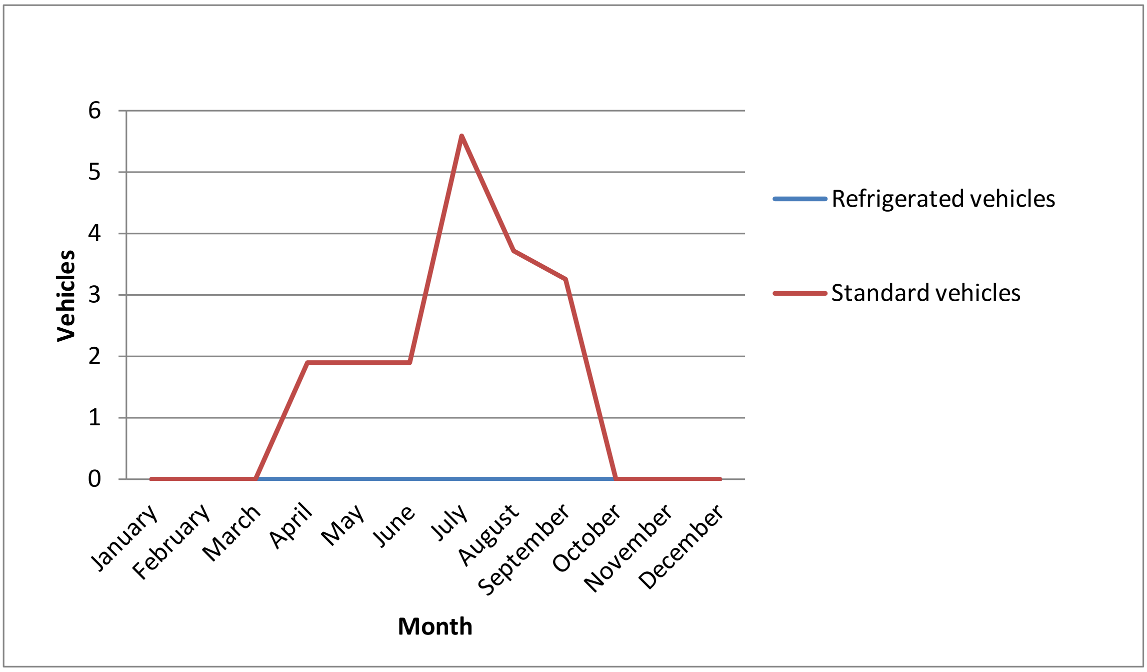

Figure 8.12 Vehicle requirements for 8000 ha of cropping in Scenario 2

The two development scenarios did not include products moving out through either of the two major shipping ports in the region, Port Hedland and Karratha. Port Hedland is Australia's largest port in terms of annual tonnages shipped – about 300 million tonnes in 2013. Although the proportion of containerised and general cargo being imported and exported is very low, the actual tonnages shipped are still significant (e.g. 281,000 t of general and containerised cargo imported in 2012–13). The export volumes of containerised and general cargo are about 10% of the import volumes, which means there are many empty containers and considerable general cargo availability for export. Given the enormous scale of iron ore export operations at a port like Port Hedland, it can be difficult scheduling general cargo, and good planning is required. Exporting containerised cargo to Asia would cost about $150/t (i.e. $35/t road transport from the central Pilbara to Port Hedland/Karratha; and $115/t in port handling, wharfage, container charges and shipping costs). This compares with about $90/t in trucking dry goods to Perth, assuming the opportunity to access favourable backloading rates.

As no refrigerated containers arrive by sea into Port Hedland or Karratha, the export of any refrigerated horticultural produce would require repositioning of containers from Fremantle at a considerable cost. This, along with uncertainties about the reliability of horticultural production in the Pilbara environment, led to horticultural production not being considered in the two development scenarios. Airports in the region have grown to service the mining developments, and there may be a possibility of using this infrastructure for air freighting high-value horticultural production to export destinations. The challenge of doing this is that the servicing aircraft would need to be coming to the Pilbara region empty, which greatly adds to the cost of air freighting produce. This contrasts with the east coast capital cities, where there is considerable air freight capacity returning north to Asia, relatively empty. This availability of air freight capacity means that it is typically more cost-effective to send some products, such as mangoes, by refrigerated truck from Darwin to Sydney to be loaded on to a plane for shipment to Asia – thereby overflying Darwin – than landing in Darwin to pick up freight. This same scenario could well apply to the Pilbara region in the context of air freight (i.e. it may be more cost-effective to truck produce to Perth and then air freight to Asia, rather than fly it directly out of the Pilbara region).

Infrastructure

Establishing a greenfields agricultural industry will require significantly more investment compared with a region where there is some history of agricultural or horticultural development. Some of this primary infrastructure is 'hard' – such as agricultural machinery – which needs to be brought into the region – for example, tractors, harvesters and centre pivot irrigation systems. However, success is probably more dependent on having the soft infrastructure in agronomic skills and agribusinesses to support development, particularly for new crops to Western Australia, such as peanuts and, to a lesser extent, cotton. This will be a particular challenge in the Pilbara, where agriculture has to compete with the mining sector, which has high labour cost structures compared with most agricultural regions. Townships that have good facilities and are vibrant will be essential to supporting agriculture in the same way as they are essential for the mining industry. The $1.2 billion Pilbara Cities Initiative is providing much of the infrastructure and services needed to support growing agricultural development. The road infrastructure between the Pilbara region and the North West Coastal Highway that connects it to Perth is being upgraded, and this will also benefit the agricultural sector.

The two development scenarios involved access to regionally sited processing infrastructure for cotton (gin) and peanuts (drying and shelling plants). It is expected that a cotton gin would be located near an existing mining operation or mining town to draw on grid power. For example, there is a 178-MW gas-fired power station at Newman that would have the capacity to supply the energy needs of a cotton gin. A four-stand cotton gin capable of processing 75,000 bales of cotton each year would cost about $20 million to $30 million to construct and commission. To support a 4000-ha area of peanuts growing, drying and shelling facilities would be required at a cost of about $4 million.

Given that surplus mine water may shift in location in response to ore deposits being either exhausted or coming into production across the region, the equipment used in farming operations and the type of irrigation system used need to be considered. Irrigation equipment such as pumps and centre pivots may need to be relocated, and low-cost materials with a short lifespan such as trickle tape may be well suited to these conditions.

8.9.2 RISK ANALYSIS

The analysis for the two regional development scenarios has used averages of yields and prices, based on historical data and simulated crop yields. Future investment needs to be based on a good understanding of risk. Price risk is one variable that needs to be considered when making investments. ABARES produces market outlooks for a range of commodities – shown in Table 8.12 for the crops used in the two regional scenarios. These market outlooks are based on medium-term drivers and, as such, do not capture shorter-term year-to-year variability. This is highlighted in Figure 8.13, which shows the market outlook for forage hay for the next 10 years, with the previous eight years of price data superimposed to illustrate the pattern of interannual variability that might be expected on top of the longer-term price trend.

Table 8.12 Ten-year forward price projections for the crops used in the two regional scenarios
Numbers represent real domestic prices (in 2012–13 dollars).

CROP	UNIT	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Maize	$/t	354	310	324	326	313	301	360	359	357	356
Peanut	$/t	1006	1068	1069	1070	1096	1095	1093	1092	1090	1089
Mungbean	$/t	1002	1063	1064	1065	1091	1090	1088	1087	1085	1084
Cotton	$/bale	504	498	509	510	518	531	530	528	527	526
Guar	$/t	na	na	na	na	na	na	na	na	na	na
Forage hay	$/t	190	202	201	201	206	206	205	205	205	204

na = not available
Source: Data from ABARES

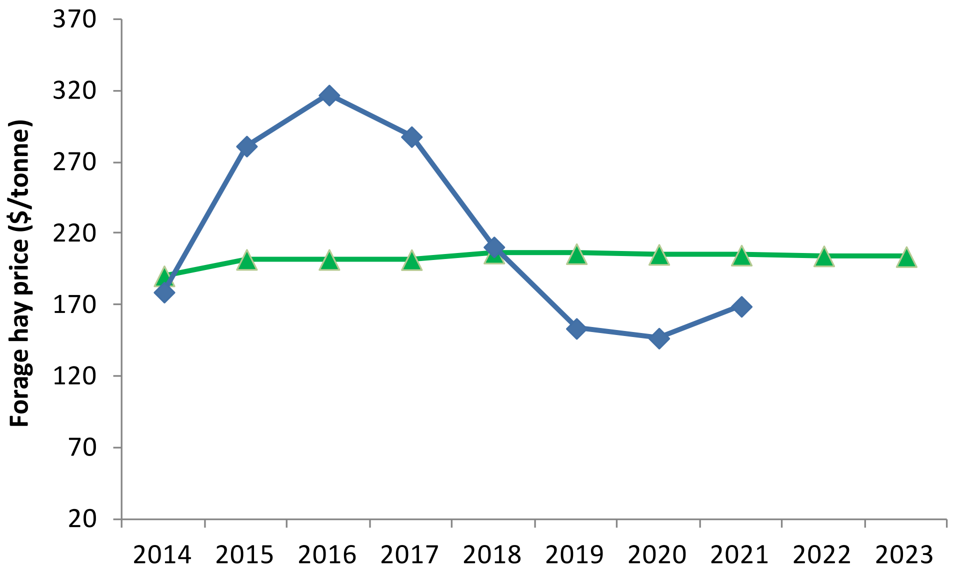

Figure 8.13 Ten-year forward projection for the price of forage hay(green line) with previous eight years (2006 to 2013) of prices (blue line) superimposed to highlight historical year-to-year price variability

As indicated earlier in the gross margins section, price variation combines with yield variation to produce gross margins that can vary significantly between years. In terms of future risk, it is useful to understand how these two primary drivers of price and yield might influence risk. Figure 8.14 shows the variability in gross margins for forage sorghum due to variability in past prices (based on ABARES results for forage hay) and the modelled variability in yield. It was assumed that the forage hay was used locally in the beef industry. The yield distribution was based on a most likely yield of 28.1 t/ha, and a low (20th percentile) and high (80th percentile) of 27.7 and 30.4 t/ha, respectively. The 20th percentile is a low-performing year that would be expected once every five years. The yield distribution has a small range compared to the historical price variability. This historical price variability resulted in a large spread for the distribution of gross margins for forage sorghum. There was a 26% chance of a negative gross margin.

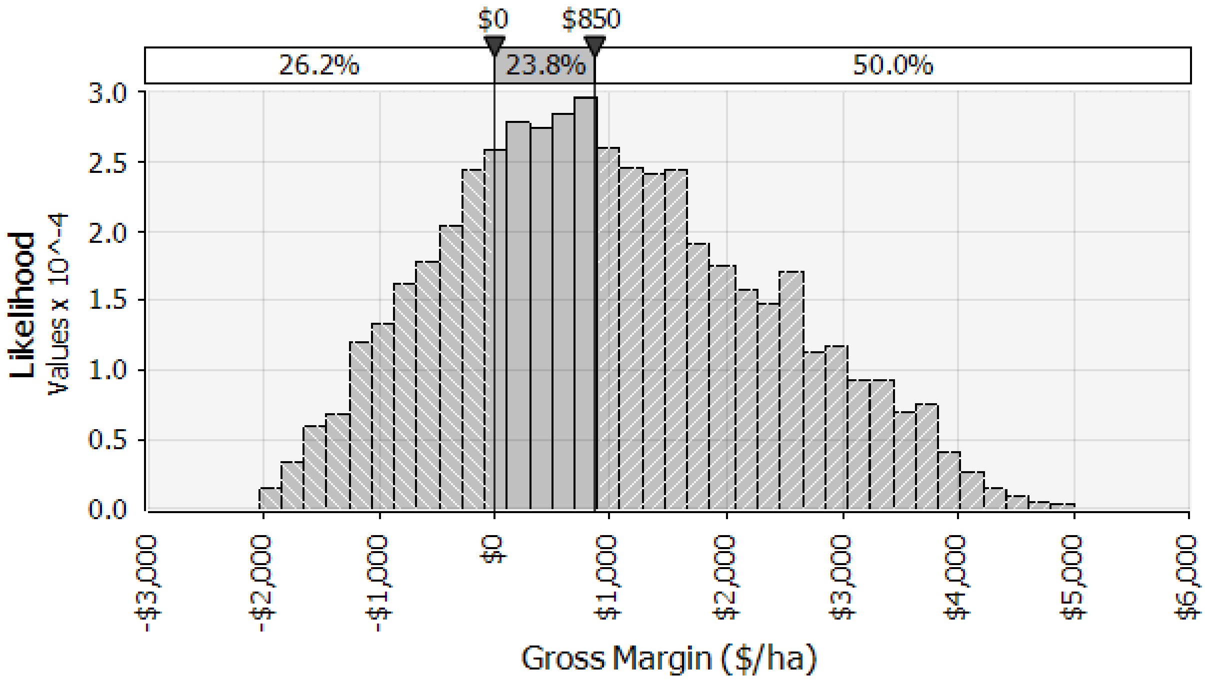

Figure 8.14 Variability in gross margins for forage sorghum in the Pilbara region due to yield and price variability

Establishing a new agricultural development involves significant capital investment, and there is a risk associated with this investment in generating sufficient returns to reduce debt. The following analysis builds upon the variability presented in the gross margin to consider the business vulnerability to a sequence of good and bad years, and the level of debt. The analysis is based on gross margin returns and not farm profit, because it does not include fixed or overhead expenses such as depreciation for equipment and buildings. Consequently, it will overstate to some degree the ability to reduce capital debt.

Figure 8.15 illustrates the effect of different starting conditions for debt, and good or bad years with a 7% interest rate. The number of good and bad years are the same in the 'better years early' and 'poorer years early' runs, and the differences are generated by the sequence in which these years occur. A random sequence was also generated that included the shock of two bad years of yield. A bad year was defined as 20% of the median yield.

In general, the gross margin is similar to or less than the interest payments for all but the best years at the beginning of each scenario. This means that 'better years early' has a large effect on the debt and subsequent interest payments. As a result, the 'better years early' scenario pays down the debt during the ten-year period. The sensitivity to poor years is shown by the increasing debt levels at the end of this scenario. In contrast, the 'poorer years early' scenario resulted in debt increasing from the outset, leading to higher interest payments and higher debt. This trend reversed in the latter half of the scenario when the better years occur. However, the debt level at the end of these scenarios had not changed substantially from the starting level.

In the two scenarios where two 'failed' crops were included in the ten-year sequence, debt was considerably higher at the end of the 10 years for both starting debt conditions. These failures in yield may be generated by an extreme weather event, such as a cyclone, a pest or disease incursion, or some significant interruption (weeks) to the surplus water provided by the mining operations.

The variation in the gross margin was due largely to the variation in historical prices. This dataset was small (annual prices for eight years) and based on national averages, and may not be representative of variability in prices for forage hay in the Pilbara. Less-variable prices would reduce the difference between 'better' and 'poorer' years early.

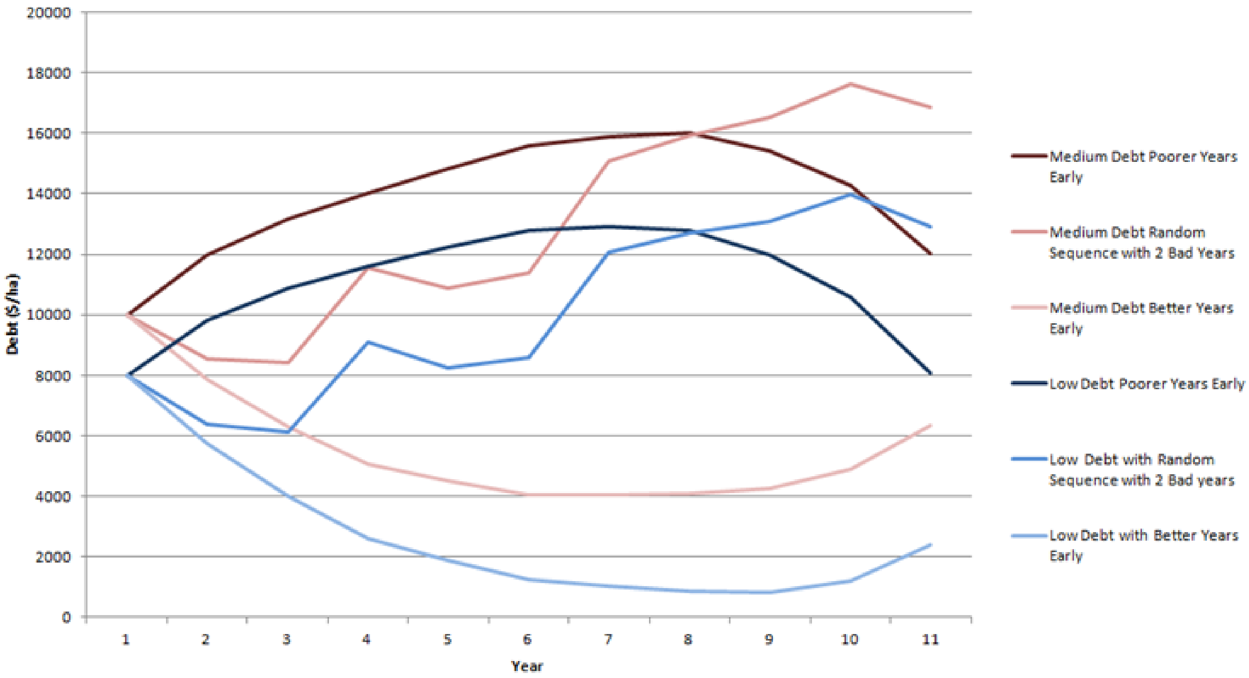

Figure 8.15 Effect of starting conditions of debt, and good or bad years on the level of debt for forage sorghum in the Pilbara region

This simple analysis highlights that, in addition to good planning and management, a certain element of good fortune is needed in the run of years experienced in the start-up phase of any capital-intensive agricultural development.

8.10 Regional economic analysis

8.10.1 PILBARA ECONOMY

The Pilbara region in Western Australia includes the areas of Ashburton, East Pilbara and Roebourne. The economy is dominated by mining. Agriculture, mainly livestock production, forms a small part. Under the reference case, economic activity in the Pilbara is projected to grow at 4.8% annually, which compares favourably with the Western Australian GSP growth rate of 4.1% and the projected GDP growth rate of 2.7%.

8.10.2 SCENARIO DESCRIPTION

Each scenario is modelled in two phases—construction and production. Public investment in roads and bridges totals $23 million in both scenarios. The increase in land suitable for cropping in both scenarios is 8000 hectares. In Scenario 1, private investment occurs in the grains and beef industries. In Scenario 2, the cotton industry receives most of the private investment. Table 8.13 reflects a stylised version of the scenarios for the Pilbara described earlier as modelled in AusRegion.

Table 8.13 AusRegion stylised scenario description for Pilbara

Development parameter	Unit	Commodity	Scenario 1	Scenario 2
Government investment	$m		23	23
Private Investment	$m	Beef Cattle	14	
	$m	Cotton		90
	$m	Grains	43	40
	$m	Total private	57	130
Total Investment	$m		80	153
Land supply	’000ha		8	8
Transport costs	%	Beef Cattle	-20	
	%	Cotton		-30
	%	Grains	-30	-10
Yield	%	Beef Cattle	20	

a Assumed change in transport costs arising from government investment. **b** Assumed increase in sectoral land productivity arising from private investment.

Government investment in ports and roads benefits the cotton and beef industries with transport costs assumed to fall by 30% and 20%, respectively. The investment in Scenario 1 also leads to a 20% increase in productivity for beef production because animal feed can be sourced locally. In Scenario 2, there are no productivity increases but transport costs decline for the cotton and grains sectors by 30% and 10%, respectively.

8.10.3 **REGIONAL ECONOMIC OUTCOMES**

The proposed investments will affect economic activity, employment and exports in the Pilbara and have consequences for the Western Australian and Australian economies. Table 8.14 shows the regional economic impacts at 2029–30.

The projected growth in GRP in the Pilbara at 2029–30 d is 0.2% under Scenario 1 and 0.6% under Scenario 2. This result reflects the far greater level of investment under Scenario 2. The Pilbara also sees small employment growth in both scenarios. Employment is projected to grow faster than GRP, reflecting the high labour intensity of agriculture in the region and the projected rise in real wages. The negative effect of the rise in real wages on other sectors can be seen in Scenario 2. For example, mining output is projected to be 0.4% below the reference case at 2029–30.

Comparing the net present value of the projected increase in GRP to 2029–30 with the investment shows that the investment flows through to the regional economy are $78 million and $250 million in Scenarios 1 and 2, respectively. However, the changes to the national economy of these investments are negligible.

Table 8.14 Economic impacts for Pilbara at 2029–30, % deviation from the reference case

	Unit	Scenario 1	Scenario 2
GRP	%	0.2	0.6
Employment	%	0.3	1.1
Real wages	%	0.1	0.4
Exports	%	0.3	1.4
Sectoral output			
Agriculture	%	25.4	75.7
Mining	%	-0.1	-0.4
Other	%	0.0	0.0
Western Australian GSP	%	0.01	0.02
GDP	%	0.0	0.0

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9 DAWSON VALLEY REGIONAL ANALYSIS

9.1 Summary and key messages

- Irrigation opportunities exist that will promote agricultural expansion in the region. The Dawson Valley Water Supply Scheme can supply 52 GL of water for irrigation per year from surface water flows. Treated water, made available as a by-product from coal seam gas extraction, has the potential to further increase water supplies by approximately 40 GL/year over the next two decades.
- Primary infrastructure (e.g. weirs, channels, roads) are already in place and the additional water to support the Dawson Valley Water Supply Scheme is being provided via a pipeline. This has the potential to significantly increase irrigated agricultural production in the region, with a high reliability water supply.
- The semi-arid, subtropical climate and suitable clay soils with a high water-holding capacity already support production of a range of summer and winter broadacre and industrial crops (e.g. sorghum, maize, cotton). With access to additional irrigation water, the current cropping activities could be expanded or new cropping opportunities explored.
- Gross margins were assessed for nine crops, based on existing domestic supply chains and infrastructure. Given the present status of a relatively high level of local infrastructure including grain depots, a cotton gin and pulse seed–processing facilities, the gross margins for all broadacre crops were positive, ranging from around $500/ha to $1700/ha. Soybeans generated the lowest gross margin due to significant freight costs associated with transporting the grain to Newcastle for oil extraction.
- Cotton generated the highest revenue and gross margin for any crop, although it also required the highest level of inputs. A second industrial crop — cassava for ethanol – produced negative gross margins due to high freight costs to a biorefinery in Dalby.
- Irrigated lablab hay, for which there is demand in the feedlot sector within the region, produced a gross margin comparable with many of the broadacre crops.
- There are presently reasonably effective supply chains for most broadacre food crops and cotton, with transport costs to market or processing representing around 5% of the total value of production. Improvements in supply chain efficiency can still be achieved through planned clustering of grain storages and depots, and better coordinated road–rail networks.
- Supply chain development scenarios were explored that included a local crushing plant for oilseed crops and a biorefinery for cassava. Both scenarios increased gross margins for the affected crops, particularly for cassava, which has a relatively low value per tonne of product that necessitates minimal transport costs for viable returns. Although the oilseed plant scenario was assessed on the basis of soybean production, a large amount of cotton is grown locally and it was assumed a multipurpose oilseed plant would be involved.
- Two regional scenarios based on 8000 ha of additional irrigated production were explored. The first scenario assumed a scaling-up of existing agricultural production, with a focus on cotton grown in rotation with wheat and chickpeas. This would require only a modest investment in infrastructure given the Moura cotton gin was built in expectation of future expanded production. The second scenario assumed soybean was grown along with wheat, maize, mungbean and lablab hay. This scenario assumed that a multipurpose oilseed crushing plant was constructed to process soybean and the large amount of cottonseed that is also produced in the region.
- The two scenarios produced comparable total gross values of production ranging between $25 million and $30 million/year. This is a relatively modest increase in the value of regional production given the well-established cropping industry in the region. Although the increased production would require some additional vehicle movements, this would most likely be met by existing freight capacity in the region or through a small growth in capacity that could be met by existing providers.

- Apart from ongoing investment required to maintain and improve the effectiveness and efficiency of regional roads, the major infrastructure requirement is an oilseed crushing facility. Currently, oilseeds are sent either to Newcastle (soybean, sunflower) or to Narrabri (cotton) for crushing. An investment of around $30 million to establish an oilseed crushing facility would provide the capacity to process oilseeds such as soybean and cottonseed. In addition to the oil produced, soybean meal is highly valued in the pig and poultry industry and cottonseed meal is widely fed to cattle, both as a direct feed supplement to grazing animals and as an ingredient in feedlot rations. Given the value of the livestock industries in this region, investment in this type of infrastructure has multiple benefits.
- The relatively small investments proposed for the Dawson increases regional economic welfare only marginally.

9.2 Description of region: existing agriculture, scale of irrigation and development

The Dawson Valley region comprises an area of approximately 50,000 km^2 in central Queensland, from the towns of Wandoan to the south, Injune to the west and Duaringa to the north. The Dawson River rises to the north of Injune and flows northwards for 650 km and joins the Mackenzie River to form the Fitzroy River near Duaringa. It discharges about 1100 GL of water each year into the Fitzroy River.

Grazing of native pastures by sheep and cattle was the first agricultural industry in the region, with the first pastoral leases being taken up in the mid-1800s. Dryland agriculture followed, with cereal crops dominating early cropping production in the region. By the early 1900s there was interest in developing irrigated agriculture in the region. This was promoted in particular by premier Edward (Ted) Theodore, who recognised the challenges that are posed by a variable climate in undertaking dryland agriculture. Implementing that vision resulted in the establishment of the Dawson Valley Water Supply Scheme (Figure 9.1). This is Queensland's oldest major irrigation development and was established by the Queensland Parliament in 1923. Construction works commenced in 1924 and the first farms were opened up and occupied in 1927. The township of Castle Creek was established, which was later renamed to Theodore. At the time, premier Theodore envisaged Castle Creek to be the first of five major settlement zones in the Dawson Valley and that these zones would support 50,000 residents (Cameron, 2005). The farm sizes were small and ultimately proved to be too small to be viable, and the development initiative lost momentum.

There was renewed interest in further developing the Dawson Valley irrigation area after World War II. The Moura Weir was constructed in 1946 and three more weirs were constructed in subsequent decades. The scheme presently provides water to irrigation farms through a network of six weirs: Theodore, Orange Creek, Moura, Glebe, Neville Hewitt and Gyranda. This water is delivered via open channels, pipelines and direct pumping from the Dawson River. The channel supply network is 56 km long and there is a 54 km system of open earth drains.[7]

Currently, 52 GL of Water Access Entitlements supply 146 bulk water customers (QCA, 2012) with high- and medium priority water in a supply scheme that is managed by SunWater. This level of availability supports around 8000 ha of irrigated cropping. The area of cropping land has remained stable over many years because the available water from existing weirs is fully allocated, noting that in drier years allocations are not 100%.

A wide range of crops is grown, including cereal grains, cotton, peanut, mungbean, soybean, chickpea, sunflower and forage crops. Cropping (both dryland and irrigated) in the Banana Shire, which spans most of the Dawson Valley, generates around $50 million/year in gross value terms, while livestock (principally beef) produces $145 million (ABS 2012a, 2012b).

Expanding the area of irrigation will require the development of new water resources. Over the past few decades there have been proposals for dams to provide additional water to the Dawson Valley, as the region has around 40,000 ha of fertile, clay soils that are suited to irrigated agriculture. Principal among

[7] www.sunwater.com.au/schemes/dawson-valley

these proposals is the Nathan Dam, which has been under discussion and consideration for around 20 years. SunWater is currently undertaking an environmental impact statement process, which is to be submitted to the Queensland Office of the Coordinator General for a final decision at state level before being considered by the Australian Government Minister for the Environment. If the Nathan Dam development proceeds, it has the capacity from its 888 GL storage to provide 66 GL/year of high-priority water to bulk water customers. There is demand for this water from the mining industry, particularly in the Surat Basin, as well as from the agricultural industry along the Dawson River. Demand for water from mining and industrial uses is predicted to be between 69 and 100 GL/ year and this demand will put price pressures on water for irrigated agriculture:

> 'the price of water from Nathan Dam is likely to be several times the irrigated agriculture viability limit so that the probability of irrigated agriculture demands being met is effectively nil' (SKM, 2012).

An additional source of water to supplement the Dawson Valley Water Supply Scheme is surplus water from coal seam gas drilling operations. A 120-km pipeline is being constructed from the QGC Queensland Curtis LNG (QCLNG) project at Woleebee Creek to Glebe Weir to provide 36.5 GL/year of treated water for mining and irrigation in the Dawson Valley.

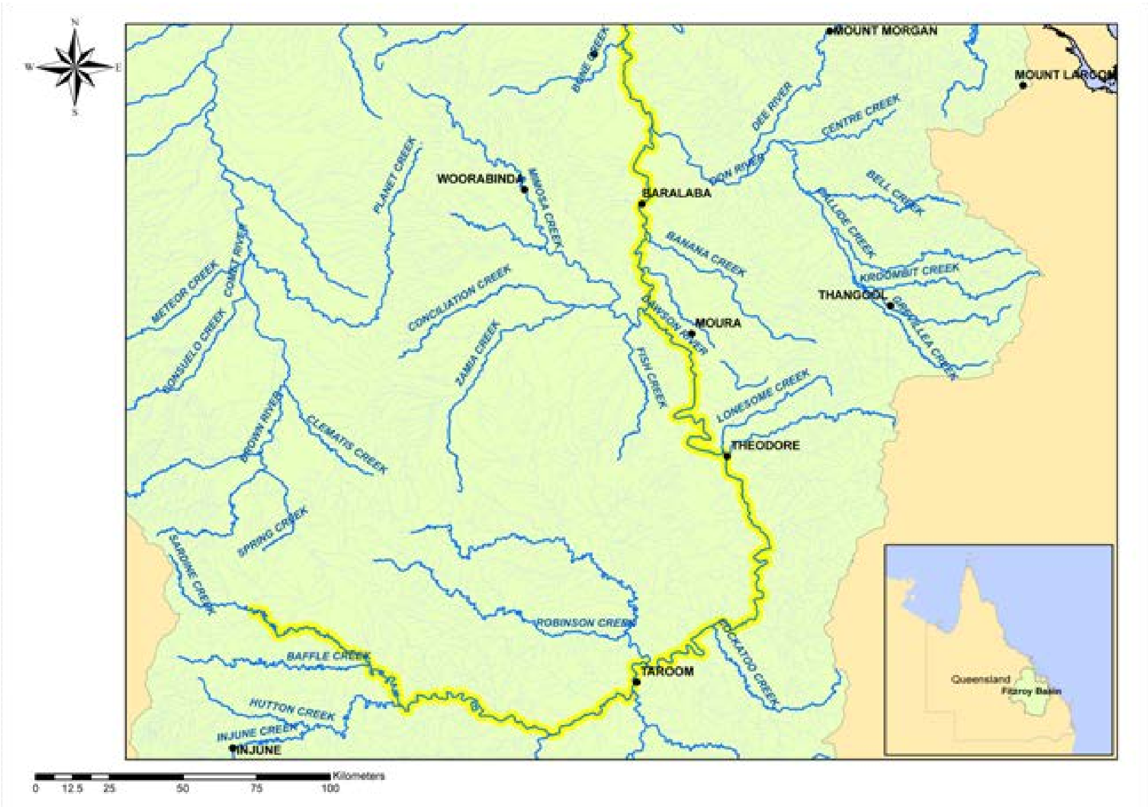


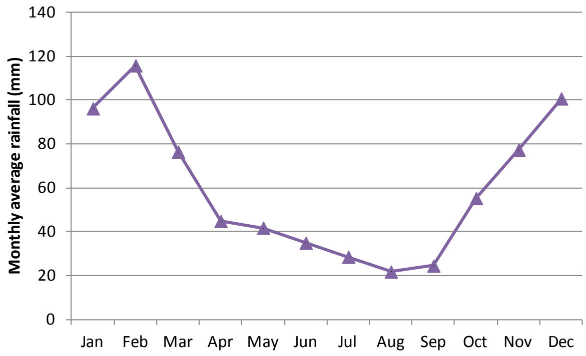
Figure 9.1 Map of the Dawson Valley region

9.3 Climate: existing and future trends

9.3.1 CURRENT CLIMATE

Baralaba, which is located in the centre of the Dawson Valley region, has a subtropical and semi-arid climate with an average annual rainfall (1963 to 2013) of 695 mm. Rainfall is summer dominant but significant falls can occur in winter (Figure 9.2). Dryland cropping can occur in both summer and winter, although for most winter-grown crops there needs to be a good store of soil moisture at planting to ensure a reasonable crop yield. Irrigation in the region increases both crop yield and the reliability of cropping, and opens up the option of more intensive rotational cropping systems. While evaporation rates are moderate

(2050 mm/year) when compared with the tropical regions that have been examined in several other regional case studies, the annual evaporation rate still greatly exceeds annual rainfall. A strong seasonal cycle in evaporation has implications for crop water demand in irrigation schemes.



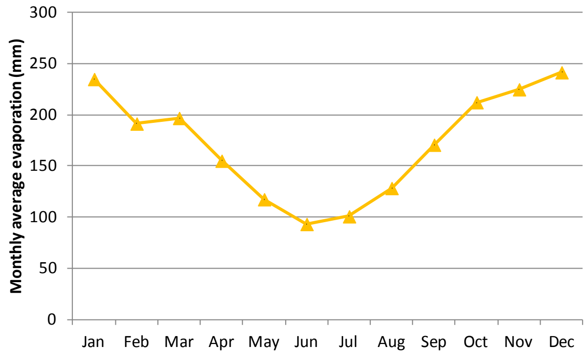


Figure 9.2 Monthly average rainfall (left) and evaporation (right) at Baralaba

The Dawson Valley region experiences moderate year-to-year variability in rainfall. A good measure of annual rainfall variability is the coefficient of variation (CV), calculated as the standard deviation of mean annual rainfall divided by the mean annual rainfall. The higher the CV the more variable is the mean annual rainfall. The CV for Baralaba is 0.29, which is considerably lower than for sites in northern Queensland where CV of annual rainfall is approximately 0.4, but it is sufficiently high that water storages need to be much larger than their annual yield to ensure a high reliability of supply. For example, the proposed Nathan Dam would have a capacity of 888 GL and an annual yield of only 60 GL.

The region has also experienced sequences of wet and dry years, which are highlighted in Figure 9.3. These rainfall sequences include several years where the rainfall is well below average and others where rainfall is well above average. This region is strongly influenced by the El Niño Southern Oscillation (ENSO), which is reflected in the run of wet years in the 1970s associated with La Niña events, and dry years in the early 1990s and early to mid-2000s when there was a higher frequency of El Niño events.

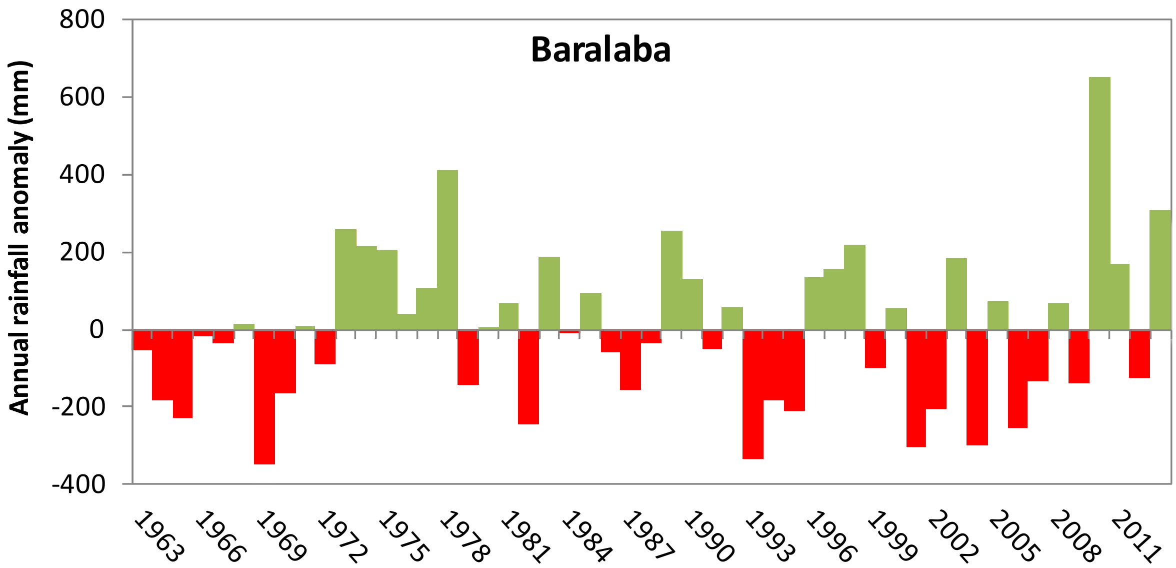


Figure 9.3 Runs of wet and dry years at Baralaba, measured by the difference in annual rainfall from the long-term average (1963 to 2013)

Wet years are denoted by the green bars and dry years by the red bars.

9.3.2 FUTURE CLIMATE

Climate projections to 2030 were assessed using four global climate models: ECHAM5, GFDL-21, HADCM3 and MIROC. Global climate models are mathematical representations of the main drivers of the climate system. Future climate is modelled by perturbing the carbon dioxide concentrations in the models, which has implications for temperature and rainfall levels and distributions. For this study, two future emission scenarios of carbon dioxide were used, based on projections from the Intergovernmental Panel on Climate Change: one was a high-emissions scenario (A1FI) and the second a moderate emissions scenario (A2). The results from the global climate models, which provide results at a regional scale, were then used to transform the historical weather station records for Baralaba (see Section 2.3.1).

Rainfall projections for 2030 under the two emission scenarios show a slight drying trend, based on the climate change models used in this study (Figure 9.4). One model shows a small increase in rainfall (7%) while two suggest a small decrease (average of 3%), and the GFDL-21 model indicates a 15% decrease in rainfall. With the exception of the tropics, broadscale climate projections for Australia tend to show a drying trend, particularly for southern Australia. This projected drying trend would need to be factored into planning for future irrigation developments because small changes in rainfall can have a much larger impact on river flows. For example, the environmental impact assessment for the Nathan Dam explored climate change scenarios and their influence on river flows in the Dawson River catchment, and for the A1FI (high) emissions scenario mean annual river flows were projected to decrease by 15 to 22% in 2050 (SKM, 2012).

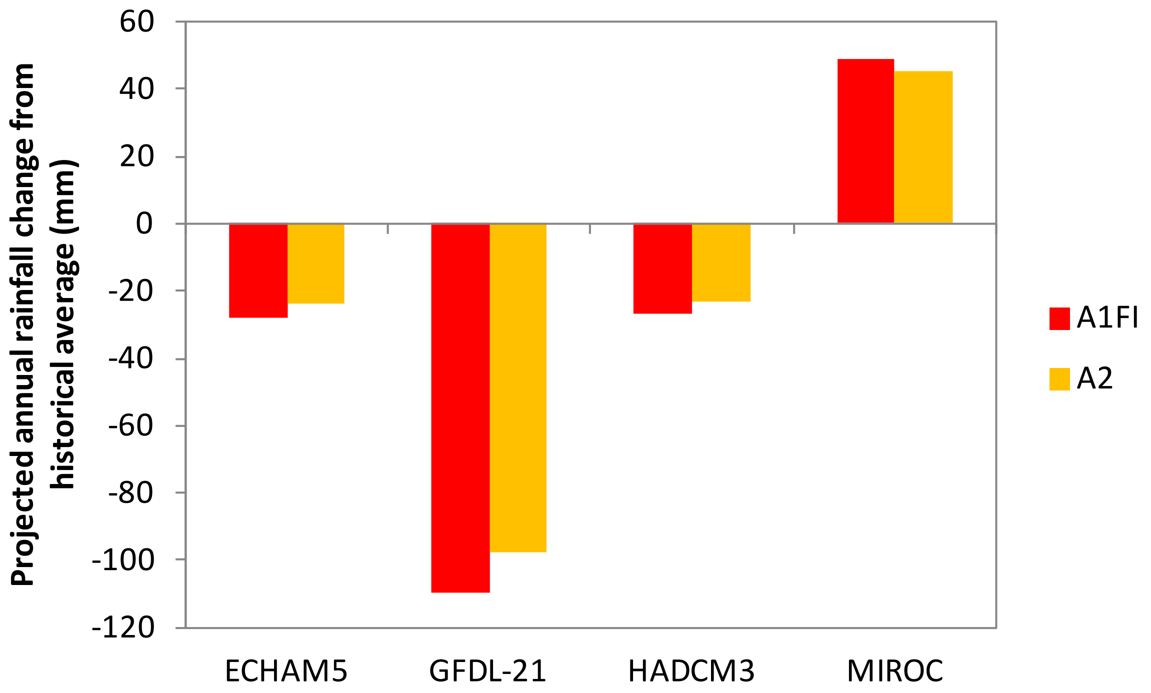


Figure 9.4 Rainfall projections for 2030 based on two emission scenarios (A1FI – high, A2 – moderate), using four global climate models
The rainfall projection is the difference in millimetres from the recent historical average annual rainfall (1970 to 2010).

Unlike rainfall, there is a stronger consensus around trends in temperature, with a projected increase in temperature to 2030 of 0.7 to 1.3°C. This mean increase can have both positive and negative impacts on agriculture in this climatic zone. Positive impacts are a potential decrease in frost incidence, which may permit more flexibility in sowing and crop growth windows for winter crops. Minimum temperatures are rising faster than maximum temperatures and even with the temperature increases that have occurred in the past 60 years this has likely had an impact on crop production in this region (Howden et al., 2003).

Future increases in minimum temperature and further reduction in frost incidence will likely provide some new opportunities for crop type and cropping system.

However, higher temperatures in spring and summer may negatively impact on some crops (e.g. quality of wheat when exposed to high temperatures during grain fill), vegetables and horticultural crops. Even a small increase in overall mean temperature can have a significant impact on extreme temperatures. Compared with other regions examined as case studies in this study, this may not be a major concern in the Dawson Valley region because the number of days exceeding 40°C is expected to increase from 1.5 days/year under current climate to around 3 days/year by 2030 (Figure 9.5).

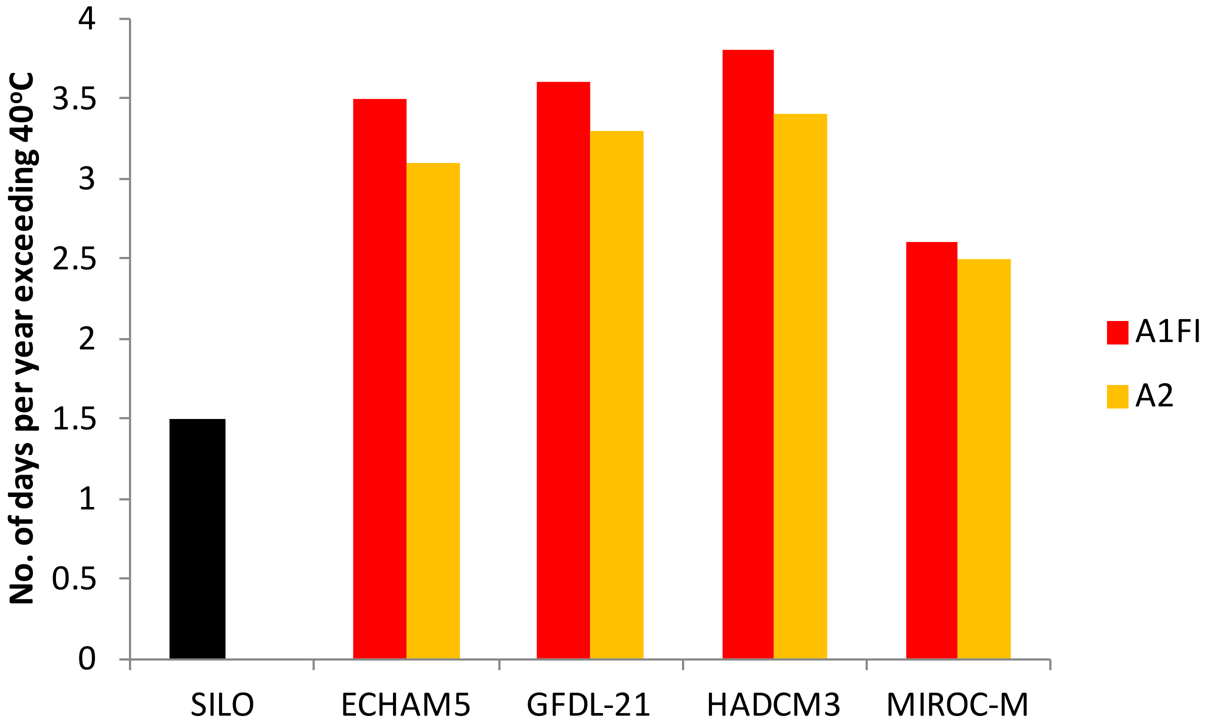


Figure 9.5 Number of days per year in Baralaba projected to exceed 40°C in 2030 for two emission scenarios (A1FI – high emissions, A2 – moderate emissions), using four global climate models, compared with historical climate (SILO data, black column)

9.4 Water resources

9.4.1 EXISTING WATER RESOURCES AND USE

The Dawson Valley region is situated between the Darling Downs and Maranoa regions to the south and central Queensland to the north. The major river system is the Dawson River, which has its headwaters near Injune and flows into the Fitzroy River, near Duaringa. Water from the Dawson River flows into the Great Barrier Reef from the mouth of the Fitzroy River near Rockhampton. The catchment of the Dawson River covers around 50,000 km^2 and the main tributaries are the Don River and the Castle, Conciliation, Eurombah, Juandah, Lonesome and Robinson creeks.

As indicated in Section 9.2, the Dawson River has had a number of weirs and an off-stream storage at Moura constructed along its length (Table 9.1). These weirs and storages provide around 52 GL in Water Access Entitlements for medium priority irrigation use. An additional 5.5 GL is available for high-priority users (towns, industrial). This water use is regulated by SunWater, who provide bulk water to the 146 users, about one-third of whom are on the channel system at Theodore, with the remaining two-thirds of users taking water directly from the river. SunWater maintains channels, pumping equipment and distribution of water. Although the overall reliability of water for irrigation in the Dawson Valley is relatively high, full allocations cannot always be provided if river flows are low in response to below-average rainfall conditions. Allocations are updated every month or two months, according to current and forecast conditions. As water availability is often low in spring, there is uncertainty for farmers planting a cotton crop in mid-spring, since water allocations are often reduced at this time. As a consequence, the actual volume of water that is used is often less than the water access entitlement, both in dry years when allocations are reduced and also in wet years when the demand on irrigation water is low. This is highlighted in Figure 9.6, which shows the water use in the Theodore channel distribution system over the past 10 years.

Table 9.1 Characteristics of the weirs and off-stream storages along the Dawson River

	ELEVATION (m AHD)	STORAGE VOLUME (ML)	USABLE VOLUME (ML)
Glebe Weir	166.04	3,678	1,828
Gyandra Weir	153.14	5,565	1,870
Theodore Weir	133.63	4,760	3,020
Moura Offstream Storage	120.10	392	31
Moura Weir	104.64	7,468	4,925
Neville Hewitt Weir	80.30	11,300	6,260

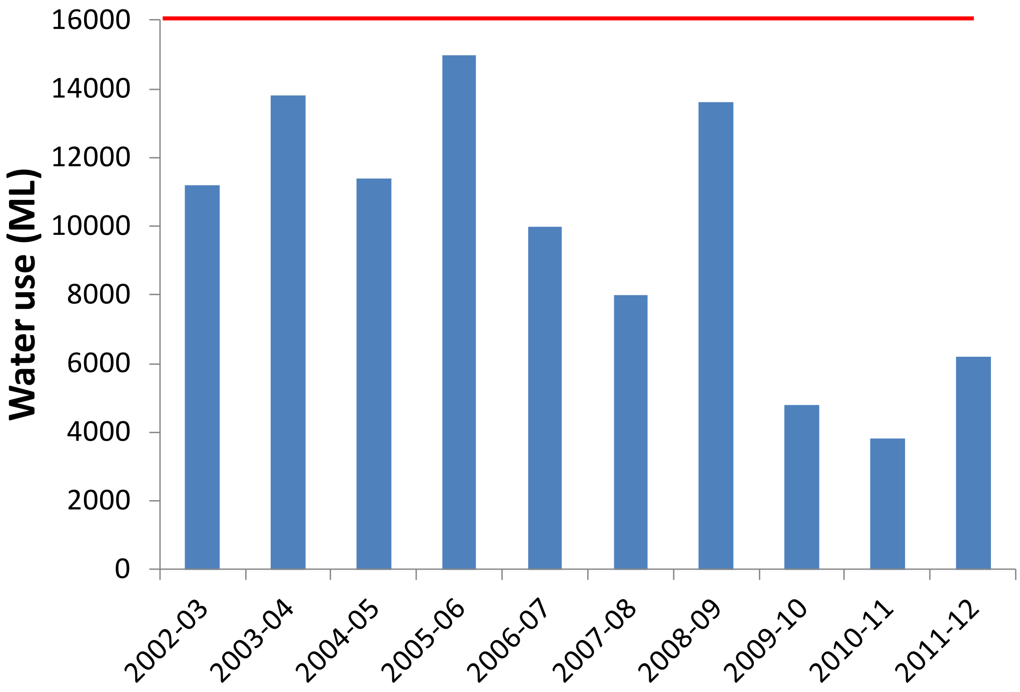


Figure 9.6 Water use within the Theodore distribution system of the Dawson Valley Water Supply Scheme
Red line at top of figure represents long-term average water access entitlement (ML).
Source: LMA Irrigation: www.lmairrigation.com.au/theodore

Set charges are in place for water provided by SunWater in the Dawson Valley Water Supply Scheme. Effective from August 2013 these charges were $15.69/ML bulk water (Parts A and B) at the Glebe Weir and $17.28/ML along the rest of the Dawson River. Irrigators who are part of the Theodore channel distribution system have additional charges ($35.65/ML – Part C and $29.15/ML – Part D), and drainage charges may also apply.

Some limited groundwater resources are presently used for irrigation in the Dawson Valley. Groundwater can be obtained from three sources: aquifers in layered sediments, fractured rock and near-surface alluvium. Within central Queensland, sedimentary and rock aquifers provide most of the irrigation water, with fractured rock aquifers providing irrigation water in the Lower Callide subcatchment, near Biloela. There have been concerns about overextraction of this groundwater resource and recently the total allocation has been reduced to 6 GL/year.

9.4.2 **PLANNED AND POTENTIAL FUTURE WATER DEVELOPMENTS**

In addition to the existing irrigation areas (see Section 9.5), large areas of clay soils are suitable for irrigation along the Dawson River. However, this potential is constrained by the lack of a large-scale storage facility. In response to this constraint, the Nathan Dam was proposed in the early 1990s (it had actually been raised politically as a possibility in the 1920s and the 1950s). An impact assessment study was released in 1997. The dam was proposed to be located 35 km to the north-east of Taroom, with a storage capacity of 880,000 ML intended for use in mining and agriculture. The proposal was approved by both the Queensland Government and the Australian Government Minister for the Environment in the context of the *Environment Protection and Biodiversity Conservation Act 1999*. The Australian Government Minister's decision was successfully challenged in the Federal Court and although there was still an opportunity to develop the dam for agricultural use, the successful private proponent for the project withdrew from the development venture because of uncertainties associated with the return on investment for irrigated agriculture.

Nathan Dam was again put forward in 2006 by the Queensland Government, who commissioned SunWater to build the business case for use of the water in mining and agriculture. The current proposal will result in an inundation area of 13,508 ha and a catchment area of 23,185 km^2. Yield of high-priority water will be approximately 66 GL/year. Associated with the dam will be a 215-km pipeline to Warra in the Surat Basin to provide water for mining and industrial uses. An environmental impact statement was released in 2012 and, following submissions, the Office of Coordinator General directed SunWater to prepare a Supplementary Report to the environmental impact statement to address a number of significant environmental concerns. That process is still under way. Under current water trading arrangements, water will be allocated to the highest value use, so it is possible that if the Nathan Dam is constructed, relatively little water will actually be available for agriculture (SKM, 2012).

Additional water is being made available for use in the Dawson Valley Water Supply Scheme (36 GL/year) via the construction of a 69-km pipeline from Woleebee Creek to Glebe Weir. The pipeline will provide treated water from coal seam gas extraction projects to users along the pipeline and downstream of Glebe Weir. The water is being provided by Queensland Gas Corporation's coal seam gas field and water treatment plant. In addition, Santos GLNG has been given approval to add 12.5 ML/day (4.6 GL/year) of coal seam gas–treated water into the Dawson River.

9.5 Land suitability for cropping

The Dawson River study area covers a 10-km wide corridor along the Dawson River, extending from Duaringa in the north to Cracow in the south. Soils in this area were surveyed by the Queensland Government (McCarroll and Forster, 1999) in response to proposed water supply development and, in particular, the Nathan Dam.

The soils in this regional case study area are mapped as dominantly grey Vertosols (uniform clay soils that swell and contract with water level) with minor areas of Sodosols (sand or loam surfaces over an abrupt increase in high-sodium clay) (Figure 9.7). The deep Vertosols are sited on flats and undulating rises, exhibit periodic cracking and have good water-holding capacity, although they may also have slow permeability and imperfect drainage. Soil pH is neutral to slightly alkaline in the surface, becoming acidic at depth.

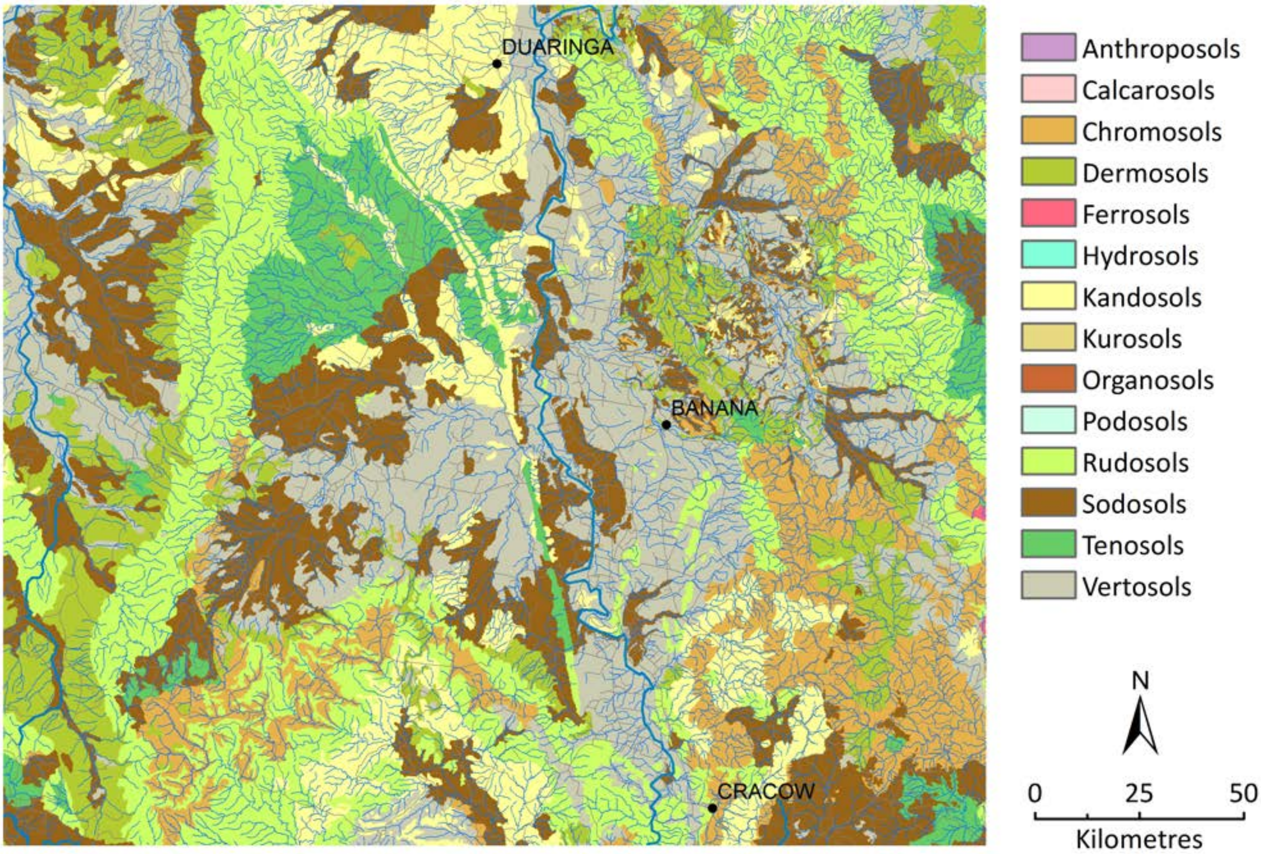


Figure 9.7 Dominant mapped Australian Soil Classification orders, Dawson study area
Source: ASRIS (2014)

McCarroll and Forster (1999) identified areas of cracking clays that are potentially suitable for furrow-irrigated cotton, areas of Sodosols that are potentially suitable for cotton, peanuts or citrus, and some minor areas of alluvial sands and gradational soils that are potentially suitable for overhead spray irrigation of peanuts or trickle irrigation of citrus. The variety of irrigation management practices that are recommended for different soils and landscape positions suggest a number of soil and land limitations that need to be carefully managed. The potential for soil erosion and salinisation are of particular concern.

The total area that is potentially suitable for irrigation was assessed to be over 60,000 ha (Table 9.2).

Table 9.2 Broadscale assessment of potential land area suitable for irrigation in the lower Dawson River

	TEXTURE CONTRAST SOIL (ha)	UNIFORM SANDS (ha)	CRACKING CLAY (FLOODPLAIN) (ha)	CRACKING CLAY (UNDULATING PLAIN) (ha)	TOTAL POTENTIAL AREA (ha)
Upstream Theodore	1,034	309	2,670	527	4,540
Theodore to Moura	6.565	980	3,896	2,864	14,305
Moura to Baralaba	3,856	370	7,187	9,694	21,107
Baralaba to Capricorn Highway	7,693	0	777	7,096	15,571
Capricorn Highway to Mckenzie River Junction	215	0	2,843	2,877	5,935
Total	19,368	1,659	17,373	23,058	61,458

Source: McCarroll and Forster (1999)

9.6 Pest and disease risk

A total of 285 species were identified as being potential pests or pathogens for seven of the crops that have been evaluated for the Dawson region case study, with many being pests or pathogens for multiple crops (Appendix 9.1). For all of these crops, it is almost certain that at least one of these pests or pathogens will invade the region (Table 9.3), because many are already present in Australia and at least one is already present in Queensland. Despite the large numbers of pests and pathogens assessed, only a small proportion of these species have actually been identified as major or significant pests of each crop (CABI, 2011) (Appendix 9.1). However, for many of these crops (sorghum, maize, mungbean, peanut and cotton), at least one of these major pest is already found in Queensland and therefore represents a significant threat, with a potentially high impact.

Table 9.3 Invasion likelihoods, most likely impact and overall biosecurity risk from insect pest and fungal pathogens to proposed crops of the Dawson Valley region in Queensland (range from 0, low to 1, high)
Values of 1 denote almost certain likelihood, very high impact and very high risk, while values of 0 reflect no likelihood, impact or risk.

CROP	INVASION LIKELIHOOD	IMPACT	RISK
Broadacre food			
Sorghum	1	0.1	0.1
Maize	1	0.4	0.4
Chickpea	1	0.1	0.1
Mungbean	1	0.4	0.4
Peanut	1	0.4	0.4
Fibre/other			
Cotton	1	0.4	0.4
Cassava (biofuel)	1	0.1	0.1

9.7 Crop production

9.7.1 BROAD OVERVIEW OF CROP TYPES AND AGRONOMY

The potential productivity of a range of broadacre and industrial crops was investigated for the Dawson Valley regional analysis. An irrigated cropping industry is already well established in the region and, for this analysis, it was considered appropriate to build the development scenarios on the existing suite of crops, given that the main supporting infrastructure is already in place. High-value intensive crops (especially horticulture) were not considered in this analysis.

Broadacre crops

Broadacre cropping is characterised by large-scale (area), relatively low-input and high-volume production of a commodity with a relatively low unit value (in volumetric terms). Dryland and irrigated cereal production is well established in Australia, with around 20 million hectares of these crops grown annually. Cereal crops are either winter or summer grown, with summer crops dominating the northern parts of Australia's cereal-cropping area. Cereals are widely grown in the Dawson Valley, predominantly in dryland farming systems, but they are also grown under irrigation, especially when river storages are not high and there is uncertainty about water allocations in the months ahead. Data from the most recent Agricultural

Census (2010–11) showed that for Banana Shire the gross value of production of winter grains (wheat, barley, oats) was $8.7 million and for summer grains (sorghum and maize) was $6.2 million (Table 9.4).

Pulses are legume crops that, like cereal crops, are primarily grown for the grain. Around 2 million hectares are grown annually in Australia. These legume crops 'fix' atmospheric nitrogen and minimise the need for inorganic nitrogen fertiliser. Because this fixed nitrogen is also available to subsequent crops, pulses are often grown in rotation with high nitrogen-demanding crops such as cereals or cotton.

Many pulse crops have a relatively short growing season, and are well suited to opportunistic production when there is sufficient available water (either as stored moisture in soil or available from irrigation). Mungbeans are grown extensively in the Dawson Valley and contributed $9.9 million in 2010–11 to total agricultural value for Banana Shire, while chickpeas returned $0.6 million (Table 9.4).

Peanut is an annual legume that is grown in tropical and subtropical regions as a summer crop (either rain fed or with supplementary irrigation) or in tropical conditions as a dry-season (winter) crop under full irrigation. Peanuts are primarily processed for human consumption of the kernels and the foliage can be used for stockfeed or as a green manure. The peanut is produced underground, and specialist equipment is used to 'pull' the crop from the soil before harvest. The requirement for peanuts to be pulled from the soil makes the crop unsuited to heavy soils where losses from breaking off can be very high. Peanuts would be well suited to the lighter soils in the Dawson Valley. However, because most broadacre cropping is sited on clay soils, only small areas of peanuts are grown in the region.

Industrial crops

For the purpose of this regional case study, industrial crops are defined as those that require a major processing step in their production soon after harvest. These crops are generally high volume relative to their value, with processing facilities sited nearby to reduce transport costs. The industrial crops that have been considered in analysis of the Dawson River region include cotton, sugarcane, sandalwood and hemp.

The cotton industry in Australia has grown significantly over the past three decades. This expansion has been supported by the development of new genetically modified (GM) varieties (to reduce pest load), better agronomic management, increased use of irrigation, cost-efficient harvesting, processing and marketing practices. A record cotton crop was produced in 2011–12, with more than 583,000 ha planted. This area yielded more than 5 million bales (c. 8.6 bales/ha), with a total value of around $3 billion. Dryland and irrigated cotton production is well established in the Dawson Valley region and is the main crop under irrigation. There were over 7000 ha of cotton grown in 2010–11 producing $12.6 million, although that value understates the average production value for recent years because of very wet conditions and floods that occurred during 2010 and 2011. Cotton gins are located at Dalby and Moura.

Cassava is a tropical root crop that is grown widely in Africa, Asia and the Pacific as a staple food crop and also for starch in industrial uses such as ethanol production. Thailand is the largest exporting nation, shipping over 4 million tonnes of dried cassava and around 2 million tonnes of cassava starch each year. The main potential use for cassava in Australia is for biofuel production, and crops have been grown commercially at a pilot scale in north Queensland. A significant amount of agronomic research was undertaken on cassava in the 1970s and 1980s, with one modelling study suggesting a production potential in central Queensland of approximately 16 t/ha on a dry-weight basis, which equates to about 40 t/ha of fresh product (Fukai and Hammer, 1987). Cassava has not been grown or tested at any significant scale in the Dawson Valley. As cassava prefers well-drained soils, it would only be well suited to lighter soils that are available for irrigation.

Given the significance of the beef industry in the region, there is strong local demand for forage hay and/or silage. Hay is used primarily to supplement livestock feedlot rations to provide the 10 to 20% of roughage required to balance grain-based diets. In addition, hay is used to feed cattle, horses and other ruminant livestock in yards, especially weaners and other animals that are being held for short periods. Both forage sorghum and leguminous crops such as lablab and lucerne are also grown in the region.

Table 9.4 Statistics of crop production in Banana Shire, which occupies a large percentage of the Dawson Valley
Values include both irrigated and dryland crops.

CROP	AREA (ha)	PRODUCTION (t)	VALUE ($million)
Maize	1,564	7,391	1.7
Sorghum	12,955	21,110	4.5
Wheat, barley, oats	22,963	35,466	8.8
Chickpea	2,233	1,607	0.6
Mungbean	13,818	12,518	9.9
Cotton (irrigated)	7,104	10,137	12.6
Cotton (dryland)	3,934	3,699	
Forage hay	3,586	27,799	0.7

Source: ABS (2012a, 2012b)

9.7.2 MARKET ANALYSIS OF CROPS

A broad range of market opportunities is available for the crops that are presently grown in the Dawson Valley region and also for those that could potentially be grown under an expansion of the irrigation area. The following subsections highlight some of these opportunities for the range of broadacre and industrial crops that are analysed in the cropping scenarios for the Dawson Valley region. A more detailed market analysis of each commodity is given in Appendix 4.1.

Broadacre crops

Chickpea

The bulk of Australian chickpea production is exported, and Australia is the world's largest exporter, accounting for 44% of global chickpea trade in 2011. In 2011–12, Australia exported 581,000 t of chickpeas from a total production of 673,400 t. More than 80% of these exports are destined for South Asia—India, Pakistan and Bangladesh.

Continuing growth in demand from South Asia for pulses is foreseen in response to projections of economic and population growth in the region and the largely vegetarian Hindu diet. Ongoing shortfalls in South Asian production will provide an expanded opportunity for Australian chickpea exports. Opportunity also exists to provide the large South Asian and Middle Eastern migrant communities in Australia with domestically produced chickpeas.

Grain sorghum

Grain sorghum is largely consumed in intensive livestock industries, such as feedlot cattle, pigs and poultry. Feedlot cattle are the main consumers of grain sorghum, consuming around half of all grain sorghum used for feed. Domestic marketing opportunities will depend largely on livestock numbers in intensive feed industries. Over the medium term, the lot-fed cattle industry is likely to continue to feel pressure from United States competition in the important grain-fed beef markets of Japan and the Republic of Korea. Reduced tariffs under the Korea–Australia Free Trade Agreement and the Japan–Australia Economic Partnership Agreement improve those prospects.

Australia exported around half of its grain sorghum production in 2010–11 and 2011–12. While Japan historically has been the major trading partner, China has recently become an important export destination, taking 25% of exports in 2012–13 and this is forecast to grow substantially.

Grain sorghum is primarily used in intensive livestock industries such as feedlot cattle, pigs and poultry, with feedlot cattle consuming around one-half of all grain sorghum used for livestock feed. Domestic marketing opportunities will depend largely on livestock numbers in intensive feed industries. Poultry numbers are projected to rise, supporting the demand for grain sorghum. Over the medium term, the lot-fed cattle industry is projected to continue to feel pressure from United States competition in the important grain-fed beef markets of Japan and the Republic of Korea. Reduced tariffs under the Korea–Australia Free Trade Agreement and the Japan–Australia Economic Partnership Agreement are likely to improve those prospects.

Australia exported around one-half of its grain sorghum production in 2010–11 and 2011–12. While Japan has historically been the major trading partner, China has recently become an important export destination, taking 25% of sorghum exports in 2012–13. The China market is forecast to grow substantially. Australia's main competitors in overseas markets are the United States and Argentina, both countries being generally lower-cost suppliers than Australia. United States grain sorghum exports are projected to be maintained over the medium term, while exports from Argentina are forecast to increase slightly.

In addition to livestock feed demand, sorghum can be processed into ethanol. For example, an ethanol plant in Dalby, Queensland, has the capacity to process approximately 200,000 t of sorghum to produce 80 million litres of ethanol annually. In 2011–12, biofuels represented around 1% of Australia's petrol and diesel production. The latest long-term projection of Australian energy supply and demand to 2050 by the Bureau of Resources and Energy Economics is for bioenergy production to grow by 3.9% per year.

Maize

Within Australia, livestock feeding of maize accounts for around 54% of total domestic consumption while food and industrial consumption accounts for the remaining 46%. Although maize is a minor component of the livestock feed complex, over 90% of feed maize is consumed by poultry or pigs; only a small amount is consumed by feedlot cattle.

Japan and the Republic of Korea are the most important export markets for Australian maize, but shipments from Australia comprises less than 1% of these countries' imports. The dominance of Japan and Korea as import markets has been falling in recent years, and growth in world maize imports is being driven by Latin America and member states of the Association of Southeast Asian Nations (ASEAN).

Asia is expected to be a future driver of world maize consumption, largely as a result of growing demand for maize as a livestock feed grain. While this may present export opportunities, Australia does not as yet have access to China's market for maize. The major competitors in Japan and Korea are the United States, Argentina and Brazil.

Domestic marketing opportunities for maize will depend largely on poultry and pig numbers. Over the medium term, these numbers are projected to rise, supporting domestic demand for maize.

Mungbean

Australian production of mungbeans has almost doubled in the two decades to 2012–13. Currently, production is largely destined for export. In 2011–12, Australia shipped 50% of mungbean exports to India, with another 22% to the ASEAN member states. Within the ASEAN region, Indonesia was the largest importer of Australian mungbeans. India and ASEAN will continue to be growing markets for Australian mungbeans.

Opportunities exist both domestically and internationally to market mungbeans as a functional food for manufacturers and consumers. Mungbeans have a range of potential applications such as starch, flour or paste and can also be used as an additive to other foods.

Soybean

Australia is a relatively small producer of soybeans, with the main production located in northern New South Wales and southern Queensland. Most Australian soybeans are consumed domestically, with the oilseed crushing market being the primary user. However, the demand for edible soybeans has increased in recent years, resulting in higher returns from the food sector and some producers switching to varieties better suited to this purpose.

The small Australian soybean export trade is primarily shipped to Asia (Japan, Republic of Korea, Malaysia and Taiwan) and the Pacific Islands. However, Australia is also a net importer of soybean meal and oil. Soybean meal is primarily used in intensive livestock feed rations and imports are mainly sourced from Argentina and the United States. Soybean oil is imported from Malaysia, Brazil and Argentina. More than 95% of Australia's edible soybean imports are sourced from China.

Strong global demand for soybean meal and soybean oil has resulted in world production of soybeans increasing 130% over the two decades to 2011–12, with yield increases largely derived from the increased use of GM seeds. The United States, Brazil and Argentina account for approximately 80% of world production. Soybean crush for oil accounts for approximately 90% of world soybean consumption. Because of its expanding livestock feed requirements, China is presently the largest consumer of both soybean meal and oil, and both China and Indonesia are the world's largest consumers of soybeans for human food, collectively accounting for 77% of world consumption.

Increased demand for soybean meal from the growing chicken and pig industries in Australia offers further opportunity for a potential increase in domestic supply of soybean. However, the cost of Australian production needs to be competitive against imported meal. Also, meeting this growth potential would require increased marketing of soybean oil derived from crushing. There are also potential opportunities to expand exports of edible-grade soybeans to Asian markets such as Japan, Taiwan, Thailand, Singapore and Indonesia – all of which have growing domestic demand for edible soybeans. These markets are traditionally supplied by the United States and Canada. It will be essential for Australian production of soybeans to be competitive against other competitors in these Asian markets.

Wheat

Wheat is the major grain produced in Australia, accounting for 62% of all grain production. Production is highly export oriented and, over the 10 years to 2011–12, approximately 12% was used domestically to produce flour and 10 to 12% used for livestock feed. Feedlot cattle are the main consumers of feed wheat, with the poultry and dairy industries also being large consumers.

Although Australia is only the eighth-largest wheat producer in the world, it is the fourth-largest exporting nation, averaging 12% of global trade. Around two-thirds of Australia's wheat exports are shipped to North Asia and ASEAN countries, with major markets being Indonesia, Vietnam, Republic of Korea, Japan and Malaysia. Other important markets for Australian wheat are in the Middle East and Africa, including Yemen, Iraq, Kuwait, the United Arab Emirates and Egypt.

Major global wheat producers are the European Union, China, India, the United States and the Russian Federation – together accounting for two-thirds of global production. The United States remains the largest exporter of wheat, but growth in global exports has been driven by Australia and the Black Sea region. South Asia, ASEAN, the Middle East and North Africa have been the main drivers of wheat consumption. Wheat consumption in ASEAN countries has accelerated in recent years and, over the medium term, income and population growth in these countries will increase import demand for wheat as consumers move towards more westernised diets.

Food consumption of wheat in Australia is expected to grow in line with population growth. Other domestic market opportunities will largely depend on livestock numbers in intensive feed industries, the availability of coarse grains and the relative prices of wheat against coarse grains. With two-thirds of Australian wheat exports currently being shipped to North Asia and ASEAN countries, there is potential for increasing livestock feed wheat exports to Asia as local diets shift towards eating more protein. Increased livestock feed demand is particularly expected from Indonesia, Vietnam and Malaysia.

Industrial and other non-food crops

Cassava

Cassava is not grown commercially in Australia, but CassTech Limited has commenced commercial cassava trials in the Burdekin region of Queensland to produce high-yielding cassava on a broadacre basis. Australia imports a small amount of cassava, largely frozen, from Fiji, Vietnam, Tonga, Thailand and Indonesia. Imports of cassava starch are more significant, totalling 11,800 t in 2011–12 and nearly all sourced from Thailand. Other smaller suppliers of starch include Vietnam, China, Malaysia and Indonesia. Cassava starch imports doubled in 2012–13 to 22,700 t, again sourced mainly from Thailand.

Africa, where cassava is an important food staple, accounts for more than one-half of global production, the bulk of which is also consumed on the continent. Asia contributes around one-third of world production and, unlike Africa, much of this is directed to industrial purposes (starch) and energy (biofuels). Thailand and Indonesia account for 60% of Asia's production, with Indonesia growing in strength. Thailand is the leading global exporter of cassava starch, which is used for food processing, pharmaceutical chemistry, foundry, textiles, paper and adhesives. Thailand exports more than 80% of its cassava production, mostly to China. Latin America and the Caribbean represent 13% of world supply, with Brazil the major producer. Around one-half of Latin American production is used for livestock feed.

Opportunities for Australian production of cassava also lie in production of bioethanol rather than as a food. Global production of bioethanol is expected to grow by 50% between 2011 and 2020. One tonne of cassava can produce approximately280 L of 96% pure ethanol. Although cassava is still a small player in the biofuel arena relative to maize and sugarcane, China is increasing production of ethanol from cassava.

Interest in clean energy investment in Australia is continuing to grow, supported by technology advancements and improving commercial viability. Biofuels in 2011–12 represented around 1% of Australia's petrol and diesel production. The Bureau of Resources and Energy Economics has forecast that primary energy consumption of all renewable fuels will grow at approximately 3.6% per year to 2049–50. Bioenergy consumption is forecast to grow faster than this, by 3.9% per year. Australia's imports of petroleum products are expected to continue to rise. Increasing the use of alternative fuels, such as biofuels, and diversifying the fuel mix in the transport market can help mitigate some of the risks of fuel insecurity in the conventional fuel market.

Cotton

Australia is the world's sixth-largest producer of cotton. In 2012–13, Australia produced 1 million tonnes of cotton lint and 1.4 million tonnes of cottonseed. About one-third of the total crop is produced in Queensland with most of the balance grown in northern New South Wales.

The level of Australian cotton production each season is highly dependent on the availability of irrigation water. About 95% of Australian cotton production is in the Murray–Darling Basin (MDB) region and more than 90% of the crop is usually irrigated. Increased diversions of irrigation water from farms to environmental uses in the MDB are expected to have a minor effect on Australian cotton production over the medium term, but the prospects of significant expansion in irrigated plantings in the MDB are limited.

Around 95% of Australian cotton lint is exported to international markets, mainly in Asia, while a large proportion of cottonseed is consumed in Australia. In the 10 years to 2012–13, Asian markets accounted for 98% of total Australian lint exports, with the remainder exported to Europe. China has emerged as the largest importer of Australian cotton, taking around 70% of national exports in 2012–13. Other important markets include Indonesia, Thailand and the Republic of Korea.

Given the small scale of Australia's textile manufacturing sector, domestic textile mills consume only around 3% of the national production of cotton. Additional demand for ginned cotton is unlikely to be created domestically due to relatively high labour costs in textile manufacturing. Demand from other ASEAN countries such as Cambodia and Vietnam is expected to grow as wage inflation in China has led to Chinese manufacturers and global textile companies relocating their manufacturing to other lower-cost nations. Other potential markets for Australian cotton that could be further developed include Bangladesh and Pakistan.

Hay/forage

Hay plays a crucial role in livestock production, particularly during times of poor weather conditions when grass from pastures is not readily available. The majority of Australia's hay production and use is located in southern Australia. However, export markets have developed over the past two decades, principally to Japan (64% of exports in 2012–13), the Republic of Korea, Taiwan and China. Other smaller markets include the Middle East (particularly the United Arab Emirates, Saudi Arabia and Qatar), Indonesia and Malaysia. Livestock export ships are also a significant user of Australian hay, although this outlet has diminished since 2008–09, with falling live sheep exports to the Middle East and disruptions to the live cattle export trade.

Recent reinvigoration of the live animal export trade – with Indonesia lifting its cattle import restrictions and cattle demand increasing from other markets such as Vietnam and Malaysia – should result in an increasing amount of hay being used by livestock-holding depots and on-board livestock transport ships. Increasing demand for meat protein and growing commercial feedlots in developing countries also provides an opportunity for expanding exports of hay to markets such as China, Indonesia, Malaysia, Vietnam and a range of markets in the Middle East.

Domestically, the development of meat processing in northern Australia, with both Yeeda Pastoral's abattoir near Broome and the Australian Agricultural Company's abattoir near Darwin close to completion, provides opportunity for increased use of hay and forage crops for finishing cattle for slaughter in northern Australia. The immediate throughput of these new processing plants will be mostly confined to lower-value cull cows from breeding herds and slaughter cattle that otherwise do not meet live export specifications. However, development of meat processing capacity in northern Australia, combined with an increased availability of fodder crops, may result in a shift to increased cattle fattening, either in feedlots on cattle stations or commercial feedlots close to the abattoirs. Such developments offer an opportunity for pastoralists to diversify their production away from a high dependency on live export markets.

9.7.3 **CROP PRODUCTION ESTIMATES**

Estimates of crop production yield were generated for a range of broadacre, high-value and industrial crops (Table 9.5). Yield estimates were made using the APSIM (Agricultural Production Systems sIMulator) model (Keating et al., 2003) for broadacre cereal and pulse crops, cotton and forage hay, and with expert-based analyses and/or historical yields for crops unable to be modelled with APSIM.

The soil used in the APSIM simulations was parameterised to represent a Sodosol (Jambin), a soil that is widely cropped in the Dawson Valley region. The soil holds 187 mm of water to a depth of 2 m. Historical meteorological data from Baralaba for 1900 to 2010 was used in the simulations to generate variation in crop yield and irrigation water required.

APSIM assumes that best practice is used for managing a crop in the absence of pest and disease-related stress. Simulations were undertaken to achieve crop growth in nonlimiting soil water and nutrient environments. Applied irrigation was triggered in the model using soil water deficit and the potential root zone of each crop. Natural reset points at the end of winter (September), when the soil profile is normally dry, were selected to initialise the soil water, soil nitrogen and surface cover each year so as to only capture the effect of seasonal climate and applied irrigation on crop production. Irrigation management assumed 100% efficiency in applying irrigation to the crop, regardless of the actual availability of supply.

The values presented for water applied to a crop do not equal the total water used to produce the crop (Table 9.6). APSIM assumes 100% efficiency of irrigation water supply, and reported figures are 'on crop', not accounting for delivery from the water storage. Losses (inefficiencies) occur in the storage, transport and on-farm application of the irrigation water. The estimated outputs for both modelled and non-modelled crops are the potential productivity and irrigation water use on a per-hectare basis.

Table 9.5 Simulated crop yields using APSIM (represented by those crops with 20th, 50th, 80th percentile values); cassava yield was not modelled and was based on published estimates

APSIM yields for broadacre crops are expressed in tonnes of dry matter per hectare and for the economic assessment these were converted to fresh yields, based on moisture contents of 12 to 14%. Cassava yields are expressed in fresh weight.

CROP	YIELD PERCENTILE		
	20th	50th	80th
Broadacre (t/ha)			
Maize	10.4	9.5	8.4
Sorghum	8.9	8.4	7.8
Wheat	5.5	5.2	4.7
Chickpea	3.5	3.2	2.9
Mungbean	2.2	1.9	1.6
Soybean	3.2	3.0	2.8
Industrial/other crops			
Cotton (bales/ha)	8.9	8.3	7.7
Cassava chips (t/ha)		20	
Lablab hay (t/ha)	12.2	11.9	11.2

Table 9.6 Irrigation water use for the broadacre and industrial crops simulated in APSIM

Actual water applied may be considerably higher because water is not used with 100% efficiency.

CROP	IRRIGATION WATER USE (mm) PERCENTILE		
	20th	50th	80th
Broadacre			
Maize	414	329	249
Sorghum	449	403	328
Wheat	425	384	311
Chickpea	254	180	140
Mungbean	168	123	74
Soybean	527	399	254
Industrial/other crops			
Cotton (bales/ha)	664	564	470
Lablab hay	398	347	270

Maize

Maize was sown at the end of January for a June–July harvest. It could be sown earlier in the summer, although the seedling is susceptible to high temperatures. The yield of approximately 10 t/ha makes it well suited to the region.

Sorghum

Sorghum was sown in the simulation on 30 September. Planting at this stage and harvesting in January–February means that the growing seedling can escape the hottest time of the year when it is vulnerable. A median dry-matter grain yield of 8.4 t/ha was simulated, which compares favourably with high-yielding commercial crops.

Wheat

Wheat was sown in the simulations on 15 June, with the harvest period being October–November. Sowing at this time in the Dawson Valley region eliminates most of the risk from frost damage that might occur at the time of flowering. On higher slopes and in less frost-prone areas, the crop could be planted earlier. Harvest must occur before early summer rains and before temperatures get too high and begin to damage protein quality. Median yields were simulated to be 5.2 t/ha.

Chickpea

Chickpea was sown in the simulations on 1 May. Chickpea develops in a relatively short time, and is deep rooted and well suited to opportunistic cropping. There is some merit in planting chickpea after a summer-grown crop, such as sorghum or cotton. Median simulated yields for chickpea were 3.2 t/ha.

Mungbean

Mungbean was sown in the simulations on 15 March. Mungbean matures quickly and can be opportunistically sown, like chickpea, but is often part of planned rotations. Mungbean price can vary greatly with seed quality when sold for human consumption (the highest value market). Rainfall during the later stages of pod fill can have a detrimental effect on grain quality, and consequently the price received, so planting is timed to ensure a low risk of receiving rainfall at this crucial time. Median yields were simulated to be 1.9 t/ha.

Soybean

Soybean was sown in mid-December in the simulations. Soybean grows best in summer in central and southern Queensland and matures fairly quickly when sown at this time because the shortening daylength after December induces flowering. Soybean was simulated to yield 3.0 t/ha when harvested in April. In central and southern Queensland, soybean has also been grazed as part of a legume–ley rotation rather than being harvested for its grain.

Cotton

Cotton was sown on 15 October. This allows cotton to grow over the warmer months, with harvest occurring in April to avoid the wetter summer months. Cotton is susceptible to rainfall during late crop development, which can downgrade cotton quality and price. Cotton yields were simulated to be 8.4 bales/ha. Over the 100-year simulation, the yield ranges from 6 bales/ha to more than 12 bales/ha, which is consistent with yields obtained commercially in the region.

Cassava

Cassava yields were simulated to be approximately 40 t/ha (fresh weight) or 23 t/ha as dried chips.

Lablab hay

Lablab was sown on 1 March to exploit the opportunity to follow a summer cereal grain such as sorghum. Sowing could also be delayed to follow a cotton crop. Lablab can fix significant quantities of nitrogen and is a good substitute for nitrogen fertiliser. Yields of lablab hay were simulated to be approximately 12 t/ha dry matter, around 90% of which can be harvested for hay or silage. An alternative to making hay would be to graze the lablab during mid- to late winter and early spring.

9.7.4 **CROPPING CALENDAR**

Cropping calendars identify the sowing time and the growing season for different crops. The time during which a crop can be reliably and profitably sown is called the sowing window, and this can vary in both timing and length between crops. The cropping calendar for the crops that were analysed for the Dawson Valley region case study are presented in Table 9.7.

The cropping calendar was constructed on the basis of local knowledge of these crops both in the Dawson Valley and surrounding regions. The sowing and growth windows correspond with the times of year that are likely to maximise potential crop yield and, where relevant, align with crop rotation sequences (e.g. summer grain crop followed by winter pulse crops). Crops can sometimes be successfully sown outside the identified sowing windows with only a small yield penalty. Also, it may not always be possible to arrange sowing times to achieve the maximum potential crop yield.

Table 9.7 Calendar of sowing for annual crops in the Dawson Valley region

CROP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Broadacre												
Maize	X	X	X	X	X	X	X					X
Sorghum	X	X	X	X					X	X	X	X
Wheat						X	X	X	X	X	X	
Chickpea					X	X	X	X	X	X		
Mungbean			X	X	X	X	X	X	X			X
Soybean	X	X	X	X								
Industrial/other										**X**	**X**	**X**
Cotton	X	X	X	X	X							X
Cassava	X	X	X	X								
Lablab			X	X	X	X	X	X	X	X	X	

9.8 Gross margin analysis: sensitivity to price, production and supply chain costs

The crop gross margin is the difference between the gross income and variable cost of growing a crop.

Variable costs include the costs that are associated with crop management, harvesting, transport and marketing. For established cropping regions such as the Dawson Valley, significant investment has been made in crop-processing facilities (grain storage, milling/grading facilities, cotton gins) close to the production areas to create efficiencies in transport and costs of production. Agribusinesses are well established in the region and provide services in fertiliser, seed, chemicals, machinery sales and repairs, and general crop agronomy.

The gross margins for a range of crops specific to the Dawson Valley region are presented in Table 9.8. The gross margins do not include overhead costs (e.g. business administration, insurance) or capital costs (e.g. farm equipment, irrigation infrastructure) that must be met even if a crop is not grown. For the crops that were modelled using APSIM, gross incomes were calculated using the median crop yields estimated for the historic climate data (1900 to 2010). For crops that could not be modelled (e.g. cassava), the estimated yields are based either on production data from the region or other regions if that crop is currently not grown. Representative costs of production estimates were based on gross margins developed by local agricultural economists and agronomists (in particular Graham Harris, an agricultural economist with the Queensland Department of Agriculture, Fisheries and Forestry in Toowoomba).

Table 9.8 Gross margin analysis for existing and potential crops in the Dawson Valley, based on existing supply chains

CROP	LOCATION FOR MARKET OR PROCESSING	YIELD UNIT/ha	MEDIAN YIELD (per ha)	PRICE PER UNIT YIELD ($)	VARIABLE COSTS LESS FREIGHT ($/ha)	FREIGHT COSTS ($/ha)	TOTAL VARIABLE COSTS ($/ha)	GROSS MARGIN ($/ha)
Broadacre								
Maize	Dawson	tonnes	10.5	280	1282	162	1444	1559
Sorghum	Dawson	tonnes	9.5	240	995	143	1138	1119
Wheat	Dawson	tonnes	5.9	240	894	89	983	832
Chickpea	Biloela	tonnes	3.6	500	842	72	914	513
Mungbean	Biloela	tonnes	2.2	810	682	44	726	1034
Soybean	Newcastle	tonnes	3.7	500	1042	263	1305	554
Industrial/other								
Cotton	Moura	bales	8.3	500	2926	83	3009	1720
Cassava	Dalby	tonnes	20	137	1765	1000	2765	–65
Lablab hay	Dawson	tonnes	10.7	180	906	107	1013	913

Gross margin analyses should be used with care because they are highly sensitive to the assumptions for price, yield, transport costs and input costs, not just within a particular region but between individual farms. Whereas horticultural crops can have significant price fluctuations over weeks and months, price variability in broadacre and industrial crops is more significant over months and years, as highlighted in Figure 9.8.

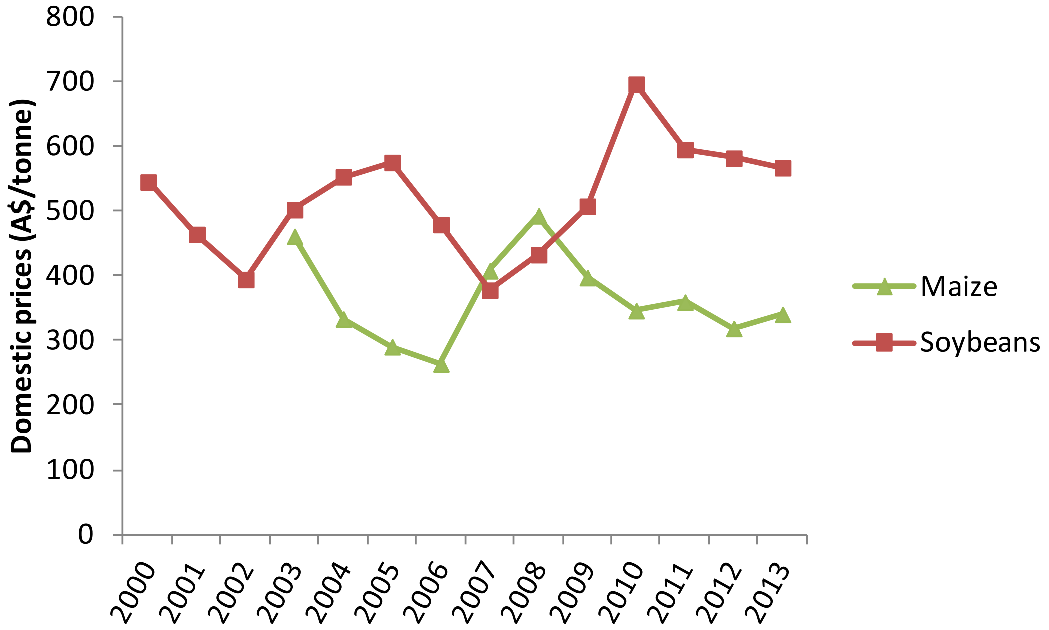


Figure 9.8 Domestic prices for maize and soybeans, 2000 to 2013.
Source: Data supplied by ABARES

9.8.1 BROADACRE CROPS

The average gross margins were all positive for the broadacre crops. High-yielding summer grains (maize, sorghum) provided the highest gross margins while wheat and pulse crops produced lower gross margins of between $500/ha and $1000/ha. Compared with the more remote tropical regions used as case studies for this study (Pilbara, Ord, Mataranka and Flinders/Gilbert), the Dawson Valley region has well-established storage and processing facilities and supply chains sited in close proximity for most crops (e.g. numerous feedlots that can use cereal grain, grain receiving depots). Given that distances to grain storage, milling and grading facilities are within 100 km of the production area, transport costs make up only a relatively small percentage of the total value of production (c. 5%) and between 5 and 12% of the total costs of production (Table 9.9). Chickpeas and mungbeans can be processed and graded in Biloela. Soybeans are an exception to the low freight costs; the harvest needs transport to Newcastle for processing to soybean oil or value-adding for export. Transport costs represent 14% of the value of soybeans and 20% of the costs of production. As a consequence, the projected gross margins are at the lower end of the scale for the broadacre crops that have been analysed.

Table 9.9 Freight costs as a percentage of total value of production and total production costs for a range of crops in the Dawson Valley region.
Location represents the point of wholesale or processing

CROP	LOCATION FOR MARKET OR PROCESSING	FREIGHT COSTS AS A PERCENTAGE OF TOTAL VALUE OF PRODUCTION	FREIGHT COSTS AS A PERCENTAGE OF TOTAL COSTS OF PRODUCTION
Broadacre			
Maize	Dawson	5.4	11.2
Sorghum	Dawson	6.3	12.6
Wheat	Dawson	4.9	9.1
Chickpea	Biloela	5.0	7.9
Mungbean	Biloela	2.5	6.1
Soybean	Newcastle	14.1	20.2
Industrial/other			
Cotton	Moura	1.8	2.8
Cassava	Dalby	37.0	36.2
Lablab hay	Dawson	2.8	3.9

9.8.2 INDUSTRIAL AND OTHER CROPS

Gross margins for the industrial crops provided a distinct contrast in financial returns. Cotton returned the highest gross margin of any crop reviewed, at the price and yield assumed for this study. Cotton is a well-established irrigation crop in the region (>7000 ha) and, as there is a cotton gin in Moura, the distances from the farms to the gin are no more than 100 km and generally less than 50 km. This resulted in freight costs comprising only a small percentage of the total value of production and the cost of production.

In contrast, cassava, a potential industrial crop that is not presently grown commercially in the region, returned projected negative gross margins. This result is due to high transport costs because the nearest processing plant for biofuels is sited in Dalby, around 400 km to the south. Freight costs absorb a significant percentage of the value of the product (37%) and this, combined with the relatively low value per tonne ($137) assumed in the analysis, contributes to the negative gross margin.

The forage hay made from lablab has a relatively high gross margin since the costs of production were relatively low and, because the hay is assumed to be used locally, freight costs were low despite the bulky nature of the product.

9.8.3 DIFFERENT SUPPLY CHAIN OPTIONS AND GROSS MARGINS

For most of the crops that have been investigated for this regional case study, markets, storage and processing facilities exist within the region. This is in contrast to most of the other case study regions where local markets and processing facilities do not exist. Although the grain enterprises are relatively well serviced by receival depots and other processing facilities, there is potential for improvements in efficiencies and effectiveness. There is a move to more clustering and centralisation of depots and storage facilities to achieve improved efficiencies through reduced handling costs and more coordinated road and rail links. Although these changes are necessary to maintain industry competitiveness, they do not represent a major transformation of supply chains.

Soybean is not widely grown in the region and any crops that are grown are presently transported to Brisbane to be processed into soybean oil (food industry) and soybean meal (livestock feed). There are also opportunities to value-add the soybean for export. For the present supply chain development scenario, it has been assumed that an oilseed crushing plant is established in Moura that is capable of processing a range of oilseeds, including cotton, soybean and sunflower. Such a development is potentially feasible given the significant area of cotton that is already grown in the region and the large area of other oilseeds grown in nearby regions (e.g. cotton in Emerald, sunflower in central Queensland and the Central Highlands). Table 9.10 shows that establishing a local oil crushing plant greatly reduces freight costs and increases gross margins by $200/ha.

Cassava produced as a biofuel crop would currently have to be transported to Dalby for processing at the United Ethanol biorefinery. To reduce this significant transport requirement, a biorefinery would need to be established in the Dawson Valley region, but would require a sufficient scale of production and potential throughput to justify the investment. For example, an ethanol refinery with a capacity of 50 million litres per year is estimated to cost approximately $100 million. Assuming an ethanol yield from dried cassava chips of 33% (Ademiluyi and Mepba, 2013), then about 8000 ha of cassava production would be required. Alternatively, a more versatile refinery could be established that can handle a range of feedstocks (e.g. sorghum as well as cassava).

Table 9.10 Change in gross margin for soybean and cassava, assuming local processing facilities are present in the Dawson Valley region

CROP	LOCATION FOR MARKET OR PROCESSING BASELINE	GROSS MARGIN ($/ha)	LOCATION FOR MARKET OR PROCESSING SCENARIO	GROSS MARGIN ($/ha)	ASSUMPTIONS FOR SUPPLY CHAIN SCENARIOS
Soybean	Newcastle	554	Moura	761	Multicrop oil crushing plant established in Moura
Cassava	Dalby	–65	Dawson Valley	735	Ethanol biorefinery established in the Dawson Valley

9.9 Integrated scenario analysis: investment and supply chain options

The analyses in the previous sections are focused on individual crops, their production characteristics in the Dawson Valley region, farm gross margins and supply chain options for those crops. In this section, scenarios are examined for agricultural production at a regional scale, with implications for the regional value of production, supply chain logistics and infrastructure adequacy. The section concludes with a case study comparing several investment options.

The regional-scale analysis assumes that 8000 ha is available for irrigation, with a 95% reliable water supply. This additional irrigation area is based on the provision of treated water from coal seam gas extraction (40 GL/year) as discussed in Section 9.4.2.

9.9.1 INVESTMENT AND SUPPLY CHAIN OPTIONS

Two scenarios were chosen to explore regional impacts of changes in crop production systems (Table 9.11).

Scenario 1

The first development scenario assumes a scaling-up of existing cropping in the region, using existing infrastructure such as cotton gins and grain depots, rather than investing in new infrastructure. This is based on the assumption that the additional water supply (40 GL/year) from the expanding coal seam gas industry in the region may be reliably provided for no more than 15 to 20 years.

Consequently, the development scenario is centred on cotton grown within either a cotton–cotton–wheat rotation or a cotton–cotton–chickpea rotation over 3 years. These two rotations are based on current industry practice (Table 9.12), which commonly involves two cotton crops followed by a rotation crop. As both of the rotation crops are widely grown in the Dawson Valley there is ample supporting infrastructure.

Table 9.11 Scenarios used to explore implications of scaled-up production at the regional scale

CROP	AREA OF LAND (ha)	CROP YIELD/ha (t)	LOCATION FOR MARKET OR PROCESSING	ASSUMPTIONS FOR REGIONAL SCENARIO
Scenario 1 – mixed cropping, no new infrastructure				
Cotton	5500	8.3 bales	Moura	Existing cotton area expanded. Grown in rotation with wheat and chickpea
Wheat	2000	5.9	Dawson	Grown in rotation with cotton
Chickpea	500	3.6	Biloela	Grown in rotation with cotton
Scenario 2 – significant processing infrastructure investment				
Wheat	3000	5.9	Dawson	Grown in double crop rotation with soybean
Soybean	3000	3.7	Moura	Oilseed crushing plant established in Moura Double cropped with wheat
Maize	3000	10.5	Dawson	Grown in rotation with mungbean
Mungbean	1000	2.2	Biloela	Opportunistically double cropped with maize – one-third of maize area
Lablab	2000	10.7	Dawson	Lablab hay for local beef industry

Table 9.12 Crops used in rotation with cotton

CROP	% FARMS GROWING CROP IN LAST THREE YEARS	% THAT THOUGHT THIS HAD MOST BENEFIT FOR COTTON
Wheat	78	46
Chickpea	31	12
Sorghum	26	4
Barley	20	5
Maize; corn	19	16
Mungbean	12	2
Faba bean	10	11
Canola	10	0
Soybean	3	4
Vetch	3	4
Sunflower	1	0
Other: French white millet, canary seed; lablab	8	9
None	11	4

Source: Roth Rural (2013)

Scenario 2

The second development scenario assumes a significant investment in an oilseed crushing plant sited at Moura that is capable of processing soybean, cotton and sunflowers (Table 9.11). Under existing infrastructure arrangements, soybeans are transported to Newcastle for processing and cottonseed is trucked to a cottonseed meal and oil-processing facility in Narrabri. Not only does this scenario shorten the supply chain, the production and availability of high-protein meals such as cottonseed meal and soybean meal would have significant benefits for the local beef industry, both for use in grazing production systems and in feedlot rations.

The scenario assumes that soybeans, grown over summer, are double cropped with winter wheat. Other crops include maize grown over summer, with mungbean double cropped opportunistically – one-third of the maize area is double cropped. Lablab is also grown in this scenario to provide forage hay for the local beef industry. All crops are either processed or sold within the region.

Results

The regional-scale implications of the two development scenarios operating at 8000 ha in the Dawson Valley region are shown in Table 9.13. The two scenarios produced between $25 and $30 million in additional value to the Dawson Valley region. This is similar to the current value of production in the region (Banana Shire) for the crops that were used in the scenarios (Table 9.4). Similarly, the total production volumes are similar to the current volume of agricultural production in Banana Shire, with some differences in individual crops (e.g. 31,500 t of maize produced compared with the around 7000 t produced at present). Because double-cropping systems were used in Scenario 2 there was considerably more production volume than for Scenario 1, but Scenario 1 generated a greater total value because of the higher value per hectare of cotton.

Soybeans are not currently grown in large quantities in the Dawson region. In Scenario 2 they were double cropped with wheat and the combined gross margin return from these two crops was approximately

$1700/ha, which is similar to cotton. This development scenario relied on having access to a local oil crushing plant; the infrastructure implications of this scenario are discussed below.

Table 9.13 Influence of the two regional scenarios on total flows of product and value of production per year

CROP	TOTAL PRODUCTION (t)	TOTAL VALUE OF PRODUCTION ($)	TOTAL VARIABLE COSTS ($)
Scenario 1 – mixed cropping, no new infrastructure			
Cotton	10,363	26,015,000	16,549,500
Wheat	11,800	3,658,000	1,816,000
Chickpea	1,800	720,000	428,500
Total	23,963	30,393,000	18,794,000
Scenario 2 – significant processing infrastructure investment			
Wheat	17,700	5,487,000	2,724,000
Soybean	11,100	5,550,000	3,174,000
Maize	31,500	8,820,000	3,909,000
Mungbean	2,200	1,760,000	700,000
Lablab	21,400	3,852,000	2,938,000
Total	83,900	25,469,000	13,445,000

Transport implications

Both development scenarios involve only dry-weight transport to either local use in the beef sector, existing processing facilities (e.g. cotton gin), proposed new facilities (oilseed crushing plant in Moura) or a local storage facility. Minimum fleet requirements for each scenario have been calculated from the supply chain analysis information that is included in Appendixes 9.2 and 9.3. The requirements are calculated by month of year to accommodate the harvest and transport requirements of each crop. Vehicle requirements account for minor rest breaks en route to the destination and the time required for loading/unloading. They do not account for major downtime or maintenance. Figures 9.9 and 9.10 shows the vehicle requirements by time of year for Scenarios 1 and 2. These requirements do not include vehicle reductions that may be potentially achieved by backloading opportunities on some routes. Compared with the other regional case studies, travel distances between production and processing, storage and end use are quite short (<100 km) and thus backloading opportunities may be limited. Note that the vehicle numbers in Figures 9.9 and 9.10 are based on the number of prime movers, and a Type 1 road train is classed as one vehicle. The vehicle numbers in Figures 9.9 and 9.10 are multiplied by 2 for Type 1 vehicles to give the number of trailers.

While both development scenarios have a peak period of demand lasting only 2 months, the vehicle requirements are low compared with those for the other case study regions. This is because the travel distances are short and a single vehicle can complete multiple trips in one day. The peak demands in vehicles may be met by existing vehicle and trailer fleets already used for cropping in the Dawson Valley and surrounding regions. If current vehicle capacity cannot meet the new demand there would need to be a modest investment in additional capacity to meet peak demand.

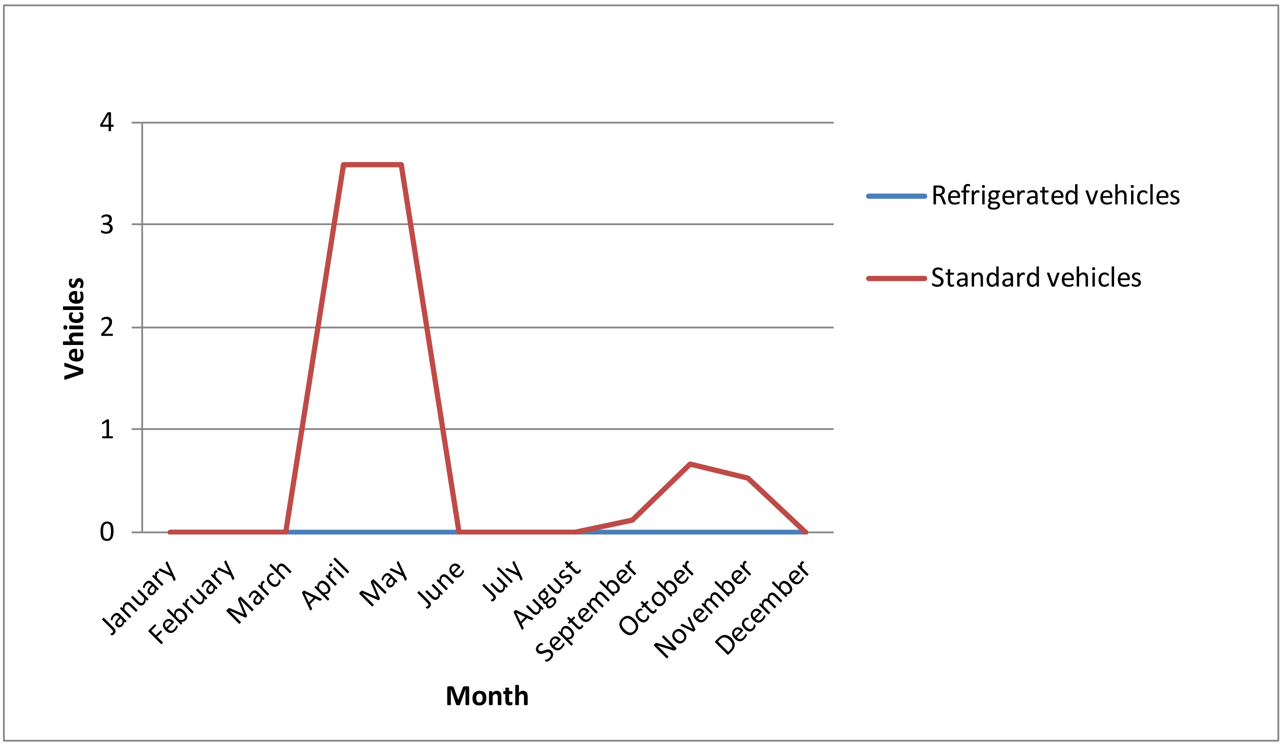


Figure 9.9 Vehicle requirements for 8000 ha of cropping in Scenario 1

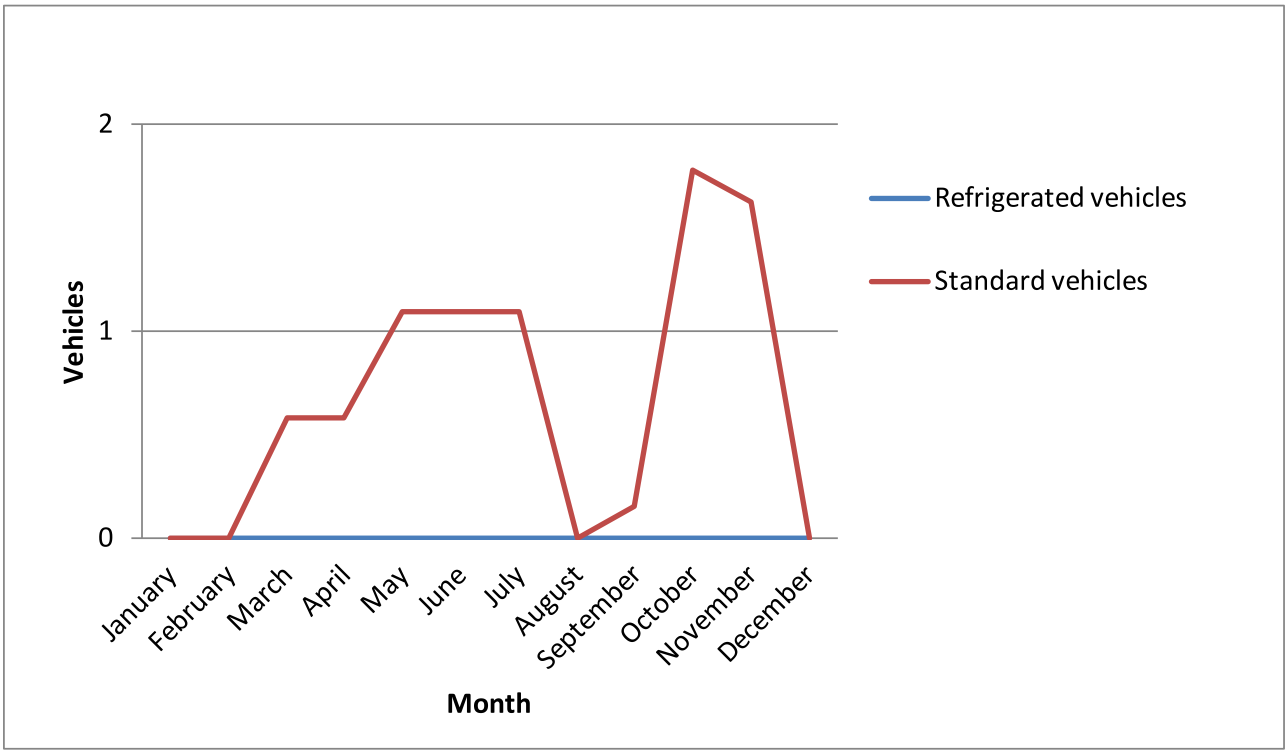


Figure 9.10 Vehicle requirements for 8000 ha of cropping in Scenario 2

Infrastructure

The main infrastructure investment in the two development scenarios is the establishment of an oilseed crushing plant in Moura. The scenario of 3000 ha of soybean on its own is not sufficient to justify the investment in an oilseed crushing plant. However, given the volume of cotton and other oilseeds that are grown in the Dawson Valley and in neighbouring regions to the north, there could be sufficient volumes to support an oil crushing plant.

Sands and Long (2012) has explored the feasibility of establishing a multipurpose oilseed plant in central Queensland. In that analysis it was suggested that an extrusion-expeller processing system be used in preference to other extraction processes such as solvent extraction. The main advantages for an extrusion-expeller processing system include:

- it is less capital intensive than other systems because there is no requirement for delinting, dehulling, cooking or flaking the oilseed before extrusion. Seeds only need to be cleaned before processing
- double pressing is not required, which means less expeller mills are needed
- a variety of oilseeds can be processed in the one mill, from low oil-content seeds such as cottonseed and soybean to high oil-content seeds such as sunflower and canola
- high-quality oil and protein meal are produced by this processing method.

The protein meal produced under extrusion-expeller processing is lower in protein than for solvent extracted methods but has a considerably higher energy content because of higher fat levels. This can be positive for livestock feeding regimes that require high levels of protein and energy, but where rations are constructed on the basis of least cost per unit of protein, then solvent extracted meals may be preferred.

Soybean meal returns a higher price per kilogram of meal than cottonseed meal because it is highly valued in the intensive pig and poultry industries. Prices are approximately $1.45/kg of protein for soybean and $0.83/kg of protein for cottonseed meal (Sands and Long, 2012).

The capital costs for construction of an oilseed plant and returns on that investment are dependent on the size of the oilseed plant. Sands and Long (2012) reported the costs of oilseed plants at $12.2, $18.5 and $26.6 million, respectively, for mills with capacities of 34,000, 64,000 and 64,000 t, with added oil refining capabilities. The two larger-capacity processing plants generated returns on capital in excess of 16%, based on a 20-year investment period. Discussions with Cargill Australia, which operates most of the oilseed crushing facilities in Australia, indicated that for a 300,000-t mill capable of processing a range of oilseeds, the cost would be around $130 to $150 million. As these costs are somewhat higher than those estimated by Sands and Long (2012), for Scenario 2, a capital cost of $30 million was used for a 60,000-t capacity mill.

For other crops included in the development scenarios, processing facilities or receiving storage depots already exist in the region. The additional volume of product that is generated from the scenarios (doubling of existing volumes in several cases) may require additional investment in infrastructure, particularly in storage capacity. For example, the current level of wheat production in the region is 36,000 t/year and in the second development scenario there is projected to be approximately 18,000 t of additional wheat produced.

Cotton production in the first development scenario is projected to include an additional 10,000 t of cotton above the current level of production of around 14,000 t (Table 9.4). This production is likely to require additional ginning capacity. The cotton gin at Moura has two stands but was built to accommodate the addition of two further stands and so the capital investment to upgrade this infrastructure would be very modest – around $1 million.

Local storage and handling facilities and road and rail transport supply chains for grains in the case study region have evolved over many decades. For the majority of grain growing enterprises, this network of facilities has resulted in short transport distances. Although these facilities have served local production well, further improvement to the handling and transport networks is needed. This requires investment in roads to maintain their condition, rail sidings and upgrading of storage facilities. In particular, there is a trend towards developing more clustered storage facilities of a larger scale at the expense of smaller handling facilities. This will require investment in these centralised sites, not just from a storage perspective but in terms of improving the efficiency of transport logistics, especially rail.

9.9.2 RISK ANALYSIS

The analysis for the two regional development scenarios has used averages of yields and prices for the gross margins, based on historical data and simulated crop yields. Future investment needs to be based on a good understanding of risk. Price risk is one variable that needs to be considered when making investments. ABARES produces market outlooks for a range of commodities, which are summarised in Table 9.14 for the crops that are included in the two development scenarios. These market outlooks are based on medium-term drivers and as such do not capture shorter-term year-to-year variability. This is highlighted in Figure 9.11, which shows the market outlook for cotton over the next 10 years with the previous 10 years price data superimposed to illustrate the pattern of interannual variability that might be expected above the longer-term price trend.

Table 9.14 Ten-year forward price projections for the crops used in the two regional scenarios
Numbers represent real domestic prices (in 2012–13 dollars).

CROP	UNIT	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Maize	$/t	354	310	324	326	313	301	360	359	357	356
Sorghum	$/t	242	216	216	213	210	206	206	206	206	206
Wheat	$/t	329	319	317	317	325	326	326	326	326	326
Chickpea	$/t	592	628	629	629	644	644	643	642	641	640
Mungbean	$/t	1001	1063	1064	1065	1091	1090	1088	1087	1085	1084
Soybean	$/t	509	466	447	445	440	435	434	433	432	431
Cotton	$/bale	504	498	509	510	518	531	530	528	527	526
Forage hay	$/t	190	202	202	202	206	206	205	205	204	204

Source: Data provided by ABARES

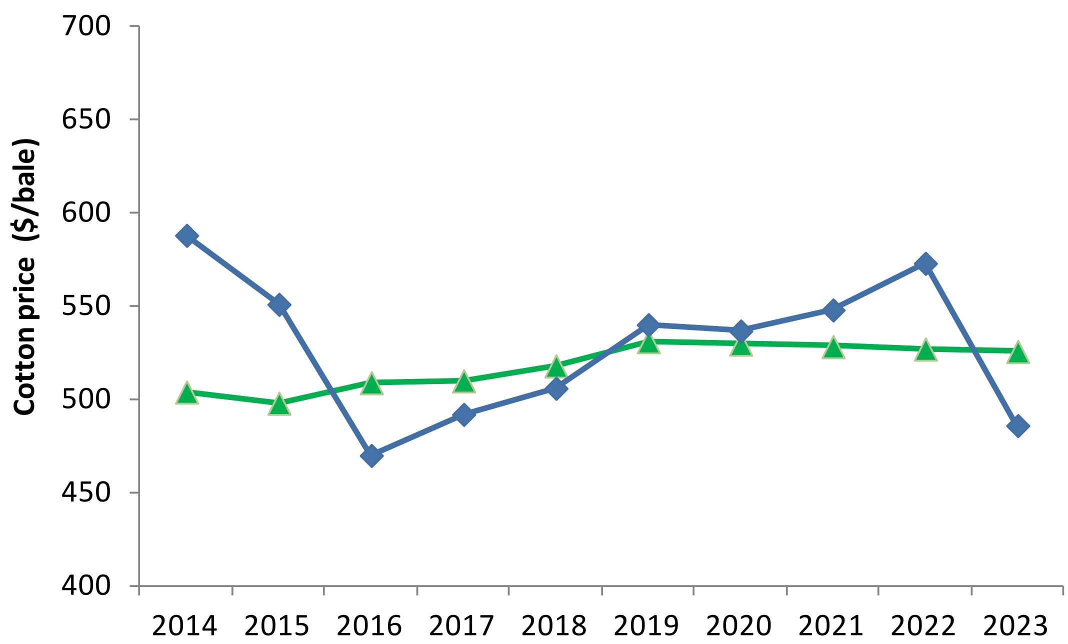


Figure 9.11 Ten-year forward projection for cotton price (green line) with previous 10 years (2004 to 2013) of prices (blue line) superimposed to highlight historical year-to-year price variability

As indicated in Section 9.8, price variation combines with yield variation to produce gross margins that can vary significantly between years. In terms of future risk, it is useful to understand how price and yield variation might influence risk. A distribution of gross margins is presented in Figure 9.12 for the cotton scenario in the Dawson Valley, based on historical yield variation over 100 years (simulated by APSIM) combined with historical price variation based on 10 years of ABARES data (Figure 9.11). The median gross margin is around $1730/ha and there is only a very small chance (about 1 in 167) of achieving a negative gross margin in any year. Negative gross margins are probably underrepresented here. Over 100 years, flood (e.g. Dawson valley in 2011) or disease outbreak could be expected to produce crop failure; these were not simulated in the modelling.

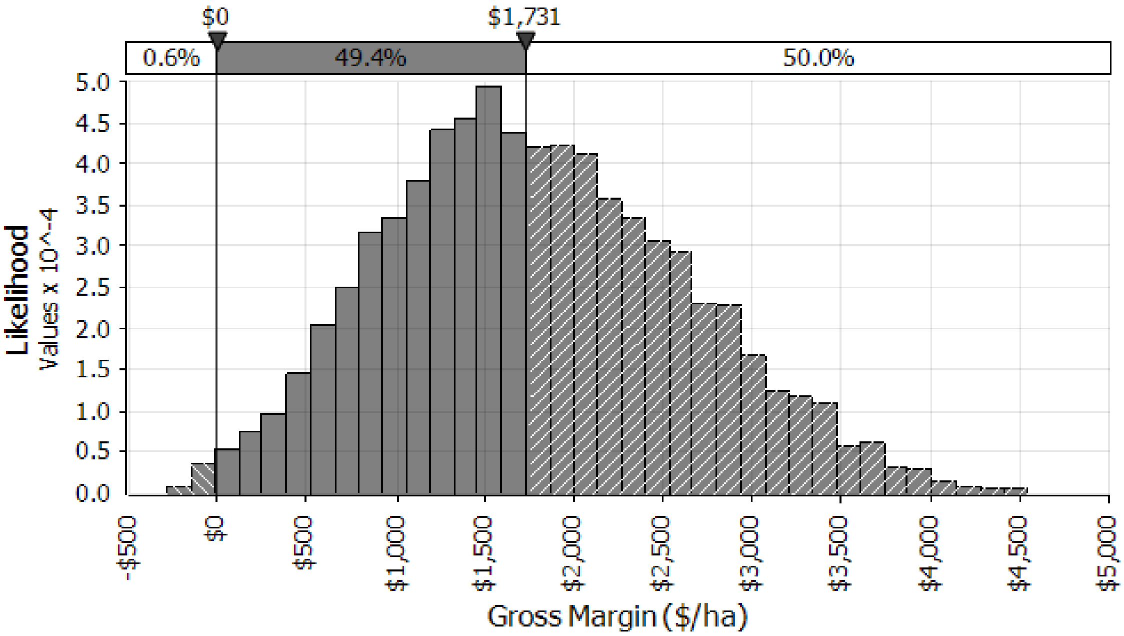


Figure 9.12 Distribution of financial outcomes for cotton as measured by gross margin for a combination of yield (100 years) and price (10 years) variation

The historical analysis of agricultural developments in northern Australia (Appendix 3.1) has identified the ability to get through the first few years of establishment and scaling-up as major determinants of success or failure. In the start-up phase it is essential to provide sufficient time to learn and adapt agronomic management to suit local conditions without the pressure of striving to achieve unrealistic yields that often underpin cash flow and investment prospectuses.

The following analysis builds on the variability presented in the gross margin analysis to consider the business vulnerability to a sequence of better and poorer years and the level of debt. Similar to the earlier gross margin analysis, this risk analysis does not specifically cover farm profit because it does not include fixed or overhead expenses such as depreciation for equipment and buildings. However, the risk being assessed will directly impact on prices and yields, which are adequately captured by changes to the gross margin projections.

The effect of different starting conditions for debt ($8000/ha and $10,000/ha) and good or bad years, with a 7% interest rate, is illustrated in Figure 9.13 for cotton. The number of good and bad years are the same in the runs for ‘better years early’ and ‘poorer years early’ and the differences are generated by the sequence in which these years occur. A random sequence was also generated, which included the shock of 2 bad years of yield. A bad year was defined as 20% of the median yield.

The ‘better years early’ scenarios reduce the debt from the outset. The starting debt has a relatively small effect on the outcome and the debt is repaid after 4 and 5.7 years for the low and medium debt scenarios, respectively. In general, the different starting debt levels cause a delay but does not shift the trajectory into a spiral of increasing interest payments and debt for the scenarios that are considered. The debt level is sensitive to shocks and causes debt to spike for each ‘bad’ year. Nonetheless, the debt level resumes its downward trajectory after each shock and most of the debt is repaid for the low debt scenario, even after two very bad years (yields 20% of median). This reflects the overall strong margins for cotton in this region and the ability to withstand severe shocks as the crop has a strong chance of allowing recovery after a bad year.

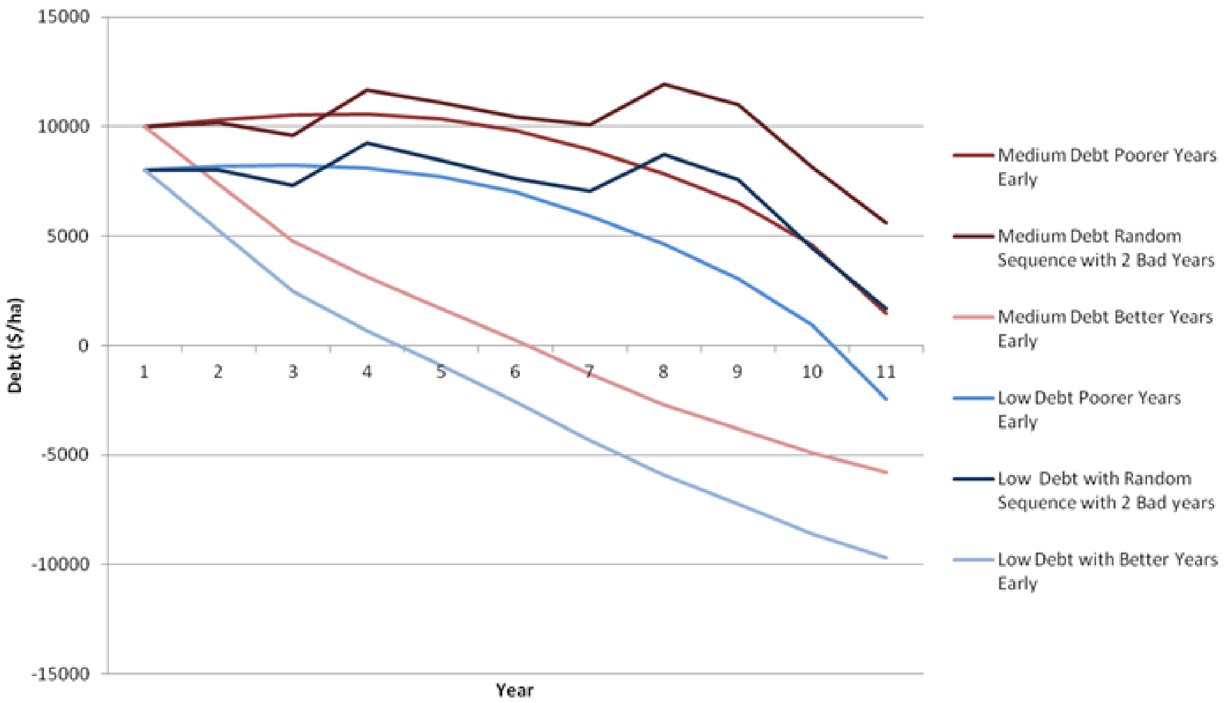


Figure 9.13 Influence of sequence of year types and starting debt level on the ability of cash flows to reduce debt of cotton cropping over a 10-year investment period

9.10 Regional economic analysis

9.10.1 **CENTRAL QUEENSLAND/DAWSON ECONOMY**

The Central Queensland region is represented in AusRegion by the areas of Emerald, Bauhinia, Banana, Peak Downs and Woorabinda. The region includes the Dawson investment. The economy of the region is projected to grow at 3.7% annually, which is faster than Queensland's GSP growth rate of 2.5%. Agriculture is a very small part of the region's economy that is dominated by mining.

9.10.2 **SCENARIO DESCRIPTION**

Each scenario is modelled in two phases—construction and production. Table 9.15 reflects a stylised version of the scenarios for Central Queensland described earlier as modelled in AusRegion. Public investment in local infrastructure totals $50 million in both scenarios. The increase in land suitable for cropping in both scenarios is 8 000 hectares. In Scenario 1, private investment occurs in cotton and grains. In Scenario 2, there is $100 million investment in grains.

Government investment benefits horticulture and cotton with transport costs assumed to fall by 10% in both Scenarios 1 and 2. The private investment in Scenario 2 also leads to an assumed 10% increase in land productivity for beef production.

Table 9.15 AusRegion stylised scenario description for Central Queensland

Development parameter	Unit	Commodity	Scenario 1	Scenario 2
Government investment	$m		50	50
Private Investment	$m	Beef Cattle		31
	$m	Cotton	65	
	$m	Grains	25	100
	$m	Total private	90	131
Total Investment	$m		140	181
Land supply	’000ha		8	8
Transport costs	%	Cotton	-10	
	%	Grains		-10
Yield	%	Beef Cattle		10

a Assumed change in transport costs arising from government investment. **b** Assumed increase in sectoral land productivity arising from private investment.

9.10.3 **REGIONAL ECONOMIC OUTCOMES**

The proposed investments will affect economic activity, employment and exports in the Central Queensland region and have consequences for the Queensland and Australian economies. GRP is projected to be 0.1% higher than the reference under Scenarios 1 and 2, once all projects are fully implemented and agricultural output has expanded (Table 9.16). Central Queensland as defined in AusRegion is a relatively large region and the proposed investment in both scenarios is small. In line with GRP, employment in the region is projected to rise relative to the reference case.

The relatively small increase in agriculture does not draw significant resources and some sectors grow because of the infrastructure investment and the increased need for transport.

Table 9.16 Economic impacts for Central Queensland at 2029–30, % deviation from the reference case

	Unit	Scenario 1	Scenario 2
GRP	%	0.1	0.1
Employment	%	0.1	0.3
Real wages	%	0.0	0.0
Exports	%	0.1	0.3
Sectoral output			
Agriculture	%	2.3	4.6
Mining	%	0.0	0.0
Other	%	0.1	0.0
Queensland GSP	%	0.0	0.0
GDP	%	0.0	0.0

9.11 References

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10 DARLING DOWNS – MARANOA REGIONAL ANALYSIS

10.1 Summary and key messages

- The Darling Downs – Maranoa Area has the capacity to provide 5000 ha of additional irrigated cropping, based on a scenario of 25 GL of water being made available from extraction of coal seam gas.
- Both dryland and irrigated agriculture are already important in the region, and more than 100,000 ha of land are either fully or supplementary irrigated. The Condamine and Balonne rivers and their major tributaries provide the majority of irrigation water; some additional groundwater resources are also used for agriculture.
- Water from coal seam gas extraction is provided continuously, so consideration needs to be given to how to use water on a year-round basis – for example, for forage crops, double crop rotations, or on-farm storages that allow the water to be stored for annual broadacre and horticultural crops.
- Gross margins were assessed for 10 crops, based on existing domestic supply chains and infrastructure. Given the present status of a relatively high level of local infrastructure, including grain depots, a cotton gin and pulse seed processing facilities, the gross margins for all broadacre crops were positive, ranging from around \$600/ha to \$1500/ha. Soybeans generated the lowest gross margin as a result of significant freight costs associated with transporting the grain to Newcastle for oil extraction.
- Watermelons and sweet corn produced gross margins of between \$3400 and \$4400/ha, generating high returns but also having high costs.
- Cotton, which is already a widely grown and profitable crop in this region, generated a high gross margin. Cotton gins and supporting industry infrastructure are already well established in the region.
- Irrigated forage sorghum hay, for which there is demand in the feedlot sector within the region, produced a gross margin that was comparable with crops such as wheat, chickpeas and soybeans.
- There are reasonably effective supply chains for most broadacre food crops and cotton, with transport costs to market or processing representing around 5% of the total value of production. Improvements in supply chain efficiency can still be achieved through planned clustering of grain storages and depots, and better coordinated road–rail networks.
- The main supply chain development scenario that was explored was centred around the current development of a new airport in Toowoomba, which could provide opportunities for high-value exports to Asia and the Middle East. Although gross margins for sweet corn were assessed to be slightly lower in this supply chain scenario than for domestic supply, if export markets can be established, they offer diversity beyond the limited growth opportunities in domestic capacity. Establishment of an oilseed crushing plant closer than Newcastle facilitated an increase in gross margin of about \$100/ha for soybeans.
- Two regional scenarios based on 5000 ha of additional irrigated production were explored. The first scenario assumed a scaling-up of existing agricultural production, with a focus on cotton grown in rotation with wheat. This would not require investment in new processing or storage facilities because the additional production could be absorbed into existing supply chains. The second scenario assumed a mix of broadacre crops, including maize and chickpeas in a double crop rotation, forage sorghum for use within the local beef sector, and expanded horticultural production, with 500 ha each of watermelons and sweet corn grown. Sweet corn was assumed to be exported via Toowoomba.
- The two scenarios produced total gross values of production ranging between \$19 million and \$34 million/year. This is a relatively modest increase in the value of regional production, given the well-established cropping industry in the region. Although the increased production would require some additional vehicle movements, this demand would most likely be met by existing freight capacity in the region, or through a small growth in capacity that could be met by existing providers.

- Apart from ongoing investment required to maintain and improve the effectiveness and efficiency of regional roads, storage and handling facilities, and processing plants, the major infrastructure requirement is the treatment and provision of water from coal seam gas extraction and facilities to air freight exports out of Toowoomba. The water infrastructure is being provided by coal seam gas companies, with water supplied at the farm gate at a modest cost to farmers. Private investment in a new airport is occurring, with the Wellcamp Airport due to be completed in 2014. When this new transport facility is available, the main challenge will be developing the export markets for horticultural and agricultural production, and achieving a two-way freight business to ensure cost-effective export freight rates.
- The moderate level of investment proposed in the Darling Downs-Maranoa region increases regional economic welfare by only 0.3% relative to the reference case.

10.2 Description of region: existing agriculture, scale of irrigation and development

The Darling Downs – Maranoa region, in southern Queensland, covers an area of approximately 166,400 km^2 and has a population of around 120,000 people (Trestrail et al., 2013). There are six local government areas in the region. Major regional towns include Dalby, Warwick, Goondiwindi, St George, Roma and Mitchell (Figure 10.1).

The region was first inhabited by Europeans in 1840, and agricultural development quickly followed. Pastoralism was the first agricultural activity in the region, with sheep farming for wool production dominating through the mid- to late 1800s. Woolsheds were dotted across the landscape as merino wool provided a good source of income for the pastoralists. Wool was in high demand and was well suited to export because it was a non-perishable product.

The rich black soils of the Darling Downs were also recognised for their cropping potential. In the first census after Queensland's separation from New South Wales, 79 ha of wheat production were recorded in Queensland, and this was mostly on the Darling Downs. In the late 1800s, the larger pastoral properties on the eastern Darling Downs were gradually subdivided into much smaller holdings, mostly for wheat production, although there was also an increase in dairying.

The intensification of agriculture into dryland wheat production and dairying continued through the early part of the 20th century. Soldier settlement schemes following World War I resulted in further subdivision of larger pastoral properties. However, this was not altogether successful in achieving greater intensification because the properties on lands that were too marginal for cropping were not large enough to be viable.

Following World War II, the introduction of large, powered agricultural machinery led to a rapid increase in cropping lands, and the clearing of the Brigalow Belt for grazing and cropping. Cotton was first grown at Cecil Plains on the eastern Darling Downs in the early 1960s, and ring tanks for supplementary irrigation first appeared.

Today, the Darling Downs – Maranoa region accounts for about 25% of Queensland's agricultural production. In 2010–11, this amounted to around $2.5 billion in total value of production (Trestrail et al., 2013). Of the more than 7000 farms in the Darling Downs – Maranoa region, around 2500 were involved in some form of crop production, with the remainder in livestock production. According to the Queensland agricultural land audit, broadacre cropping and horticulture accounts for around 2.4 million hectares of the 15 million hectares used for agriculture (Queensland Government, 2013). The land audit identified that the potential land area that could be used for broadacre cropping and horticulture is more than 15 million hectares. There are many small farms, with 40% of total farms having an agricultural value of operations of less than $50,000 (Figure 10.2). However, this large number of small farms makes up less than 5% of total value of agricultural operations in the region. In contrast, large farms represent less than 10% of farm numbers but account for more than 50% of the value of agricultural operations in the region.

Irrigated agriculture is important in the region, and more than 100,000 ha of land is either fully or supplementary irrigated. The Condamine and Balonne rivers and their major tributaries provide the majority of irrigation water; some additional groundwater resources are also used for agriculture. Construction of public storages commenced in the 1950s with the Jack Taylor Weir at St George in 1959. This was followed by construction of the Chinchilla Weir in the early 1970s, and the Leslie and Beardmore dams in the 1980s. In total, these provide 123 GL of water for irrigation in four managed water supply scheme areas. However, water storage capacity is dominated by numerous private off-stream water storages in the lower parts of the region's river system. These storages are filled in times of large flow events and have an estimated combined storage volume of 1582 GL (Webb et al., 2007).

Because rainfall is highly variable in the region, water availability for irrigation is also highly variable – although around 100,000 ha is irrigated on average, this varies considerably, with larger areas able to be irrigated in the years following large river flows. Based on an irrigated area of 100,000 ha, the contribution in 2005–06 from irrigated agriculture was about $400 million, representing 25% of the total value of crop production in the region (ABS et al., 2009).

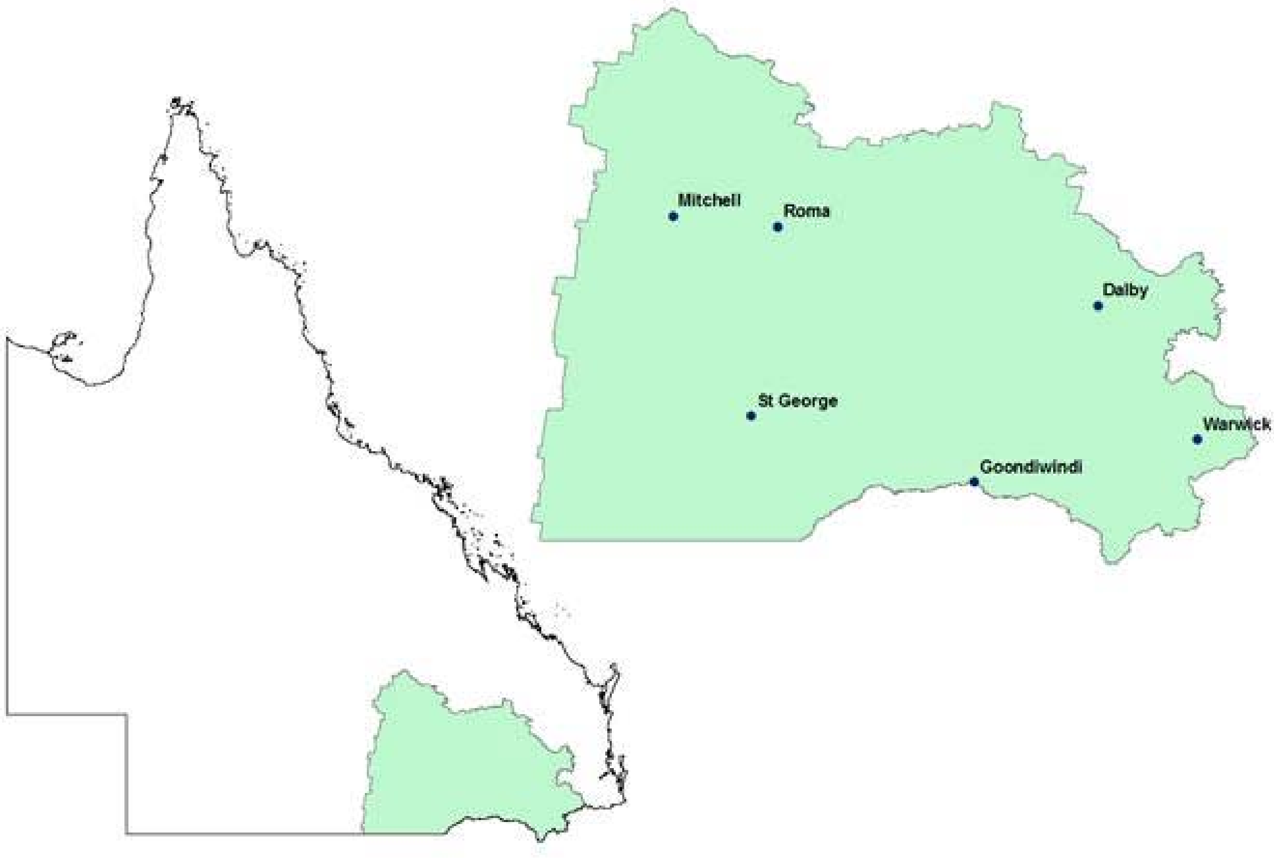

Figure 10.1 Location of the Darling Downs – Maranoa region in southern Queensland
Source: Trestrail et al. (2013)

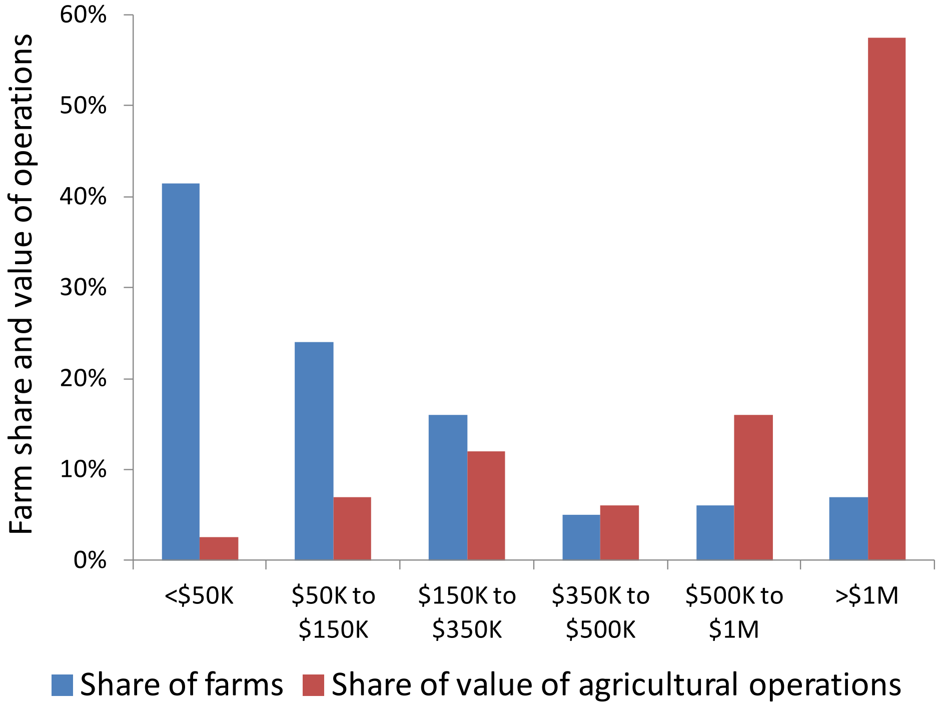

Figure 10.2 Distribution of farms by estimated value of agricultural operations, Darling Downs region, Queensland, 2010–11
Source: Trestrail et al. (2013)

Treated water from coal seam gas extraction provides an opportunity to increase the area available for irrigation, because reliable water supplies are produced for the life of the gasfield. Most liquefied natural gas companies operating in the Darling Downs – Maranoa region are working with the agricultural sector to provide treated water for agriculture. These supplies are either provided by pipe under pressure to farms or are put into streams and then pumped by farmers directly onto crops or into buffer dams and ring tanks on farm for later use.

In this regional analysis, opportunities for increased irrigation are based on additional water made available from coal seam gas extraction. Because the water from coal seam gas extraction is provided continuously, consideration needs to be given to water uses on a year-round basis – for example, for forage crops, or on-farm storages that allow the water to be stored for use on annual broadacre and horticultural crops.

10.3 Climate: existing and future trends

10.3.1 **CURRENT CLIMATE**

Roma, which is located in the central west of the Darling Downs – Maranoa region, has a subtropical to temperate semi-arid climate, with an average rainfall (1963 to 2013) of 602 mm. Rainfall is summer dominant, but significant falls can occur in winter – rainfall in winter averages more than 30 mm/month (Figure 10.3). Dryland cropping can be undertaken in both summer and winter, although for most winter crops there needs to be a good store of soil moisture at planting to ensure a reasonable crop yield. Irrigation increases both crop yield and the reliability of cropping in this region, and opens up the option of more intensive rotational cropping systems. Evaporation rates are moderate (2100 mm/year pan evaporation) compared with the tropical regions in this study, but annual evaporation still greatly exceeds annual rainfall. There is a strong seasonal cycle in evaporation, which has implications for crop water demand in irrigation schemes and for evaporative losses from storages.

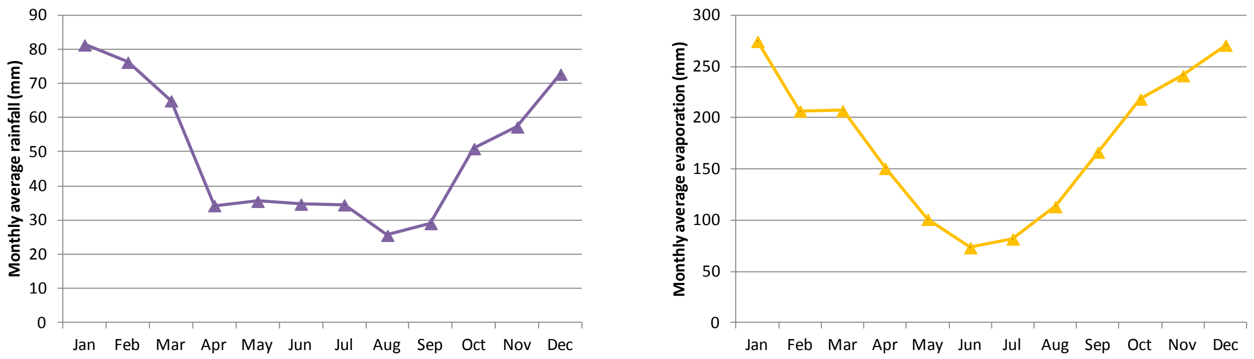

Figure 10.3 Monthly average rainfall (left) and evaporation (right) at Roma

The Darling Downs – Maranoa region experiences moderate year-to-year variability in rainfall. A good measure of annual rainfall variability is the coefficient of variation (CV), calculated as the standard deviation of mean annual rainfall divided by the mean annual rainfall. The higher the CV, the more variable is the mean annual rainfall. The CV for Roma is 0.29, which is similar to the Dawson Valley region but considerably lower than in northern Queensland, where the CV of annual rainfall is approximately 0.4. However, it is sufficiently high that water storages that are dependent on rainfall need to be much larger than their annual yield to ensure high reliability of supply.

The region also experiences runs of wet and dry years (Figure 10.4). There can be series of years when the rainfall is either well below or well above average. This region is moderately influenced by the El Niño Southern Oscillation (ENSO) – this can be seen in the run of wet years in the 1970s, in the 2009–11 period associated with La Niña events, and dry years in the early 1990s and early to mid-2000s, which were characterised by a higher frequency of El Niño events. Floods are common, and the well above-average rainfall in 2010–11 and 2011–12 caused significant flooding in much of the region.

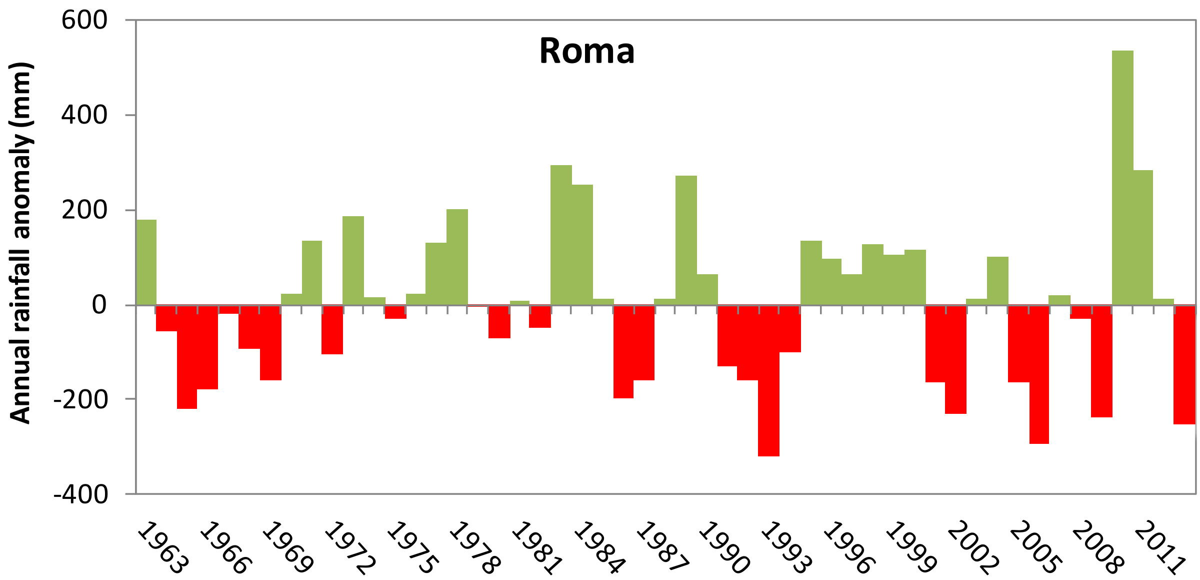

Figure 10.4 Runs of wet and dry years at Roma, measured by the difference in annual rainfall from the long-term average (1963 to 2013)

Wet years are denoted by green bars and dry years by red bars.

10.3.2 **FUTURE CLIMATE**

Climate projections for 2030 were assessed using four global climate models: ECHAM5, GFDL-21, HADCM3 and MIROC. Global climate models are physical representations of the main drivers of the climate system. Future climate is modelled by perturbing the carbon dioxide concentrations in the model, which has implications for temperature and rainfall. In this study, two future emission scenarios of carbon dioxide were used, based on scenarios from the Intergovernmental Panel on Climate Change – one was a high-emissions scenario (A1FI), and the other a moderate-emissions scenario (A2). The results from the global climate models, which provide results at a regional scale, were then used to transform the historical station records for Roma (see Section 2.3.1).

Rainfall projections for 2030 under the two emissions scenarios show a slight drying trend under the four climate change models used in this study (Figure 10.5). One model suggests a modest increase in rainfall (12%), while two suggest a small decrease (around 2%) and one (the GFDL-21 model) indicates a 15% decrease in rainfall. With the exception of the tropics, broadscale climate projections for Australia tend to show a drying trend, particularly for southern Australia. This projected drying trend would need to be factored into planning for future irrigation developments because small changes in rainfall can have a much larger impact on river flows. For example, the environmental impact statement for Nathan Dam, just to the north of this study region, explored climate change scenarios and their influence on river flows in the Dawson River catchment; for the A1FI (high) emissions scenario in 2050, mean annual river flows were projected to decrease by 15 to 22% (SKM, 2012).

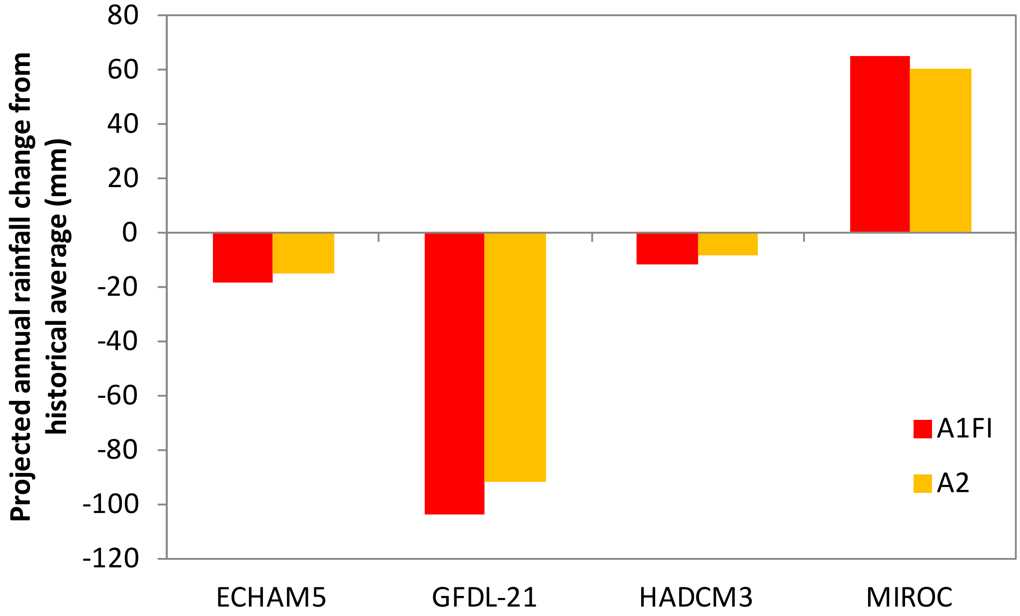

Figure 10.5 Rainfall projections for 2030 based on two emissions scenarios (A1FI – high, A2 – moderate), using four global climate models
The rainfall projection is the difference, in millimetres, from the recent historical average annual rainfall (1970 to 2010).

Unlike rainfall, the projected trend in temperature is much more certain, with a projected increase in temperature to 2030 of 0.7 to 1.3°C. This mean increase in temperature can have both positive and negative impacts in this climatic zone. Positive impacts are a potential decrease in frost incidence, which may permit more flexibility in sowing and lead to longer crop growth windows for winter crops. However, higher temperatures in spring and summer may negatively affect some crops – for example, reduction in the quality of wheat when exposed to high temperatures during grain fill, and negative impacts on vegetables and horticultural crops. Even a small increase in overall mean temperature can have a significant impact on extreme temperatures. This is highlighted in Figure 10.6, where the number of days exceeding 40°C in Roma is expected to increase from an average of nearly 4 days/year under historical climate to an average of more than 10 days/year by 2030.

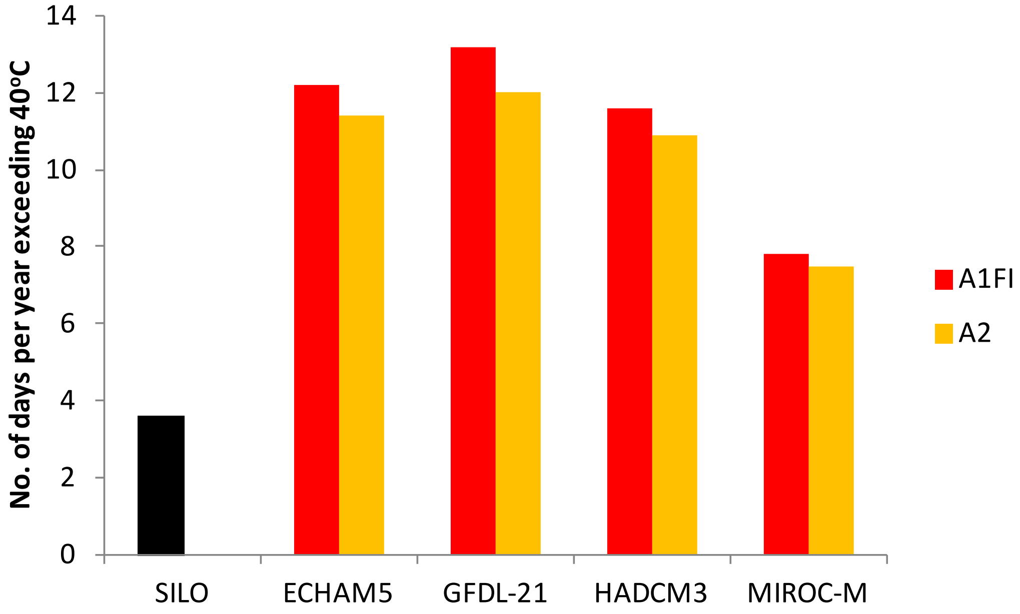

Figure 10.6 Number of days per year in Roma projected to exceed 40 °C in 2030 for two emissions scenarios (A1FI – high emissions, A2 – moderate emissions) compared with historical climate (SILO data for1970 to 2010, black column)

10.4 Water resources

The Condamine–Balonne river system rises in the Great Dividing Range near Warwick. The major water resources in the region include the Condamine, Balonne and Culgoa rivers; alluvial aquifers; wetlands; and water storages. Both surface water and groundwater are used for irrigation. The Condamine River flows in a north-western direction and becomes the Balonne River downstream of Surat, flowing west and south-west. It then becomes the Culgoa River and other distributaries – Bokhara, Ballandool and Narran rivers – all flowing south-west. The Maranoa River flows southward from the Carnarvon Range into Beardmore Dam near St George. The Nebine Creek in the west of the region flows in a southerly direction and joins the Culgoa River in northern New South Wales upstream of Collerina. There are several nationally significant wetlands located on the lower Balonne River system. The Ramsar-listed Narran Lake Nature Reserve (which includes Back and Clear lakes) in New South Wales is part of large terminal wetlands of the Narran River at the end of the Condamine system flowing out of Queensland. The Culgoa River floodplain supports a significant area of remnant coolibah woodlands.

The Condamine–Balonne region is underlain by the Great Artesian Basin (GAB) Jurassic and Cretaceous confined sandstone aquifers, and these are the primary source of groundwater resources in the mid-Condamine subcatchment.

Groundwater in the GAB flows from the intake beds in the north and east of the catchment to the south and west, becoming artesian beneath the mid-Condamine subcatchment. Salinity is variable, but generally adequate for stock and domestic use. High sodium levels preclude general irrigation use. The water resources of these GAB aquifers are not considered in this assessment, except where intake beds for the GAB outcrop within the region, and where groundwater has the potential to be connected with surface water systems. The aquifers of the mid-Condamine subcatchment between Chinchilla and Beardmore Dam largely consist of the Jurassic and Cretaceous sandstone aquifers that form the GAB intake beds, consolidated Tertiary sediment and minor modern alluvium flanking the major rivers.

There is significant (estimated 84 GL/year) groundwater extraction from the GAB, and 67 GL/year comes from the intake beds. Groundwater within the deeper aquifers is separated from upper aquifers by thick confining beds. This means that there is little interaction with the overlying surface water or groundwater contained in near-surface aquifers.

The most significant aquifers in the upper Condamine subcatchment are the alluvial systems associated with major rivers and creeks in the area. Recharge to the alluvial aquifers occurs via rainfall infiltration throughout the catchment; flood recharge in the lower areas of the catchment; lateral flow from adjacent, upstream aquifers; and upward leakage from basalt units, where these underlie the upper tributary alluvial aquifers (Wilson and Adams, 2004). Yields from the alluvial aquifers vary between 5 and 30 L/s. Water quality is generally suitable for most purposes, and salinity values range from 900 to 2100 mg/L total dissolved salts (Wilson and Adams, 2004).

10.4.1 **EXISTING WATER USE AND REGULATION**

There are three main irrigation areas in the Condamine–Balonne region: the Upper Condamine, Chinchilla Weir and St George water supply schemes. There is also some licensed water harvesting for irrigation via interception and on-farm storage of overland flow. Around 75% of the irrigation water used within the region is sourced from surface water diversions. The construction of public storages in the upper Condamine and Balonne rivers near St George has resulted in a degree of regulation, particularly the Balonne River downstream of Beardmore Dam.

There are four significant public water storages in the region. Leslie Dam (106 GL, completed 1985) and Chinchilla Weir (10 GL, completed 1974) are on the Condamine River. Beardmore Dam (82 GL, completed 1982) and Jack Taylor Weir (10 GL, completed 1959) are on the Balonne River at St George. Water storage capacity is dominated by numerous private off-stream water storages in the lower parts of the region's river system. These have an estimated combined storage volume of 1582 GL (Webb et al., 2007). These private storages are used for harvesting of stream flow and overland flow at times of higher river flow.

CSIRO (2008) provides a comprehensive description of water use and availability in the Condamine–Balonne region.

10.5 Land suitability for cropping

The area of interest for irrigated agricultural development is largely confined to the broad alluvial corridors south-west of Chinchilla and leading south from Roma. Agricultural soils in these areas are dominated by Vertosols (cracking clays). Other areas of Rudosols (minimally developed soils), Sodosols (high sodium and an abrupt increase in clay) and Chromosols (soils with an abrupt increase in clay) are generally not suitable for intensive agricultural development (Figure 10.7).

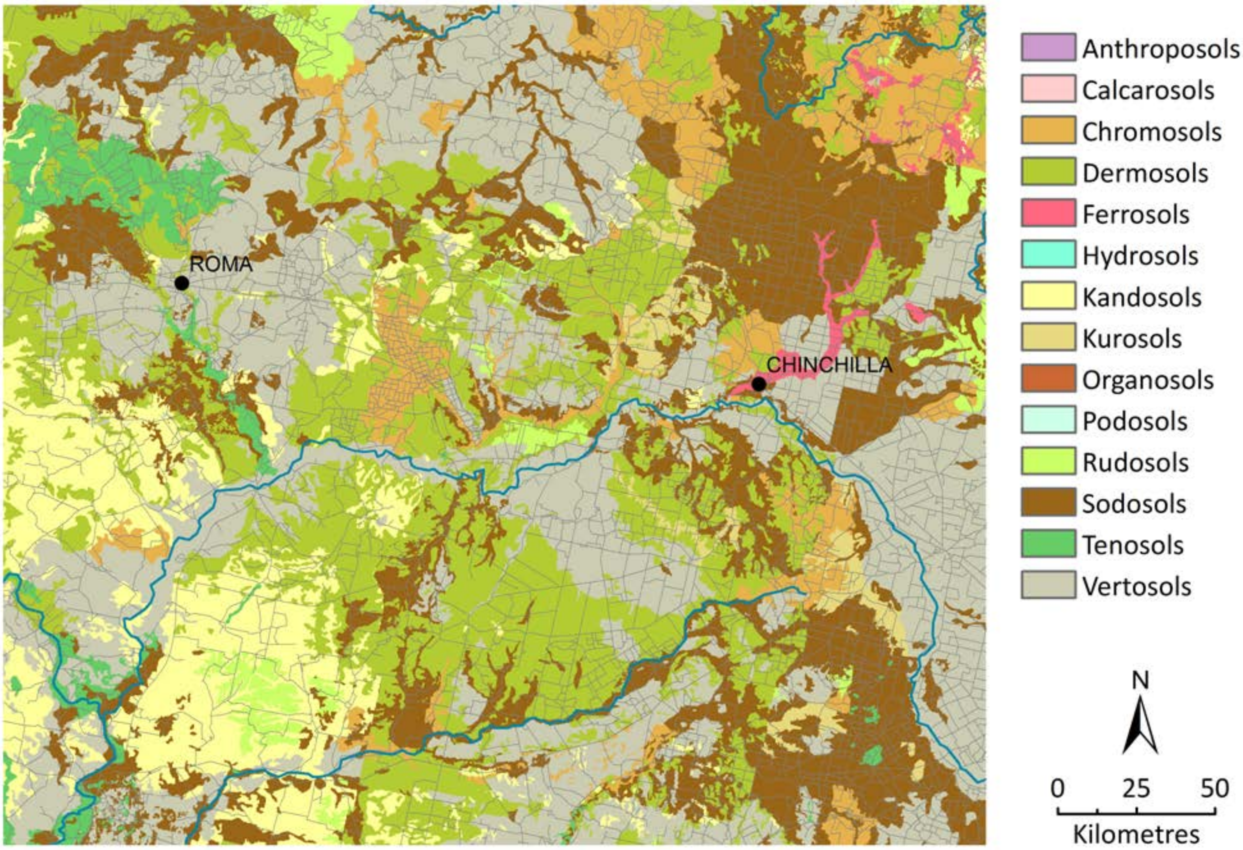

Figure 10.7 Dominant mapped Australian Soil Classification orders, southern Queensland study area
Source: ASRIS (2014)

The soils in this area have been relatively intensely studied and mapped through CSIRO and Queensland Government land resource activity (see Galloway et al., 1974 and Maher, 1996). A number of soil characteristics that are important to agricultural production, requiring significant management consideration and ongoing inputs, have been identified. These include important nutrient deficiencies (P, N, Zn); significant areas of acidic subsoils, often associated with high salinity levels; low organic carbon levels that would be easily depleted through cropping practices; and reduced effective plant-available water-holding capacity due to subsoil accumulation of salts, or impermeable layers associated with high sodicity levels. Risk of erosion on bare soils can also be significant. The Queensland agricultural land audit (Queensland Government, 2013) identified that most soils throughout the region exhibit characteristics that constrain or prevent their use for one or more agricultural land uses or crop types. More than half of the potential cropping area exhibits four or more limitations.

10.6 Pest and disease risk

A total of 236 species were identified as potential pests or pathogens of five of the crops evaluated for the southern Queensland region; many of these were pests or pathogens on multiple crops (Appendix 10.1, separate document). For all these crops, it is almost certain that at least one of these pests or pathogens will invade the region (Table 10.1), because many are already present in Australia and at least one is present in Queensland. Despite the large numbers of pests and pathogens assessed, only a small proportion of species have been identified as major or significant pests of each crop (CABI, 2011) (Appendix 10.1). However, for many of these crops (sorghum, maize, mungbeans, cotton), at least one of the major pests is already found in Queensland and therefore represents a significant threat, with a potentially high impact.

Table 10.1 Invasion likelihood, most likely impact and overall biosecurity risk from insect pest and fungal pathogens to proposed crops of the Darling Downs – Maranoa region

Values of 1 denote almost certain likelihood, very high impact and very high risk, while values of 0 reflect no likelihood, impact or risk.

CROP	INVASION LIKELIHOOD	IMPACT	RISK
Broadacre food			
Sorghum	1	0.1	0.1
Maize	1	0.4	0.4
Chickpea	1	0.1	0.1
Mungbean	1	0.4	0.4
Fibre/other			
Cotton	1	0.4	0.4

10.7 Crop production

10.7.1 BROAD OVERVIEW OF CROP TYPES AND AGRONOMY

The potential productivity of a range of broadacre and industrial crops was investigated for the Darling Downs – Maranoa region. There is already a well-established irrigated cropping industry in the region. In this analysis, it was decided to build largely on the existing suite of crops, given the infrastructure already in place. Discussions with agronomists and farmers indicated that this was the most likely scenario for new water available from coal seam gas extraction.

Broadacre cropping is characterised by large-scale (area), relatively low input, high-volume production of a commodity with a relatively low unit value (in per-tonne terms). Dryland and irrigated cereal production is well established in Australia, with around 20 million ha grown annually. Cereal crops are either winter or summer grown; summer crops dominate the northern parts of Australia's cereal-cropping area. Cereals are already widely grown in the Darling Downs – Maranoa region, predominantly in dryland farming systems, but also under irrigation, especially where there may be reduced certainty about water allocations in the months ahead, or as a rotation crop with cotton. Data from the latest Agricultural Census in 2010–11, undertaken at the Statistical Local Area scale, showed that, in the Western Downs statistical region, which takes in a large proportion of the Darling Downs – Maranoa region, winter grains (wheat, barley, oats) produced $84.3 million in gross value, sorghum $84.7 million and maize $3.8 million (ABS 2012a, 2012b). Together, cereal crops occupied around 340,000 ha (Table 10.2).

Pulses are legume crops that, like cereal crops, are grown for the grain. Being legumes, these crops 'fix' atmospheric nitrogen and minimise the need for inorganic nitrogen fertiliser. Because this 'fixed' nitrogen is also available to subsequent crops, pulses are often grown in rotation with high-nitrogen-demanding crops, such as cereals or cotton.

Approximately 2 million ha of pulse crops are grown annually in Australia. Many pulse crops have a relatively short growing season, and are well suited to opportunistic production when there is sufficient available water (either stored in soil or available from irrigation). Chickpeas and mungbeans are grown extensively in the Darling Downs – Maranoa region. In 2010–11, they contributed $12.5 million in gross value from the Western Downs region, with chickpeas providing $0.6 million in gross value (Table 10.2) (ABS 2012a, 2012b).

Horticulture production is an important industry for Australia, occurring in every state, and accounting for approximately 20% of the farm-gate value of Australian agriculture. Production is highly seasonal, and annual crops will often include staggered planting on a single farm during the growing season to extend the harvest time.

Market price of horticulture products can be highly volatile, and subject to multiple supply, demand and substitution forces. The Darling Downs – Maranoa region produces melons, pumpkins, vegetables and citrus fruit. Melons are the most important crop, with production centred around Chinchilla and St George in the southern part of the region. Melon production occurs from November to April, which is seasonally opposite to the other tropical melon-growing areas examined in this project.

For the purpose of this study, industrial crops are defined as those that require a major processing step in their production soon after harvest. Industrial crops are generally high volume, with processing facilities sited nearby to reduce costs of transport from where they are grown to where they are processed. The industrial crop considered in analysis of the Darling Downs – Maranoa region was cotton.

The cotton industry in Australia has grown significantly over the past three decades. This has been a result of new genetically modified varieties, better agronomic management, increased use of irrigation for cotton, cost-efficient harvesting and processing, and marketing. A record crop was produced in 2011–12, with more than 583,000 ha planted. This area yielded more than 5 million bales (around 8.6 bales/ha), with a total forecast value of close to $3 billion.

Dryland and irrigated cotton production is the single most valuable crop grown in the Darling Downs – Maranoa region, generating more than $115 million in 2010–11 from more than 500,000 bales of cotton (Table 10.2) (ABS, 2012a, 2012b). The area of irrigated cotton grown in the region in 2010–11 was more than 20,000 ha, compared with 33,000 ha of dryland cotton. Because of the variable supply of irrigation water, the area of cotton either fully irrigated or supplemented with irrigation varies greatly from year to year. Numerous gins are located in the region around Dalby, Cecil Plains, Goondiwindi and St George.

With the significance of the beef industry in the region, there is strong local demand for forage hay and/or silage. This hay is used primarily to supplement feedlot rations, to provide the 10 to 20% of roughage required to balance grain-based diets. In addition, hay is used to feed cattle, horses and other ruminant livestock in yards, especially weaners and other animals being held for short periods. Both forage sorghum and leguminous crops such as lablab and lucerne are grown in the region.

Table 10.2 Crop production in the Western Downs region

Values include both irrigated and dryland crops.

CROP	AREA (ha)	PRODUCTION (t)	VALUE ($million)
Maize	3,030	16,627	3.8
Sorghum	125,262	397,842	84.7
Wheat, barley, oats	227,197	330,874	84.3
Chickpea	29,604	15,725	6.3
Mungbean	9,277	7,947	6.2
Melon	460	3606	2.7
Pumpkin	41	193	0.1
Fruit trees (citrus)	986	1001	0.6
Cotton (irrigated)	22,490	29,365	115.5[a]
Cotton (dryland)	32,790	22,204	
Forage hay	4,212	15,180	3.9

a Value is aggregated over both dryland and irrigated cotton.
Source: ABS (2012a, 2012b)

10.7.2 **MARKET ANALYSIS OF CROPS**

There is a range of market opportunities for the crops that are currently grown in the Darling Downs – Maranoa region, and for those that potentially could be grown under an expansion of the irrigation area. The following section highlights some of these opportunities for the range of broadacre, higher-value and industrial crops that are analysed in the cropping scenarios for the Darling Downs – Maranoa region. A more detailed market analysis of each commodity is given in Appendix 4.1.

Broadacre crops

Maize

In Australia, livestock feeding of maize accounts for around 54% of total domestic consumption, and food and industrial consumption accounts for the remaining 46%. Maize is a minor component of the feed complex, but more than 90% of feed maize is consumed by poultry or pigs; only a small amount is consumed by feedlot cattle.

The most important export markets for maize are Japan and the Republic of Korea, but Australian maize comprises less than 1% of these countries' imports. The dominance of Japan and Korea as import markets has been falling in recent years, and growth in world maize imports has been driven by Latin America and member states of the Association of Southeast Asian Nations (ASEAN).

Asia is expected to be a driver of world maize consumption, largely as a result of growing demand for maize as a feed grain. This may present export opportunities. However, Australia does not yet have access to China's market for maize. Australia's status as a producer of non–genetically modified (GM) maize provides marketing opportunities to access high-value niche markets. Main competitors in Japan and Korea are the United States, Argentina and Brazil. Increasing demand for non-GM maize in Asian markets means that Australian exporters can command a premium above the world price.

Domestic marketing opportunities will depend largely on poultry and pig numbers. Over the medium term, pig and poultry numbers are projected to rise, supporting domestic demand for maize.

Wheat

Wheat is the major grain produced in Australia, accounting for 62% of all Australian grains production. Production is highly export oriented and, over the 10 years to 2011–12, around 12% was used domestically to produce flour and 10 to 12% used for livestock feed. Feedlot cattle are the main consumers of feed wheat, and the poultry and dairy industries are also large consumers.

Although only the world's eighth-largest wheat producer, Australia is the world's fourth-largest exporter, averaging 12% of the world's trade. Around two-thirds of Australia's wheat exports are shipped to North Asia and ASEAN countries. Major markets in these regions are Indonesia, Vietnam, the Republic of Korea, Japan and Malaysia. Other important markets lie in the Middle East and Africa, including Yemen, Iraq, Kuwait, the United Arab Emirates and Egypt.

Major global wheat producers are the European Union, China, India, the United States and the Russian Federation, which together account for two-thirds of global production. The United States remains the largest global exporter of wheat, but growth in exports has been driven by Australia and the Black Sea region. South Asia, ASEAN countries, the Middle East and North Africa have been the drivers of wheat consumption. Wheat consumption in ASEAN countries has accelerated in recent years and, over the medium term, income and population growth in these countries will increase import demand for wheat as consumers move towards more westernised diets.

In Australia, food consumption of wheat is expected to grow in line with population growth. Other domestic market opportunities will depend largely on livestock numbers in intensive feed industries. With two-thirds of Australian wheat exports currently shipped to North Asia and ASEAN countries, there is potential for increasing feed wheat exports to Asia as diets move towards eating more protein. Increased livestock feed demand is particularly expected from Indonesia, Vietnam and Malaysia.

Chickpea

Most of Australia's chickpea production is exported. Australia is the world's largest chickpea exporter, accounting for 44% of global chickpea trade in 2011. In 2011–12, Australia exported 581,000 t of chickpeas from a total 673,400 t produced. More than 80% of Australia's chickpea exports are destined for South Asia (India, Pakistan and Bangladesh).

Continuing growth in demand from South Asia for pulses is likely, given projections of population growth and the largely vegetarian Hindu diet. Ongoing shortfalls in South Asian production will provide opportunities for Australian chickpea exporters. Opportunity also exists to provide the large South Asian and Middle Eastern migrant communities in Australia with domestically produced chickpeas.

Grain sorghum

Grain sorghum is largely consumed in intensive livestock industries, such as feedlot cattle, pigs and poultry. Feedlot cattle consume around half of all grain sorghum used for feed. Domestic marketing opportunities will depend largely on livestock numbers in intensive feed industries. Poultry numbers are projected to rise, supporting the demand for grain sorghum. Over the medium term, the lot-fed cattle industry is likely to continue to feel pressure from United States competition in the important grain-fed beef markets of Japan and the Republic of Korea. Reduced tariffs under the Korea–Australia Free Trade Agreement and the Japan–Australia Economic Partnership Agreement improve those prospects.

Australia exported around half of its grain sorghum production in 2010–11 and 2011–12. Japan historically has been the major trading partner, but China has recently become an important export destination, taking 25% of exports in 2012–13. The China market is forecast to grow substantially. Australia's main competitors in overseas markets are the United States and Argentina, both generally lower-cost suppliers than Australia. United States grain sorghum exports are projected to be maintained over the medium term, while Argentina's are forecast to increase slightly.

In addition to livestock feed demand, sorghum can be processed into ethanol. For example, an ethanol plant in Dalby, Queensland, has the capacity to process around 200,000 t of sorghum to produce 80 million litres of ethanol annually. In 2011–12, biofuels represented around 1% of Australia's petrol and diesel production. The latest long-term projection of Australian energy supply and demand to 2050 by the Bureau of Resources and Energy Economics is for bioenergy production in Australia to grow by 3.9% per year.

Mungbean

Australian production of mungbeans has almost doubled in the two decades to 2012–13. Currently Australian mungbean production is largely destined for export. In 2011–12, Australia shipped 50% of mungbean exports to India and 22% to the ASEAN member states. Within the ASEAN region, Indonesia was the largest importer of Australian mungbeans. India and ASEAN will continue to be growing markets for Australian mungbeans.

Domestically and internationally, opportunities exist to market mungbeans as a functional food to food manufacturers and consumers. Mungbeans have a range of potential applications, such as starch, flour or paste, and can also be used as an additive to other foods.

Soybean

Australia is a relatively small producer of soybeans. The main production is in northern New South Wales and southern Queensland. Most Australian soybeans are consumed domestically, with the crushing market the primary user. However, demand for edible soybeans has increased in recent years, resulting in higher returns from the food sector and some producers switching to varieties suited to this purpose.

The small Australian exports of soybeans are primarily shipped to Asia (Japan, Republic of Korea, Malaysia and Taiwan) and the Pacific Islands. However, Australia is a net importer of soybean meal and oil. Soybean meal is imported for use in intensive livestock feed, sourced mainly from Argentina and the United States. Soybean oil is imported from Malaysia, Brazil and Argentina. Of Australia's edible soybean imports, more than 95% are supplied by China.

Strong global demand for soybean meal and soybean oil has resulted in world production of soybeans increasing by 130% over the two decades to 2011–12, with yield increases largely the result of increased use of GM seeds. The United States, Brazil and Argentina account for around 80% of world production. Soybean crush accounts for around 90% of world soybean consumption. China is the largest consumer of meal and oil; its expanding livestock feed requirements are the reason for its strong consumption growth. China and Indonesia are the world's largest consumers of soybeans for food, together accounting for 77% of world food consumption of soybeans.

Increased demand for soybean meal from the growing chicken and pig industries in Australia offers an opportunity for potential increased domestic supply of soybeans. However, the cost of Australian production needs to be competitive against imported meal. Also, meeting this growth potential would require increased marketing of the oil resulting from crush. There are also potential opportunities to expand exports of edible-grade soybeans to Asian markets such as Japan, Taiwan, Thailand, Singapore and Indonesia, all of which have growing demand for edible soybeans. These markets are traditionally supplied by the United States and Canada. It will be essential for Australian production of soybeans to be competitive against other competitors in these Asian markets.

High-value food crops

Watermelon

The major melon cultivars produced in Australia are watermelons, rockmelons and a number of honeydew varieties. Watermelons account for 60% of production, while rockmelons account for 30%. Queensland's melon production was around 70,500 t in 2010–12, around one-third of Australia's total production. In the Darling Downs, melon production was estimated at 13,400 t in 2010–11, 19% of Queensland's total production.

The melon industry's exposure to international markets is limited. Most production is sold into the domestic retail and food service markets. Only around 5 to 6% of melon production is exported. New Zealand is the largest market, taking 38% of total melon exports in 2012–13. Imports of melons are negligible.

World melon production has almost trebled over the past two decades. Two-thirds of global watermelons and just over half of all other melons are now produced by China. China is also one of the world's largest melon-consuming countries, second to the United States and ahead of the European Union. The United States and China are also the world's largest importers of watermelons, together accounting for more than one-third of world imports in 2011. For other melons, the largest import markets are the United States and the European Union.

There are perhaps greater opportunities for producers to export high-quality fresh produce to Northern Hemisphere countries, particularly to ASEAN countries and the Middle East, which are already important markets for Australian melon exports. Although China is a major producer of watermelons, its status as one of the largest importers offers market opportunities for Australian exporters of high-quality melons.

Sweet corn

Sweet corn production in Australia is around 70,000 t/year. New South Wales and Queensland produce more than 90% of the national production, which goes into both retail markets and the processing sector. Sweet corn is available all-year round. The main varieties grown are Golden Jubilee, Golden Sweet (super sweet) and Pearl (bicolour super sweet). The domestic retail market value of fresh sweet corn is about $110 million. The processing sector requirements are met by both local production and imports, with more than 17,000 t of processed corn imported into Australia in 2009.

Industrial and other non-food crops

Cotton

Australia is a relatively minor cotton producer on a global scale, but in recent years became the world's sixth-largest producer. In 2012–13, Australia produced 1 million tonnes of cotton lint and 1.4 million tonnes of cotton seed. About one-third of production is in Queensland, with most of the remainder in northern New South Wales.

The level of Australian cotton production depends largely on the availability of irrigation water. Currently, about 95% of Australian cotton production takes place in the Murray–Darling Basin (MDB) region, and usually more than 90% is irrigated. Increased diversions of irrigation water away from farms to environmental uses in the MDB are expected to have a minor effect on Australian cotton production over the medium term, but the prospects for significant expansion in irrigated plantings in the MDB are slight.

Around 95% of Australian cotton lint is exported to international markets, mainly in Asia, while a large proportion of cotton seed is consumed in Australia. In the 10 years to 2012–13, Asian markets accounted for 98% of total Australian lint exports, with the remainder exported to Europe. China has now emerged as the largest importer of Australian cotton, taking around 70% of Australia's exports in 2012–13. Other important markets are Indonesia, Thailand and the Republic of Korea.

Given Australia's small textile manufacturing sector, domestic textile mills consume only about 3% of the cotton industry's output. It is unlikely that additional demand for ginned cotton will be created domestically because labour costs in textile manufacturing are much lower overseas. Demand from other ASEAN countries, such as Cambodia and Vietnam, is expected to grow because wage inflation in China has led to Chinese manufacturers and global textile companies moving their manufacturing to other low-cost nations. Other potential markets for Australia that could be further developed include Bangladesh and Pakistan.

Hay/forage

Hay plays a crucial role in livestock production, particularly during times of poor weather conditions when grass is not readily available. The majority of Australia's hay production is in southern Australia and is used domestically by livestock sectors in southern Australia. Hay and silage play an important role in Queensland in the feedlot sector. Queensland's feedlot capacity is around 600,000 head, with nearly 500,000 head being fed in feedlots at any particular time (ALFA, 2014) – this is about 60% of Australia's total feedlot cattle numbers. Hay or silage usually contributes 10 to 20% of the feedlot ration. This requires around 200,000 to 300,000 t of hay and/or silage per year for Queensland feedlot cattle, in addition to the hay that is fed as part of more extensive beef operations.

Export markets for hay have developed over the past two decades, principally to Japan (64% of exports in 2012–13), the Republic of Korea, Taiwan and China. Other smaller markets include the Middle East (particularly the United Arab Emirates, Saudi Arabia and Qatar), Indonesia and Malaysia. Livestock export ships are also a significant destination for Australian hay exports, although this outlet has diminished since 2008–09, with falling live sheep exports to the Middle East and a live cattle trade affected by Indonesia's import restrictions.

10.7.3 **CROP PRODUCTION ESTIMATES**

Estimates of crop production for identified broadacre, high-value and industrial crops were made using the APSIM (Agricultural Production Systems sIMulator) simulation model (Keating et al., 2003) for crops that ASPIM has the potential to simulate (broadacre cereal and pulse crops, cotton, forage hay) (Table 10.3), and expert-based analyses and/or historical yields for the crops without APSIM capability.

The soil used in the APSIM simulations was parameterised to represent a 'Condamine' grey clay, a dominant Vertosol soil in the Darling Downs region that supports both dryland and irrigated cropping. The soil holds 164 mm of water to a depth of 2 m. Historical meteorological data from Condamine for the period 1900 to 2010 was used in the simulations to generate variation in crop yield and irrigation water required. It should be noted that this is a different climate station from that used to summarise the climate for the overall region in Section 10.3. The Condamine climate station is representative of the areas most prospective in terms of new irrigation water made available from extraction of coal seam gas.

APSIM assumes best practice for managing a crop, and the absence of pest- and disease-related stress. Simulations were undertaken to achieve crop growth in non-limiting soil water and nutrient environments.

Applied irrigation was triggered in the model using soil water deficit and the potential root zone of each crop. Natural reset points at the end of winter (September), when the soil profile is normally dry, were selected to initialise the soil water, soil nitrogen and surface cover each year, so that only the effect of seasonal climate and applied irrigation on crop production were captured. Irrigation management assumed 100% efficiency in applying irrigation to the crop, regardless of availability of supply.

The values presented for water applied to a crop do not equal the total water use to produce the crop (Table 10.4). APSIM assumes 100% efficiency of irrigation water supply, and reported figures are 'on crop', not accounting for delivery from the water storage. Water inefficiencies exist in the storage, transport and on-farm application of the water. The outputs from modelling (and estimated for non-modelled crops) are potential productivity and irrigation water use on a per-hectare basis.

Table 10.3 Simulated crop yields using APSIM (for those crops with 20th, 50th, 80th percentile values); for melons and vegetables, yields were based on local consultations with agronomists from the Queensland Department of Agriculture, Fisheries and Forestry

APSIM yields for broadacre crops are expressed in tonnes of dry matter per hectare. For the economic assessment, these were converted to fresh yields, based on moisture contents of 12 to 14%.

CROP	YIELD PERCENTILE		
	20th	50th	80th
Broadacre (t/ha)			
Maize	12.0	11.2	10.4
Sorghum	9.2	8.6	8.0
Wheat	6.9	6.6	6.2
Chickpea	3.5	3.2	3.0
Mungbean	2.2	2.0	1.7
Soybean	3.4	3.1	2.8
High value			
Watermelon		30 t/ha	
Sweet corn (fresh)		11.8 t/ha	
Industrial/other crops			
Cotton (bales/ha)	9.6	9.0	8.4
Forage sorghum (t/ha)	16.4	15.9	14.4

Table 10.4 Irrigation water use (mm per crop) for the broadacre and industrial crops simulated in APSIM
Actual water applied may be considerably higher because water is not used with 100% efficiency.

CROP	IRRIGATION WATER USE (mm) PERCENTILE		
	20th	50th	80th
Broadacre			
Maize	670	581	498
Sorghum	355	286	240
Wheat	300	268	207
Chickpea	232	166	128
Mungbean	170	117	76
Soybean	413	351	286
Industrial/other crops			
Cotton (bales/ha)	375	333	277
Lablab hay	375	315	240

Maize

Maize was sown in September for a January–February harvest. This avoids high temperatures in the seedling stage. This provides a high yield of more than 11 t/ha, but this high yield of grain is associated with high water use.

Sorghum

Sorghum was sown in the simulation on 30 September. Planting at this stage and harvesting in January–February means that the growing seedling can escape the hottest time of the year when it is vulnerable. A median dry-matter grain yield of 8.6 t/ha was simulated, which compares favourably with high-yielding commercial crops.

Wheat

Wheat was sown in the simulations on 15 June, with harvest in October–November. Sowing at this time eliminates most risk from frost damage occurring at the time of flowering. Harvest needs to occur before early summer rains, and before temperatures become too high and begin to damage protein quality. Median yields were simulated to be 6.6 t/ha.

Chickpea

Chickpeas were sown in the simulations on 1 May. Chickpea develops in a relatively short time period, and is deep rooted and well suited to opportunistic cropping. There is some merit in planting chickpea after a summer-grown crop such as sorghum or cotton. Median yields simulated for chickpea were 3.2 t/ha.

Mungbean

Mungbeans were sown in the simulations on 15 September. Mungbean is quick maturing and, like chickpea, can be opportunistically sown, but is often part of planned rotations. Mungbean price can vary greatly with seed quality when sold for human consumption (which generates the highest prices). Rainfall during the later stages of pod fill can have a detrimental effect on grain quality, and consequently price received, so planting is usually timed to ensure a low risk of receiving rainfall at this crucial time. Median yields were simulated to be 2.0 t/ha.

Soybean

Soybeans were sown in mid-December in the simulations. Soybeans grow best in summer in southern Queensland**.** They mature fairly quickly when sown at this time because the shortening day length after December induces flowering. When harvested in April, soybeans were simulated to yield 3.1 t/ha. In southern Queensland, soybeans have also been grazed as part of a legume ley rotation, rather than being harvested for their grain.

Cotton

In the simulations, cotton was sown on 15 October. This allows cotton to grow over the warmer months, with harvest occurring in April to avoid the wetter summer months. Cotton is susceptible to rainfall during late crop development, which can downgrade cotton quality and price. Cotton yields were simulated to be 9.0 bales/ha. Over the 100-year simulation, the yield ranges from 6 bales/ha to more than 12 bales/ha, which encompasses the yields obtained commercially in this region.

Forage sorghum

Forage sorghum was sown at the end of September in the simulations. It was grown as a hay crop and was cut three times during the growth period until the following June–July. Yields of forage sorghum hay were simulated to be nearly 16 t/ha of dry matter, and approximately 90% of this simulated yield is harvested as hay. An alternative to making hay would be to graze forage sorghum or to make silage.

10.7.4 **CROPPING CALENDAR**

Cropping calendars identify sowing times and the growing season for different crops. The time during which a crop can be reliably and profitably sown is called the sowing window. Sowing windows vary in both timing and length among crops. The cropping calendar (Table 10.5) identifies sowing and growth windows for the crops analysed for the Darling Downs – Maranoa region.

The cropping calendar was developed based on knowledge of these crops in the region. The sowing and growth windows identified correspond with the times of year that are likely to maximise potential crop yield and, where relevant, align with crop rotation sequences – for example, summer grain crop followed by winter pulse. Sometimes, crops can be successfully sown outside of the identified sowing windows with only a small yield penalty. It should be noted that sowing to achieve maximum potential crop yield may not always be possible.

Table 10.5 Calendar of sowing for annual crops in the Darling Downs – Maranoa region

CROP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Broadacre												
Maize	X	X	X						X	X	X	X
Sorghum	X	X	X	X					X	X	X	X
Wheat						X	X	X	X	X	X	
Chickpea					X	X	X	X	X	X		
Mungbean	X	X	X						X	X	X	X
Soybean	X	X	X	X								
High value												
Watermelon	X	X	X	X				X	X	X	X	X
Sweet corn	X	X	X	X	X			X	X	X	X	X
Industrial/other												
Cotton	X	X	X	X	X					X	X	X
Forage sorghum			X	X	X	X	X	X	X	X	X	

10.8 Gross margin analysis: sensitivity to price, production and supply chain costs

The crop gross margin is the difference between the gross income and variable cost of growing a crop.

Variable costs include those associated with crop management, harvesting, transport and marketing. For established cropping regions like the Darling Downs – Maranoa, there has been significant investment in processing facilities (grain storage, milling/grading facilities, cotton gins) close to the production areas, to create efficiencies in transport and costs of production. Also, agribusinesses are well established and provide services in fertiliser, machinery sales and repairs, and agronomy.

Table 10.6 shows the gross margins for a range of crops specific to the Darling Downs – Maranoa region. The gross margins do not include overhead costs (e.g. business administration, insurance) or capital costs (e.g. farm equipment, irrigation infrastructure) that must be met even if a crop is not grown. For crops modelled using APSIM and more than 100 years of historical climate data, gross incomes were calculated using the modelled 20th, 50th and 80th percentile exceedance crop yields over the historical period. For crops that could not be modelled (e.g. watermelon and sweet corn), estimated yields are based on production data in the region, or in other regions if that crop is currently not grown. Costs of production were based on gross margins developed by local agricultural economists and agronomists – in particular, Graham Harris and Clinton McGrath (Queensland Department of Agriculture, Fisheries and Forestry, Toowoomba).

Gross margin analyses should be used with care because they are highly sensitive to price, yield, transport costs and input costs, not just within a particular region but between individual farms.

For horticultural crops, which mostly supply domestic markets that have a finite demand and can be easily oversupplied, there can be rapid price movements over days and weeks. This is highlighted in Figure 10.8, which shows movements in the wholesale price of watermelons and round beans at the Brisbane markets in 2013. In contrast, significant price movements in broadacre crops commonly play out over a timescale of months and years (Figure 10.9).

Table 10.6 Gross margin analysis for existing and potential crops in the Dawson Valley, based on existing supply chains

Yields of crops simulated by APSIM on a dry-matter basis have been adjusted upwards to account for moisture content of marketed product.

CROP	LOCATION FOR MARKET OR PROCESSING	YIELD UNIT/ha	MEDIAN YIELD (per ha)	PRICE PER UNIT YIELD ($)	VARIABLE COSTS LESS FREIGHT ($/ha)	FREIGHT COSTS ($/ha)	TOTAL VARIABLE COSTS ($/ha)	GROSS MARGIN ($/ha)
Broadacre								
Maize	Darling Downs	tonnes	12.7	280	1,819	191	2,010	1,546
Sorghum	Darling Downs	tonnes	9.8	240	1,041	147	1,188	1,164
Wheat	Darling Downs	tonnes	7.5	260	978	113	1,091	859
Chickpeas	Darling Downs	tonnes	3.6	500	792	54	846	954
Mungbeans	Darling Downs	tonnes	2.3	810	583	35	618	1,253
Soybeans	Newcastle	tonnes	3.5	500	961	210	1,171	579
High value								
Watermelons	Brisbane	tonnes	30	650	13,023	2,100	15,124	4,376
Sweet corn	Brisbane	cartons (9 kg)	1,200	12	9,760	1,200	10,960	3,440
Industrial/other								
Cotton	Darling Downs	bales	9.0	500	2,887	134	3,021	1,857
Forage sorghum	Darling Downs	tonnes	14.3	160	1,350	143	1,493	795

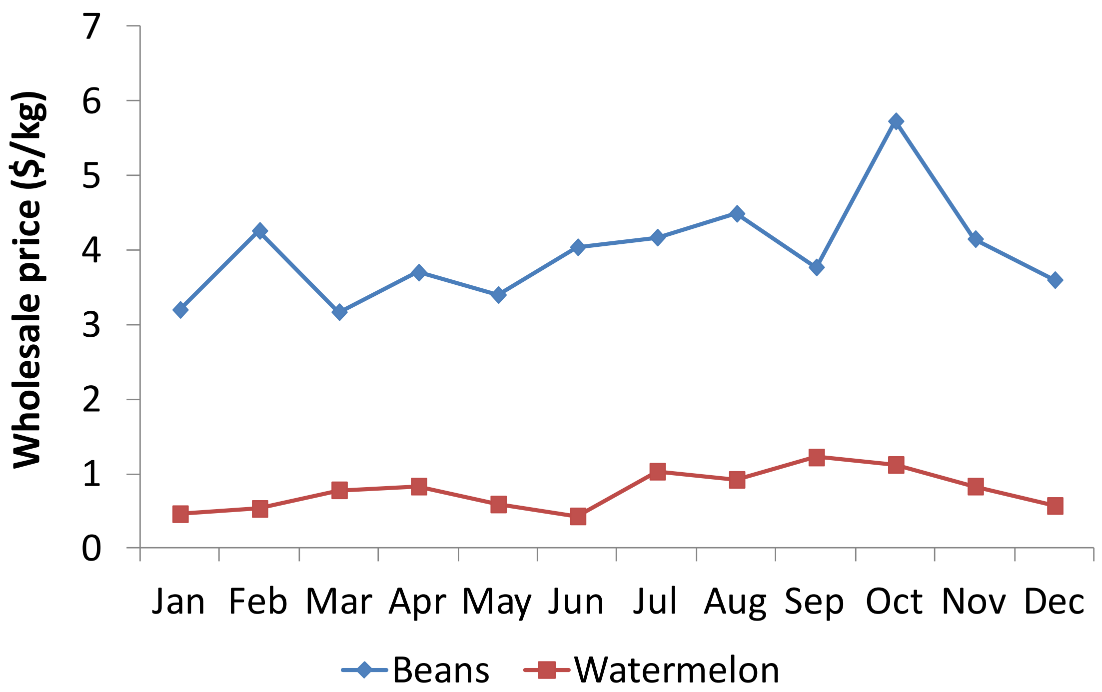

Figure 10.8 Wholesale prices for round beans and seedless watermelons at the Brisbane markets during 2013

Source: Data provided by Ausmarket Consultants, Brisbane

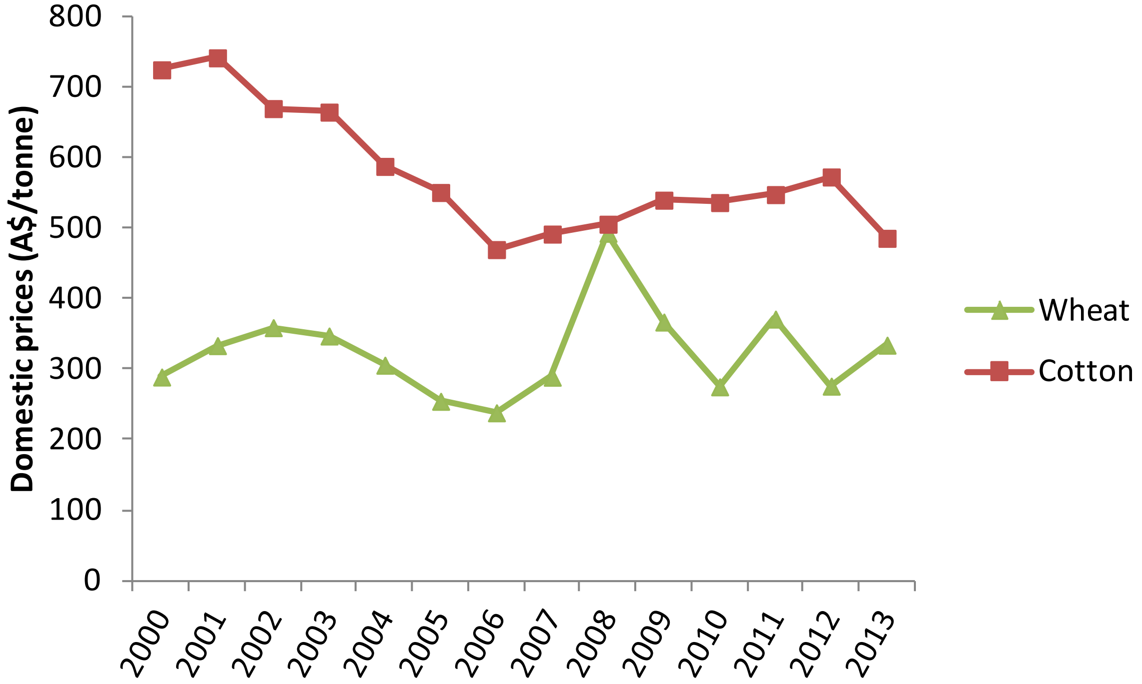

Figure 10.9 Domestic prices for wheat and cotton, 2000 to 2013
Source: Data supplied by ABARES

10.8.1 **BROADACRE CROPS**

For the broadacre crops, the average gross margins were all positive. Sorghum, wheat, chickpeas and mungbeans all provided gross margins from $800/ha to $1200/ha. The combination of high yields of maize and a slightly better price compared with other grains led to a higher gross margin (around $1500/ha). Compared with the more remote tropical regions in this study (Pilbara, Ord, Mataranka and Flinders/Gilbert), the Darling Downs – Maranoa region has well-established and well-located storage and processing facilities, and supply chains in close proximity for most crops – for example, numerous feedlots that can use cereal grain, grain receiving depots, cotton gins, and pulse seed grading and processing facilities. Since grain silos/storages, or milling and grading facilities are within 100 km of the production area, transport costs make up only a relatively small percentage (2 to 5%) of the value of production, and between 5 and 12% of the total costs of production (Table 10.7). An exception to the low freight costs is for soybeans, which need to be transported to Newcastle for processing to soybean oil. Transport costs represent 12% of the value of soybeans and 18% of the costs of production. As a consequence, gross margins are at the lower end of the scale for the broadacre crops analysed.

Table 10.7 Freight costs as a percentage of total value of production and total production costs for a range of crops in the Darling Downs – Maranoa region
Location represents the point of wholesale or processing

CROP	LOCATION FOR MARKET OR PROCESSING	FREIGHT COSTS AS A PERCENTAGE OF TOTAL VALUE OF PRODUCTION (%)	FREIGHT COSTS AS A PERCENTAGE OF TOTAL COSTS OF PRODUCTION (%)
Broadacre			
Maize	Darling Downs	5.4	9.5
Sorghum	Darling Downs	6.3	12.4
Wheat	Darling Downs	5.8	10.4
Chickpea	Darling Downs	3.0	6.4
Mungbean	Darling Downs	1.9	5.7
Soybean	Newcastle	12.0	17.9
High value			
Watermelon	Brisbane	10.8	13.9
Sweet corn	Brisbane	8.3	10.9
Industrial/other			
Cotton	Darling Downs	2.7	4.4
Forage sorghum	Darling Downs	6.3	9.6

10.8.2 **HIGH-VALUE FOOD CROPS**

The gross margins for intensive horticultural production in the Darling Downs – Maranoa region were strongly positive, based on the assumptions used in this analysis. All horticultural crops have high input costs and, as indicated in Figure 10.8, price movements can occur rapidly in response to supplies at a national scale. The sensitivity of gross margins to price of watermelons and sweet corn grown in the Darling Downs – Maranoa region is highlighted in Table 10.8, which demonstrates that, although gross margins per hectare can be high, large losses can also occur when product is oversupplied and prices fall.

Table 10.8 Gross margin sensitivity to price for horticultural crops in the Darling Downs – Maranoa region
Baseline gross margins are the same as reported in Table 10.6. The price sensitivities are in steps of 15%.

PRICE SENSITIVITY	WATERMELONS ($/ha)	SWEET CORN ($/ha)
–45%	–$3,083	–$2,068
–30%	–$596	–$232
–15%	$1,890	$1,604
Baseline	$4,376	$3,440
+15%	$6,863	$5,276
+30%	$9,349	$7,112
+45%	$11,835	$8,948

It was assumed in this analysis that both watermelons and sweet corn were sold in Brisbane. Consequently, freight costs as a percentage of total value of production or of total costs were modest, at 8 to 14%. Labour costs for harvest and postharvest activities were higher, representing 15 to 25% of total production costs for watermelons and sweet corn; they therefore have a significant influence on net returns. Labour supply is sourced largely from backpackers, who can obtain a second-year holiday visa if they undertake three months of work in a regional area of Australia. Labour can be a particular constraint in this region because of the high level of mining activity and its rapid expansion in the region in recent years.

10.8.3 **INDUSTRIAL AND OTHER CROPS**

Gross margins for cotton were higher than for any other crop and highlight the growth of this crop under irrigation in recent decades. Cotton is a well-established irrigation crop in the region (>20,000 ha in the Western Downs statistical region), and there are numerous cotton gins in the region – the distances from the farm to the gin are no more than 100 km and generally less than 50 km. This resulted in freight costs making up only a small percentage of the total value of production and the costs of production.

Compared with most of the food crops, forage sorghum generated a lower gross margin, but was still highly positive at around $800/ha. The variable costs are reasonably high because of the amount of nitrogen fertiliser and water applied, and the need to bale and harvest the crop three times during its 9–10-month growth cycle. Given the bulky nature of the product, it needs to be used locally to keep freight costs down to a small percentage of the value of production and overall costs.

10.8.4 **DIFFERENT SUPPLY CHAIN OPTIONS AND GROSS MARGINS**

For most crops investigated in the Darling Downs – Maranoa region, there are markets, storage and processing facilities within the region. This is in contrast to the tropical regions in this study, where there are no local markets or processing facilities. Although the grain industries are relatively well serviced by receival depots and other processing facilities, there is potential for improvements in efficiencies and effectiveness. There is a move to more clustering and centralisation of grain depots and storages, to achieve improved efficiencies through handling costs, and more coordinated road and rail links. While these changes are necessary to maintain ongoing industry competitiveness, they do not represent a major shift in supply chains.

Compared with all other broadacre crops, soybeans cannot be processed locally except for a boutique oil plant on the Darling Downs. Soybeans need to be transported to Newcastle for oil extraction or, in some cases, can be exported via Brisbane as a food crop after value-added processing. Building on the Dawson Valley region case study, it has been assumed in the supply chain scenario that an oilseed crushing plant is established in Moura that is capable of processing a range of oilseeds, including cotton, soybean and sunflower. Table 10.9 shows that establishing an oil crushing plant in Moura halves the freight costs and increases gross margins by around $100/ha.

High-value watermelon and vegetable crops are sold mostly in the Brisbane, Sydney or Melbourne wholesale markets, or are contracted directly to supermarket chains. As noted for horticultural crops in other regions, expanding production needs to focus on export markets because of the capacity constraints in the domestic markets. In this supply chain scenario, new Asian markets were assumed for premium sweet corn production, and freight was via the new airport, outside Toowoomba. Although that airport has not yet been completed, both inbound and outbound freight is seen as a key opportunity for the region. This airport should offer some reduced handling costs compared with large airports in the capital cities. Current air freight costs from Brisbane to Singapore or Hong Kong range from $600 to $900/t, when handling, documentation and quarantine costs are considered. In this supply chain scenario, air freight costs of $650/t were assumed; it was also assumed that a premium Asian market can be achieved for sweet corn at a premium price 33% higher ($16/carton) than assumed for domestic production. Even with the price premium, the gross margin is somewhat less than for domestic production. However, it offers an alternative market to offset price risks associated with oversupply in the domestic market.

Table 10.9 Change in gross margin for soybeans and sweet corn, assuming local processing facilities are present in the Darling Downs region (soybeans) or a new export market has been established (sweet corn)

CROP	LOCATION FOR MARKET OR PROCESSING – BASELINE	GROSS MARGIN ($/ha)	LOCATION FOR MARKET OR PROCESSING – SCENARIO	GROSS MARGIN ($/ha)	ASSUMPTIONS FOR SUPPLY CHAIN SCENARIOS
Broadacre					
Soybean	Newcastle	579	Moura	683	Multicrop oil crushing plant established in Moura
High value					
Sweet corn	Brisbane	3440	Hong Kong	2520	Export via air freight from Toowoomba

10.9 Integrated scenario analysis: investment and supply chain options

The analyses in the previous sections have focused on individual crops, their production characteristics in the Darling Downs – Maranoa region, farm gross margins, and supply chain options for the individual crops. In this section, scenarios are examined for agricultural production at a regional scale, with implications for the regional value of production, supply chain logistics and infrastructure. The section concludes with a case study comparing investment options.

The regional-scale analysis assumes that 5000 ha is available for irrigation, with a 95% reliable water supply. This is based on likely amounts of coal seam gas water available (25 GL averaged over 15 years) for beneficial (agricultural) use within the region. This water will have high reliability (95%), given continuous coal seam gas extraction from the various gas fields.

10.9.1 INVESTMENT AND SUPPLY CHAIN OPTIONS

Two scenarios were chosen to explore crop production systems (Table 10.10).

Scenario 1

The first scenario assumes a scaling-up of existing cropping in the region, using existing infrastructure such as cotton gins and grain depots, rather than investing in new infrastructure. This was based on the assumption that the additional water supply (25 GL/year) from the coal seam gas industry may be reliably provided for no more than 15 to 20 years.

Consequently, the scenario centres on cotton grown in a cotton–cotton–wheat rotation over 3 years. These rotations are based on industry practice (Table 10.11) and use the most common cycle of rotation – that is, two cotton crops followed by a rotation crop. Both of the rotation crops are widely grown in the Darling Downs – Maranoa region, which means that there is adequate supporting infrastructure.

Table 10.10 Scenarios used to explore implications of scaled-up production at the regional scale

CROP	AREA OF LAND (ha)	CROP YIELD (t/ha)	LOCATION FOR MARKET OR PROCESSING	ASSUMPTIONS FOR REGIONAL SCENARIO
Scenario 1 – mixed cropping, no new infrastructure				
Cotton	3400	9.0 bales	Darling Downs	Existing cotton area expanded. Grown in rotation with wheat
Wheat	1600	7.5	Darling Downs	Grown in rotation with cotton
Scenario 2 – mixed cropping and significant horticulture				
Maize	2000	12.7	Darling Downs	Grown in double crop rotation with chickpeas
Chickpea	2000	3.6	Darling Downs	Grown in double crop rotation with maize
Watermelon	500	10.5	Brisbane	Grown in rotation with mungbeans
Sweet corn	500	2.2	Hong Kong	Exported by air freight from Toowoomba
Forage sorghum	2000	14.3	Dawson	Hay for local beef industry

Table 10.11 Crops used in rotation with cotton

CROP	% OF FARMS GROWING CROP IN PAST 3 YEARS	% THAT THOUGHT THIS HAD MOST BENEFIT FOR COTTON
Wheat	78	46
Chickpea	31	12
Sorghum	26	4
Barley	20	5
Maize (corn)	19	16
Mungbean	12	2
Faba bean	10	11
Canola	10	0
Soybean	3	4
Vetch	3	4
Sunflower	1	0
Other: French white millet, canary seed, lablab	8	9
None	11	4

Source: Roth Rural (2013)

Scenario 2

The second scenario assumes a range of mixed broadacre crops, including maize and chickpeas double cropped in rotation to achieve two crops per year. This facilitates close to year-round use of water. Given the presence of a significant beef sector, a significant area was devoted to forage sorghum for use as high-quality roughage in feedlot rations, or as a supplement to grazing cattle held in yards for weaning or in preparation for transport.

Horticulture also features in this scenario, with 1000 ha devoted to an even mix of watermelons and sweet corn. Watermelons are assumed to be marketed through normal domestic channels. For the sweet corn scenario, it is assumed that export markets have been developed into Asia. There is good export potential for sweet corn, which has not been realised, partly because live insects have been discovered in past shipments from Australia. Removal of pests before export is achievable through a new cost-effective fumigant combining ethyl formate with carbon dioxide (AUSVEG, 2011).

Results

The regional-scale implications of the two scenarios operating at 8000 ha in the Darling Downs – Maranoa region are shown in Table 10.12. The two scenarios produced $20 million to $35 million in additional value to the Darling Downs – Maranoa region over and above existing production. Given the extent of agricultural development in this region, which generates production of many hundred millions dollars per year, this is a very modest additional contribution. Scenario 2 produced considerably more value than Scenario 1 because of the relatively large area (1,000 ha) of high-value horticultural production in the form of watermelons and fresh sweet corn. While watermelons are already an important crop in the region, this scenario explored the opportunity for increased vegetable production to be exported to Asia. This was based on the assumption that significantly increased production cannot be absorbed by the domestic market. In this indicative analysis, sweet corn was used as a case study crop, but there are also opportunities for other crops, such as beans and broccoli. Because of the higher costs of air freight, scenarios involving fruit or vegetable export will almost inevitably need to attract premium prices in the destination country.

As with other regions in this study, labour supply is likely to be a constraining factor on expansion of irrigated agriculture. Sourcing labour for seasonal harvests can be challenging. Coupled with the high costs of labour, this may push operations towards crops that involve higher levels of mechanised harvesting – for example, beans, carrots and sweet corn. Skilled labour is also in short supply, particularly in the area of machinery equipment maintenance, because of the demand for these trades in the oil, gas and mining sectors that operate within the region.

Table 10.12 Influence of the two regional scenarios on total flows of product and value of production per year

CROP	TOTAL PRODUCTION (t)	TOTAL VALUE OF PRODUCTION ($)	TOTAL VARIABLE COSTS ($)
Scenario 1 – mixed cropping, no new infrastructure			
Cotton	6,946	16,585,200	10,271,400
Wheat	12,000	3,120,000	1,745,600
Total	18,946	19,705,200	12,017,000
Scenario 2 – mixed cropping and significant horticulture			
Maize	25,400	7,112,000	4,020,000
Chickpeas	7,200	3,600,000	1,692,000
Watermelons	15,000	9,750,000	7,562,000
Sweet corn	5,400	9,600,000	8,340,000
Forage sorghum	28,600	4,576,000	2,986,000
Total	81,600	34,638,000	24,600,000

Transport implications

Both scenarios involve transport to either local use, existing processing facilities (e.g. cotton gin), a local silo, the new airport in Toowoomba, or Brisbane. For watermelons transported to Brisbane, refrigeration was not required because of the short travel time of 4 hours, compared with watermelons grown in northern Australia. From the supply chain analysis information shown in Appendixes 10.2 and 10.3 for each of the two scenarios, minimum fleet requirements have been calculated. They are calculated by month of year, accommodating harvest and transport requirements of each crop. Vehicle requirements account for minor rest breaks en route to the destination, along with time required for loading and unloading. They do not account for major downtime or maintenance. Figures 10.10 and 10.11 show the vehicle requirements by time of year for Scenarios 1 and 2. These requirements do not include vehicle reductions that may be achieved by backloading opportunities on some routes. Compared with other case studies in tropical regions of northern Australia, travel distances are short, with the longest being transport of watermelons to Brisbane. The likelihood of backloading for watermelon transport is likely to be high because of the large amount of general freight (refrigerated and non-refrigerated) transported west to townships along the Warrego Highway. This will significantly reduce the costs from $49/t.

Note that the numbers in Figures 10.10 and 10.11 are based on the number of prime movers, and a Type 1 road train is classed as one vehicle. The numbers in Figures 10.10 and 10.11 are multiplied by 2 for Type 1 vehicles and by 1.5 for B-doubles to give the number of trailers. For both scenarios, the peak total demand is less than two vehicles per day, with the peak period being at least 3 months. This is because the travel distances are short, and a single vehicle can complete multiple trips in one day. These demands are likely to be easily met by vehicle and trailer fleets used for other cropping systems and general freight in the Darling Downs region.

As indicated in the supply chain scenario in Section 10.8, exporting sweet corn by air freight out of Toowoomba is based on a cost structure that is less than existing air freight costs from major ports such as Sydney and Brisbane. Shorter trucking distances to Toowoomba and an airport designed to be able to load directly from trucks creates the potential to reduce the land-based costs associated with air freight. Competitive air freight costs will be dependent on two-way movement of freight – that is, sufficient inbound goods to share the costs with outbound freight.

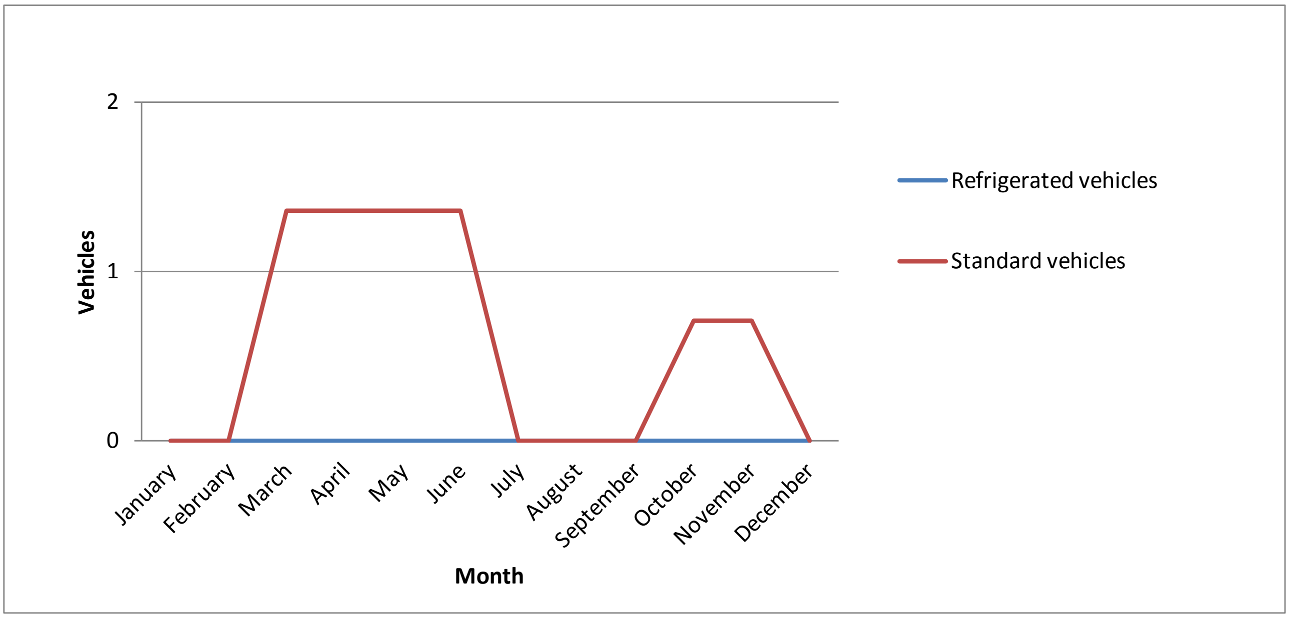

Figure 10.10 Vehicle requirements for 5000 ha of cropping in Scenario 1

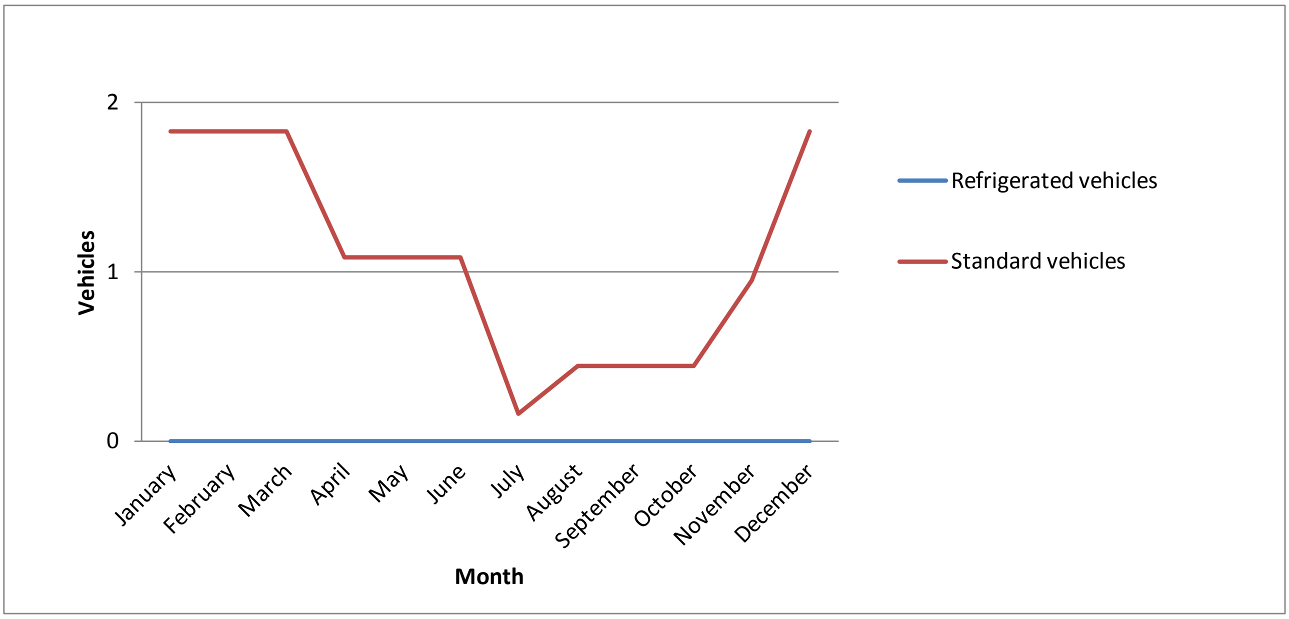

Figure 10.11 Vehicle requirements for 5000 ha of cropping in Scenario 2

Infrastructure

The two scenarios did not reveal any single major item of infrastructure investment that is not already in development. Cotton ginning capacity in the region would be sufficient to cope with the additional production projected to occur in Scenario 1.

For other crops included in the development scenarios, processing facilities or receiving storage depots already exist in the region, particularly for grains and pulses. The modest increase in production identified for grains and pulses in the two scenarios is unlikely to require additional investment in storage infrastructure.

However, that does not mean that ongoing investments in infrastructure are not needed to improve efficiencies. Local storage and handling facilities, and road and rail transport supply chains for grains in the Darling Downs – Maranoa region have evolved over many decades. For the majority of grain growing enterprises, this network of facilities has resulted in short transport distances. Although these facilities have served local production well, there is a need to further improve the handling and transport networks. This requires investment in roads to maintain their condition, investment in rail sidings, and upgrading of storage facilities. In particular, there is a trend towards developing more clustered storage facilities of a larger scale at the expense of smaller handling facilities. This will require investment in these centralised sites, not just from a storage perspective but also in terms of improving the efficiency of transport logistics, especially rail.

10.9.2 **RISK ANALYSIS**

The analysis for the two scenarios has been undertaken using averages of yields and prices, based on historical data and simulated crop yields. Future investment needs to be based on a good understanding of risk. Price risk is one variable that needs to be considered when making investments. ABARES produces market outlooks for a range of commodities. These are summarised in Table 10.13 for the crops that are included in the two regional scenarios. These market outlooks are based on medium-term drivers and, as such, do not capture shorter-term year-to-year variability. This is highlighted in Figure 10.12, which shows the market outlook for cotton over the next 10 years; the previous 10 years of price data are superimposed to illustrate the pattern of interannual variability that might be expected on top of the longer-term price trend.

Table 10.13 Ten-year forward price projections for the crops used in the two regional scenarios
Numbers represent real domestic prices (in 2012–13 dollars).

CROP	UNIT	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Maize	$/t	354	310	324	326	313	301	360	359	357	356
Wheat	$/t	329	319	317	317	325	326	326	326	326	326
Chickpea	$/t	592	628	629	629	644	644	643	642	641	640
Watermelon	$/kg	1.17	1.24	1.24	1.24	1.27	1.27	1.27	1.27	1.27	1.26
Sweet corn	$/carton	na	na	na	na	na	na	na	na	na	na
Cotton	$/bale	504	498	509	510	518	531	530	528	527	526
Forage hay	$/t	190	202	202	202	206	206	205	205	204	204

na = not available
Source: Data provided by ABARES

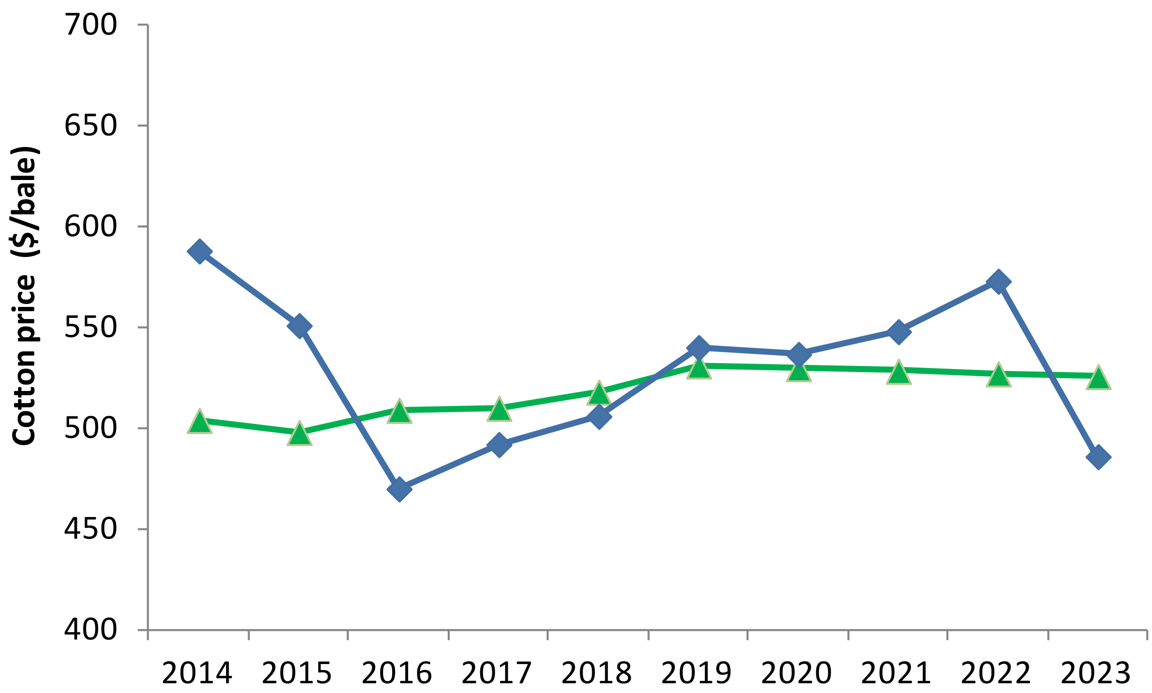

Figure 10.12 Ten-year forward projection for cotton price (green line), with previous 10 years (2004 to 2013) of prices (blue line) superimposed to highlight historical year-to-year price variability

As indicated above in Section 10.8, price variation combines with yield variation to produce gross margins that can vary significantly between years. In terms of future risk, it is useful to understand how these two primary drivers of price and yield might influence risk. Figure 10.13 shows the variability in gross margins for seedless watermelon due to variability in past prices and the assumed variability in yield. The yield distribution was based on a most likely yield of 30 t/ha and a low (20th percentile) and high (80th percentile) of 20 and 40 t/ha, respectively. The 20th percentile is the low performance that would be expected every 1 in 5 years. The distribution of prices was based on a most likely price of $650/t, with a 20th and 80th percentile of $611/t and $725/t, respectively. The most likely price was based on the seasonal price, which corresponds to southern Queensland production. As noted earlier in the chapter, there is a large difference in the price for watermelons depending on the time of year. The variation in price was based on annual averages over the past 8 years for the production window (November–May/June) in which most melons are harvested in this region. The median gross margin is approximately $4800/ha, and there is approximately a 28% chance of a negative gross margin.

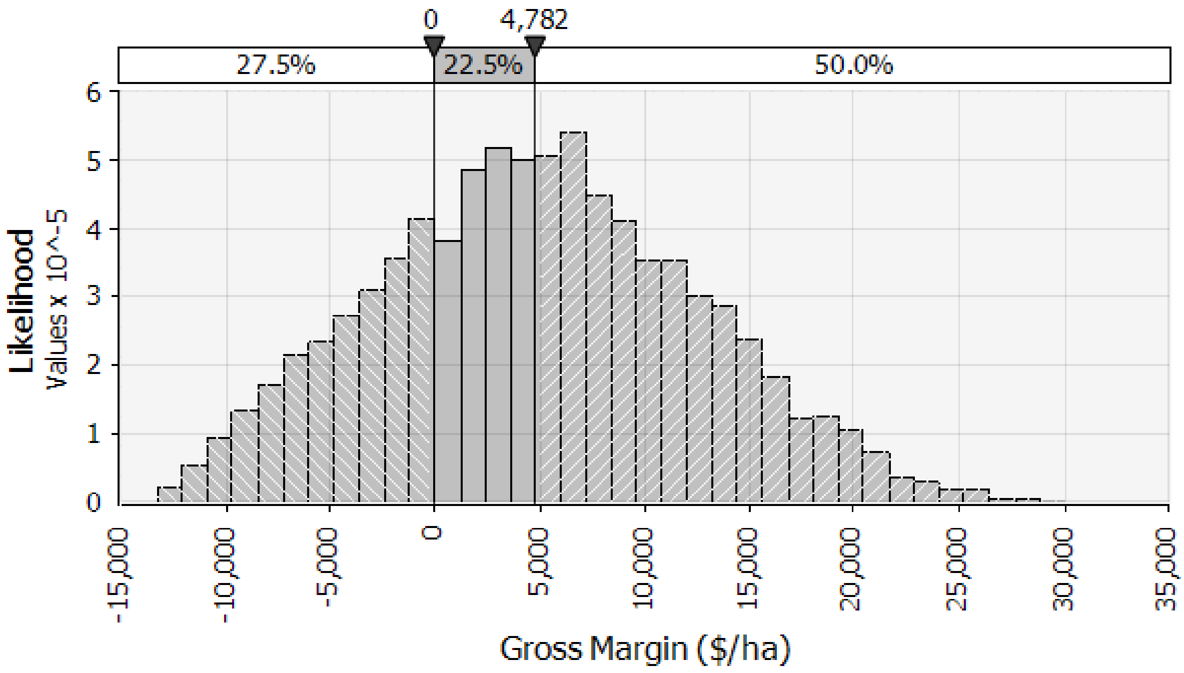

Figure 10.13 Variability in gross margins for watermelons in southern Queensland due to yield and price variability

The historical analysis of agricultural developments in northern Australia (Appendix 3.1) identified the ability to get through the first few years of establishment and scaling-up as a major determinant of success or failure. In the start-up phase, it is essential to provide time to learn and adapt crop management to suit local conditions, without the pressure of unrealistic yields that often underpin cash flow and investment analysis.

Figure 10.14 illustrates the effect of different starting conditions on debt. One sequence assumes a run of poorer years in the first half of the 10-year sequence, while a second sequence assumes a higher proportion of good years in the first half of the 10 years. A third sequence is also included, where two crop failures (defined as receiving 20% of median yield) occur randomly within the 10-year period of analysis. This is to simulate unexpected extreme events, such as a pest or disease outbreak, or an extreme weather event. The analysis is based on a simple approach in which there are two levels of starting capital investment/debt ($8000/ha or $10,000/ha), and the gross margin returns are used to reduce (or increase) this capital debt. Interest rates are assumed to be 7%. The debt levels encompass the ranges of investment needed to develop land for irrigation, including irrigation equipment such as centre pivots and pumps, and some provision for ring tanks and farm dams to provide some storage buffer for water that is delivered on a largely continuous basis from coal seam gas treatment plants. It is recognised that this does not represent a full financial cash flow analysis, as fixed overhead costs are not considered, but the objective is to demonstrate how the sequence of years influences the pattern of cash flows and the ability to achieve a return on investment.

The most noticeable trend in Figure 10.14 is that all scenarios result in a good position regarding debt after the 10-year period for the assumptions on price and yield used in this analysis. There is an initial increase in debt for the ‘poorer years early’ scenarios, but even these scenarios reverse the trend after a couple of years and have paid off the debt by about year 5. Shocks to the yield reduce the rate of debt repayment but do not cause a large change in the trend of repayments. The net loss or gain each year is partly buffered by the costs, which reflect the yield. For example, agent and transport costs increase in years with high yields but decrease in years with poor yields.

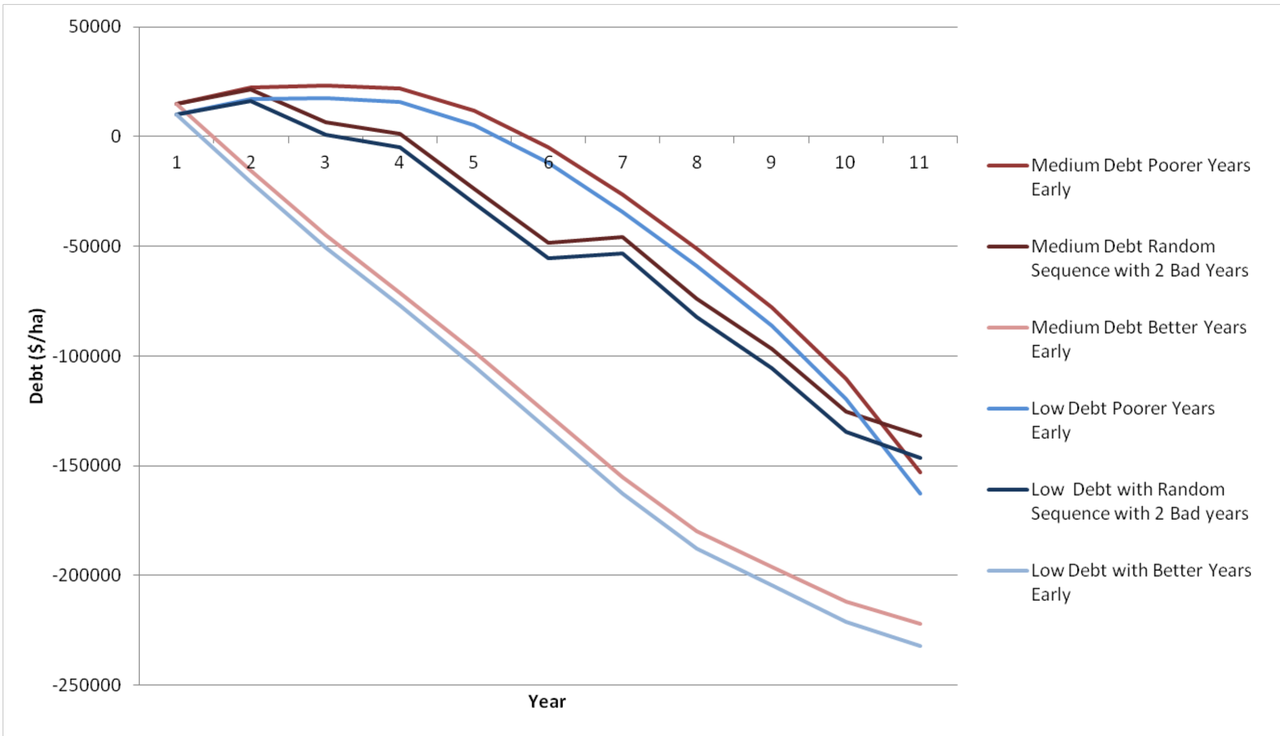

Figure 10.14 Effect of starting conditions of debt, and good or bad years, on the level of debt for seedless watermelons in southern Queensland

10.10 Regional economic analysis

10.10.1 DARLING DOWNS–MARANOA ECONOMY

Southern Queensland, incorporating the Darling Downs–Maranoa investment, includes Roma, Chinchilla, and Bendemere in AusRegion. Under the reference case, economic welfare in this Southern Queensland region is projected to grow at 3.1% annually, marginally faster than the Queensland GSP growth rate of 2.5% and the projected GDP growth rate of 2.7%. Agriculture forms a small part of a diverse regional economy.

10.10.2 SCENARIO DESCRIPTION

Each scenario is modelled in two phases—construction and production. Table 10.14 reflects a stylised version of the scenarios for Darling Downs–Maranoa as modelled in AusRegion. Public investment in roads and bridges totals $50 million in both scenarios. The increase in land suitable for cropping in both scenarios is 5000 hectares. In Scenario 1, private investment occurs in cotton and grains and horticulture. In Scenario 2, investment is made in cotton and beef industries.

Government investment in local infrastructure benefits horticulture with transport costs assumed to fall by 20% in Scenario 1. The private investment also leads to 10% increase in land productivity for beef production in Scenario 1 and 20% in Scenario 2.

Table 10.14 AusRegion stylised scenario description for Darling Downs–Maranoa

Development parameter	Unit	Commodity	Scenario 1	Scenario 2
Government investment	$m		50	50
Private Investment	$m	Beef Cattle		31
	$m	Cotton		40
	$m	Grains	80	
	$m	Horticulture	110	
	$m	Total private	190	71
Total Investment	$m		240	121
Land supply	'000ha		5	5
Transport costs	%	Horticulture	-20	
Yield	%	Beef Cattle		10
	%	Horticulture	20	

a Assumed change in transport costs arising from government investment. **b** Assumed increase in sectoral land productivity arising from private investment.

10.10.3 **REGIONAL ECONOMIC OUTCOMES**

The proposed investments will affect economic activity, employment and exports in the Southern Queensland region and have consequences for the Queensland and Australian economies. Table 10.15 shows the regional economic impacts of the construction and production phases.

GRP is projected to be 0.3% higher than the reference case under both Scenarios 1 and 2 at 2029-30. The Darling Downs–Maranoa investment is small relative to the size of the existing agricultural industry and the regional economy. Employment in the region is projected to rise relative to the reference case. In Scenario 1, the projected GRP growth is comprised of expansion in the agriculture and associated sectors, principally food, balanced by some contraction in mining resulting from higher wages and capital costs. The investment also increases output in the construction sector relative to the reference case.

Table 10.15 Economic impacts for Darling Downs–Maranoa at 2029–30, % deviation from the reference case

	Unit	Scenario 1	Scenario 2
GRP	%	0.3	0.3
Employment	%	0.2	0.4
Real wages	%	-0.1	-0.1
Exports	%	0.0	
Sectoral output			
Agriculture	%	0.7	2.4
Mining	%	-0.04	-0.1
Other	%	0.7	0.2
Queensland GSP	%	0.0	0.0
GDP	%	0.0	0.0

10.11 References

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Shortened forms

ABS	Australian Bureau of Statistics
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
APSIM	Agricultural Production Systems sIMulator
ASEAN	Association of Southeast Asian Nations
CPS	concentrate of poppy straw
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFWA	Department of Agriculture and Food Western Australia
ECHAM5	global climate model developed in Hamburg at the Max Planck Institute for Meteorology European Centre for Medium-Range Weather Forecasts
GAB	Great Artesian Basin
GCM	global climate model
GFDL-21	Geophysical Fluid Dynamics Laboratory
GM	genetically modified
HADCM3	Hadley Centre Coupled Model, version 3
KP	Kensington Pride
MIROC	Model for Interdisciplinary Research on Climate
ORIA	Ord River Irrigation Area
PBR	Plant Breeder's Rights
SILO	climate database

Units

MEASUREMENT UNITS	DESCRIPTION
GL	gigalitre; 1,000,000,000 litres
GWh	gigawatt hour
ha	hectare
kg	kilogram
km	kilometre
km^2	square kilometres
kWh	kilowatt-hour
L	litre
m	metre
m AHD	metres above Australian Height Datum
ML	megalitre; 1,000,000 litres
mm	millimetre
MW	megawatt
t	tonne

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