Rural Economies Centre of Excellence

and

The Burnett Inland Economic Development Organisation

Irrigation from the Boyne River

The Value of Improved Water Security

Jason West, formerly The University of Queensland

Jim Cavaye, University of Southern Queensland, and

Kristy Frahm, Burnett Inland Economic Development Organisation

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Irrigation from the Boyne River - The Value of Improved Water Security

Introduction

The Boyne River Irrigation Area in south east Queensland includes approximately 30 irrigators growing a diverse range of agricultural products (figure 1). These include high value horticultural field crops such as watermelons and pumpkins, perennial horticultural tree crops such as mandarins and pecans, perennial blueberry shrubs and irrigated pastures for cattle fattening.

Figure 1. The Location of the Boyne River in Southern Queensland

The irrigation area relies on water stored in the Boondooma Dam near the town of Proston (figure 2). However, the Tarong power station receives a large allocation (29,990 ML) of high priority water from the dam and irrigation water is 9,142ML of medium priority water. Some irrigators also have additional but quite limited on-farm water storages. Water available for irrigation is released from the dam, and it flows downstream where irrigators with a water allocation pump out of the river either directly onto crops or into on-farm storages.

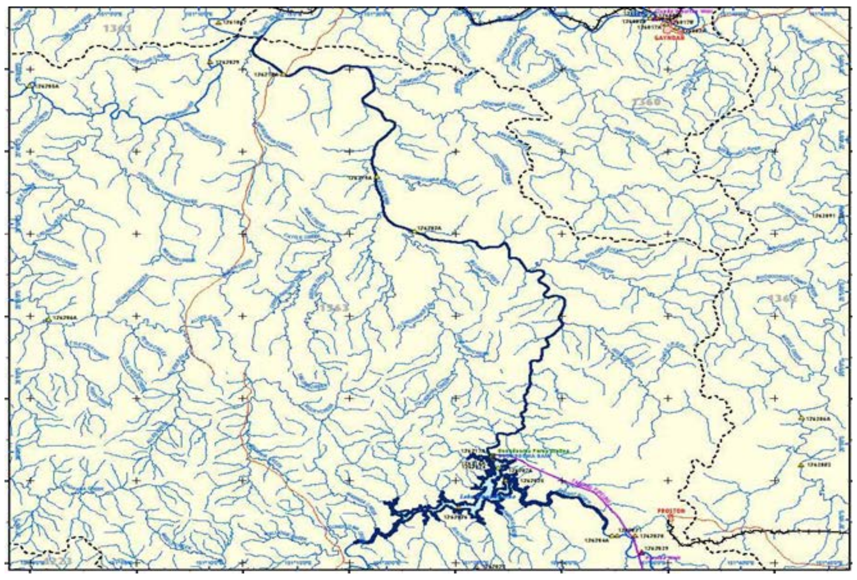

Figure 2. The Boyne River downstream from the Boondooma Dam

Table 1 shows the water entitlements based on the 2018/19 Boyne River Bulk Water Network Service Plan (NSP).

Table 1. Boyne River Supply Customer Entitlements

Customer Segment	Water Entitlements (ML)	High Water Priority (ML)	Medium Water Priority (ML)
Irrigation	9,142	0	9,142
Urban	1,825	1,825	0
Industrial (excluding Tarong pipeline)	343	0	343
Industrial (Tarong Pipeline)	29,990	29,990	0
SunWater (excluding distribution loss)	5	5	0
SunWater (distribution loss)	1,620	1,620	0
Other	480	480	0
Total	**43,405**	**33,920**	**9,485**

Water Reliability

The supply of irrigation water in the system is notoriously unreliable. High priority water for the Tarong Power station has been very reliable. High priority entitlements have been fully allocated at the start of the water year (1 July), every year since 2002. The only exception was in the 2007 water year which was fully allocated 7.5 months after July 1 (in Feb 2008) (Sunwater, 2018).

Medium priority water for irrigation is also intended to be fully allocated at the start of the water year. In years where this hasn't occurred, full allocations have been announced later in the year as listed below:

- For 2007, in Feb 2008 – 7.5 months later (80 per cent allocated)
- For 2008, in Mar 2009 – 8 months later
- For 2009, in Mar 2010 – 8 months later (Sunwater, 2018).

While water is allocated to irrigation, it is not enough to meet demand. This leads to two situations. First, irrigators opt to fully irrigate crops and trees from July onwards but water allocations are fully utilised by about February/March each year. During this period, some growers supplement crops with limited on-farm stored water and some use excavation equipment to dig for water in the bed of the Boyne River. This is expensive, inefficient and not environmentally desirable. Some growers have no option but to grow crops and trees dryland until another allocation is potentially available in July.

Second, in dry years such as 2018/2019 when dam levels are low, little water is available to be released for irrigation. Growers have an allocation that they have purchased but virtually no water can be accessed.

In addition to these limitations on supply, the flow of water from Boondooma Dam to downstream properties through a porous sandy riverbed is quite inefficient. Water for irrigation can be released into a dry riverbed on multiple occasions during a growing season with considerable loss of water in "wetting up" the river channel. Distribution loss is 18% of the irrigation allocation (29,990 ML is provided to Tarong Power Station in a pipeline with negligible distribution loss) (Sunwater, 2018).

Overall, water availability in the Boyne system for irrigation is 73%. That is, on average water is available to fill 73% of allocations for irrigation.

Purpose of the Study

There has long been an interest in improving the reliability of water for irrigation. This would lead to major economic benefits for agriculture with multiplier impacts across the regional economy. The construction of a weir downstream of the Boondooma Dam at Cooranga is seen as the most practical solution. This would store water adjacent to the main irrigation area reducing distribution losses and a relatively small weir (compared to the dam) would allow water to "cycle" with the weir filling and refilling with relatively small flows in the river.

While there has been a community and government focus on the specific costs and the feasibility of the weir, it is also important to better understand the issues and potential economic and social benefits of increased water reliability per se, both for agriculture and for the broader regional economy. The issue is not just a simple cost/benefit of the weir with a focus on return from the cost per ML of supplied water. Rather, this study assesses the broader economic and other benefits of improved reliability of water. The benefits may include increased production, better opportunities to access markets, the establishment of different crops such as blueberries, pecans etc. or changes to production systems.

It provide a broad context for the economic contribution of the irrigation industry and an assessment of improved water reliability per se. The study consists of two components – a largely qualitative assessment of the current issues and potential advantages of improved water reliability, and an Input/Output economic analysis.

The potential benefits of the improved reliability of irrigation extend beyond agricultural production and its service sectors. It can also provide the opportunity for the North Burnett region to diversify its economy, have higher skill employment that retains young people in communities, have value-adding to primary industries and improve entrepreneurship and the liveability of the region.

Methodology

The study a detailed economic analysis combined with qualitative feedback from irrigators and other informed stakeholders such as local government staff and industry support services. The economic analysis involved the refinement and use of a regional input output model available through the Rural Economies Centre of Excellence (via the University of Queensland). Sixteen irrigators and other stakeholders were interviewed, where they provided largely qualitative information as well as production data.

Input/Output Economic Analysis

Input/output analysis used in the study is explained in detail later in the report but a basic overview is that it provides a total accounting of the expenditure and income of sectors in the local economy. It shows the economic relationships between each sector in a local economy that is unique to each community or region. Local economies are categorised into a standard set of sectors such as agriculture, manufacturing, retail etc. A transaction table is developed that tabulates the value in dollars of both input and output for each sector as shown in table 2.

Table 2. The concept of an Input/Output Transaction Table

Sector	**Agriculture**	**Mining**	**Manufacturing**	**Utilities**	**Etc.**	**TOTAL**
Agriculture	Output from agriculture used in agriculture itself	Output from agriculture used by mining	Output from agriculture used by manufacturing	Output from agriculture used by utilities		Total Output from agriculture
Mining	Output from mining used in agriculture	Output from mining used in mining itself	Output from mining used in manufacturing	Output from mining used by utilities		Total output from Mining
Etc.						
TOTAL	Total Input to agriculture	Total Input to mining	Total Input to manufacturing	Total Input to utilities		

Each row lists output produced by each sector in the local economy. The output in each row also represents input for each sector in the columns. For example, in Table 3, the manufacturing sector produces $3163000 of output (shown in bold) that is consumed in the Agriculture sector such as agricultural equipment. The utilities sector produces $17528000 of output (shown in bold) that is consumed in the manufacturing sector such as generated power.

Table 3. A Hypothetical Example of an Input/Output Transaction Table (showing input and output by sector in $ x1000)

Sector	Agriculture	Mining	Manufacturing	Utilities	Construction
Agriculture	786	33	20427	13	122
Mining	2	229	9523	14994	2497
Manufacturing	**3163**	3831	224249	3193	69503
Utilities	730	10069	**17528**	17274	1479
Construction	27	1719	461	101	256
Wholesale	337	3228	21968	166	4628
Retail	847	8101	55141	416	11615

The total input to each sector is shown as column totals. If output from each sector in the rows is divided by the total input for each column a coefficient is produced. Hence, the table is converted into a set of coefficients that show the economic relationship between all the sectors in the economy. For example, for every dollar of output from manufacturing, 32c of that is consumed as input to agriculture. This set of coefficients is unique to each local economy.

This table of coefficients allows two key things to be derived. First, because input/output analysis shows the production from each sector contributed to all other sectors in the economy, it shows each sectors "echo" or "ripple" effects across the rest of the local economy. This allows multipliers to be calculated i.e. the extent of the additional economy activity generated across the local economy from output from each sector. For example, a multiplier for agriculture of 1.7 means that every dollar of output from the agriculture sector generates an additional 70c of economic output in total across all other sectors.

Second, because each sector has a multiplier across the economy, the overall effect of changes in output in particular sectors can be calculated. For example, the impact of increased (or indeed reduced) production in agriculture on the whole regional economy can be derived.

Interviews

Interviews were held in person with the following stakeholders.

4 exclusively citrus growers (mostly mandarins for domestic (Imperial) and export (Murcot) markets)

1 exclusive pecan grower

2 citrus and pecan growers

1 irrigated horticultural crop grower (watermelons and pumpkins)

1 grower providing horticultural services to other growers

1 local government water manager

2 local government councillors

1 accommodation provider for farm labourers

1 exclusive blueberry grower

1 irrigated pasture grower

1 table grape grower

Interview questions focuses on current production systems, the impacts of poor water reliability, business options if water reliability were to be improved and management of risks. A full list of interviews questions are shown in Appendix A. Interviews lasted about 1 hour and comments were recorded in note form and then collated.

Results

Interviews

The following is a summary of the key themes from all the interview responses.

Current Production Systems

Production from irrigation on the Boyne River is both very diverse and extremely important to the local economy. While citrus production has been the mainstay of irrigated horticulture, production also includes other permanent tree/shrub crops such as pecans, mangoes, grapes and blueberries; annual or seasonal crops such as watermelons and pumpkins; and irrigated fodder crops and pastures for beef production.

Production occurs year-round and yield, profitability, and indeed the survival of tree crops, is highly dependent on irrigation with high quality water. The area is somewhat unique in that the topography and soils allow a wide variety of crops to be grown ranging from mangoes in frost-free areas on the top of hills down to frost prone alluvial flats that are suited to pecans.

Unlike many other areas such as the Burnett Irrigation Area, the Boyne has a large area of suitable soils where irrigation could expand with increased access to water. The irrigated area has a mix of basalt, red soils, and river loams with areas of non-horticultural land in between. The ideal soil type for horticulture is alluvial loams and alluvial basalts. These soils can support any tree crop. The suitability to each tree crop depends on where growing areas are located in relation to frost zones.

Almost all permanent crops are drip irrigated with growers accessing water from releases from Boondooma Dam and/or from on farm sources of underground water. Some producers are able to store water from either source in on-farm dams. Other growers can only directly irrigate during periods of permissible pumping from the river, when water is available. When water is not available from flows in the river, some growers use excavation equipment to dig holes in the bed of the river to pump water from.

Irrigation on the Boyne (and the Burnett River) is very important for the North Burnett economy. In an area that is largely dependent on the largely native pasture based beef industry, irrigated horticulture provided major economic activity, "export" income, employment and investment. It has a major impact on local service industries, retail, food and accommodation, transport and agricultural supply sectors. Several interviewees noted that the irrigation industry was also culturally enriching for the community, bring new people to communities, increasing social activities and interaction between people, and in supporting activity and optimism.

Marketing

About 60% of citrus production is exported. This includes specific export varieties of mandarins - murcots, freemots and low seeded murcots. Murcots are generally sold for approximately approx. $38 per 15kg box with the cost of production being about $1 per kg. The remaining 40% are imperial mandarins grown for the domestic market.

Growers sell produce in a variety of ways. There is a Qld Citrus Exporters Group which is a group of growers working with TIQ to market citrus and expand markets. There are also other farmers marketing groups. Domestically, growers sell through private wholesalers, marketing groups and existing markets such as the Brisbane Market.

Pecans yield approximately 4 tonne/hectare (of kernel, not in shell) with a tree density of 200 trees per hectare. This is approximately 100 tonne total harvest from 5000 trees. The pecan price has been $5.50/kg consistently for last three years. Prices are not volatile because there is very high consistent demand in the market without oversupply. Pecans are often forward sold and exported mainly to China

Annual irrigated crops include mostly watermelons and pumpkins. These seasonal crops can be easier to manage with unreliable access to water because there is no permanent crop to maintain year-round.

Progressive growers are becoming more cohesive. This is aligned with the shift from supplying domestic markets to export markets. This is reflected in local cooperative marketing groups and in the long-running Irrigators Association. Other organisations supporting the horticulture industry are Growcom, the Queensland Regional Advisory Panel advising Citrus Australia and Horticulture Innovation Australia (HIA).

Impact of Poor Water Reliability

Water reliability has been a long term challenge for irrigators on the Boyne system. It has been discussed and managed for several decades. Poor water reliability has a major impact on production, on-farm decision making, cash-flow and debt management, and on the long term future of growers.

There are major production limitations. The lack of water availability in the latter part of the growing season each year, can limit yield and in drought it can threaten the survival of trees. Water is particularly needed at certain times such as when fruit is setting. Water shortages can also affect fruit and nut quality depending on the stage of fruit development. It can lead to small fruit size and kernel fill in pecans.

On-farm decisions are made around managing water reliability. Because of the inefficiency of the dam/river system, growers implement a full irrigation schedule from when water allocations are available in July each year (rather than ration water). When water becomes unavailable (usually the first quarter of year calendar year) they use alternative sources or manage the crop dryland. Some growers arrange various ways of accessing water such as access agreements with neighbours, investment in on-farm storage, use of bedsands and developing bores. Water from bedsands is expensive to access and is generally of poor quality and growers use it as a last resort. Many growers have the only option of pumping directly from the river.

Water availability determines the area in production with growers putting expansion plans on-hold. Many can't expand their operation to take advantage of their full water allocation because of water shortage risk. Unreliability of water limits the amount of lease land available, some landholders are reluctant to lease land in case they need it themselves. Some growers will have a core horticultural allocation and an "optional" part of their allocation for pasture or fodder crops. When water is available they will irrigate both components. When water is scarce they cease irrigating the lower value fodder.

All growers have a long term commitment to their enterprise with many holding considerable debt on their property. Cash flow to service debt is crucial and poor water reliability can threaten this. Some growers have invested significantly in on-farm water storage, providing some reliability but increasing debt. Growers are paying 100% for licences but can't access water when it is not available.

Poor water reliability also affects businesses providing services to the irrigation industry. If production is affected so the season is reduced a range of labour providers, agronomic services and packagers will have reduced capacity.

On-Farm Strategies

The Boyne is an inefficient system and it is difficult for growers to manage their access to water from the river, particularly as the flow of water slows down. There are several on-farm strategies used by growers to manage poor water reliability.

Most growers limit their production area. They make a judgement about the area under irrigation and how reliably it can be irrigated. Many growers will plant a conservative area that they can manage in dry times. Some growers derive off-farm income to support their cash flow. Those providing services to other growers are impacted by reduced demand when irrigation water is scarce.

Growers use agronomic practices to improve water efficiency such as mulching of trees, efficient irrigation technology and establishing more drought tolerant crops such as pecans, where suitable.

Impact of Continued Water Shortages

Continued poor water reliability is likely to lead to limited production and development of the industry and subsequent economic activity in the region. It may also lead to a rationalisation of growers with some ceasing irrigation or leaving the industry.

Growers have "sacrificed" blocks of trees due to water shortages and some blocks that have become severely water stressed in the past have not returned to full production. One grower mentioned that a block of mandarins normally producing 70 tonnes of fruit, reduced to 35 tonnes due to lack of irrigation and it hasn't returned to 70 tonne levels after several years.

Trees may also be changed not necessarily due only to water challenges. Growers may make business decisions such as pulling out Imperial mandarin trees to replace them with export varieties.

Poor water reliability limits investment on the Boyne River, Yet, ironically, in order to improve reliability growers are faced with major on-farm investments in water infrastructure such as in installing pipelines, on-farm storage dams and bores. This is not always possible, it increases farm debt significantly and may not be as cost effective as a weir on the river.

Yet, almost all interviewees stated that the long term consequences of poor water reliability would be a decline in the irrigation industry and loss of irrigation farms. They saw that without a strong irrigation industry on the Boyne, the regional economy would suffer considerable economic decline.

Production Challenges and Risks

The irrigation industry faces a range of economic, logistic, market and biological challenges and risks.

Labour

A major challenge is reliable access to labour. Pecan harvesting is mostly mechanical but almost all other crops require a considerable number of workers for thinning fruit and pruning trees during the growing season with the peak of demand during harvesting for both field harvesting and packing. Most growers access backpackers and the Pacific Islander Seasonal Worker Scheme. This generally provides a consistent supply of workers but there is often a challenge in sourcing workers during harvest.

Backpacker turnover is high but the seasonal worker program provides a reliable labour force. There is concern that a possible change in government policy may see changes or reductions on the Seasonal Worker Program.

Sourcing skilled labour for the farm office, field and packing shed was also seen as a challenge.

Production Risks

Poor water reliability and drought were, by far, the main production risks. Apart from this, other production challenges included hail and the cost of inputs. Hail can affect both quality and yield and crop insurance was prohibitably expensive. Frost can also affect citrus and other crops. The overheads for irrigation such as electricity costs for pumping were a major cost with a risk of escalating prices. The cost of fuel and fertiliser was also as a risk to profitability.

Financial Risk

Trees crops have a long lag time for return on investment and the cost of on-farm water storage was seen a major cost with concerns about overall farm debt as a result.

Biosecurity

Some interviewees raised concerns about biosecurity. The introduction of exotic diseases such as pecan scab disease would have a major impact on the Australian industry. Growers saw that it was important to continue biosecurity protocols and vigilance.

Market Risk

Growers saw risk in market access, and in export and domestic markets. While export has been a major benefit for citrus and pecan growers in particular, there are risks in competition from China and if there is a change in export markets. Some growers felt that if the Chinese market declined there may be the opportunity for another market to grow such as India.

In domestic markets, growers felt that they had no control over supermarket decisions, there was a concentration of marketers of fruit and "losses" can be due to fruit agent decision-making. These would be major issues particularly if export markets fail.

Some growers saw risks in poor transport access particularly to Wellcamp Airport in order to access export markets. Access road were poor and improvements could see growers accessing the export hub at Wellcamp particularly for Hong Kong markets.

Other Challenges and Risks

Poor mobile phone coverage and internet access is also a major challenge. Better access is needed for all business operations particularly for continuity of contact with agents and buyers.

Impact of Improved Water Reliability

If water reliability were to improve there would be transformational benefits. Every grower saw the only option to improve reliability as a weir on the Boyne River.

Improved Efficiency

The establishment of Cooranga Weir (or any other potential way of improving water reliability) would vastly improve the efficiency of water use. It would not only allow greater water access through the growing season but would particularly contribute to improved water availability at crucial times such as fruit set and in the latter growing season when water often is currently unavailable.

A weir would reduce the major transmission losses of water released from Boondooma Dam and reduce the time of approximately 8 days from when water is released from Boondooma Dam until it reaches Boyne River irrigators to 2-3 days. Increased reliability of water would make it more viable for growers to invest in on-farm storage.

Production

Improved water reliability would lead to bought major improvements in production and increased productive area. Some growers said that they would expand their operation from 10000 to 20000 trees supplemented by on-farm storage. The Boyne area has considerable suitable soils available for orchard and field crops expansion.

Figure 3 shows the existing irrigation area in the Boyne River region. Limited water availability limits horticultural production to areas adjacent to the river.

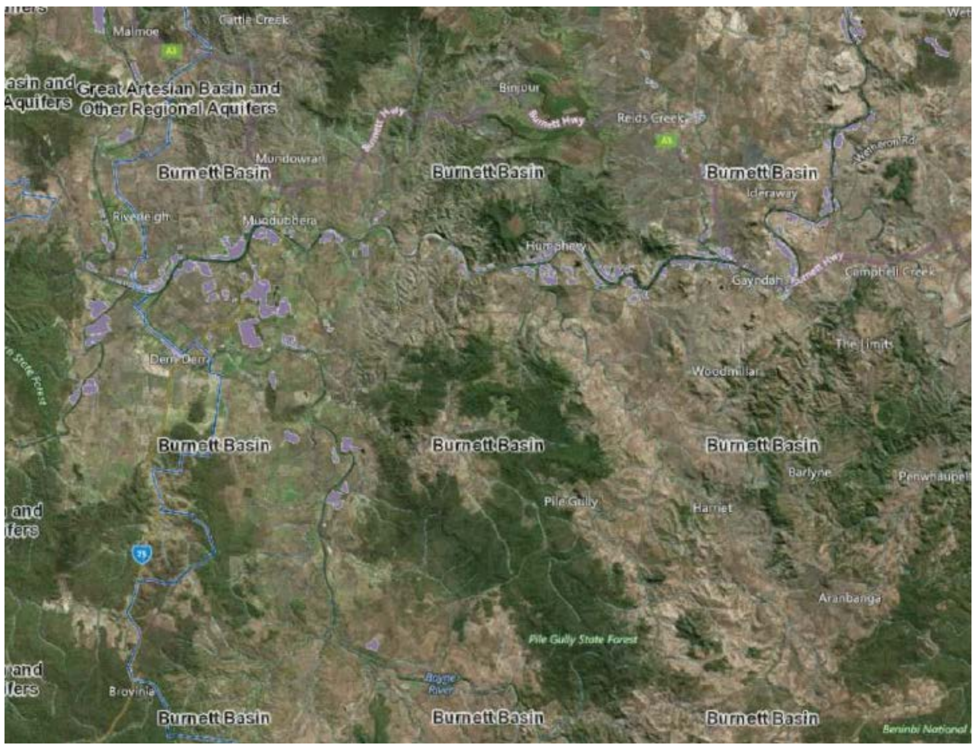

Figure 3. Current horticultural production in the Boyne River region (areas shown in purple). *Source:* National Map, Australian Government.

Figure 4 shows the potential horticultural production area showing the considerable areas of suitable soils in the region.

Figure 4. Potential horticultural production in the Boyne River region (areas shown in light green). *Source:* National Map, Australian Government.

Many growers noted that their decision-making could be more reliable and confident and greatly improved yearly planning of operations. Land value would increase and leasing of land would probably not be cost effective. Horticulture would diversify with crops such as macadamias and avocadoes being established. The management of established crops would improve and intensify. There would also be more permanent tree crops established.

Regional Economy

Growers saw major benefits for the regional economy in terms of increased employment, investment, and economic development generally. One grower calculated that 1ML of water would be equivalent to approx. $3000 spend on wages and costs, and $10000 in farm turnover.

Many growers noted the multiplier effect across the regional economy with increased turnover in a range of sectors. They also recognised social benefits such as attracting new people to the region, renewing interest in the area, and in providing opportunities for local people.

Economic Analysis of Improved Water Security

This section of the report presents the results of the economic impact Input-Output (IO) modelling for the North Burnett Regional Council area, with a specific analysis of irrigators with water allocations to the Boyne River. The IO modelling calculates the regional industrial support value-added and effect on employment resulting from the expected improvement in economic outputs given increased water security from an investment in water storage infrastructure. The broader regional economic impact occurs within the Northern Burnett Regional Council area using data from the regional industry input-output tables. The results show that the value added of increased water security would generate over double the initial V.A. and employment via industry support effects to all industries through the supply chain.

The positive effect that irrigation has on crops, both in terms of yield and quality, and therefore revenue, is crop specific (Weatherhead et al.,1997). Each crop responds differently to a given application of water. Several studies have estimated the yield response to irrigation allowing us to estimate the average net yield increase for each unit (mm) of water applied up to a known certain threshold. We scale these estimates to obtain net yield increases for each crop type. We estimated the benefits of irrigation on crop quality, expressed as a percentage increase in crop price (AU$/t) based on published literature corroborated by interviews with regional producers. These data have been used to derive estimates of the quality benefits of irrigation for each crop. All costs and prices used in this assessment, including the additional costs due to increased production shown are shown in Table 4.

Table 4. Price, yield (irrigated and rainfed), costs and crop yield response for main horticulture output in the Boyne River region.

Crop category	Crop price ($/t)	Yield* (t/ha) - irrigated	Yield* (t/ha) - rainfed	Additional costs of increased production (% gross)	Average crop yield response/ha (t/mm)
Citrus	1800	54 (5.4)	36 (4.6)	25	0.02
Table grapes	2800	7.6 (3.2)	5.0 (2.2)	25	0.02
Berries (blueberries)	8000	50 (4.5)	30 (7.5)	25	0.03
Tree nuts	5000	5 (1.2)	3.5 (1.4)	25	0.03
Grass (grazing)	200	15 (3)	4.5 (1.5)	0	0.03
Grass (silage)	200	17 (3)	5 (1.5)	22	0.03

* annual variation measured using standard deviation provided in parentheses

Conventionally, it is generally assumed that crop prices rise during a drought as agricultural production is affected by weather conditions. However, the final impact on price is influenced by many factors including the timing and onset of the drought, global market prices, the impact of imported products on local domestic markets, and so on. Therefore, to estimate the benefits of irrigation in financial terms, we use the average crop price ($/tonne, adjusted for inflation) over the past three drought episodes in the region (2003, 2004–2006, 2010–2012). Regionally disaggregated price information is available for some crop types, but not all. We therefore assumed regional average crop prices for the analysis, having checked that differences were not significant relative to other local areas for the available price data.

For each crop, the additional costs associated with the increased production were deducted from the gross benefit. Variable irrigation costs (repairs, fuel, labour and machinery, water charges) also are deducted. The costs of irrigation vary considerably depending on local circumstances, the type of irrigation and storage systems, water source and crop requirements. For calculation purposes, we assumed average variable costs of irrigation of $2.50/ha mm). By combining the yield and quality benefits, the total financial benefit of supplemental irrigation can be estimated.

We consider only the extra net benefits derived from irrigation in comparison with the benefits that growers would derive from the same crops grown under non-irrigated conditions. Figure 5 illustrates that yield and quality benefits are multiplicative, not additive, as the quality premia are relevant to the entire crop and not just the yield increase. From the gross benefits irrigation costs and additional costs associated with higher levels of production must be deducted to obtain the net extra margin ($/ha mm) derived from supplemental irrigation.

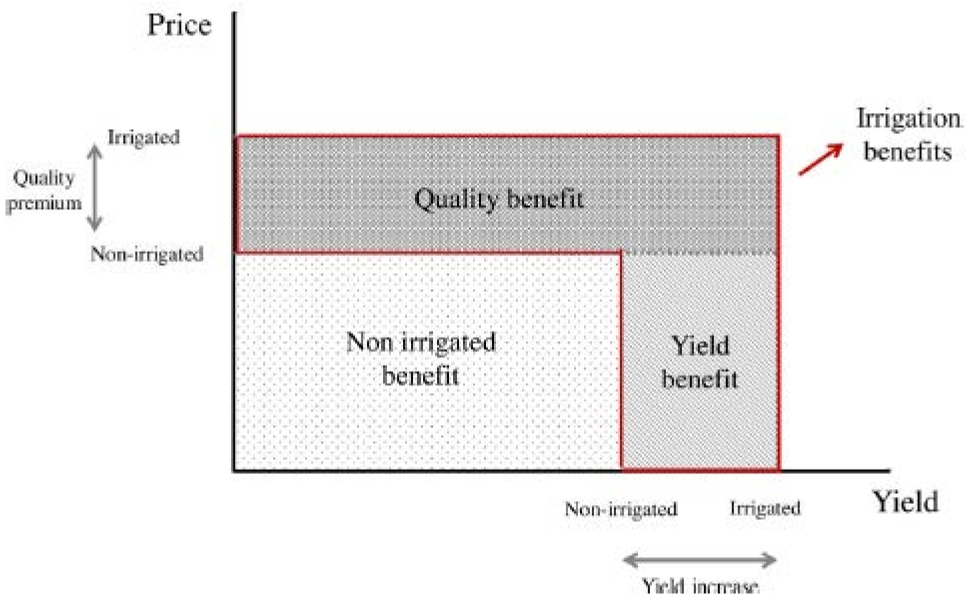

Figure 5. Representation of crop and yield benefits from supplemental irrigation.

Input-output modelling and multipliers

Costs and benefits

Indications of the economic viability of water projects can be obtained using benefit-cost analyses which provide a good conceptual framework to evaluate projects of various dimensions. However, this approach offers a largely one-dimensional criterion which accounts for increased income through productivity growth while ignoring distribution and equity considerations. While it is assumed that irrigation development can influence regional income, production, employment and income distribution, a lingering issue is the question of whether indirect growth effects of water projects can be included in benefit-cost calculations. This will depend largely on the existence of surplus capacity in the regional economy, especially when secondary or economic growth benefits are negated by costs incurred elsewhere in the economy.

Indirect benefits from a regional perspective are important because the presence of such benefits is more obvious on regional level than on national level. For private irrigation development, indirect impacts are of secondary importance. But indirect impacts are an important consideration for public projects with respect to the sustainability of outcomes and provision of funding. The impact of indirect effects and their concentration are of high importance, particularly for agricultural projects that tend to concentrate impacts on the local economy.

Apart from the direct impact of higher yields, sales and expenditure on farms, linkages between different sectors and industries in the economy cause a multiplier effect in reaction to the direct impact. Each sector in the regional economy reacts individually to the increased production and activity in agriculture, resulting in an increase in general economic activity in the area. This increase in economic activity is an important indirect benefit of irrigation development that has been observed in different regions around the world for decades. Indirect multiplier effects at the regional level are generated from interdependencies in the regional economy and linkages manifest between economic sectors.

Investment projects can generate substantial indirect effects or pecuniary external economies, which stem mainly from production linkages. The production linkages can be either backwards or forwards. Backward linkages refer, for instance, to the linkage of irrigation agriculture with input suppliers, while forward linkages are based on impacts to downstream marketing and processing industries.

Separate from production linkages are consumption linkages caused by higher income from irrigation agriculture that results in an increase in final demand. Irrigation development is expected to lead to increased production, which implies greater consumption of inputs, as well as higher production receipts to primary producers. The interdependencies in the economy stimulates a multiplier effect that eventually results in an increase in economic activity, caused by higher incomes and greater demand for inputs.

Regional Input-Output model

Input-Output (IO) models generate multiplier values, which reflect the 'ripple effects' that are assumed to flow through a regional economy given a change in output from a given industry sector. Output changes may be positive (e.g. from a growing sector) or negative (e.g. a shrinking sector). Ripple effects can be measured using output value, value-added, income or employment.

Multipliers are classified as either Type I or Type II. Type I output and employment multipliers include only the intermediate direct and industrial support effects. That is, industries buying inputs from each other to produce outputs, upstream of each industry sector. Type I multipliers do not include consumption induced effects. Type I multipliers are further classified as either Type IA or Type IB. Type IA multipliers include the initial change industry output while Type IB multipliers excludes the initial change and include only the net flow-on effect in output, value added, employment or income.

Type II multipliers include consumption induced effects and are usually greater than Type I multipliers. Type II multipliers can be classified as either Type IIA and Type IIB in a similar way as Type I multipliers. An increase in output by a given industry is likely to generate an increase in income from both itself and other industries to which it is related, which will increase consumption of intermediate inputs from other industries and increase final demand components in the IO model (e.g., household consumption, government expenditure).

Multiplier types (output, income, employment, etc.) are summarised below:

- Type IA: Multiplier = [initial + first-round]/initial
- Type IB: Multiplier = [initial + production-induced]/initial
- Type IIA: Multiplier = [initial + production-induced + consumption-induced]/initial
- Type IIB: Multiplier = flow-on/initial

For the purposes of this analysis, we apply the Type I multipliers to measure output, employment and value-added impacts to ensure we do not overstate interindustry impacts. The IO model includes 34 industry sectors (see Appendix B), of which 7 are categorised as primary industry.

This report focuses on value added and employment Type I multipliers which indicate industrial support effects net of consumption induced effects, however all forms of multipliers are reported. An open (not including household or government consumption) model is assumed so that the results do not overstate the inter-industry impacts of a structural shift in irrigation available to the horticultural sector resulting from the construction of a weir. For completeness, we also consider the use of closed models to ensure the appropriate effects are accounted for when deriving the relevant multipliers.

Type I Value Added Multipliers

Value-added refers to the sum of compensation of employees (wages), plus cash operating profit (company operating profits plus depreciation allowances). This compares to gross operating surplus, which is gross value-added (total value of production less intermediate inputs) less compensation to employees, less taxation of production and imports payable plus subsidies. The Type 1 value-added multiplier reflects the true indicator of the net contribution to an economy of a change in value of industry output.

The breakdown of value-added by industry is an indicator of business productivity. Figure 6 provides the value-added amounts for the Wide Bay region while Figure 7 refines this data to focus on the North Burnett Regional Council area. This represents a specific measure of the productivity of each industry sector relative to output (i.e., total gross revenue), because some industries have high levels of output but require large volumes of inputs to achieve that. Agriculture is the dominant industry in the North Burnett RC and changes in productivity

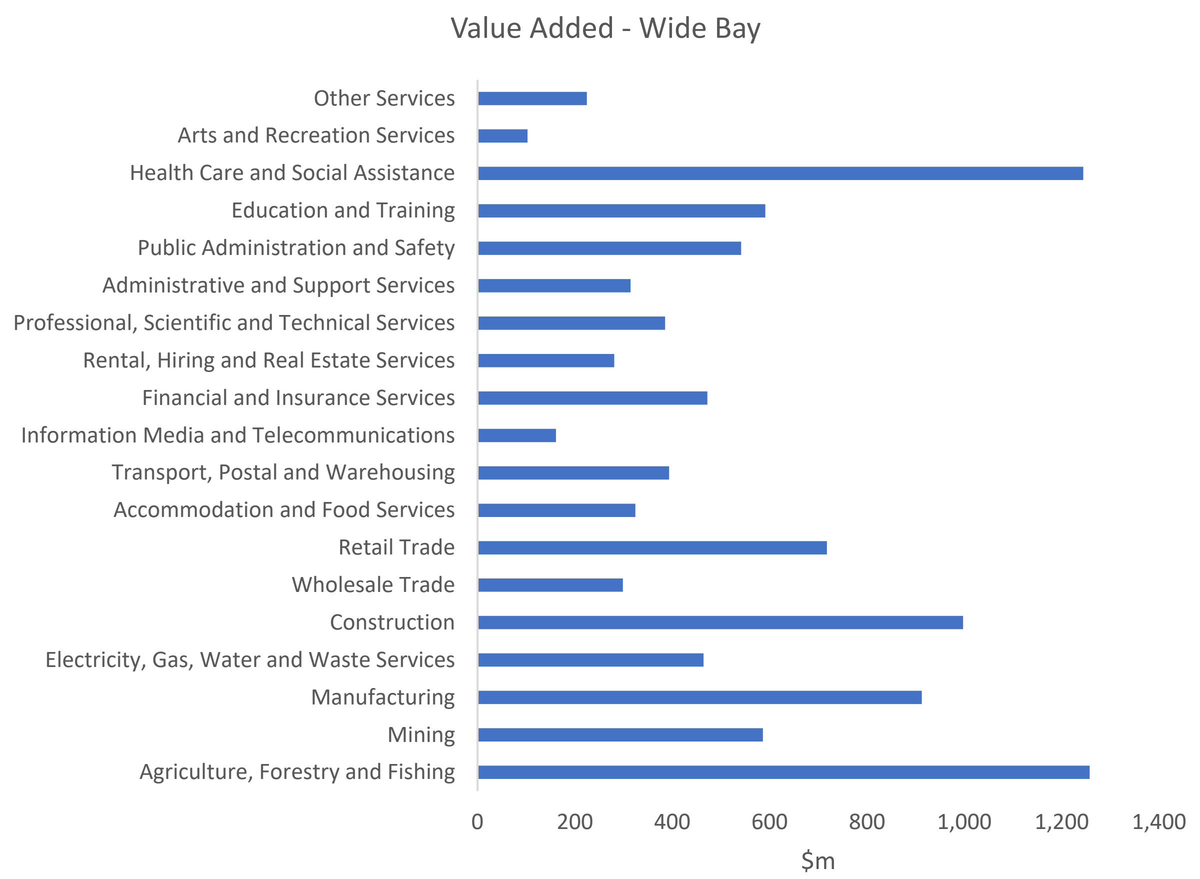

Figure 6. Value added, by industry, for the Wide Bay Region, 2017-18 ($m). *Source:* Economy ID.

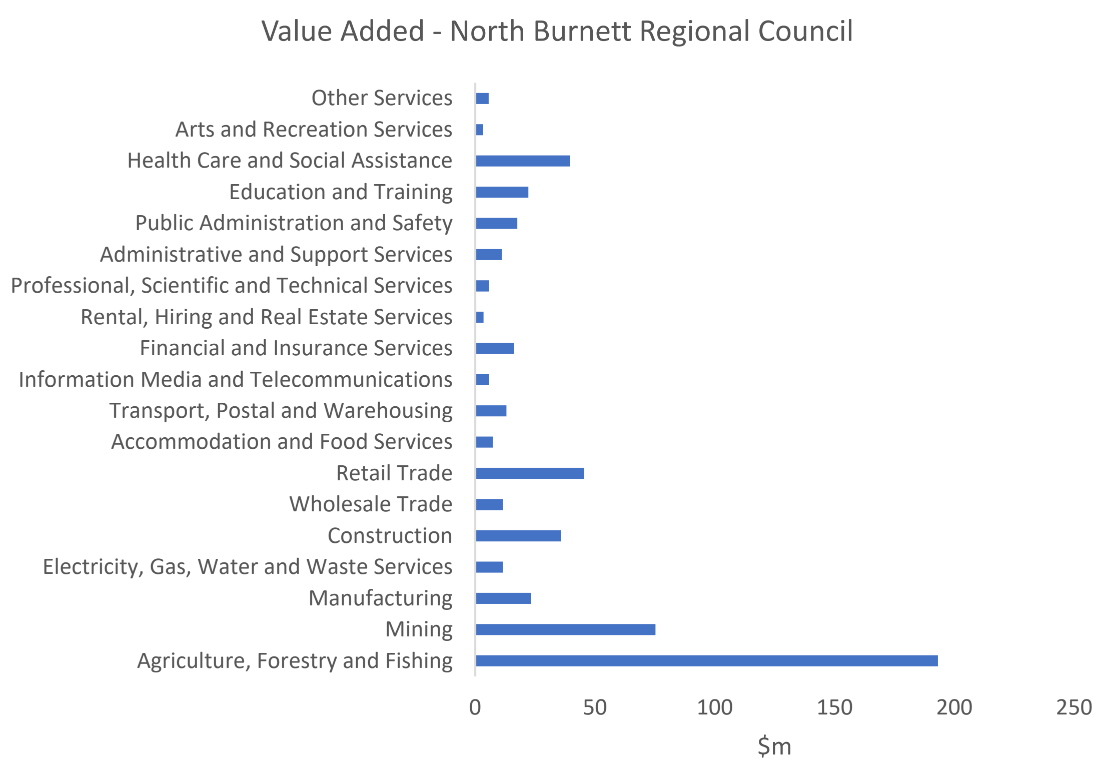

Figure 7. Value added, by industry, for the North Burnett Regional Council, 2017-18 ($m). *Source:* Economy ID.

Output by Industry

Output by industry is a gross measure of the total sales of each industry sector. It does not measure how productive each industry sector is at producing this output. This is measured using the value- added metric. Figure 8 shows output by industry for the Wide Bay region and figure 9 shows output for the North Burnett Regional Council area. Agriculture contributes approximately $366 million of exports from the North Burnett Regional Council area.

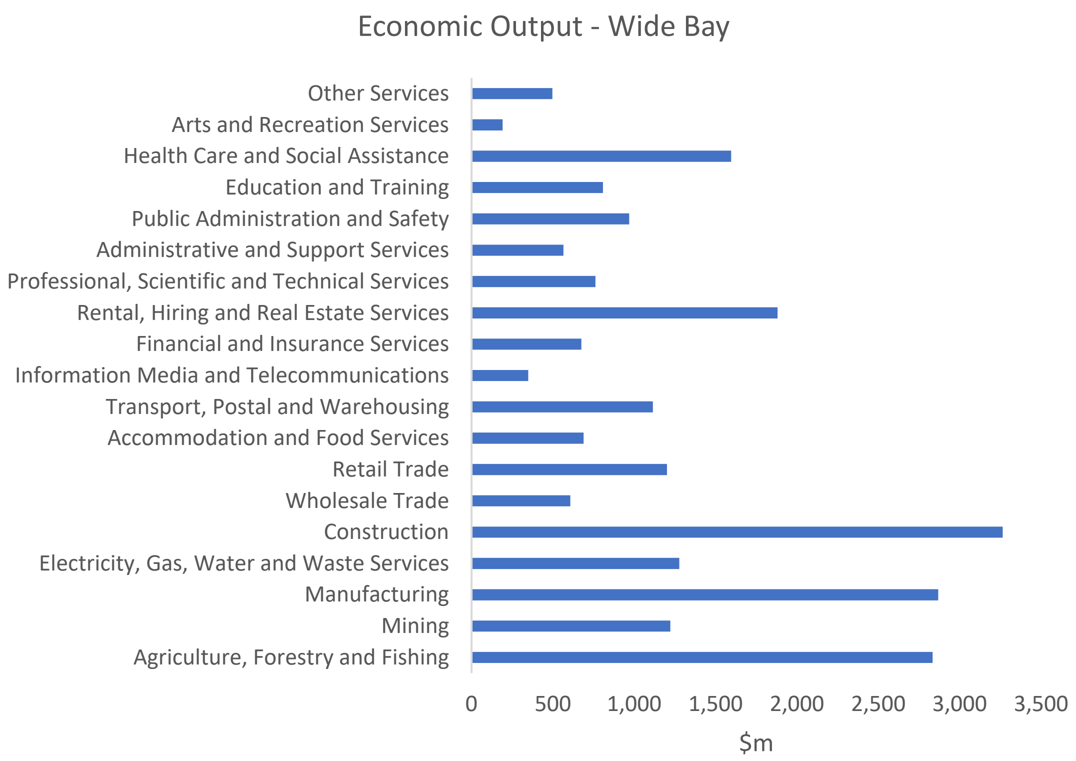

Figure 8. Economic output, by industry, for the Wide Bay Region, 2017-18 ($m). *Source:* Economy ID.

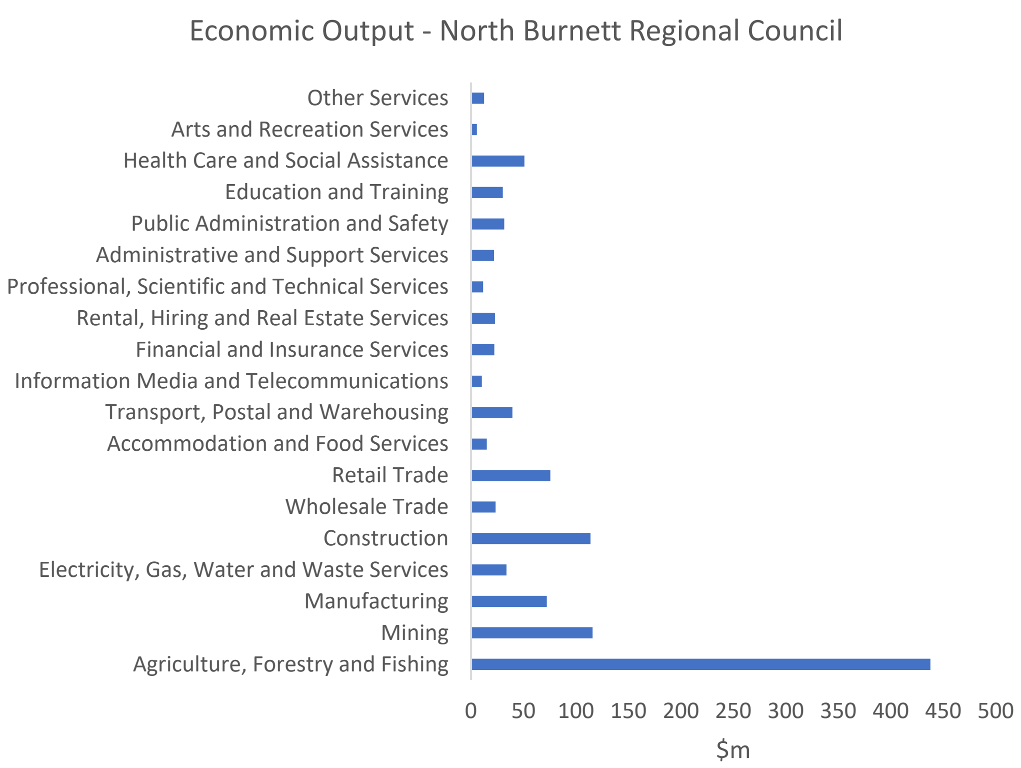

Figure 9. Economic output, by industry, for the North Burnett Regional Council, 2017-18 ($m). *Source:* Economy ID.

Output by Agriculture (excluding livestock)

Figure 10 provides an overview of aggregate agricultural output for the North Burnett Regional Council area, excluding the large value attributed to livestock production, which is the dominant agricultural output in terms of value. Citrus exports represent a significant component of the economy. These statistics exclude the rapid increase in the volume of other exports including blueberries and pecans.

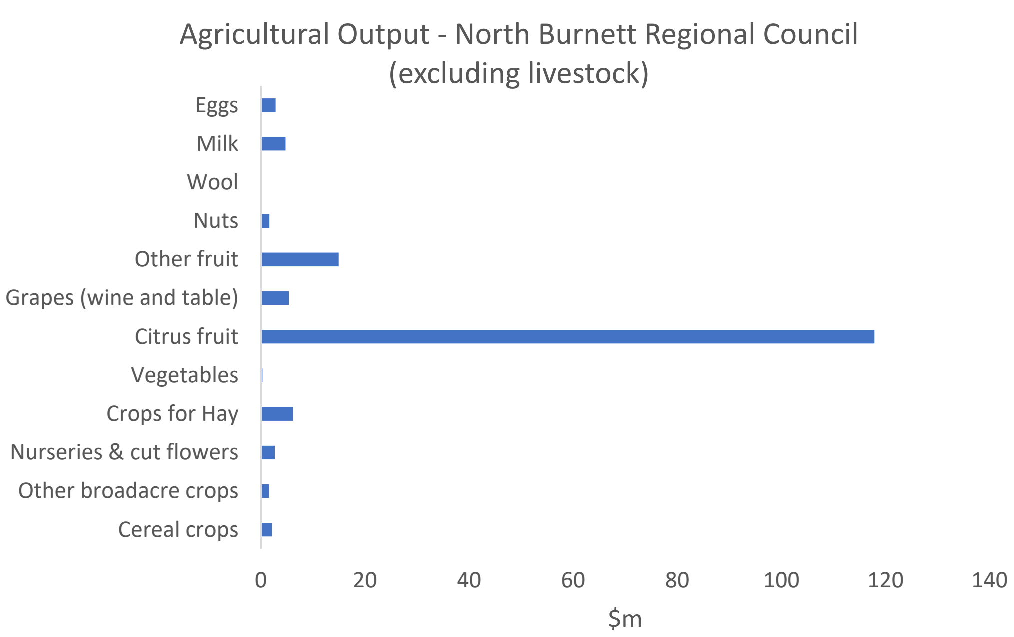

Figure 10. Agricultural output, by subsector, for the North Burnett Regional Council, 2015-16 ($m). Livestock slaughtering ($212m) not shown. *Source:* Economy ID.

Employment

Employment by industry in the North Burnett Regional Council area is provided in Table 11. Of the 1,552 FTE categorised in the agriculture, forestry and fishing subsector, 1,455FTE (94 per cent) are directly employed in the agriculture sector with the remainder employed in forestry and agricultural support services.

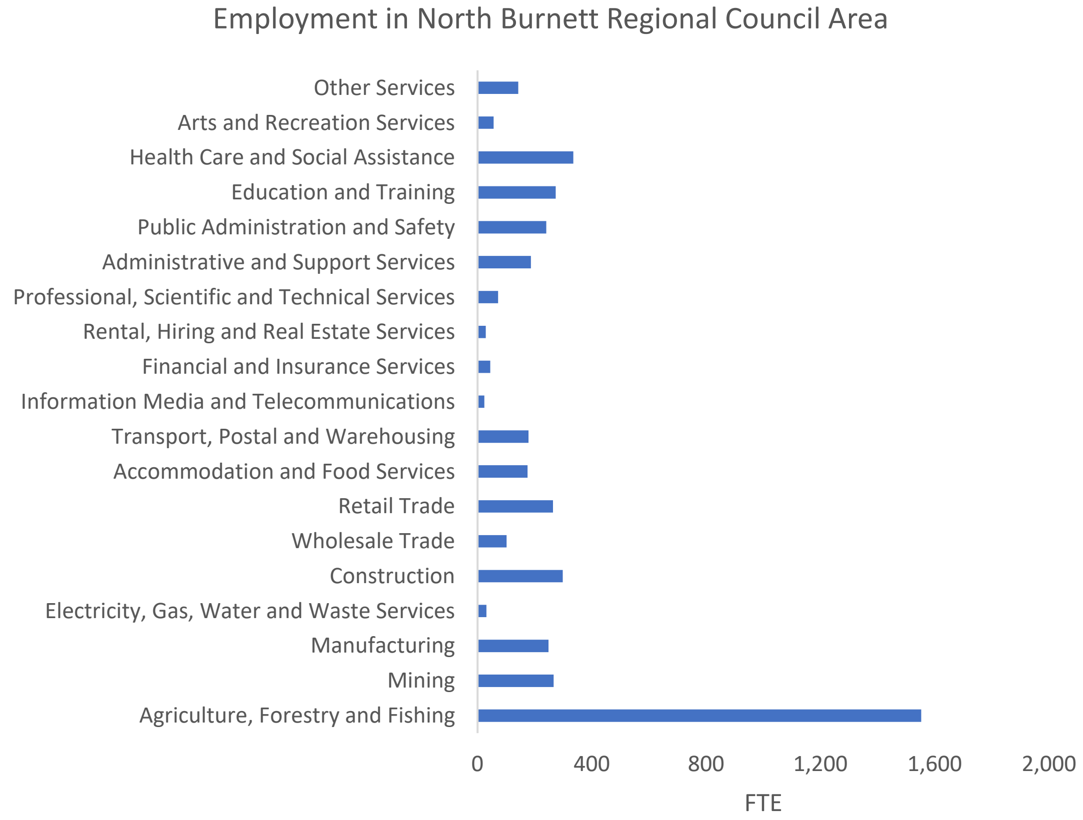

Figure 11. Employment by industry across North Burnett Regional Council, 2017-18 ($m). *Source:* Economy ID.

The above statistics were incorporated into the input-output analysis to ensure the most recent data is being used to measure the economic impact of increasing infrastructure and other resources to support the agricultural sector in the North Burnett Regional Council area.

Results of Input/Output Analysis

The input-output (IO) table was constructed for the North Burnett region with 2017-18 as base year. This was built using the most recent IO table for the 34 industry sectors in 2001-02 and then scaled to 2017-18 values using 2017-18 ABS and ABARES statistics. Initial, first round, industrial support, consumption-induced, total and flow-on multipliers were computed for the North Burnett Regional Council area. The results are provided in Table 5.

Table 5. Sector output, income and employment multipliers, North Burnett Regional Council area, 2017-18.

Sector	Initial	First round	Industrial support	Consumption-induced	Total	Flow-on
Output multipliers ($)						
Agriculture, Forestry and Fishing (excluding livestock)	1.000	0.411	0.257	0.652	2.321	1.321
Mining	1.000	0.170	0.038	0.375	1.583	0.583
Manufacturing	1.000	0.383	0.156	0.669	2.207	1.207
Electricity, Gas, Water and Waste	1.000	0.176	0.043	0.236	1.456	0.456
Construction	1.000	0.265	0.103	0.424	1.792	0.792
Transport	1.000	0.219	0.053	0.459	1.730	0.730
Retail Trade	1.000	0.152	0.049	0.777	1.977	0.977
Income multipliers ($)						
Agriculture, Forestry and Fishing (excluding livestock)	0.226	0.094	0.059	0.158	0.538	0.312
Mining	0.164	0.044	0.011	0.091	0.310	0.146
Manufacturing	0.250	0.098	0.041	0.162	0.551	0.301
Electricity, Gas, Water and Waste	0.086	0.038	0.013	0.057	0.195	0.109
Construction	0.144	0.075	0.027	0.103	0.349	0.205
Transport	0.189	0.064	0.015	0.111	0.378	0.190
Retail Trade	0.402	0.037	0.012	0.188	0.640	0.238
Employment multipliers (FTE)*						
Agriculture, Forestry and Fishing (excluding livestock)	0.044	0.017	0.011	0.023	0.095	0.051
Mining	0.014	0.005	0.001	0.013	0.033	0.019
Manufacturing	0.016	0.009	0.004	0.024	0.054	0.037
Electricity, Gas, Water and Waste	0.005	0.003	0.002	0.008	0.018	0.013
Construction	0.017	0.006	0.003	0.015	0.041	0.024
Transport	0.027	0.007	0.002	0.016	0.052	0.025
Retail Trade	0.050	0.004	0.001	0.028	0.083	0.033

* full-time equivalent per additional $1000 of agriculture sector output.

The initial impact refers to the assumed dollar increase in sales; that is, it represents the stimulus or the cause of the impacts. It is the unity base for the output multiplier. Associated directly with this dollar increase in output is an 'own-sector' increase in household income in wages, salaries, etc. used in the production of that dollar of output. For non-livestock agriculture in the North Burnett Council area the income multiplier of $0.226 is the increase expected to incomes expected from additional dollar invested in agricultural output. Also associated will be an 'own-sector' increase in employment, represented by the size of the sector employment coefficient. The employment coefficient represents an employment/output ratio and is interpreted as 'employment per thousand dollars of output.' The household and employment coefficients for selected sectors are provided in the second column of Table 5.

The first-round effect refers to the effect of the first round of purchases by the sector providing the additional dollar of output. For instance, the direct effect of an increase in one dollar in agricultural output is 41.1 cents from all intermediate sectors of the local economy. First round effects for income and employment are also provided, representing 9.4 cents in income due to first round effects and an additional 0.161 persons per thousand dollars of agricultural sector outputs.

Industrial support effects (also known as production-induced effects) represent the second and subsequent round effects, as successive waves of output increases occur in the local economy to provide industrial support as a response to the original dollar increase in sales to final demand. This term excludes any increases caused by increased household consumption. The industrial support effects of an increase of one dollar of sales from the agriculture sector to end-consumers is 25.7 cents over all sectors, with positive values also being felt in other sectors.

Consumption induced effects are defined as the effect manifest in the increase in household income associated with the original dollar stimulus in output. The consumption induced effect for the agricultural sector is relatively high at 65.2 cents in added consumption from every dollar of increased output in that sector.

The flow-on effects are defined as the impacts which occur in all sectors due to an initial dollar increase in output from a given sector. These are represented as the difference between total impacts and the initial impact and allows for the separation of cause and effect factors in the multipliers themselves. The cause of the impact is felt through the initial impact (original dollar-increase in a given sector) and the effect is given by the first-round, industrial support and consumption induced effects which together constitute the flow-on effects. For the agricultural sector the flow-on effect equates to $1.32 in first round, industrial and consumption outputs for every added dollar of output in that sector.

Added output from agriculture, excluding outputs from the livestock sector, represents a source of significant multiplier effects on the local economy.

This reflects the fact that that industries which supply inputs to the agriculture sector have a higher than average regional economy value added as a component of total production value. A value of over 1 indicates significant input linkage from all industries to the industry undergoing an increase/decrease in turnover.

The non-livestock agriculture sector, which is dominated by horticulture production, contributes the highest value net value added (V.A.) per dollar with a Type I multiplier of $1.41 and a Type II multiplier of $2.32. These multiplier levels, which are significant, indicates that agriculture is already a highly productive industry sector and could be positioned to extract substantially greater economic benefits in the region if increased agricultural outputs could be secured on a sustainable basis. The net flow-on value added effect of $1.32 in wages, profits and depreciation from its own sector and all other industry sectors for every dollar of output is substantially higher than other industry sectors in the region. The agriculture (horticulture) industry generates the highest net industry support effects in value added terms out of all industry sectors in the region. This is a reflection of the backward linkage index through the supply chain of agricultural products, with a value of 2.321.

The Type I and II multipliers for income and employment are provided in Table 6.

Table 6. Type I and II income and employment ratios, North Burnett Regional Council area, 2017-18.

Ratio	Sector	Income	Employment
Type IA	Agriculture, Forestry and Fishing	1.417	1.391
	Mining	1.271	1.344
	Manufacturing	1.391	1.581
	Electricity, Gas, Water and Waste	1.447	1.553
	Construction	1.524	1.360
	Transport	1.337	1.266
	Retail Trade	1.093	1.077
Type IB	Agriculture, Forestry and Fishing	1.262	1.237
	Mining	1.065	1.080
	Manufacturing	1.165	1.266
	Electricity, Gas, Water and Waste	1.154	1.288
	Construction	1.188	1.157
	Transport	1.079	1.059
	Retail Trade	1.030	1.030
Type IIA	Agriculture, Forestry and Fishing	1.962	1.763
	Mining	1.622	2.054
	Manufacturing	1.815	2.750
	Electricity, Gas, Water and Waste	1.822	2.873
	Construction	1.902	2.033
	Transport	1.669	1.663
	Retail Trade	1.498	1.589
Type IIB	Agriculture, Forestry and Fishing	1.378	1.155
	Mining	0.893	1.398
	Manufacturing	1.206	2.330
	Electricity, Gas, Water and Waste	1.269	2.426
	Construction	1.425	1.393
	Transport	1.006	0.929
	Retail Trade	0.591	0.666

The Type IA ratio illustrates that for each unit of initial employment in the agriculture sector, caused by increased output, the associated first-round employment coefficient is 4.629. This represents a substantial boost in local area employment effects for every dollar in increased output generated through agricultural investments. The income multipliers for the agricultural sector is also substantially high and in line with the increases in income that would be expected to flow from increased output in other sectors. Type 1 value added multipliers can be negative, applicable from the impact of natural disasters, industry shutdowns or a disease outbreak.

Water security

Economic outcomes from the development of infrastructure to help improve water security for the substantial horticultural operations with water allocations from the Boyne River can be estimated using the above analysis. Horticulture earned the region roughly $120m in annual revenue (2016-17). This estimate pre-dates the development of new horticultural operations in the recent two years. A conservative estimate given an increase in water security from 2017-18 levels of 73 per cent to 88 per cent upon the construction of water storage infrastructure for the expected increase in volumetric output is approximately 25 per cent. That is, existing horticultural operations are expected to increase their production volumes by one-quarter of 2017-18 levels upon more reliable access to water allocations. This study excludes improvements in quality of agricultural produce from the economic assessment, however an increase in price premiums would be a consideration for fine-tuning the model.

The net Type IB multiplier results derived from the model indicate that for every $1million in output from the construction of water storage infrastructure will generate an extra $1.668 million in industry support effects through the supply chain, excluding economic activity generated by the construction process itself. For horticulture, this would represent an increase of roughly $50 million (1.668 x $30m). The industries that will benefit most from the construction of assets that improve water security are horticulture ($120 million, accounting for nearly 50 per cent of industrial support V.A effects), other agriculture ($4.9 million, 11 per cent) and transport ($3.7 million, 8 per cent). The model results indicate that an extra 0.072 jobs per $1,000 would be generated through the supply chain, dominated by up to 2000 additional jobs in horticulture, representing 50 per cent of additional jobs.

Assumptions and Limitations

Assumptions and limitations govern the adaptability and accuracy of input-output model multipliers:

- Fixed proportionality between inputs and outputs assumes that every dollar of inputs to an industry generates a dollar of output;
- The fixed productivity coefficient assumes that economies of scale are fixed, such that, as production expands, the cost per unit of production remains constant;
- Unlimited access to resources as inputs;
- The simulated impacts of reduced turnover due to weather events assumes that the input resource slack is made available to other industries. This absorption to other sectors would then need to be reflected in an increased demand for goods and services for those sectors;
- The use of IO model multipliers is only useful for industry output shocks that don't exceed roughly $0.5bn. Production value increases beyond this level increase the demand for inputs of goods and services which inflates the local consumption costs of capital, labour, land, overheads and variable inputs. This generally results in lower growth in input demand which can then lead to a lower overall net multiplier effect. Economic shocks that exceed $0.5bn will bias IO multipliers and overstate the ripple effects through an economy (for output, employment, income or value-added models).
- General equilibrium modelling is more appropriate for industry shocks and large transactions.

There are some shortcomings of using multiplier values of IO modelling, such limitless resources, zero opportunity cost to other industries, no economies of scale, fixed proportionality between inputs and outputs, and fixed input/output costs and prices irrespective of production scale. Therefore, multiplier values should be used with some caution.

Although the Queensland regional IO tables depict inter-industry production relationships of 2005-06, production technologies and processes, and labour to capital ratios may have changed, particularly in the productivity of horticultural and food processing sectors.

Conclusions

This work assessed the regional economic benefits of increasing the reliability of supply of irrigation water for horticultural production in the Boyne system. It does not provide a cost/benefit analysis or feasibility study of any specific water infrastructure such as the proposed Cooranga Weir. Rather, it provide both a detailed qualitative and quantitative assessment of clear benefits from improved water reliability, not just for horticultural producers, but for the broader regional economy across all sectors.

Increasing irrigation water reliability from the current 73% to a future 88% would have a major economic impact, not just in the Boyne area, but in the whole North Burnett Regional Council area. The multipliers of increased agricultural output (2.32), income (0.54) and employment (0.01) are considerable. The output multiplier means that for every additional dollar of agricultural output in the North Burnett Region (excluding livestock), $1.32 of additional economic output is produced in other economic sectors. Each dollar of increased output from agriculture (excluding livestock), an additional 54c of income is generated across the regional economy. For every $10,000 of additional agricultural sector output (excluding livestock), 1 full time equivalent job is created in the North Burnett economy.

The agriculture (horticulture) industry generates the highest net industry support effects in value added terms out of all industry sectors in the region. For each unit of initial employment in the agriculture sector, caused by increased output, the associated first-round employment coefficient is 4.629, which is relatively high. These considerable multiplier effects reflect the close economic linkages between agriculture and other sectors in the regional economy.

Increased water reliability would also have other industry effects. Major increases in production output are likely from increased yield and quality. Irrigated area may also increase given that, unlike many other areas, the Boyne area has suitable irrigable soils for horticulture to expand. However, in expanding irrigation area, the industry would need to be careful not to replicate problems of disparity between irrigation demand and water availability.

Apart from these production increases, increased water reliability would also allow producers, processors and transporters to more reliably invest. It would allow yield and quality to be more reliable allowing the industry to better meet volume and quality standards in export markets. It would also support diversification where movement into pecans and blueberries could be extended into avocadoes and mangoes. Importantly, water reliability would reduce or avoid the current impacts and threats to the industry posed by poor water availability and inefficient practices such as running out of water during the growing season and digging in bedsands.

While livestock is the major agricultural industry in the North Burnett, horticulture is critically important to the local economy. Its impact on employment and economic activity is clear. The North Burnett has many economic challenges, while relatively small in area, the Boyne irrigation industry is crucial to economic development and diversification. Increasing the reliability of water supply will have major regional economic benefits particularly as rainfall is predicted to be more variable into the future.

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Appendix A. Interview Questions

The following questions were used in irrigator and other stakeholder interviews.

1. Describe the main irrigated agricultural production systems now?
2. What are the production limitations?
3. With poor reliability of water – how do growers cope? What strategies do they use?
4. What do people see as the outlook for water supply/reliability?
5. With continued poor reliability – what will be the consequences/implications?
6. Given better reliability, what are the industry's options?
7. If you expand irrigation area, what is the true cost of establishing irrigation?
8. What are the main production risks?
9. What is the likelihood of risk and impact of risk?
10. What is the labour situation (availability and cost)?
11. Are there sufficient support industries (local technicians)?
12. Transport cost generally?
13. Distance to market issues?
14. Other Issues – e.g. Access to high speed internet?

Appendix B: Details of Input Output Analysis

We use I/O symmetric tables for an economy comprising *n* sectors

$$x = Ax + y = \begin{pmatrix} A_{s,s} & A_{s,-s} \\ A_{-s,s} & A_{-s,-s} \end{pmatrix} \begin{pmatrix} x_s \\ x_{-s} \end{pmatrix} + \begin{pmatrix} y_s \\ y_{-s} \end{pmatrix}, \quad (1)$$

where $x = x_i$ is the production vector (i.e., total output), $y = y_i$ is the vector of final demand (i.e., final output of the regional economy) and $A = A_{i,j}$ is the matrix of technical coefficients. The economy can be split into sectors comprising one or more sub-sectors. Subscript *s* refers to a specific sector, and the subscript *-s* to the remaining sectors of the regional economy.

Equation (1) can be formulated as

$$x = (\mathrm{I} - A)^{-1} y = \begin{pmatrix} \Delta_{s,s} & \Delta_{s,-s} \\ \Delta_{-s,s} & \Delta_{-s,-s} \end{pmatrix} \begin{pmatrix} y_s \\ y_{-s} \end{pmatrix}, \quad (2)$$

where

$$\begin{pmatrix} \Delta_{s,s} & \Delta_{s,-s} \\ \Delta_{-s,s} & \Delta_{-s,-s} \end{pmatrix} = \begin{pmatrix} (\mathrm{I} - A_{s,s})^{-1} & (\mathrm{I} - A_{s,-s})^{-1} \\ (\mathrm{I} - A_{-s,s})^{-1} & (\mathrm{I} - A_{-s,-s})^{-1} \end{pmatrix} \quad (3)$$

with $(\mathrm{I} - A)^{-1}$ formulated by the Leontief inverse.

The HEM measures the impact of every sector (s) by comparing the production vector of that economy with (Xx) and without (x^*) that sector, which are a function of the technical coefficients with (AA) and without (A^*) that sector and the final demands with (Yy) and without (y^*) that sector, respectively. The production of the economy in which a given sector (*s*) is extracted is

$$x^* = (\mathrm{I} - A^*)^{-1} y^* = \begin{pmatrix} (\mathrm{I} - A_{s,s})^{-1} & 0 \\ 0 & (\mathrm{I} - A_{-s,-s})^{-1} \end{pmatrix} \begin{pmatrix} y_s \\ y_{-s} \end{pmatrix}, \quad (4)$$

The change in production is obtained as the difference between Xx (Equation (2)) and x^* (Equation (4)) and shows the effect of sector *s* over the remaining sectors of the regional economy

$$x - x^* = \begin{pmatrix} C_{s,s} & C_{s,-s} \\ C_{-s,s} & C_{-s,-s} \end{pmatrix} \begin{pmatrix} y_s \\ y_{-s} \end{pmatrix}. \quad (5)$$

Every sector has four separate effects over the economy: an internal effect, a mixed effect, an external or net backward linkage and an external or net forward linkage. The internal effect of sector *s* (IE_s) represents the effect of the goods produced, sold and purchased inside sector *s* to obtain its final demand y_s. The mixed effect (ME_s) measures the impact of the products sold by sector *s* to other sectors and later re-purchase to produce y_s. The net backward linkage (BL_s) represents the direct and indirect requirements of sector *s* from the rest of the economy to obtain y_s (i.e., the 'import' for each sector). The net forward linkage (FL_s) represents the direct and indirect requirements of the remaining regional economy from sector *s* to obtain y_{-s} (i.e., the 'export' from each sector):

$$IE_s = c'(\mathrm{I} - A_{s,s})^{-1} y_s, \quad (6)$$

$$ME_s = c' \left[\Delta_{s,s} - (\mathrm{I} - A_{s,s})^{-1} \right] y_s, \quad (7)$$

$$BL_s = c' \Delta_{-s,s} y_s, \quad (8)$$

$$FL_s = c' \Delta_{s,-s} y_{-s}, \quad (9)$$

where c' is the vector (1,…,1).

Appendix C: Industry Sectors used in the Analysis

The industry sectors and sub-sectors used in the analysis are as follows:

- Agriculture
  - Sheep
  - Grains
  - Beef cattle
  - Dairy cattle and pigs
  - Other agriculture
  - Sugar cane growing
  - Forestry and fishing
- Mining
  - Coal, oil and gas
  - Non-ferrous metal ores
  - Other mining
- Manufacturing
  - Food manufacturing
  - Textiles, clothing and footwear
  - Wood and paper manufacturing
  - Chemicals, petroleum and coal products
  - Non-metallic mineral products
  - Metals, metal products
  - Machinery, appliances and equipment
  - Miscellaneous manufacturing
- Electricity supply, gas and water
- Construction
  - Residential building construction
  - Other construction
- Trade
- Accommodation, cafes and restaurants
- Transport
  - Road transport
  - Rail and pipeline transport
  - Other transport
- Communication services
- Finance, property and business services
- Ownership of dwellings
- Government administration and defence
- Education
- Health and community services
- Cultural and recreational services
- Personal and other services