NORTHERN HEALTH SERVICE DELIVERY

TRADITIONAL OWNER–LED DEVELOPMENT

AGRICULTURE & FOOD

Northern Australia beef situation analysis

A report to the Cooperative Research Centre for Developing Northern Australia

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Disclaimer

Peer review statement

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

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

- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the

Australian Code for the Responsible Conduct of Research (NHMRC 2018), and provided constructive feedback which was considered and addressed by the author(s).

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Shortened forms

SHORT FORM	FULL FORM
AADIS	Australian Animal Disease Spread Model
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ACCC	Australian Competition and Consumer Commission
ACIAR	Australian Centre for International Agricultural Research
AE	adult equivalent
AGECL	age at first corpus luteum
Agvet Code	Agriculture and Veterinary Chemicals Code
AHA	Animal Health Australia
AI	artificial insemination
AMIC	Australian Meat Industry Council
AMR	antimicrobial resistance
ANU	The Australian National University
APSIM	Agricultural Production Systems Simulator
APVMA	Australian Pesticides and Veterinary Medicines Authority
ASEAN	Association of Southeast Asian Nations
ASEL	Australian Standards for the Export of Livestock
BBSE	bull breeding soundness evaluation
BCR	benefit–cost ratio
BCS	body condition score
BEF	bovine ephemeral fever
BIC	buyer identification code
BICON	Biosecurity Import Conditions system
BIRA	biosecurity risk analysis
BOM	Bureau of Meteorology
BVDV	pestivirus
BCR	benefit–cost ratio
BSE	bovine spongiform encephalopathy
BTEC	Brucellosis and Tuberculosis Eradication Campaign
CCA	Cattle Council of Australia
CIE	Centre for International Economics
CITES	Convention on International Trade in Endangered Species
COAG	Council of Australian Governments
CO_2	carbon dioxide

SHORT FORM	FULL FORM
CO_2e	carbon dioxide equivalent
CSU	Charles Sturt University
CRC	Cooperative Research Centre
CRCNA	The Cooperative Research Centre for Developing Northern Australia
Cth	Commonwealth
CV	coefficient of variation
DAF	Department of Agriculture and Fisheries
DAWE	Department of Agriculture, Water and the Environment
DPIR	Department of Primary Industry and Resources
DPIRD	Department of Primary Industries and Regional Development
DSS	decision support systems
DTC	days to calving
EBIT	earnings before interest and tax
EBV	estimated breeding value
EIA	environmental impact assessment
EIAA	Environmental Impact Assessment and Approval
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Authority
ESCAS	Exporter Supply Chain Assurance System
EY	Ernst & Young
FIRB	Foreign Investment Review Board
FMD	foot-and-mouth disease
FNIRS	functional near-infrared spectroscopy
FTE	full time equivalent
gEBV	genomically enhanced estimated breeding value
GHG	greenhouse gas
GM	gross margin
GMI	global meat industries
GPS	global positioning satellite
GRASP	Grass Production Model
HGP	hormonal growth promotant
ICT	information communication technology
IF	integrated framework
ILUA	Indigenous Land Use Agreement
IPP	Indigenous Pastoral Program
IRR	internal rate of return
LiDAR	light detection and ranging (remote sensing method)
Livecorp	Australian Livestock Export Corporation Limited

SHORT FORM	FULL FORM
LPA	Livestock Production Assurance
LTS	Australian Standards and Guidelines for Welfare of Animals – Land Transport of Livestock
MISP	Meat Industry Strategic Plan
MLA	Meat and Livestock Australia
MSA	Meat Standards Australia
NABF	Northern Australia Biosecurity Framework
NABRC	North Australia Beef Research Council
NABS	Northern Australian Biosecurity Surveillance project
NABSA	North Australian Beef Systems Analyser
NAHIP	National Animal Health Information Program
NAHIS	National Animal Health Information System
NAIF	Northern Australia Infrastructure Facility
NAMP	National Arbovirus Monitoring Program
NAQS	Northern Australia Quarantine Strategy
NAWRA	Northern Australia Water Resource Assessment
NHVR	National Heavy Vehicle Regulator
NIRS	near-infrared spectroscopy
NLIS	National Livestock Identification System
NLMP	National Livestock Methane Program
NNTT	National Native Title Tribunal
NPV	net present value
NRS	National Registration Scheme
NSDI	National Significant Disease Investigation Program
NSW	New South Wales
NT	Northern Territory
NTPS	Northern Territory Planning Scheme
NTSESP	National TSE Surveillance Project
NWI	National Water Initiative
P4M	the percentage of cows pregnant within four months of calving
PEG	poly ethylene glycol
PIC	property identification code
PLM	precision livestock management
PMAV	property map of assessable vegetation
PNG	Papua New Guinea
PPAI	post-partum anoestrus interval, or time between giving birth and cycling
PV	present value
QAAFI	Queensland Alliance for Agriculture and Food Innovation
QLD	Queensland

SHORT FORM	FULL FORM
R&D	research and development
RDEA	research, development, extension and adoption
RELRP	Reducing Emissions from Livestock Research Program
RFID	radio frequency identification
RMAC	Red Meat Advisory Council
ROSI	Roads of Strategic Importance
SA	South Australia
SDI	Significant Disease Investigation
SOI	Southern Oscillation Index
SWF	Old World and New World screw-worm fly
SWFSPP	Screw-Worm Fly Surveillance and Preparedness Program
SWOT	strengths, weaknesses, opportunities, threats
TB	bovine tuberculosis
THI	temperature–humidity index
TraNSIT	Transport Network Strategic Investment Tool
TSE	transmissible spongiform encephalopathy
TSEFAP	TSE Freedom Assurance Program
UAE	unmanned aerial vehicle
WA	Western Australia
WAOL	Western Australian Organism List
WoNS	Weeds of National Significance
WoWW	War on Western Weeds

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Part I SWOT analysis and recommendations

1 Background

1.1 Scope of work

The approach for this analysis was to undertake a comprehensive review of the literature on beef production technologies and beef system outcomes, including supply-chain issues such as transport and logistics, and then to 'socialise' the findings of that review and gain the perspectives of different stakeholders and industry representatives. Based on these inputs, a strengths, weaknesses, opportunities and threats (SWOT) analysis was undertaken from which recommendations were developed and refined via further stakeholder engagement.

1.2 Structure of report

The report is structured in two parts. Part A describes the northern Australia beef industry, provides a SWOT analysis and presents recommendations. The recommendations meet the requirement to '…inform the Cooperative Research Centre for Developing Northern Australia (CRCNA) on strategic research investments, assist with coordination of investment across the northern Australia beef sector and improve strategic alignment across the research, policy and service delivery arms of the sector'. The input from the socialisation with different stakeholders of the review (Part B, described below) was integrated into the SWOT analysis and recommendations.

Part B of the report comprises detailed reviews of the different aspects of the northern Australia beef industry. The report is structured to follow the northern Australia beef supply chain (Figure 1), reviewing relevant literature and reports in each section. The last section quantitatively estimates and compares the industry-level benefit for different investments or portfolios of investments.

1.3 The northern Australia beef industry

The beef industry is a critical component of the economy of northern Australia. It represents the largest economic land use, covering around 60% of the land area (Figure 2). The last comprehensive assessment of the economic value of the industry estimated its worth at appropriately $5.03 billion, of which $3.7 billion was production at the farm gate and $1.3 billion in first stage processing (Gleeson et al., 2012). The industry is largely export focused. Around 1 million live animals per year are exported into South-East Asian markets, with 59% into Indonesia (ABS, March 2019). Breeding and grazing properties in northern Australia are part of the beef export and domestic supply chains that include feedlots and processing facilities in south-east Queensland.

The production systems are mostly extensive grazing of rangelands consisting of 'unimproved' native and naturalised grasses, herb, forbs and shrubs. Production is largely dependent on seasonal rainfall and, given the location in the tropics, is vulnerable to seasonal variability. The low-input, low-cost approach has been a strength of the industry for decades, but recent increases in input costs and market disruptions have not been matched with productivity gains, making many properties financially marginal at best (McCosker et al., 2010; Holmes et al., 2017). The land types on which grazing occurs are typically low in nutrient and organic content, which together constrain opportunities to plant crops. Thus, broadacre farming is restricted and irrigation accounts for only a small proportion of the total area (0.15%, Figure 2). Consequently, for the majority of northern Australia, beef production is the only viable agricultural product. Sheep numbers used to be high on the Mitchell Grass Downs of western Queensland but they have declined drastically due to predation and, until recently, poor profitability of wool production following the collapse in the 1990s of the price support mechanism for wool. Harvest of feral goats and to some extent donkeys, camels and other feral animals, as well as kangaroos, make up small industries of localised importance.

Property sizes are large and supply chains have a vast geographic spread, including the movement of animals through breeding, growing and fattening properties through to feedlots and processing at abattoirs concentrated near major population centres, mostly on the east coast of Australia. Live export represents a significant proportion of northern Australia beef supply chains and these live export supply chains are in regions with sparse road networks, coupled with long-distance transport, seasonal access issues, and limited port and shipping capacities.

Grazing is undertaken on family-owned grazing properties, as well as large corporate operations which own hundreds of thousands of cattle. The diversity of cattle businesses support a variety of production systems, from breeding only to breeding and fattening, to just fattening in more productive areas in central Queensland or on the tropical coast. In the high-rainfall zone (600 mm and above) moderate stocking rates are achievable (one animal per 2–5 ha), with options to augment production through improved pasture grasses and legumes that can support both breeder and finishing operations. In the lower rainfall zones stocking rates are lower, and consequently property sizes are larger with limited ability to achieve weight gains to domestic market specification. These properties are predominately breeder operations for the live export market.

In general, supply chains involve long-distance transport almost exclusively reliant on road transport for both inputs and exports. Approximately 5.3 million cattle movements occur per year, with most movements (2.4 million) between properties and over 1 million to export depots. Most cattle properties are a substantial distance from their major domestic market or export ports, in general not transacting with the final buyer of their product. Expected market and seasonal conditions influence cattle inventory (both numbers and type) and production decisions are made well in advance of actual market outcomes. This provides a challenge because of limited market feedback, the length of time to change the end product of production and low levels of adoption of new technology. These factors result in long lead times to transform individual businesses and the industry as a whole.

Beef production in northern Australia experiences two disparate sets of issues in relation to natural resource management. First, the industry is exposed to environmental risk because it depends on water from the natural environment and the feed base is largely comprised of intact native pastures. Changes in the conditions of the natural environment, whether driven by factors external to the industry or by the actions of the industry itself, impact the profitability and sustainability of beef cattle production. Second, extensive beef cattle production occupies a large proportion of the land mass of northern Australia. The industry plays a significant role as a land manager. This role requires the industry to focus on environmental management both to allow functioning of the beef value chain and for broader whole-of-community needs. This latter point is underappreciated, but it has important implications for social licence to operate. Specifically, pastoralists are the only land managers present across much of northern Australia and the Australian community is reliant (and has been reliant) on pastoralists to effectively manage the environment for the range of ecosystem services that are required and as a defence from biosecurity incursions. This reality is both a challenge and an opportunity but its relevance to pastoral production is intensified by recent policy initiatives seeking to incorporate ecosystem accounting into assessments of environmental services.

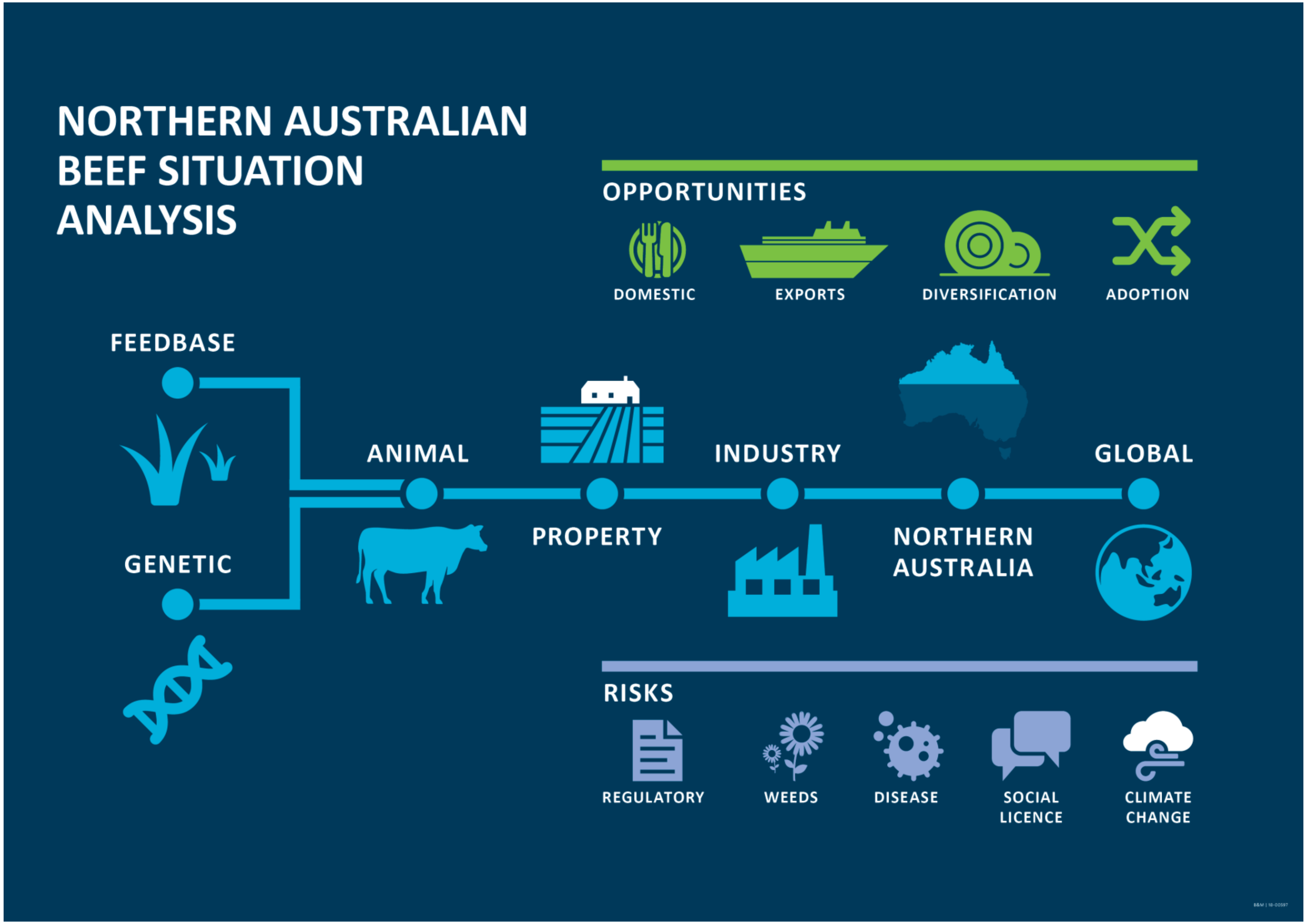

Figure 1 Northern Australia beef supply chain

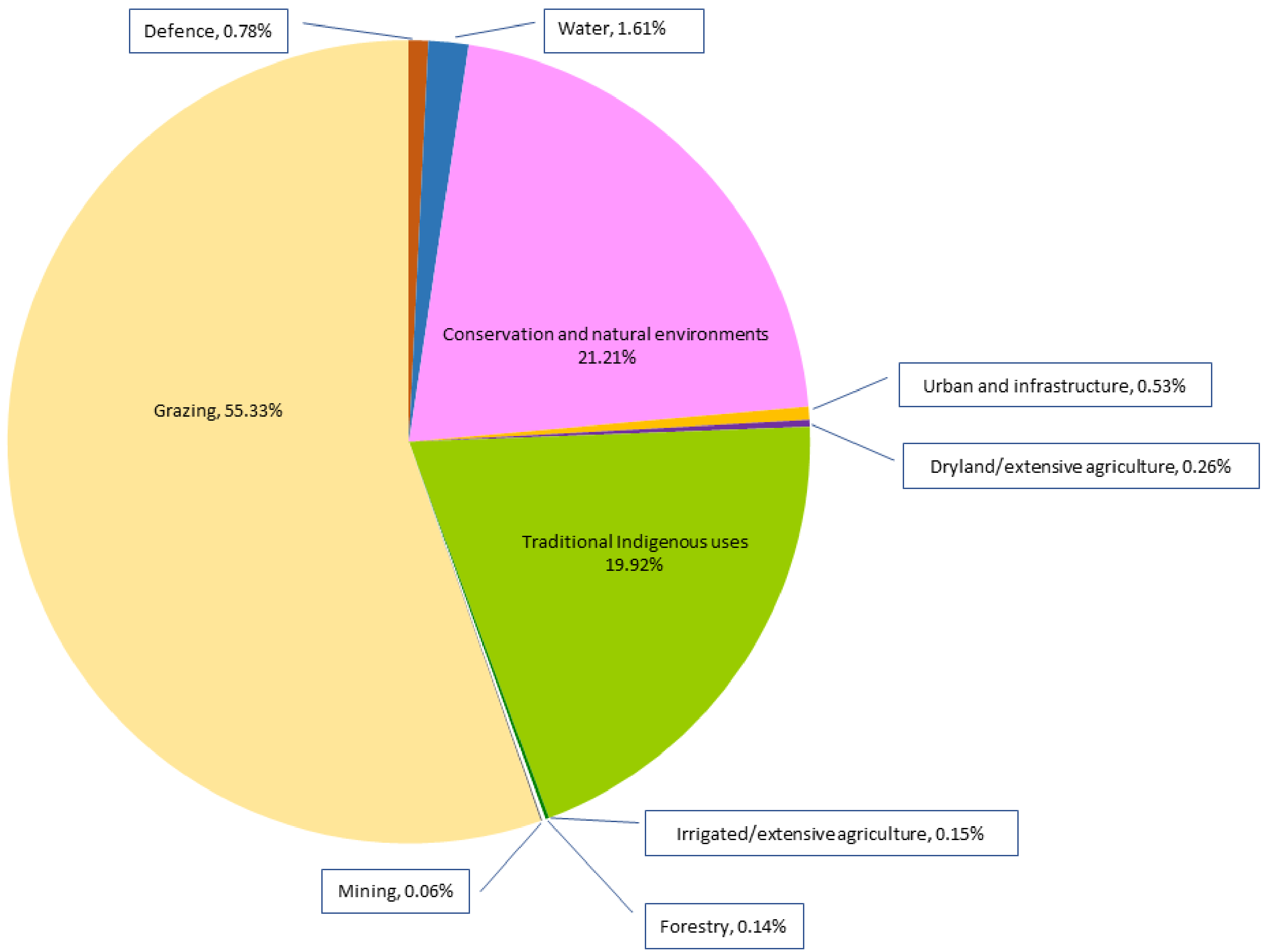

Figure 2 Land use by area across northern Australia

2 SWOT analysis

There have been a number of previous reviews of the Australian, and specifically the northern Australia, beef industry. The most comprehensive and recent review was that undertaken by Gleeson et al. (2012), which assessed risks and opportunities. The authors listed a number of critical factors that would determine the growth and sustainability of the industry:

- The need to maintain a good trading relationship with Indonesia to take advantage of the demonstrable synergies between the production systems of northern Australia and Indonesia, where northern Australia produces tropically adapted feeder cattle for the Indonesian market to fatten utilising low-cost and abundant labour and feed sources.
- The need to establish a viable alternative market in northern Australia such as local meat processing, although in this suggestion there was the recognition of:
  – the need to increase market opportunities through the reduction of trade barriers
  – the need for a stable supply of cattle rather than cattle only being supplied opportunistically
  – the lack of a reliable source of skilled labour.
- The need for a feed-on sector or the need to diversify production from breeding to breeding and fattening enterprises. To achieve this objective, the feed base could be improved through irrigated agriculture developments that could supply fodder and cheap protein. This could also catalyse a change in cattle breeds to improve eating quality while maintaining sufficient tick resistance.

The northern Australia beef industry underwent significant changes from the 1950s through improved breeds (particularly Brahman cattle); infrastructure such as roads, water and fences; and pasture improvements and herd productivity gains. These changes allowed it to respond to the rapid growth in the export of live cattle in the 1990s (Bortolussi et al., 2005a). Over the last decade productivity gains in the agricultural sector (including the beef sector) have plateaued and a business as usual approach is unlikely to maintain profitability in the northern Australia beef sector. Jackson and Valle (2015) identified several factors that negatively affect the productivity growth, and hence profitability, of specialist beef producers. These include the availability and the under-adoption of new technologies to improve production efficiency, reduced returns to scale compared with other agricultural activities, and industry structure. In particular, the large proportion of small-scale producers have lower productivity and profitability than larger farms. This significantly reduces the productivity and profitability of the industry as a whole.

There is a large diversity in business performance across northern Australia beef operations. This has been highlighted in the *Australian beef report* (Holmes et al., 2017), which surveyed family-owned beef operations across Australia. The top 25% of producers had considerably better performance than the bottom 75% with the distinguishing features of the top 25% of producers being: better herd productivity, targeted herd expenditure to achieve the most gain per dollar spent, efficient use of labour, and more operating scale. The picture is similar for the top 25% of pastoral companies that had greater herd productivity compared with the bottom 75% (McLean et al., 2018).

This review updated the Holmes et al. (2017) report to provide a more detailed analysis of the regions of interest to this study (Section 9). The review concluded:

> There is a significant variation in industry performance generally, and across the regions. The factors separating the top performers from the rest are clear and straightforward. There is considerable scope for improvement by the poorer performers in the industry.
>
> Effective improvement will require significant changes across the industry, and individual producers will have to want to change before performance will improve. There needs to be a good understanding of what are, and what are not, the profit drivers by producers and the R,D&E community. There are no silver bullets; increasing demand for protein, R&D breakthroughs or new technologies cannot be relied on to improve industry performance. A good understanding of, and clear focus on, the fundamentals of profitable beef production will improve performance regardless, as well as position producers to benefit from any advances that may occur.
>
> The adoption of existing R&D is arguably more of a bottleneck to industry performance than R&D gaps are. One area where there is a genuine R&D gap is the understanding of land condition, what it is, how it is changing and its interrelation with business performance. This area has significant implications for the long-term sustainability of the industry.

The conclusion that use and adoption of existing research and development (R&D) is more of an issue than lack of new technologies and research breakthroughs is open to debate and discussion. Certainly, there would be little question that a major impediment to lifting performance is the low rate of adoption of best management practices. Industry acknowledges this is a major concern. However, while R&D may not be the priority for the bottom 75% of producers, there is a demand from innovative producers for new technologies, practices and systems. The R&D that provides these new technologies and practices can help to keep innovative producers at the frontier of productivity gains.

Further, there is evidence to suggest that declining gains in productivity in broadacre agriculture since the 1990s can, in part, be attributed to stagnating public sector R&D (Sheng et al., 2011). There has also been a steady decline in the terms of trade for the agricultural sector, which has resulted in pressure to improve productivity. Productivity growth has been slower in the beef industry than in the cropping sector (Jackson and Valle, 2015). One of the reasons put forward is that broader developments in science and technology are not as applicable to grazing industries (e.g. digital technologies have had far more impact in the cropping sector than in the beef industry) (Jackson and Valle, 2015). Nevertheless, adoption of technologies remains a key issue for the beef industry.

The concentration of value chains beyond the farm gate could also contribute to reduced returns, with cattle sellers at a competitive disadvantage to buyers who have market power due to the lack of competition (Australian Competition and Consumer Commission, 2017).

Presented below is the SWOT analysis for the northern Australia beef industry (Strengths: Table 1; Weaknesses: Table 2; Opportunities: Table 3; and Threats: Table 4). These tables represent a combination of multiple lines of evidence, including:

- the literature review documented in Part II of this report
- previous reviews of the northern Australia beef industry (Table 5)
- consultation with industry representatives and supply-chain actors.

Table 1 Strengths of the northern Australia beef industry

STRENGTH	EXPLANATION	WHERE	SOURCE
Feed base			
Dominance of natural pastures	In a market that is increasingly placing emphasis on provenance and organic production, the rangeland pastures of northern Australia provide a market advantage. There is a positive consumer perception of beef production	Northern Australia	12, 13, 30 and Section 13
Genetics			
Tropically adapted beef breeds	Since the introduction of Brahmans (*Bos taurus indicus*) (*Bos indicus*) to northern Australia, this breed, its cross-breeds and composite breeds with *Bos taurus taurus* (Bos taurus) have underpinned industry productivity in the north. The breeds are selected for the climate regions and the receiving markets	Northern Australia	14, Section 5 and Section 7
Cross-bred Bos taurus cattle in the semi-arid zone	The herd and industry are well established with a calf factory herd structure, with some flexibility for alternative finishing markets and slaughter	Northern WA, NT and North QLD	14
Animal			
Quality	Australian livestock have a reputation for good performance in overseas markets and are attractive to overseas consumers	Domestic and live export markets	5
	There are a diverse range of animals that can meet multiple markets	Northern Australia	11, 14 and 18
Property			
Efficient property management	There have been significant investments in on-property infrastructure to improve property management	Australia	1, 14 and 17
Land values	From an international investor's perspective land values in the north of Australia are actually quite affordable compared to other parts of the world	Australia	47
Industry			
Concentration of processing capacity	The processing capacity is dominated by a few large operators, which provides economies of scale, access to skilled labour and economic viability	Australia	33, 35 and Section 13
Quality assurance	The Exporter Supply Chain Assurance System (ESCAS) currently provides the industry with the regulatory controls to safeguard animal welfare outcomes through overseas supply chains	Live exports	5
	There are government regulations and industry-based quality assurance programs that allow the industry to demonstrate environmental credentials, animal welfare outcomes, food safety standards, and that provide access international markets	Domestic and live export markets	18, 19, 20, Section 9 and Section 10
	Australian animal welfare and transport standards support animals being delivered to domestic and international markets in good condition	Domestic and live export markets	5, 18, 19, Section 9 and Section 10
People	The industry is well coordinated and well represented, providing national leadership	Australia	4 and 30

STRENGTH	EXPLANATION	WHERE	SOURCE
Scale	The industry is mature and established with large-scale (12 million head) adapted property management that is tailored to meet current market requirements	Northern Australia	1, 14, 20, Section 6 and Section 7
Northern Australia			
Government investment	There have been significant recent investments in off-property infrastructure, regulation reform, and research initiated by the Agricultural Competitiveness and Northern Australia White Paper	Australia	9, 21 and Section 13
	There is significant jurisdictional co-investment in off-property infrastructure, regulation reform and research	Northern Australia	16, 22, 23, 24 and 27
	Australian Government currently provides strong ongoing support to the livestock export trade, particularly under the ESCAS regulatory framework	Live exports	5 and Section 9
	Disaster recovery support is available to the industry, for example, the support through northern Queensland floods in 2019	Australia	4, 21 and 25
	The industry co-invests in research, development and adoption, domestic and international marketing, and market development via the collection of transaction levies and through government co-investment	Supply chain	4, 5, 26, 27, 28 and 30
	Australia has world-class R&D capacity that can be deployed to resolve issues across the supply chain	Australia	5, 26, 27 and 28
Proximity	Northern Australia is well positioned geographically to capitalise on expanding Asian markets	Live exports	1, 5 and Section 13
Global			
Export market opportunities	Opportunities to expand live export trade to near South-East Asian markets	Live exports	1, 4 and 10
	Australia has signed and is pursuing free trade agreements, which will reduce trade barriers, increase demand for exports and allow access to foreign investment	Australia	8, 9, 10, 11 and 21
Clean, green product	A major strength of the Australian beef industry is that it is disease free, and 'clean, green and safe' (biosecurity and health)	Domestic and export markets	2, 4, 18, 27, 29 and Section 13
Export market	Industry-imposed self-regulation provides quality assurance (biosecurity and food safety) to customers	Australia	4, 9, 18, 19 and 27
	Australia has long-term mature relationships with its key Asian markets based on 30 years of live export trade and supply arrangements	Live exports	5 and 22

Table 2 Weaknesses of the northern Australia beef industry

WEAKNESS	EXPLANATION	WHERE	SOURCE
Feed base			
Restriction on woody vegetation management	Lack of flexibility to clear and thin woody vegetation that reduces pasture productivity and asset value in Queensland	Queensland (e.g. eucalypt woodlands and mulga)	4, Section 5 and Section 12
Managing climate variability	Inability of many producers to adjust animal numbers in a timely manner in response to large inter-annual variability in forage supply	All of northern Australia, west of the Dividing Range	Section 4, Section 8 and Section 11
Overgrazing	Overgrazing of pastures resulting in long-term declines in land condition, productivity and profitability	Northern Australia	4, Section 4, Section 7 and Section 8
Improved pastures	Little investment for two decades and issues such as cost and reliability of establishment and maintenance still a constraint on adoption	Northern Australia	4, Section 4, Section 6, Section 7 and Section 8
Genetics			
Reproductive efficiency	The Brahman-influenced cattle breeds of northern Australia show lower reproduction rates	Northern Australia	Section 5
Meat quality	Cattle with high Bos indicus content are less likely to achieve Meat Standards Australia grading	Northern Australia	31
Adoption	Generally low rates of adoption of science-based genetics	Northern Australia	32
Animal			
Herd structure	Large proportion of breeders in herds means less able to hold onto younger trading stock when drought occurs, and hold a variety of different aged steers, reducing capacity to target markets other than feeder steer markets	Northern Australia	1 and 14
	Adjustment of herd structure from one concentrating on breeders, to one holding steers of various ages, will result in reduced farm incomes for the adjustment periods, and takes a significant period of time	Northern Australia	1, 14 and 38
	Lack of markets for out-of-specification cattle with limited local abattoirs, resulting in higher proportion of non-productive cattle	Northern Australia	1, 18, 33 and 38
Domestic markets	The use of hormonal growth promotants may limit the marketability of beef into specific domestic and international markets	Northern Australia	1
Property			
Managing climate variability	Overall lack of natural disaster preparedness and resilience to extreme events in terms of market strategies and property management planning	Northern Australia	2, 4, Section 12 and Section 12
Productivity	Inherently low productivity per head and per hectare	Northern Australia	1, Section 5 and Section 7
	Barriers of uptake are limiting the ability to see productivity gains at property level	Northern Australia	Section 8 and Section 14

WEAKNESS	EXPLANATION	WHERE	SOURCE
Capital costs	The capital costs of purchasing properties are high and this limits succession and opportunities for new market participants. There are few alternative investment options currently in northern Australian agriculture	Australia	4, 9, 21 and Section 8
Land values	Land value, while low for international investors, is viewed as high for domestic buyers and can result in high debt levels and an inability to invest further capital into the business	Australia	47 and Section 9
	There are regulatory and policy barriers to foreign investors, especially where those investments involve land	Australia	4 and Section 9
Industry			
Concentration of processing capacity	The processing capacity is dominated by a few large operators, with over half of processing undertaken by the five largest processors	Australia	2, 3 and Section 13
	Attracting skilled labour to remote locations requires higher salaries and reduces margins for processors	Northern Australia	1, 4, 30 and 35
	Input costs for processing are high, making it less competitive in the north	Australia	16 and 36
Live export	There is a concentration of live export buyers that skew market dynamics, particularly in WA	Northern Australia	16 and 19
People	Generally low adoption of productivity improving technologies (e.g. wet-season phosphorus supplementation, legumes)	Northern Australia	4, Section 4 Section 7 and Section 8
Indigenous pastoral production	Tensions between community ownership and commercial requirements contribute to underperformance of Indigenous-managed properties	Northern Australia	1 and 4
Vegetation and fire management	High rates of vegetation clearance and inappropriate fire management are contributing to greenhouse gas emissions	Australia	Section 11 and Section 12
Northern Australia			
Infrastructure	Small, geographically dispersed and fragmented supply chains coupled with poor transport infrastructure offers challenges in transporting cattle to processing facilities and meat to markets in a cost-effective manner	Northern Australia	1, 4 and 6
	Many roads are inaccessible during the wet season and access remains restricted for some time after flooding has occurred	Northern Australia	1, 4, 6, 16 and 39
	Inefficient and insufficient transport options and infrastructure reduces cost-effective access to markets for irrigated agriculture or horticulture products, limiting diversification opportunities	Northern Australia	1, 4, 16, 23 and Section 14.4
	Ports where live cattle are exported from are not exclusively for cattle loading, and there is competition with other port users	Northern Australia	1, 4, 16, 39 and Section 13
	Tidal conditions restrict access to some ports	Northern Australia	1, 4 and 39

WEAKNESS	EXPLANATION	WHERE	SOURCE
	A lack of reliable and affordable connectivity has limited the ability of the agriculture sector to innovate and implement digital technologies	Australia	4, 34 and Section 13
Limited selling options	Transport costs make selling directly to processors less attractive for northern Australian cattle producers. There is also a reluctance to sell through forward contracts	Northern Australia	1, 3, 4, 6, 33, 35 and 39
	Supply chains beyond the farm gate are highly concentrated and farms act independently, meaning that buyers have a commercial advantage and can exercise significant market power. There is little collaboration at farm level to develop scale for selling	Australia	3
Global			
Export market opportunities	There is an overreliance on two major markets for live beef cattle, Indonesia and Vietnam, and trade policies are subject to frequent change	Live exports	1, 2, 4 and 5
	The continued strengthening of economies in key markets is creating a shift in purchasing trends leading to increased demand for processed meat	Live exports	5
	The proximity to Asia is regularly cited as a competitive advantage, but this is highly dependent on the country and even the destination within that country. Existing trade relationships, improvements in infrastructure, subsidies and advancement in preservation techniques will reduce northern Australia's competitive advantage	Northern Australia	6 and 10
Social licence	There is strong ongoing community and political unease about the welfare of Australian livestock in overseas markets	Live exports	4, 5 and Section 13
	There is a continual focus of animal welfare groups on agriculture and, in particular, closing the livestock industry	Live exports	4, 5, 8 and Section 13
Global markets	Adverse economic conditions affect beef demand, along with increased competition in preferred markets such as Indian buffalo into Indonesia and the United States, and Brazilian beef into Japan and Korea	Beef exports	1, 5, 8 and 15
Regulatory compliance	The requirements of ESCAS can make it difficult for parts of the supply chain to comply	Live exports	5
	Staff working throughout the supply chain in overseas markets are generally paid low wages and have little incentive to comply with animal health and welfare regulations	Live exports	5
	The cost of regulatory compliance will reduce Australia's competitiveness and open opportunities for alternative suppliers	Live exports	4, 5, 40 and 49

Table 3 Opportunities for the northern Australia beef industry

OPPORTUNITIES	EXPLANATION	WHERE	SOURCE
Markets – domestic			
Feedlotting	Demand for beef expected to increase, and increased access to grains and protein sources through expanded irrigation will allow feedlotting	Northern Australia	1, 2, 8, 10 and 11
	Investment in processing facilities may provide opportunities for vertical integration or alternative business models (partnerships)	Meat processing	1, 4, 11, 15 and 16
Markets – export			
Export market opportunities	Opportunities to expand live export trade to near South-East Asian markets and increase demand and growth	Live exports	1, 2, 4, 6, 10, 16 and 22
	Expanding Asian and Middle Eastern economies have the potential for significant market demand and growth	Live exports	4, 5, 10 and 22
	Opportunity to grow exports of breeding cattle and genetic material to Indonesia and other South-East Asian markets	Live exports	1, 5 and 41
	Australian food and agribusiness sector has established a strong global reputation for producing safe, sustainable and healthy foods, supported by regulation, transport food chains and natural environments that can be capitalised upon	Northern Australia	8, 9 and 21
	Increasing food security concerns in developing markets will expand demand for Australian livestock to meet these requirements	Live exports	4, 5, 8 and 21
Regulation	ESCAS provides the livestock export industry with the mechanism to strengthen community and political confidence in the trade. Using technology to capture objective evidence will enhance this	Live exports	1, 5 and Section 9
Productivity			
Rumen efficiency and methane	New feed technologies to increase feed conversion efficiency	Australia	Section 7
	Unlocking the potential of the rumen increases productivity and reduces methane emissions	Australia	Section 7
Feed base	Improving cattle nutrition through improved pastures and/or supplementary feeding will lead to faster finishing of cattle and increased beef quality	Australia	1 and Section 5
Reproduction	Reducing variability of nutrient supply improves productivity of breeding females, enabling earlier weaning	Northern Australia	Section 5 and Section 6
	Herd improvement, either through animal selection or cross-breeding, has the potential to boost productivity across northern Australia	Northern Australia	1, Section 5 and Section 8
Diversification			
Pastoral opportunities	Pastoral lease estates offer opportunities for diversification	Northern Australia	1, 4, 16, 21 and Section 9

OPPORTUNITIES	EXPLANATION	WHERE	SOURCE
	Mosaic irrigation to grow broadacre and/or forage crops with forage sold as hay or used as 'stand and graze'. Crop by-products from irrigated agriculture could benefit a finishing sector	Northern Australia	1, 42, 43 and Section 4
Indigenous pastoral production	There is an opportunity to develop commercial capacity to run beef businesses and there is significant land area that can come into production	Northern Australia	1, 37 and 38
Natural resource management			
Land condition	Develop whole-of-industry system of natural capital accounting to incorporate natural assets into property planning	Northern Australia	4, Section 12 and Section 13
Biodiversity management	Identify best-practice property-level management to improve biodiversity outcomes to demonstrate environmental credentials	Northern Australia	4, Section 12 and Section 13
	Undertake whole-of-industry baseline assessment of biodiversity values to showcase the role of the industry in conserving threatened species, and to use as part of pre-competitive data to support diversification proposals and encourage investment	Northern Australia	4, Section 9, Section 12 and Section 13
	Develop a whole-of-industry approach to payment for environmental service schemes and to take the opportunities of new revenue streams	Northern Australia	4, Section 9 and Section 12
Greenhouse gas emissions	Develop strategy by which the industry can achieve carbon neutrality by 2030, including the development of practical property-level tools and calculators to measure and verify this	Northern Australia	4, Section 12 and Section 13
Adoption			
Attainment of greater efficiencies	Productivity gains on property can be achieved through investments in infrastructure (e.g. water points and fences)	Northern Australia	2, Section 4, Section 7, Section 8 and Section 13
	Increasing scale through consolidation of properties to improve economies of scale and reach a sufficient scale of breeders will improve viability	Northern Australia	2 and Section 8
	Once connectivity issues are overcome there are already a suite of digital technologies that could be implemented on properties that would improve profitability and reduce costs	Northern Australia	4 and 8
Regulation	Continual improvement in animal welfare and security through the use of ESCAS and the introduction of new systems will strengthen community and political support for the livestock export trade	Live exports	5
	Development of quality assurance system operated by industry is likely to reduce the potential for greater government cost recovery and price pressures on Australian livestock exports	Live exports	5
Research and development	R&D to deliver further innovations to improve animal welfare, animal genetics, productivity,	Live exports	5 ,27 and 30

OPPORTUNITIES	EXPLANATION	WHERE	SOURCE
	performance and management of livestock in the supply chain. Including the development of a monitoring system to measure the performance of the industry		
Indigenous pastoral estate	Increasing production can contribute to the community's economic development by providing jobs on traditional lands	Northern Australia	1
Infrastructure	Build evidence-based business cases to advocate for strategic infrastructure investments (such as the Northern Australia Beef Roads Program)	Northern Australia	1, 4, 16, 23, 39 and Section 14.4

Table 4 Threats (risks) to the northern Australia beef industry

THREATS	EXPLANATION	WHERE	SOURCE
Regulatory			
Live export market	Decline or closure of live export markets due to government policies within Australia and receiving markets	Live exports	1, 4 and 5
	Increasing costs of complying with Australian Government regulatory requirements is reducing the competitiveness and attractiveness of live exports	Live exports	4, 5 and 19
	Some live export markets are unable or unwilling to commit to animal welfare regulations (ESCAS)	Live exports, diversification	1, 4 and 5
	Increasing restrictions may be imposed on overseas market access, conditions, policies and protocols as political agendas drive self-sufficiency goals	Live exports	5
	In the absences of feed-on sector or a move towards fattening enterprises, northern Australian producers will only have access to low-value cattle for the manufacturing beef market	Northern Australia	1, 4, 16, 38, Section 4 and Section 6
Diversification	Regulation (approvals, permits and licences) constrains the ability to diversify and attract investment	Northern Australia	4, Section 9 and Senate Enquiry 2011
Quality assurance	Increasing number of private and industry standards that require separate audits are increasing costs and industry-imposed regulations	Australia	9, 18, 19, 43, 44 and Section 9
Vegetation management	Restrictions on clearing and thinning of woody vegetation are reducing pasture productivity and value of assets	Queensland	4 and Section 10
Biosecurity			
Disease risks	Climate change will see a spread of diseases and pests beyond their current extent	Australia	1, 2, Section 10 and Section 11
	Ineffective biosecurity surveillance and management could increase the risk of disease spread	Australia	4 and Section 10
Cattle ticks	Not maintaining tick control zones risks expansion of the tick endemic zone. This will have significant impacts on Bos taurus cattle	Northern Australia	1, 4 and Section 10
	Acaricide performance has declined due to increased tick resistance and the lack of a vaccine will cause a shift to more tick resistant cattle	Northern Australia	1 and Section 10
Pests	Australia is classified as having a high risk of invasion and establishment of new pests, some of which would reduce market access	Northern Australia	7 and Section 10

THREATS	EXPLANATION	WHERE	SOURCE
Social licence			
Animal welfare	Concerns over husbandry practices such as de-horning, surgical spaying, branding and castration have the potential to increase input and regulatory compliance costs for cattle operations	Northern Australia	4, 27, 30, 31, 45, 46 and Section 13
Environmental footprint	Concerns over methane emissions from beef production systems operating at lower efficiencies may lead to legislative change and increased compliance costs	Northern Australia	Section 11 and Section 12
	Concerns over biodiversity, soil and water impacts of pastoral industry in northern Australia may lead to legislative change	Northern Australia	4, 12, Section 9, Section 12 and Section 13
Human health	Concerns over human health impacts of red meat consumption may erode public support for the beef industry in Australia	Australia	8, 12, 30, 46 and 48
Climate change			
Impacts on the production system	Increased woody thickening and lower effective rainfall (higher evaporation) reduces pasture productivity and carrying capacity	Northern Australia	1, 2, 4 Section 4 and Section 11
	Calf loss, which can already be high, likely to increase significantly	Northern Australia	4, Section 5 and Section 11
	Increased temperature–humidity index affects cattle production through reduced feed intake	Northern Australia	Section 5 and Section 11
Property management	Dramatic increase in number of days over 40 °C makes it harder to retain labour and reduces options for transporting cattle	Northern Australia	Section 5 and Section 11
	More extreme rainfall (flood events) and drought events create management challenges	Australia	Section 11 and Section 13
Infrastructure			
Transport	Supply chains are geographically isolated and long, and even with targeted investment in infrastructure, transport costs will always remain a significant proportion of the price of live cattle and beef	Australia	1, 4, 6, 39 and Section 13
	Supply chains are largely disconnected with little vertical integration, meaning that there are few opportunities to improve efficiencies or improve economies of scale	Northern Australia	1, 4, 6, 39 and Section 13

Table 5 References and sources for the SWOT analysis
As presented in Table 1, Table 2, Table 3 and Table 4.

SOURCE	REFERENCE
1	Gleeson et al. (2012)
2	PricewaterhouseCoopers (2011)
3	Australian Competition and Consumer Commission (2017)
4	Stakeholder feedback (Appendix C)
5	Australian Livestock Export Corporation Limited (2016)
6	Higgins et al. (2017)
7	Panini et al. (2016)
8	KPMG (2018)
9	Commonwealth of Australia (2015a)
10	Western Australian Agricultural Authority (2015)
11	EY (2018a)
12	CSIRO (2017)
13	IBISWorld (2019)
14	Bortolussi et al. (2005a,b)
15	EY (2018b)
16	ACIL Allen (2018)
17	Cowley et al. (2015)
18	Safe Food Production Queensland (2016)
19	Productivity Commission (2016)
20	EY (2018c)
21	Commonwealth of Australia (2015b)
22	Northern Territory Government (2017a)
23	Northern Territory Government (2017b)
24	Department of Agriculture and Fisheries (2019)
25	Productivity Commission (2009)
26	Council of Rural Research and Development Corporations members (2018)
27	Meat and Livestock Australia (2016)
28	EY (2019)
29	Meat and Livestock Australia (2018c)
30	Red Meat Advisory Council (2015)
31	Meat and Livestock Australia (2018d)
32	McGowan et al. (2014)
33	Department of Agriculture, Fisheries and Forestry (2012)
34	KPMG (2019)
35	Meateng (2018)
36	Australian Meat Processor Corporation (2018)
37	EY (2014)

SOURCE	REFERENCE
38	Neithe and Quirk (2008)
39	Chilcott et al. (2019)
40	ASEL Review Technical Advisory Committee (2018)
41	Australia-ASEAN Chamber of Commerce (2019)
42	Grice et al. (2013)
43	Petheram et al. (2018a)
44	Petheram et al. (2018b)
45	Futureeye (2018)
46	Angus and Westbrook (2019)
47	Savills (2018)
48	IARC Working Group on the Evaluation of Carcinogenic Risks to Humans (2015)
49	MLA (2016b)

3 Summary and recommendations

With an ongoing interest in developing northern Australia, this situation analysis was undertaken to assist the Cooperative Research Centre for Developing Northern Australia (CRCNA) in tailoring their investment decisions. The northern Australia beef industry is dominated by rangeland enterprises that include family farms, Indigenous pastoral enterprises and large corporate interests. The analysis was a whole of supply-chain examination of current practices, strategies and plans. It included consultation with producers, industry groups, research organisations and government departments.

The competitive advantages of the northern Australia beef industry are its adapted production systems, low cost base and geographic positioning that allows it to take advantage of South-East Asian markets. However, the inherent low productivity, high capital costs and overreliance on a small number of markets make it vulnerable to market shocks. It was found that the industry faces challenges in maintaining profitability, the ability to translate research into practice to enhance productivity, and its social licence to operate. Further, it is not immune to global megatrends (where megatrends are defined as a significant shift in environmental, economic and social conditions that will play out over the coming decades) and the impacts of associated policy responses (some of which are already influencing industry strategies and investments). Recommendations in response to key challenges and opportunities facing the northern Australia beef industry that explore potential solutions and suggestions for further investment are then provided in four themes.

Theme 1: Implementing proven R&D

There was widespread recognition that there is sufficient technical research currently available to make the vast majority of enterprises more profitable and that the key challenge is translating science into practice. Traditional approaches to research extension are no longer effective, and the social and behavioural characteristics in which research findings are presented need to be better understood. The development of participatory processes where producers and researchers work together to bridge differences in knowledge systems, to build social and political capital, and to strengthen the capacity of farmers is required. A most obvious solution would be to include end-users in any research design. This would be facilitated by a better understanding of pathways to uptake of research based on a typology that characterises the different ways producers behave, find and use R&D products. Given the decline in government extension services, this may require consultants who are system science translators; individuals who are not specialists in one technical or disciplinary area, but rather, who can integrate different findings across production, animal health, resource management and economic aspects into a form that can be put into practice on property.

Stakeholders made the following relevant observations:

> *Beef businesses are subject to a very complex set of factors that all influence net profit; this already makes it difficult to decide where to innovate or adopt R&D; add to that the*

high cost of compliance with complex regulatory requirements, there is no time to spare for thinking.

R&D can be irrelevant when fences are what is required. Smaller producers aren't willing to or able to adopt R&D and there is a question as to what is the best form to get information to them.

Failure to adopt is the number one issue for the industry.

Extension services focus on management not on the business.

Research system in the current approach is a disconnect between the research providers and funders in publishing research, and there isn't an assessment of the impact of the research and where the 'gold' is, which is the most valuable research. Can they take a systematic approach and see where they will have the best benefits and outcomes?

Solutions to these (productivity issues) have been researched. No lack of research for gains from what we currently know. It is to make what we already know work well.

Need for different and bespoke approaches to extension and outreach of research findings and translating research to practice.

Can we use research opportunities to move some of the 'better' 75% up? R&D only as good as the adoption, and the extension services are lacking.

Recommendation 1

At an individual property level, significant improvements in productivity and profitability could be achieved by applying existing R&D. The CRCNA should invest in on-farm productivity research only where there are specific gaps not being addressed by other providers.

Recommendation 2

Increase investment in innovative ways of translating research into practice and integrate into business operations throughout the supply chain. This should include development of private sector capacity. Research and adoptions projects should be co-designed with industry partners and end-users.

Theme 2: Investing in R&D for profitability and productivity gains for top businesses

The situation analysis found that there was a large diversity in business performance, with the 'top 25%' of businesses characterised by better herd productivity, targeted herd expenditure, more efficient use of labour and greater scale. But in order to remain profitable, the top cohort of beef businesses need to continue to adopt new innovations and reduce costs to maintain or improve profitability.

Stakeholders made the following relevant observations:

In order to keep up, let alone get ahead, we need to better deploy new technology on farm, but there is limited good advisory and technical services and the lack of connectivity is a real constraint.

What changes to practice (the low-hanging fruit) would immediately impact profitability? Could you go to each region and see what the two next best things are to make businesses more profitable?

What are the options to really improve turn-off weights on properties and what are the right types of animals? Do we need centre pivots, improved pasture, improved nutrition to get the livestock gains? Also, how to get a feedlot industry as our current markets are changing.

Recommendation 3

More investment is needed to support: (i) transformational change to diversify production systems and increase their productivity to create new market opportunities, and (ii) a holistic, systems approach to improving productivity, profitability and natural capital so that the 'whole is much greater than the sum of the parts'.

Recommendation 4

Beef businesses will need to test novel and risky technologies in order to make transformative gains. Blue-sky research should be supported, such as digital technologies, alternative protein sources, methane reduction technologies and targeted feed base improvements, including mosaic irrigation. This should also include evaluating farm system changes such as mixed farming, intensification and diversification of production systems (e.g. carbon farming).

Theme 3: Investing in infrastructure and supply chains

There is a need to support the northern Australia beef industry to transform from its current state to a higher productivity state and ensure future viability. The competitive advantages of the northern Australia beef industry are its adapted production systems, low cost base and geographic positioning that allows it to take advantage of South-East Asian markets. However, the inherent low productivity, high capital costs and overreliance on a small number of markets make it vulnerable to market shocks. A number of challenges are constraining the industry to its current status. These include lack of infrastructure and lack of feed-on capacity, and all are interrelated. For example, there is currently insufficient scale and intensity of production to justify investment in local processing capacity. Intensification requires an affordable source of protein to allow finishing, and that requires the development of local irrigated broadacre cropping. For irrigation to be affordable a crop such as cotton requires scale to justify the investment in local cotton processing (a cotton gin). That development then provides a source of cottonseed, which would be used as a protein source in feedlotting. This in turn would justify investment in cattle breeds that could meet meat processing standards and eventually justify local processing (noting that most of the northern and tropical breed selection has focused on improved reproductive success not eating quality, See Section 6.2).

There has been significant and ongoing investment in the collection of 'pre-competitive data, information and insights' to support agricultural developments in northern Australia. For example, land and water assessments that identify highly prospective regions for development will allow investor and regulator access to objective information, allowing investment and resource allocation decisions to be made and justified. There has also been considerable success in identifying bottlenecks and constraints in the transport network, and the delivery of objective data to support business cases for investments. However there has not been a similar systematic identification of economic enabling infrastructure that would enable new development, and the associated development of business cases. Pre-emptive investments in enabling infrastructure are necessary to reduce the risk and increase the competitiveness of the northern Australia beef industry. Prudent investment would position the industry to take advantage of opportunities that might otherwise be lost because of an inability to deliver infrastructure with the certainty needed to secure private investment. There is also a need to look at alignment of infrastructure that could support more than one sector, for example onshore gas development, where the NT beef industry could take advantage and lobby for the development of multi- and common user infrastructure. An analysis like this would inform decisions of groups such as the Northern Australia Infrastructure Facility (NAIF), which can fund infrastructure that results in 'an increase in economic activity in a region, including efficiency in developing or connecting markets', among other criteria.

Stakeholders made the following relevant observations:

Building infrastructure that enables new development as well as enhancing the existing infrastructure, overcoming truck breakdown costs (last mile issues such as access to abattoirs).

It isn't correct to assume there is sufficient infrastructure, sometimes it needs to be built before it is really needed.

Recommendation 5

A comprehensive assessment of enabling infrastructure that would support the northern Australia beef industry is required, considering the needs of all industries and prioritising common and multi-user infrastructure for investment.

Theme 4: Future-proofing and de-risking

There are probably other barriers to investment that require investigation, such as stalled regulatory reforms. For decades, voices within and associated with the pastoral industry have raised concerns about the security of the land tenure arrangements for graziers in northern Australia. The main points of contention concern the restrictions that relevant Crown leases impose on non-pastoral uses and development, the term-limited nature of many Crown leases, and the uncertainty and costs associated with the resolution of native title issues. There is conflicting evidence about the extent to which land tenure and land-use restrictions imposed under Crown leases are holding back investment. Past inquiries into land tenure arrangements have also found problems with the trends in the ecological condition of pastoral leasehold land. There are differing views on whether the liberalisation of the conditions on land use could exacerbate this problem, leading to an intensification of unsustainable practices.

There have been several recent reviews of the costs of regulation to the Australian beef sector motivated by the need to reduce government and industry red and green tape that are perceived to be hampering profitability and productivity (Cattle Council of Australia, 2012). In 2014–2015 the cost of regulation was about 10% of total revenue (ProAnd, 2016) and about 20 days for the farm operator to meet regulatory compliance requirements. Most of those costs were from transport regulation (including fuel excise, driver fatigue and animal welfare requirements); labour on-cost (including superannuation and workplace safety); and land management (shire rates, lease rental costs and land stewardship costs such as weed control) with none seemingly specific to the sector (i.e. apply across the economy not just to the beef sector).

The 2016 Productivity Commission inquiry into the regulation of Australian agriculture (Commonwealth of Australia, 2016) concluded that:

- Farm businesses are subjected to a vast and complex array of regulation imposed by all levels of government, meaning the cumulative burden is substantial.
- The need for regulation was not disputed and biosecurity and food safety regulation provide clear benefits, but the industries would benefit from better application of those regulations.
- There are however many regulations that have no sound justification, or are the wrong policy tool, or are inconsistently applied across different jurisdictions.

The review specifically recommends changes to the regulation of pastoral leases. They conclude that the current restrictions place unnecessary burdens on farm businesses and hamper the ability of farmers to flexibly respond to environmental, economic and other factors that affect their business. The reforms identified were: extending the length of leases or introducing rolling leases; allowing the conversion of leases to freehold land; and that land management objectives should be implemented directly through land-use regulation rather than pastoral lease conditions, and in implementing that enable the removal of restrictions on land use from pastoral leases. They also recommended that those who benefit from any additional property rights should pay for the higher value of the land and any costs associated with implementing the change (including administrative costs). This would ensure that 'the incidence of the costs and the benefits of property rights helps ensure that the land is put to its most valuable use' (Commonwealth of Australia, 2016).

Stakeholders made the following relevant observations:

What is the path of less resistance for WA producers to become more profitable?

Need to look at what we can do to 'bulletproof' the industry against all the forces that want to bring it down.

The severity of the (North Queensland) floods washed away roads and infrastructure that has been in place for 40 plus years. There probably isn't a better spot to rebuild, but it is worth considering before you do.

Recommendation 6

Further research is warranted to investigate the specific nature and magnitude of the barriers associated with pastoral interests and native title, and to identify the most cost-effective solutions to the issues that are identified.

The slow rate of progress with water reform and the ability to diversify on pastoral leases could potentially be holding back development in the northern Australia beef industry. The risk here relates predominantly to new developments. The day-to-day operations of most pastoral enterprises are unlikely to be materially affected by the uncertainties associated with water planning and access regimes, and the ability to diversify from grazing. However, the institutional uncertainties potentially create obstacles to new investment that may be limiting the capacity of pastoral enterprises to diversify, intensify and expand their operations.

A further challenge for industry is policy uncertainty. For example, a defining feature of the vegetation management laws over the past two decades has been instability, particularly in Queensland. Major changes to Queensland vegetation management laws were made in 2004, 2009, 2013 and 2018, along with significant changes in relevant maps and regulations. The policy instability in the area increases the costs of compliance and magnifies uncertainty in the eyes of investors.

In addition to the approvals associated with diversification and intensification, regulation in general has evolved over many decades, creating a complex web of impediments to efficient beef supply-chain operations. While each piece of regulation/legislation may be well justified, together they impose a significant cost on business.

Recommendation 7

Undertake a whole of beef supply-chain analysis of regulations that encompasses not just approvals and regulations associated with new developments but also includes existing regulations that impede efficiency and impose high costs.

There is a good story to tell in the northern Australia beef industry: the low-input production systems of northern Australia can be carbon neutral, consistent with the Australian red meat and livestock industry target to be carbon neutral by 2030 (CN30, see http://www.mla.com.au/research-and-development/Environment-sustainability/cn30/) and can be recognised for the biodiversity values they currently retain. But the industry cannot be complacent, as the impacts of climate change will lead to more extreme weather events and make current management practices unviable. A baseline assessment of the biodiversity values of the northern Australia beef industry has not previously been undertaken. This could outline the management practices that conserve biodiversity while maintaining productivity, building on examples such as Biocondition (Eyre et al., 2011), and feed into the Australian Beef Sustainability Framework (https://www.sustainableaustralianbeef.com.au/). Biodiversity stewardship programs will require the identification of market-based policy instruments that provide a financial incentive for the northern Australia beef sector.

Recommendation 8

Producers' abilities to effectively manage climate variability to better maintain profitability and land condition is underdeveloped. Further, climate change poses a significant threat to the northern Australia beef industry. Investment is required in tools to facilitate better management of more extreme weather events and heat-related stresses.

Recommendation 9

Develop a suite of case studies that demonstrate the economic and environmental opportunities, trade-offs and risks associated with proactively addressing the environmental footprint of beef developments.

The relative disease-free status of Australian livestock is a key element in the competitiveness of Australian livestock in international markets. Australian livestock exporters are in a unique position to help maintain Australia's current superior biosecurity status, and to ensure Australia can recover quickly from any biosecurity incidents. It is projected that the northern Australia beef industry is likely to experience an escalation in biosecurity challenges in the future. These may stem from increased development; increased movements of livestock, goods and people; and a warming climate altering pest and diseases ranges. All of these challenges create heightened opportunities for the introduction and spread of weeds, pests and diseases. Thus, biosecurity must be explicitly considered in any plan to expand the northern Australia beef industry, and agriculture in general, so that threats can be addressed where possible. There should be recognition that with growth there will be increased biosecurity risks and therefore biosecurity is a critical issue for northern Australia.

Recommendation 10

Biosecurity issues must be kept in focus for research and adoption investments, especially programs that strengthen surveillance activities through technological development and improved stakeholder engagement and skills.

4 Implementation Pathway

An impact pathway sets out the plausible steps of how research activities/outputs will contribute to an outcome (or outcomes). It explains the causal links between outputs, outcomes and impacts. It covers the different phases of work, the stakeholders who need to be involved to achieve the desired changes, the flow of resources and the progressive integration of different forms of knowledge into outcomes (changes in behaviour) and impacts (the result of the behaviour change). It may include processes for communication and negotiation among networks of stakeholders as well as proposed mechanisms for increasing impact beyond the original project.

The benefits of an impact pathway are:

- they help implementation teams to uncover assumptions about how their research will lead to impact, which may mean adjustment to planned activities to support outcomes
- they form the basis of the design of monitoring, evaluation and learning to enable teams to track progress towards impact, which supports an adaptive response to project management

A full impact pathway should be developed as part of the implementation of the recommendations of this study. The implementation pathway for the recommendations are summarise in Table 6 below.

Table 6 Implementation pathways for recommendations

KEY PRIORITY ACTIONS FOR SECTOR DEVELOPMENT	ACTION OWNER AND KEY PARTNERS	PATHWAY TO IMPLEMENTATION	INTENDED INDUSTRY IMPACTS
Theme 1: Implementing proven R&D	WA Department of Primary Industries and Regional Development (DPIRD) NT Department of Primary Industry and Resources (DPIR) Queensland Department of Agriculture and Fisheries (DAF) The Cooperative Research Centre for Developing Northern Australia (CRCNA) Meat and Livestock Australia (MLA) Private sector consultants State farming organisations Banking and finance sector	Productivity gains are necessary to ensure farm profitability. Clearly with better translation of proven R&D, significant improvements in productivity and profitability could be achieved. There are some simple management interventions that can have big immediate gains and the industry could benefit focusing on the adoption of those practices to immediate effect. Most of those management practices are already incorporated into a range of extension packages. This could include the banking and finance sector, who could mandate through the provision of finance. Firstly, pathways to uptake of research based on a typology that characterises the different ways producers behave, find and use R&D products and interact across scale and sector is needed to improve the current practices within the northern Australia beef sector (such as Theory of Change). Given the decline in government extension services, this may require consultants who are system science translators; individuals who are not specialists in one technical or disciplinary area, but rather, who can integrate different findings across production, animal health, resource management and economic aspects into a form that can be put into practice on property. However, this must recognise that there is a reluctance to pay for specialised advice or consultants, and a lack of evidence of the economic impacts of uptake.	Increased productivity and profitability at the property level. Targeted effort in adoption research to increase on-farm profitability and productivity of exiting technology. Improved understanding of the way to effectively translate research to impact; development of impact pathways. Improved profitability through increased production, reduced cost of production, improved quality and a price premium, and/or a combination of those pathways. The estimated net benefit of implementing known technologies to improve animal performance are approximately $12/AE to $22/AE. The estimated net benefit of implementing known technologies to improve the feed base are approximately $42/AE to $70/AE.
Theme 2: Investing in R&D for profitability and productivity gains for top businesses	CRCNA Research and Development Corporations other than the MLA CSIRO Universities DPIRD DPIR DAF MLA Banking and finance sector	There have been transformational changes in the northern Australia beef industry previously, such as the introduction of Bos indicus and increased investment in on-farm infrastructure (fences and water points). For the top businesses, the next transformations are required. Many R&D programs focus on incremental improvement of different components of the beef supply chain. Incremental changes will not provide the necessary gains in productivity, and transformational changes require significant investment in R&D to reduce business risk. R&D where the goal is to diversify production and/or create new market opportunities is a priority. Research into 'blue-sky' and promising prospects but where foundational evidence is required before further development can occur should be supported, such as digital technologies, alternative protein sources, methane reduction technologies and targeted feed base improvements, including mosaic irrigation. This should also include evaluating farm system changes such as mixed farming, intensification and diversification of production systems (e.g. carbon farming). Multi-sector research investments could be coordinated through the CRCNA to allow multi-party investments from various RDCs.	New R&D of transformation technologies that are proven to increase profitability. Integrated development and extension that trials new and novel technologies on farm and throughout the supply chain. Multi-party research investments that are across different farming sectors, that lead to diversification of the production base in northern Australia. Long-term research in future technologies have a benefit–cost ratio ranging between 4:1 and 7:1, with a payback period of greater than 13 years (See Table 45). The high technical risk would be reduced through R&D investments that are both targeted at innovation and future adoption.

KEY PRIORITY ACTIONS FOR SECTOR DEVELOPMENT	ACTION OWNER AND KEY PARTNERS	PATHWAY TO IMPLEMENTATION	INTENDED INDUSTRY IMPACTS
Theme 3: Investing in Infrastructure and supply chains	CRCNA Research and Development Corporations CSIRO Universities DPIRD DPIR DAF MLA Department of Agriculture, Water and the Environment (DAWE) (Australian Government) Northern Australia Infrastructure Facility (NAIF) Austrade	Development of business cases for investment into inter-modality, cross sectoral infrastructure that supports supply chains, diversification and intensification is recommended. Such an investment should be modelled on the approach taken with the development and implementation of the Transport Network Strategic Investment Tool (TraNSIT) model for the Northern Australia Beef Roads Program. The combined outcomes of the CRCNA situation analyses can be used to assess the infrastructure needs of all industries and prioritise common and multi-user infrastructure for investment. This should be done with NAIF and Austrade, who will be able to connect with international supply chains. This should include the identification of regulatory barriers to investment.	Systematic identification of infrastructure that enables the sector to be more profitable and diversify. Coordination of effort to develop business cases for enabling infrastructure investments. Development of multi-sector business cases to establish infrastructure. The secondary benefits to businesses from developing new industries. For example, small-scale irrigation could provide returns from cropping and secondary products such as forage and cottonseed that increase the productivity of cattle businesses. The estimated gross margin of having access to a cheap protein source (such as cottonseed) is approximately $205/AE.
Theme 4 Future-proofing and de-risking	DPIRD DPIR DAF CRCNA MLA Private sector consultants State farming organisations Banking and finance sector	Regulatory reform is slow and holding back development. Uncertainty in policy settings (e.g. Queensland vegetation management laws) could be making investments difficult. A whole of northern Australia beef supply-chain analysis of regulations should be undertaken to look at impediments to improving profitability through diversification and intensification recommended in Theme 2. The costs associated with these changes could be borne by the beneficiaries, making this less attractive to the industry Development of a suite of analytical case studies that demonstrate the economic and environmental opportunities, trade-offs and risks associated with proactively addressing the environmental footprint of beef developments is a recommended first step. These case studies would provide the information base to better guide both investments and policy. Maintain biosecurity at the forefront of the development, especially programs to strengthen surveillance activities through technological development, increased investment and personnel, and improved stakeholder engagement are required.	Evidence base to support regulatory changes that allow for investment, diversification and increase investor confidence. Reduced regulatory and policy impediments to diversification and intensification will increase property and industry profitability. Increased productivity of the northern beef sector through reduced disease and pest risks and the maintenance of market access. De-risk investment in the industry and protect the beef industry's social licence. And leverage investment into research on social licence to operate by other industries in northern Australia (such as the onshore gas industry).

Part II Review

5 Managing the native pasture feed base

5.1 Background

Beef production in northern Australia is underpinned by a feed base comprising mostly native pastures. There are a number of key vegetation systems that support these native pastures: open eucalypt woodlands, open grassy plains dominated by Mitchell grass (*Astrebla* spp.) and bluegrasses, arid spinifex lands, and dense and shrubby woodlands interspersed with perennial grasses. Pastoral lands, in their natural state, are generally dominated by tussock perennial grasses. Not only are perennial grasses an important forage resource for cattle, they also play an important role in protecting and stabilising the soil by retaining litter, sediment and nutrients in the landscape, and providing habitat for native fauna. Maintaining the health and productivity of these perennial grasses is therefore a critical component of good pastoral management. In addition to perennial grasses, annual grasses, forbs and native legumes are also important contributors to the herbaceous layer.

Exotic grass and legume species have been introduced into the region to improve pasture productivity, forage quality and beef production and some of these have become naturalised to varying extents across northern Australia. In more recent times there has been interest in irrigated forages at scale in northern Australia as a means of improving enterprise productivity and providing some alternative markets for sale cattle.

Optimal productivity from the native pasture feed base is dependent on maintaining and managing the basic ecological processes (energy flow, nutrient cycling and water cycling). There is a great degree of common ground between those wanting to sustain animal production from these lands and those wanting to ensure that the lands are maintained in good condition. However, climate variability, price variability, declining terms of trade, variable landscapes, and the nature of beef and sheep production systems often constrain the ability of producers to precisely and proactively manage grazing pressure and the timing and frequency of fires. In addition, managing land condition has generally received much less attention from producers, compared to animal husbandry and management. As a result, declines in land condition have occurred, although the extent and severity vary greatly from paddock to paddock, property to property, and region to region. The major symptoms of declining land condition include reduced ground cover, increased runoff and soil erosion, reduced density of desirable perennial grasses, proliferation of native woody plants, and invasion and spread of weeds.

An assessment of the condition of pasture lands in northern Australia (Queensland, NT and WA) by Tothill and Gillies (1992) became a catalyst and point of reference for more investment in sustainable management from industry and others. There was significant investment in rangeland management work in the semi-arid grazing lands by Wool Corporation (as it then was), and in the mulga lands by the Queensland Government since the 1960s (Beale, 1973; Johnston et al., 1996). Research in eastern and northern Australia has been largely production-focused. Research projects such as Wambiana (O'Reagain et al., 2011), Ecograze (Ash et al., 2011), Galloway Plains grazing trial (Orr et al., 2010), the Aristida-Bothriochloa woodland ecology trials (Silcock et al., 2005), and in the NT (Walsh and Cowley, 2011; Walsh and Cowley, 2014) were largely a result of the change in emphasis by research organisations. More recently the focus of grazing management research has concentrated on off-site impacts of rangeland management on water quality, particularly in the Great Barrier Reef catchments (Bartley et al., 2017), and the use of remote sensing to assess land condition (some of which was in response to policy imperative rather than production). But since the 2000s grazing research has declined significantly and is a minor component of the research funding from Meat and Livestock Australia (MLA) (Table 16).

5.2 Native pasture systems

5.2.1 Plant functional types

A typical rangeland plant community in tropical Australia will contain from around one hundred to a few hundred herbaceous plant species. The suite of species present at a site is very much dependent on the soil type, the type of vegetation community and the historical and current grazing management.

Because of the great diversity of grasses in the tropical savanna environments of northern Australia, it is useful to group species into plant functional types; that is, groupings of plants that display similar characteristics and/or responses to disturbance. Functional types allow comparisons among plant communities and make it easier to explain the effects of management (grazing, fire, etc.) on plant species composition. The plant functional groupings generally used in the rangelands of northern Australia (Ash et al., 1994) are:

- 'Decreaser' native perennial grasses – these are native perennial tussock grasses that are preferred by cattle and tend to decrease under grazing. These grasses are commonly referred to as the '3P' grasses – perennial, productive and palatable. In an undisturbed environment they tend to dominate the herbaceous layer and account for 70 to 90% of the standing biomass. In contrast, under moderate to heavy grazing regimes, their relative abundance may vary typically between 10 and 50%. Where overgrazing occurs for a number of years they may be completely lost from the pasture.
- 'Increaser' native perennial grasses – these native perennial tussock grasses are not preferred by cattle, though they will be eaten when more preferred species are not present. In environments that do not have a history of grazing, they usually account for 10 to 30% of the standing biomass.
- Exotic perennial grasses – these perennial grasses have naturalised in the region. Some have been intentionally planted to improve pasture productivity and animal production while others are accidental introductions. Once established, these species tend to increase over time and the rate of increase is usually greater with higher grazing pressures.
- Annual grasses – these short-lived grasses are shallow rooted and usually persist for six to nine months. They regenerate by producing large amounts of seed before they die off. The conditions for germination and establishment vary between species and this results in different annual

grasses being more prominent in different years. The contribution of annual grasses to the herbaceous biomass depends on the type of wet season and the competition from perennial grasses. In poor wet seasons, annual grasses may not be seen at all. They are usually a minor part of the herbaceous sward (<10%), though where perennial grasses are absent they can contribute 70 to 90% of the biomass. They are also common in Mitchell Grass Downs areas in autumn and winter following a good wet season or late wet-season rainfall.

- Native legumes and forbs – both annual and perennial native legumes and forbs are common throughout the region. They comprise a large number of species that are quite abundant, although, due to their small size and/or slow growth, they usually do not contribute much to the total biomass of the sward.
- Exotic legumes – exotic legumes have been planted widely through the region to improve dietary quality of cattle. The exotic legumes used are more productive than native legumes and are more palatable.
- Exotic forbs – these are common throughout the region and are particularly abundant in riparian and alluvial parts of the landscape. Few of the exotic forbs have been intentionally introduced; most have arrived as contaminants in commercial seed and as such are mostly weeds. Most are unpalatable to cattle and tend to increase in response to higher grazing pressures.

5.2.2 Growth patterns and seasonal variation of native grasses

The seasonal pattern of rainfall (strong summer dominance) and high variability in rainfall from year to year has a strong influence on the growth pattern and seasonal variation of the available forage in the rangelands of northern Australia. The growing season lasts from 100 to 160 days depending on climate and soil type, but it can vary greatly from year to year. Greater than 70% of the growing days occur during the six months between November and May. As a result of these growing conditions, the tussock perennial grasses grow rapidly over the wet season. Initially, there is rapid leaf development followed by stem elongation. Most perennial grasses flower and seed set between January and April, depending on growing conditions and species. After flowering and seed set, the perennial grasses usually remain dormant over the dry season, though they can grow in response to winter rainfall. The exotic perennial grasses tend to have better developed root systems than the native grasses. They tend to re-shoot in response to early wet-season rains more quickly than do the native species.

Germination and establishment of annuals (grasses, legumes and forbs) is very much dependent on the amount and distribution of rainfall in the wet season. Each species requires distinct conditions for germination and establishment. Hence, the annual species mix can vary dramatically from year to year. In years of poor rainfall, few annuals may establish and persist. If rainfall conditions are conducive to flowering and seed set, the annual species produce large numbers of seeds before dying off completely.

5.2.3 Roles and values of the grassy layer in the rangelands of northern Australia

Grasses that occur naturally in the woodlands and grasslands of northern Australia play important and diverse roles for the biophysical functioning of the landscape. Being the base resource of pastoralism, their condition and long-term persistence is also of paramount value for the economy and the social fabric of the region. The functions that healthy grassy layers perform in the rangelands are:

- supporting landscape processes
- providing pastoral value
- contributing to biodiversity value.

Supporting landscape processes

Herbaceous plants play an important role in the cycling of nutrients, in the movement of water into soil and in the regulation of water and nutrient movement across the landscape. As plants grow, they extract nutrients from the soil. Over time, these plants die and leaf and stem materials detach to form litter. This litter is broken down by invertebrates and soil microorganisms and is incorporated into soil organic carbon and nutrient pools. Perennial grass tussocks are a focus for nutrient cycling processes and for nutrient concentration. This highlights the role that perennial grasses have in maintaining landscape health, in addition to their importance as a stable forage supply necessary for animal production. When perennial grasses are lost from the system, organic carbon and soil nutrient levels decline, resulting in the potential for forage growth reduction. Vegetation and other obstructions (sticks, litter, etc.) interrupt the flow of water, nutrients and sediments across the landscape. Perennial grasses, with their large crowns, are very effective in interfering with flow and where tussock density is high, the runoff path becomes tortuous, which gives maximum opportunity for infiltration to occur and for sediments and nutrients to be trapped in the landscape.

Providing pastoral value

The amount of production of the herbaceous layer is dependent on the growing conditions over the wet season as well as the inherent soil fertility of the site. Although growth can occur after rain during the dry season, low temperatures result in modest amounts of production. In most parts of northern Australia, native grasses tend to have low concentrations of most nutrients, which reflects the low nutrient content of most soils in the region. In the early part of the wet season, nutrient concentrations can be high in new green leaf but, with the rapid growth of the grasses, nutrients are quickly diluted to low levels. With senescence, the nutrients in the leaf and stem decline even further as a result of translocation from the above-ground parts of the plant to the roots.

As grasses are the main forage resource for cattle in the region, the pattern of nutrient concentration creates seasonal patterns in forage quality (Gramshaw and Lloyd, 1993). Good animal gains usually occur in the wet season, but during the dry season forage quality is often below the maintenance requirements of animals.

Forbs and legumes generally have higher concentrations of most nutrients and do not show the same large seasonal variation as the grasses, though there is a decline in nutrient concentrations during the dry season. However, unlike grasses, forbs and legumes often contain secondary compounds, which may be harmful to livestock (e.g. *Pimelia* spp.) (Ash and McIvor, 1998).

Contributing to biodiversity value

The grassy layer is critically important for supporting a whole suite of plants and animals, either indirectly through the way its structure provides habitat and shelter or more directly as a food source for a range of animals. For example, seed-eating birds require a continual supply of seeds through the year and may face critical shortages in the early part of the wet season when seed supply is low because of germination of the previous year's seed. These birds are reliant on a mix of grass species, especially those that can grow, flower and set seed quite quickly after the onset of the wet season. A loss of critical grass species can result in an inadequate food supply and the eventual decline in the population of that species (e.g. golden shouldered parrot in Cape York).

5.3 The feed base response to grazing

5.3.1 Effects of grazing

Grazing animals will adopt a number of strategies to optimise their forage and nutrient intake. Consequently, grazing of the grassy layer is not uniform, with effects such as selection for specific species and plant parts (leaf over stem), patch grazing and preferences for different vegetation communities in diverse landscapes that make up paddocks in extensive beef operations in northern Australia.

Effects of grazing on plant growth, survival and seed production

In their attempt to optimise diet quality and intake, animals prefer to eat green material rather than dry material and leaf rather than stem (Stobbs, 1973; Chacon and Stobbs, 1976). When the green leaf of perennial grasses near the top of the sward is consumed, the grasses can quickly recover and regrow. However, if the plants are repeatedly defoliated down to the bottom of the plant the growing points can be damaged. Both black speargrass (*Heteropogon contortus*) and kangaroo grass (*Themeda triandra*) have elevated growing points some centimetres above the ground and are therefore vulnerable to grazing animals. Their morphology is poorly adapted to grazing (Howden, 1988). In contrast, introduced species such as buffel grass (*Cenchrus ciliaris*) have growing points closer to the ground and are well adapted to grazing.

In addition to the influence of plant morphology on the response to grazing, the way the plant responds physiologically to defoliation is also important. For example, kangaroo grass spends a lot of its root reserves initiating new growth at the start of the wet season (Mott et al., 1992). If these new shoots are heavily grazed, the plant uses its remaining root reserves for regrowth. If regrowth is grazed again, the plant struggles to maintain a positive carbon balance and it may die if grazed repeatedly.

Grazing can also impact on plant productivity. As grazing intensity increases, plants are unable to compensate with regrowth and their productivity declines. Increasing levels of utilisation can lead to a decline in plant productivity down to as little as 20 to 40% of more lightly grazed plants. In addition to the direct physiological effect on regrowth, there are also indirect effects of grazing on plant productivity, through altered microclimate around the plant (increased vapour pressure deficit) and decreased water use efficiency, and through loss of plant cover, leading to increased soil runoff during rainfall events. The response of plants to grazing may also depend upon the time of the year at which defoliation occurs. Research conducted at Katherine, NT, showed that at moderate to high levels of utilisation early in the wet season, the pasture responded negatively to defoliation, failing to compensate for plant tissue lost to grazing. This effect carried over to the next wet season, when paddocks that had been grazed at medium and high intensities in the previous early wet season produced significantly less herbage than those grazed at either a low level of utilisation or those grazed at any intensity during the dry season (Ash and McIvor, 1998).

5.3.2 Effects of species selection by cattle on composition of grass communities

Grazing animals have quite distinctive preferences for plant species. Some of these preferences are universal, for example kangaroo grass is preferred in most pasture systems in northern Australia (Ash and Corfield, 1998). However, for many species, preference depends on the plant community in which they are growing.

While grasses are the main component of the diet of cattle grazing in the tropical rangelands, forbs, legumes and browse are also important. The introduced legume stylo (*Stylosanthes* spp.) is generally preferred to grasses during the dry season (Gardener, 1980; Gardener and Ash, 1994). The proportion of non-grass in the diet increases as land condition declines and the more preferred tussock grasses are not as abundant in the pasture (Ash et al., 1995). Sown and native legumes, forbs and browse are generally higher in protein than the grasses and can improve diet quality, although some of the native browse species are low in digestibility.

Diet selection patterns can lead to a change in species composition at the plant community scale, which in turn alters the selection patterns of cattle. For example, as kangaroo grass is selectively grazed and plants are lost from the system, their contribution to pasture biomass declines and extra selection pressure is placed on the remaining plants. With the loss of preferred species the animals start to actively select what were less preferred species (Ash and Corfield, 1998). This diet selection process leads to the loss of desirable perennial grass species from the pasture. Even where dietary preference is for a grazing tolerant grass, species composition alters through time because the less preferred species out-compete the more heavily grazed species for light and nutrients (Brown and Stuth, 1987).

5.3.3 Effects of patch grazing on composition of grass communities

Within a pasture, sward animals often repeatedly graze a small area (a few metres to tens of metres in diameter). This is known as patch grazing and it appears that animals practise patch grazing to maintain a pasture sward that is short and leafy. Patch grazing leads to the appearance in the paddock of overgrazed areas, characterised by loss of desirable perennial grass species (Mott, 1987) and, where soils are prone to surface sealing, the formation of scalds (Bridge et al., 1983).

On the other hand, patch grazing can be important in improving the nutritive value of the diet and intake of the animal (Houliston et al., 1996). Animals attempt to 'manage' a patch in a way that maintains short leafy material of high quality throughout the wet season. At the end of the wet season, when the grasses in the patches stop growing and they can no longer sustain the animals, they shift their attention to taller tussocks, which were left largely ungrazed during the wet season.

5.3.4 Effects of changes in pasture utilisation

A key concept in managing pastures to maintain perennial grasses is that of *pasture utilisation*. Pasture utilisation is defined as the percentage of pasture growth in a year that is consumed by cattle. With a set stocking regime, pasture utilisation will vary from year to year according to rainfall variability, the amount of pasture grown and stocking rate.

Given the year-to-year variation in rainfall and pasture growth, this balancing of forage supply with animal demand in achieving a safe overall utilisation rate remains a major challenge for producers in northern Australia (McIvor, 2010; Hunt et al., 2014; O'Reagain et al., 2014). Despite the basic principles of grazing management being known for many decades and many experimental grazing trials supporting these concepts (e.g. Burrows et al., 2010; Hunt et al., 2010; Ash et al., 2011; O'Reagain et al., 2011) having been undertaken in the rangelands of northern Australia, overgrazing of pastures is still a common event. This leads to land degradation and loss of long-term pasture and animal productivity (O'Reagain et al., 2011). Overgrazing is most common during a drought event, with producers hanging on to stock for too long before being forced to sell or agist cattle (Landsberg et al., 1998). This repeated phenomenon of overgrazing and degradation events is well documented in the literature (Gardener et al., 1990; Stafford Smith et al., 2007).

In addition to managing overall utilisation to maintain pasture condition, there can be benefits from providing strategic rest to pastures during the wet season. This is because grasses are most sensitive to grazing during the early wet season and rest at this time can accelerate recovery (Ash et al., 2011). However, if the soil and pasture is badly degraded it can take many years for recovery to occur (Bartley et al., 2014).

For property management, spelling of pasture can be practically achieved on a rotational basis where paddocks are rested for varying periods. Low intensity rotational grazing is where the rest period is for the wet season and grazing occurs more or less continually over the rest of the year. A series of paddocks can be established so that a pasture is rested for the wet season every few years. Alternatively, high intensity rotational grazing systems have been gaining attention, whereby the paddocks are quite small and are grazed by large mobs of cattle for just a few days and then have a long rest period before being grazed again. There is considerable producer following for cell grazing, although most formal comparisons show little animal production or economic benefits (Cowley et al., 2016; Hall et al., 2017a).

5.3.5 Effects of grazing distribution

Commercial grazing paddocks in the rangelands of northern Australia are often many thousands of hectares in size. Generally, grazing distribution is not uniform in paddocks of this size because of variations in pasture composition and nutritive value, distance to water and topography (Ash and Smith, 1996a). As a result, degradation can occur in some parts of the paddock and underutilisation in other parts, even where stocking rates have been set to achieve a 'safe' level of utilisation (Hunt et al., 2007; Ash and Smith, 1996b).

This problem raises the issue of managing the overall level of stocking as well as the grazing distribution at the paddock scale, in order to maintain desirable perennial grasses and to minimise degradation. The spelling strategies outlined above are ideal in this regard because the whole paddock is spelled. In contrast, simply reducing stock numbers and grazing continually may not reduce the grazing pressure on the favoured parts of the landscape.

One obvious solution to poor grazing distribution is to fence according to land type. Fencing creek and river frontages is particularly important. This will alleviate the direct impacts of grazing on the vegetation and soil and minimise the effects of grazing on aquatic environments, thus preventing downstream effects of grazing. Riparian areas also provide ideal habitat for many exotic weed species. Exclusion from grazing provides improved flexibility for controlling such infestations and the opportunity to minimise dispersal via grazing animals. Riparian fencing has been widely practised in eastern Queensland, particularly in catchments draining into the Great Barrier Reef. However, fencing according to land type is still rare in more extensive grazing lands of northern Australia.

Another option is to increase fencing and water distribution, without emphasis on land type, so that paddock size is reduced to achieve more even utilisation. In very large paddocks where distance to water is greater than 5 km, subdividing paddocks can allow an increase in carrying capacity (Douglas et al., 2015). Property subdivision provides increased flexibility to introduce a rotational grazing regime that allows resting paddocks when needed. While such infrastructure developments can be costly, if other improvements in management are introduced such that overall productivity increases, then increasing water and/or subdividing large paddocks may be economic. The evidence on the economics of this infrastructure development is still equivocal (Walsh and Cowley, 2014).

5.4 Effects of fire and fire management on the feed base

The rangelands of northern Australia are well adapted to fire (Gill et al., 1990). Before grazing by domestic livestock, fire frequency was relatively high as a result of both lightning activity in the late dry season and intentional burning practised by Indigenous people (Pyne, 1991). Fire frequency remained high following the introduction of cattle, with pastoralists using fire as a tool to remove rank, mature grass of low nutritive value and allow animal access to fresh green pick. However, in Queensland, fire has been used less frequently as a management tool in recent decades, partly because of a long drought sequence in the 1980s and 1990s but mostly because with drought resistant cattle and feed supplements, there is much greater opportunity to utilise the herbage for grazing. However, in the NT and WA, fire is still used as a management tool but there are also unintended fires, especially in the late dry season.

There is little evidence that burning during the dry season reduces productivity of the pasture in the following wet season. However, new growth is more exposed to grazing animals after fire than new shoots at the bottom of an unburnt sward. If the wet season following a fire fails, then there can be considerable grazing pressure placed on the limited amount of new growth. Grazing management following fire is therefore very important, and it is desirable that burnt areas are spelled or lightly grazed during the following wet season if there is only a limited amount of growth.

Fire has the potential to be used to improve the distribution of grazing animals (Andrew, 1986) and prevent or minimise the formation of patches prone to degradation (see above discussion on grazing distribution). Animals form patches on recently burnt country during the next wet season but grazing is shifted away from these patches in the following wet season when another portion of the paddock is burnt. Using such a fire regime and light utilisation (average of 12%) has been successful in experimental paddocks near Katherine for 18 years (Ash et al., 1997). These results demonstrate that both perennial grasses and animal production can be maintained in these systems with this management regime. Although not yet fully tested, fire could also prove useful for manipulating grazing distribution in large paddocks containing a number of plant communities. Pilot studies commenced in the Pilbara in 2017 to test paddock-scale fire management to reduce late dry-season wildfires, improve pasture productivity and benefit biodiversity (https://rangelandswa.com.au/projects/improved-fire-regimes/).

5.5 Integrating the responses to grazing

Plant community responses to grazing are manifested at the paddock scale. It is at this paddock scale that management decisions are made that influence overall pasture condition and plant composition. State and transition models (Westoby et al., 1989) provide a useful framework for describing pasture condition states and the management actions that drive the transitions between these states. An example of a state and transition model for perennial grass communities in north-eastern Queensland is highlighted in Figure 3.

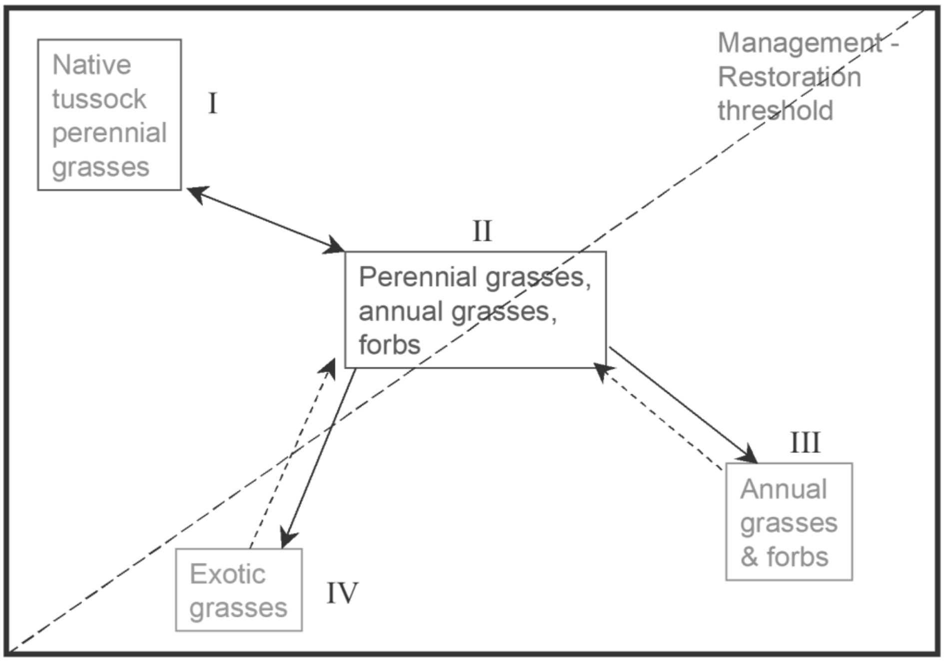

Figure 3 General state and transition model for the grassy layer of the upper Burdekin rangelands
Transition from State I to II occurs under moderate to heavy utilisation, particularly during the wet season. It is hastened in poor seasons. The 'return' transition from State II to I depends on resting or much reduced level of utilisation. It is hastened in good seasons. The transition from State II to III occurs with continued moderate to heavy utilisation. The transition to recover from State III to II requires complete rest for a number of seasons. The transition from State II to IV occurs with moderate to heavy grazing and/or severe drought with a seed bank of exotic grass present. The ability to return from State IV to II is unknown and has not yet been observed.
Source: Adapted from Ash et al. (1994)

The challenge for grazing management is to develop a set of recommendations and guidelines that can maintain native perennial grasses in pastoral lands or can recover land that has been degraded (i.e. can bring about transitions that improve land condition). Hunt et al. (2014) have brought together much of the understanding on grazing and fire management into an integrated set of principles and guidelines, which are shown in Table 7.

Table 7 Principles and guidelines for grazing management

PRINCIPLE 1. MANAGE STOCKING RATES TO MAINTAIN LAND CONDITION AND ECONOMIC RETURNS
Guideline 1.1. Set stocking rates to match long-term carrying capacity. Plan for the average paddock stocking rate to match its estimated long-term carrying capacity, as operating at or around the long-term carrying capacity will help maintain land in good condition. The extent to which stocking rates can exceed the long-term carrying capacity without reducing economic returns and/or reducing land condition is unclear.
Guideline 1.2. Regularly assess the need to adjust stocking rates in response to current and anticipated forage supply and quality. Some variation in stocking rates over time is required to manage periods of below-average herbage growth. Capacity to vary numbers over time also provides opportunities to take advantage of periods of above-average herbage growth. The degree of variation that is most beneficial, and achievable, for different production systems is not clear.
Guideline 1.3. Management factors and issues other than forage supply also determine the need to vary livestock numbers. The adjustment of stocking rates over time should also consider land condition trend, ground cover, grazing pressure from other herbivores, and economic risk.
PRINCIPLE 2. REST PASTURES TO MAINTAIN THEM IN GOOD CONDITION OR TO RESTORE THEM FROM POOR CONDITION TO INCREASE PASTURE PRODUCTIVITY
Guideline 2.1. Rest pastures during the growing (wet) season. As a rule of thumb commence the rest period after 38–50 mm of rain or sufficient to initiate herbage growth at the beginning of the growing season. If access to paddocks is difficult after rain then resting should commence before the wet season starts.
Guideline 2.2. Rest pastures the whole growing season. Resting pastures the whole growing season is likely to provide the most reliable benefit but most of this benefit accruing from rest during the first half of the growing season.
Guideline 2.3. Pastures need two growing season rests to improve by one ABCD condition class. Pastures in B condition need rest for one or two growing seasons to improve to A condition. Pastures in C condition will need longer so plan on taking four good growing seasons to recover to A condition. Where growing conditions are poor, more rest periods will be required. Feral and native herbivores should also be managed to maximise the benefit of resting, although this can be hard to achieve in some circumstances.
PRINCIPLE 3. DEVISE AND APPLY FIRE REGIMES THAT ENHANCE GRAZING LAND CONDITION AND LIVESTOCK PRODUCTIVITY WHILE MINIMISING UNDESIRABLE IMPACTS
Guideline 3.1. Use fire to manage woody species. It may not be necessary to kill target species – topkill can be sufficient to alter the structure of woody populations. Mid-to-late dry-season fires of moderate to high intensity are most likely to be effective in reducing the density and biomass of woody plants. Fuel loads are a critical issue – to reduce populations/mass of woody species, a minimum fuel load of 2000 kg/ha is suggested.
Guideline 3.2. Use fire to change the composition of the herbaceous layer in certain pasture types (e.g. Mitchell grasslands and black speargrass pastures) by killing less desirable plants such as wiregrass (*Aristida* spp.), influencing recruitment or altering grazing preferences.
Guideline 3.3. Use fire to change grazing patterns by temporarily increasing the attractiveness of previously ungrazed areas and providing rest to previously grazed areas.
PRINCIPLE 4. USE FENCING AND WATER POINTS TO MANIPULATE GRAZING DISTRIBUTION
Guideline 4.1. Smaller paddocks and additional water points can achieve more effective use of pastures (i.e. reduce the proportion of the paddock that experiences little grazing). In the more extensive grazing areas of northern Australia producers should aim for paddocks of 30–40 km^2 with two water points, and a maximum distance to water of ~3–4 km to strike a balance between the evenness of grazing distribution and the cost of development. For the more intensive regions in the eastern part of northern Australia, it is likely that paddocks of 20 km^2 with two water points are sufficient from the perspective of optimising grazing distribution. Smaller paddocks may still benefit from subdivision where cattle show a strong preference for land types within a paddock. To minimise the development of large sacrifice areas around water points, the number of head per water point should be limited to no more than 300 head per water point. To protect biodiversity and grazing-sensitive pasture species during drought ~10% of key land types should be kept remote, i.e. 8–10 km, from water.
Guideline 4.2. Smaller paddocks and additional water points do not overcome uneven utilisation by cattle within paddocks at the plant community or patch scales. Other methods (e.g. fire, careful selection of water point locations) are needed to increase the evenness of utilisation at these scales.
Guideline 4.3. Property development can generate significant increases in livestock production only where it results in more effective use of the pasture (increasing carrying capacity) as substantial improvements in individual livestock production are unlikely. If an undeveloped paddock is already operating at its long-term carrying capacity, paddock development may improve the sustainability of grazing through more even grazing distribution.
Guideline 4.4. Fencing and water points can be used to help protect preferred land types and sensitive areas from overgrazing. Fencing to separate markedly different land types is an important strategy for controlling grazing pressure on preferred land types, and to get more effective use of all pasture resources on a property. It can be a practical option in some situations and should be considered where property development is planned.

Source: Extracted from Hunt et al. (2014)

5.6 Future Research and Development implications

The density of the cattle population across northern Australia varies considerably as a function of the inherent productivity of the land types, the grazing management regime, and the amount of paddock infrastructure (fencing and water) that supports the distribution of grazing pressure. Productivity gains can be made across northern Australia by on-farm investments that intensify production by improving water distribution and decreasing paddock size through fencing. Hunt et al. (2010) found that 12 properties in the Victoria River District in the NT had 27% of the land beyond 5 km of water, and effectively un- or under-grazed. It was estimated that about 2000 km^2 of productive land across the 12 properties was effectively unwatered, representing livestock production that is forgone by those pastoral businesses, while areas near water often become degraded through overgrazing. Hunt et al. (2010) estimated that intensification of the 12 properties within the study had the potential to increase cattle numbers by about 154,000 AE (adult equivalents), generating an additional annual gross margin of about $17 million. However, the study did caution that the long-term effects of intensification on land condition, potential livestock production and biodiversity were not well known and required more research (See Section 13). There has been more recent investment in property infrastructure in other regions of northern Australia, especially in the Barkly region. While it is clear that productivity gains can be made, the economics of such developments and long-term consequences for biodiversity are still uncertain (Walsh and Cowley, 2014).

6 Herd and breeder management

6.1 Breeder herd productivity in northern Australia

The CashCow project (McGowan et al., 2014) was a study of 78,000 cows in 142 breeder herds in northern Australia between 2008 and 2011 in order to establish benchmark performance data on reproductive performance of beef cows and to identify the major factors impacting on this performance.

The final report provides data on annual pregnancy rate, foetal and calf loss, cow mortality, and production, divided into four broad country-type categories: Southern Forest, Central Forest, Northern Downs and Northern Forest. In the following, the data on the Southern Forest properties will be mostly disregarded, as they are not, strictly speaking, part of northern Australia (Figure 4). The authors chose the 75th percentile (being in the top 25%) as an 'achievable commercial level of performance' for the different country types.

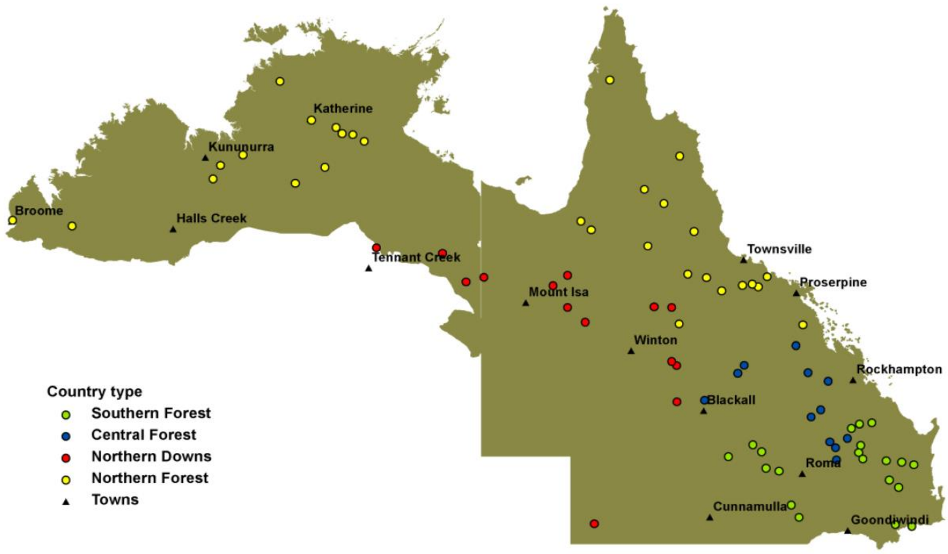

Figure 4 Map of properties by country types studied in the CashCow project
Source: Adapted from McGowan et al. (2014)

The project team assembled benchmark data on annual weaner production (kg weaned/retained cow) for the four country types. Achievable weaner production in the Central Forest properties was almost double that of the Northern Forest region (220 kg/cow versus 112 kg/cow). They found a strong correlation between these measures and annual steer growth. They suggest that annual steer growth data, which may be more readily obtainable, could be used as a guide for annual weaner production where steers are grazing on the same country type.

Annual pregnancy rates for all country types were quite high (79%) across year classes of heifers and cows. The median annual pregnancy rates observed in the Northern Forest were 66% overall. First lactation cows in the Northern Forest were found to have an annual pregnancy rate of 43%.

The project team argues that the ‘P4M’ measure of the reproductive performance of breeder herds is a more useful descriptor of female reproductive performance than annual pregnancy rate. P4M is the percentage of cows that are pregnant within four months of calving, and provides an indication of the probability of weaning a calf in consecutive years.

A median P4M value of 6% was observed for second lactation cows in the Northern Forest country type, while this value was around 65% in the other country types. The ‘achievable’ 75th percentile P4M for all age classes of females was above 75% for the Central Forest and Northern Downs, but only 25% for the Northern Forest.

The median rate of foetal/calf loss (the percentage of pregnant cows that fail to wean a calf) had a median value of 9.5% across regions. In the Northern Forest, foetal/calf loss was almost double that of the Central Forest (12.9% versus 6.7%), with the ‘achievable’ 75th percentile value for the Northern Forest at 9.6%. The median mortality of pregnant cows (cows going missing within an annual production cycle) across all country types was 8.4%. In the Northern Forest properties, the median was 10.6% and the ‘achievable’ 75th percentile 5.8%. These values are consistent with the breeder mortality rates reported by Henderson et al. (2013).

Where information from two production cycles was available, the authors also calculated the proportion of females that contributed a weaner – that is they were diagnosed as pregnant in one year and recorded as lactating in the following year. While the number of records on which this measure is based comprises only a subset of the CashCow data, it provides a useful illustration of the productivity gap in northern Australian breeder herd performance (Table 8).

Table 8 Percentage of females that contributed a weaner within a year based on averages across property types in the four different regions of northern Australia

The achievable level of performance was defined as the 75th percentile value (top 25% of all recorded values).

		CONTRIBUTED A WEANER (%)		
COUNTRY TYPE	NO. OF PROPERTY–YEARS	25TH PERCENTILE	MEDIAN	75% PERCENTILE (ACHIEVABLE)
Southern Forest	35	62	76	88
Central Forest	32	69	77	87
Northern Downs	27	57	72	78
Northern Forest	51	44	53	62
Overall	145	53	70	79

Source: Adapted from McGowan et al. (2014)

CashCow identified the major factors affecting the performance of northern Australia beef herds as follows:

- The body condition score (BCS) of cows at pregnancy diagnosis was a significant determinant for the percentage P4M. The percentage P4M increased as the BCS increased. Cows with a poor BCS also had a significantly higher incidence of mortality (Table 9).

- The calving period in the previous reproductive cycle was one of the main factors impacting on the fertility of breeder herds in northern Australia. This term refers to which season a cow's previous calf was born into. Cows calving in the July to September period were significantly less likely to reconceive within four months of calving than cows calving during the wet season (Table 10).
- Phosphorus deficiency and availability of rumen degradable nitrogen had an effect on P4M. The average ratio of phosphorus to estimated metabolisable energy in faecal samples collected during the wet season was used as a measure of the wet-season phosphorus status. Cows that were grazing pastures with a higher proportion of phosphorus during the wet season were predicted to have a higher percentage P4M. The difference in first lactation cows was particularly large, probably due to their own skeletal growth requirements while supporting foetal growth and lactation. The percentage P4M for cows grazing pastures with a higher average crude protein to dry matter digestibility ratio during the wet season was significantly higher than that for cows grazing lower quality pastures. The quality of dry-season pasture had no significant impact on P4M.
- Infectious disease can affect calf output. A high incidence of bovine pestivirus (BVDV) or vibriosis (*Campylobacter fetus*) is associated with lower calf output. Both infectious agents cause conception failure and early embryonic loss. The study found no evidence of an impact of *Neospora caninum* on calf loss.

Table 9 Predicted percentage P4M by BCS at the previous muster
Based on marginal means generated from the multivariate model and adjusted for all other factors in the model.

		95% CONFIDENCE INTERVAL	
BODY CONDITION SCORE	MEAN PERCENTAGE P4M†	LOWER	UPPER
1.0–2.0	30.9^{A}	24.3	27.4
2.5	38.6^{B}	31.6	45.6
3.0	44.6^{C}	37.5	51.6
3.5	48.9^{D}	41.7	56.1
4.0–5.0	52.4^{E}	42.3	59.6

†Means not sharing a common superscript (A–E) are significantly different.

Table 10 Predicted percentage P4M by calving period

Based on marginal means generated from the multivariate model and adjusted for all other factors in the model. Limited observations recorded in Southern or Central Forest.

		95% CONFIDENCE INTERVAL	
PREVIOUS CALVING PERIOD	MEAN PERCENTAGE P4M†	LOWER	UPPER
July – Sept.	14.8	11.1	18.4
Oct. – Nov.	45.5	38.6	52.4
Dec. – Jan.	63.6	57.1	70.1
Feb. – March	55.1	47.8	62.4
April – June	43.4	35.1	51.8

†Means not sharing a common superscript (A–E) are significantly different.
Source: Adapted from McGowan et al. (2014)

6.2 Opportunities for improvements in breeder herd productivity

6.2.1 Controlled mating

In northern Australia, cows that lactate through the wet season when feed quality is at its best, have the best chance of producing a calf in consecutive years (Table 10). The CashCow study results are backed up by Henderson et al. (2013), who reported a 2.76-fold higher breeder death rate for properties that practised continuous mating, compared to those that used controlled mating.

Based on these figures, some estimates can be made on the impact of property-level interventions. If it is assumed that 10% of a breeder herd calves between April and September each year, and that the remaining 90% calve between October and March, shifting the 10% out-of-season calvings to the wet season, or identifying and managing those females separately, would result in a >5% increase in reconception rate overall. In addition, the breeder mortality rate could drop from around 10 to 3% in a property that implemented controlled mating.

The removal and re-introduction of bulls on an annual basis also provides an opportunity to subject bulls to breeding soundness examination. This in turn provides an opportunity to optimise the bull ratio used in breeder herds and to significantly reduce the capital cost per calf (McCosker et al., 2010). Bull control and management is also a prerequisite for the implementation of any genetic strategies aimed at lifting breeder herd productivity (see Section 6.2.2 below).

A tighter calving interval presents a clear opportunity for improving the reproductive rate of breeder herds, but the interventions necessary to make this a reality are not currently attainable by all producers. Relatively high rates of P4M are required for properties to employ controlled mating, which makes this strategy less feasible for properties in the Northern Forest.

Interventions to control calving interval address the risk factors of low BCS at weaning and previous calving period (see above).

Property-level interventions to achieve controlled mating include:

- making management decisions based on pregnancy test outcomes
- using bull control – fences, culling of scrub bulls
- using controlled mating of heifers only
- removing bulls at annual pregnancy diagnosis muster (mid-dry season) and re-introducing them to the herd in January (7-month mating period)
- removing and re-introducing bulls each year for an even tighter mating period (three or five months)
- using bull breeding soundness evaluation (BBSE) before re-introducing bulls each year.

The lack of out-of-season labour or even basic bull control makes the implementation of these measures challenging in many cases. Alternative methods of bull or mating control, particularly if they represent a saving in labour, may therefore be an important opportunity for technology development.

Conversely, it could be considered that the inability to implement controlled mating systems might in future disqualify operators from breeding livestock, due to its impacts on calf losses, cow mortality and overall production efficiency. There probably remains a need for R&D activities aimed at eliminating the barriers to adoption of controlled mating practices.

6.2.2 Genetic selection and choice of sires

Cross-breeding with Bos taurus to generate more fertile breeder cow herds

From recording the reproductive rate of these females at four Queensland research stations, which represented a range of breeder cow herd environments, it was established that pure Brahman *Bos taurus indicus* (Bos indicus) females perform worse than cattle with a *Bos taurus taurus* (Bos taurus) content of around 50% or greater (Johnston et al., 2014).

While cross-breeding approaches have up until now been mostly a matter of taking an educated guess or a gamble on picking a particular breed of sire, modern genomic DNA-based methods can be used to help predict which Bos taurus bulls are most likely to produce resilient cross-bred offspring (fertile daughters, steers with good carcass and meat quality outcomes). These commercial performance data can come into play when selecting sires for cross-breeding, as genomic technology is able to use data from non-pedigreed, commercial animals in the evaluation.

Development of methods for the selection of pure-bred beef sires for cross-breeding purposes is at the cutting edge of beef genetics and breeding research. The Angus Australia breeding society is starting to develop genetic programs for their clients in northern Australia. Further R&D investment would accelerate the progress that can be made by such initiatives, as well as by companies undertaking herd transformation programs.

Phenotypic selection for male and female fertility traits

In breeder cow environments where cross-bred or tropical composite cattle are unable to succeed, the genetic variation present in the Brahman breed can still be exploited. The Beef CRC team

(Cooperative Research Centre for Beef Genetic Technologies, which ran from 2005 to 2012) was able to show that the age at first corpus luteum (AGECL) and post-partum anoestrus interval (PPAI), both of which can be measured relatively early in the cow's lifetime, are moderately heritable (Johnston et al., 2009). For example, within the 1000 Brahman cows studied, the age at puberty had a mean of 750 days, with a standard deviation of 142 days (Johnston et al., 2009). By comparison, in the same study tropical composites reached puberty at 650 days.

The earliest age at which the first ovulation in a Brahman heifer was observed was 354 days, and the latest 1211 days. Similarly, the 54 Brahman sires that were used in the study received widely varying estimates for their genetic merit compared to the daughter AGECL.

Schatz et al. (2010) documented the results of a 10-year selection program to increase fertility, applied to Brahman males and females, at a NT research station. They applied phenotypic measures of age at puberty in males and females as selection criteria. They found that the pregnancy rate from yearling mating increased from 30 to 65% due to selection for earlier age at puberty.

It has long been known that scrotal circumference in young bulls is correlated with age at puberty in their daughters. Johnston et al. (2014) were able to confirm this correlation and in addition found that measures of semen quality such as motility and percentage normal sperm were genetically related to female reproductive outcomes at the second mating.

Bull selection decisions based on semen traits established at BBSE will have a positive impact on the fertility of daughters, particularly the length of anoestrus at the first lactation.

Phenotypic selection for other traits correlated with female fertility

The CashCow project found association between hip height and reconception as well as foetal/calf loss rate (McGowan et al., 2014). The Beef CRC team identified a variation on chromosome 14 that explains a large proportion of the age at puberty variation, and was previously proposed to cause differences in live weight in dairy cows (Fortes et al., 2012).

The genetic trend in Brahman sire selection over the past 30 years has favoured large mature size and 'tall' animals (increased hip height). This trend may have shifted age at puberty by increasing the time required to attain mature size.

Barwick et al. (2014) estimated the impact of selection in Brahmans on a number of phenotypic traits (such as hip height at 24 months, coat score) when no direct data on reproductive performance is available. They estimated that substantial genetic gains in lifetime annual weaning rate were possible. The suggested gains in lifetime annual weaning rate in 10 years were of the order of 8 to 12 calves weaned per 100 cows from selection of sires using combinations of phenotypic measures.

Barwick et al. (2014) point out that 'these gains are only attainable if a concerted selection effort could be made across the Brahman breed'. The full implementation of a selection index aimed at maximising breeder herd fertility would require additional development in partnership with the breed society and influential breeders.

Genomic prediction of female fertility traits

The highly heritable traits AGECL and PPAI developed by the Beef CRC team rely on ultrasound detection of ovulation events (scanning at 3-week intervals) and are therefore not easily implemented, not even at the stud level. The Beef CRC began the process of deriving DNA-based predictions for estimated breeding values (EBV) for fertility (Zhang et al., 2014). DNA-based predictions allow selection decisions to be made on animals for which no phenotypic information is available. They are essential tools for accelerating genetic progress for fertility traits, which are expressed late in life and are sex limited, as they permit improvements to the selection intensity and the generation interval.

Genomic predictions for moderately heritable traits such as reproduction rely on the trait in question being measured in thousands of genotyped animals (so-called reference population). The Brahman breed now has genomically enhanced EBV (gEBV) available through its breed society, based on Beef CRC and industry investment in reference populations and computational methodology. However, Barwick et al. (2014) estimated that the accuracies of genomic predictions for daughter fertility would have to reach 60% before overtaking phenotypic measures as the most important contributor to genetic gains.

Any registered Brahman animal with a genotype can currently be assigned a gEBV for daughter fertility, expressed as days to calving (DTC). This technology holds promise for accelerating genetic gains in the industry; however, the predictions will require continued investment to achieve higher accuracies and greater uptake.

The collection of evidence for ovulation by ultrasound is prohibitively expensive and one of the main reasons for very slow increases in the size of relevant reference populations. Corbet et al. (2018) have shown that a one-off ovarian scan at around 600 days produces useful phenotypic data related to age at puberty. These measures are the basis of the Northern Genomics Project, which is a Meat and Livestock Australia (MLA) and Queensland Alliance for Agriculture and Food Innovation (QAAFI) collaboration. In future, automated measures of ovulation, based on wearable proximity and/or movement sensors, could be one of the ways in which the collection of reproductive data on genotyped populations will be carried out.

In addition, the contribution to reference databases by data from non-pedigreed commercial herds needs to be maximised. The pregnancy diagnosis data acquired as routine management practice on large year cohorts of beef cows can be used to genomically predict daughter fertility in bulls available for selection (Reverter et al., 2016). This strategy is available to bull breeding operations linked to large pastoral companies, but could also end up contributing to breed society genetic evaluations.

7 Nutritional management and production efficiency

7.1 Introduction

The following review focuses on the environmental and production challenges and opportunities with reference to nutritional management and production efficiency of the northern Australia beef sector.

Holmes (2015) made the following observation that goes to the heart of the long-term economic sustainability of the northern Australia beef sector:

> The central point in herd productivity that escapes most business managers, is that it is leveraged. If more breeding cows (low mortality rate) produce more calves (higher reproductive rate) which are sold heavier (higher turn-off weight) many more kg of beef leave the farm gate for sale. This is further escalated by operating scale. If concurrently, attention is paid to labour efficiency and its related expenses, operating expenses will fall and the end result is lower cost of production.

Among the three components for productivity – mortality, reproduction and turn-off weight – reproductive efficiency has the largest impact on productivity followed by turn-off weights and mortality. Yet all three of these aspects are driven by ensuring adequate nutrition year-round. For the northern Australian cattle industry, marked between season and within season climate variability make delivery of adequate nutrition from pasture a challenge. Grazing land management is fundamental to the success of pastoralism in northern Australia. Increasing the utilisation of this feed base through adaptable pasture management and improved efficiency of conversion of standing biomass to animal product is central to raising productivity.

This review will focus on feed base utilisation as the biophysical underpinning of herd productivity in the north.

7.2 Drivers of production

Pasture productivity and nutritive value are the primary drivers of cattle production. With a marked seasonal rainfall pattern, pasture growth is confined mostly to the wet season, which can be erratic in both timing and quantity of rainfall. Uncertainty around the wet season is a significant management issue over which the producer has limited strategies for mitigation. During the wet season, pasture growth is rapid in the warm, humid conditions. Grasses quickly dominate the botanical composition of the pasture and the high growth rates can have a diluting effect on essential nutrients such as nitrogen and phosphorus. Biomass production of over 100 kg/day is readily achieved, resulting in a potential yield at the end of the wet season of 5 to 10 t/ha. Digestibility and consequently metabolisable energy reach their zenith in the wet season. As a result, at the end of the wet season the productive paddock should provide a sufficient store of feed to last the grazing herd until the next break of season. The utilisation rate (that is the proportion of biomass remaining at the end of the dry season) varies depending on the land condition but typically ranges between 20 and 30%.

Cattle in more intensive production systems function at close to their genetic potential, thus management, reproductive and nutritional interventions may elicit only incremental improvements in productivity. However, in many extensive northern systems, reproductive performance and growth performance are well below the genetic potential of the animal. Thus, responses to changes in the production system can have important benefits for productivity and profitability. Increasing digestibility by just 3 percentage units can increase beef turn off by 28% and gross margin per AE by 15%, with an estimated value of $160 million (Ash et al., 2015). The protein content of northern pastures can be as low as 4%, restricting the ability of the rumen to convert cellulosic feeds to a useful energy source. Increasing protein through legumes in the diet can increase beef production and gross margin per AE by 10%, with an estimated value of $112 million (Ash et al., 2015).

However, over the last 30 years, nutritional management of beef production in northern Australia has remained more or less unchanged. Reproductive potential has increased through genetic improvement within breeds and more importantly the widespread adoption of composite breeding programs that have seen inclusion of taurine genetics into many formerly indicine-dominated herds. Yet over this period, grazing and management practices have failed to match the genetic potential of cattle. Surveys over the past 40 years suggest that gains in reproductive performance in the 1970s and 1980s have stalled and failed to increase beyond 60 to 80% since the mid-1990s, when disease limitations were overcome. O'Rourke et al. (1992) quoted branding rates of 50 to 70% in 1990 compared to rates of 60 to 80% in the late 1990s (Bortolussi et al., 2005a,b,c) and in 2008–2011 (McLean et al., 2014). Low reproductive rate is the single greatest impediment to increased productivity and profitability (Holmes, 2015).

Annual liveweight gains are closely related to land type and rainfall (Bortolussi et al., 2005c) but typically range between 100 and 200 kg/ha. These are considered industry best practice but have not changed since the widespread adoption of Brahman genetics. Liveweight gain is a function of the amount and quality of feed intake and the efficiency with which feed is converted to production. Efforts to improve quality of pasture in the latter part of the 20th century through introduction of exotic legumes and grasses have largely ceased (Walker and Weston, 1990) and the science of supplementation and feeding standards has not advanced in 30 years (Standing Committee on Agriculture, 1990). Thus, the opportunity to achieve significant improvements in both reproductive and growth performance is real and ready to be exploited.

7.3 The role of improved pastures to lift productivity

Woody vegetation is typical of the climax communities in the higher rainfall zones of eastern Australia. Land clearing in the 1960s onwards has increased pasture productivity with the removal of trees reducing competition for moisture, nutrients and light. However broad-scale clearing such as in the Brigalow country of central Queensland has changed the ecology of the region, reduced carbon stores and been met with criticism from many quarters. Striking the right balance between trees and pasture can be achieved through the controlled use of fire to maintain to manage the woody cover and assure long-term pasture productivity.

While many native grass species can be palatable, productive and persistent (Section 5), the development of northern Australia saw the introduction of many exotic grass species. Foremost among these are buffel and Rhodes grass (*Chloris gayana*), which have been widely grown and in some areas represent a nuisance species out-competing the native flora, for example in central Australia (Friedel et al., 2011). Economics dictate that chemical fertilisers are the exception not the rule for northern grasslands. One consequence of this is the need for nitrogen-fixing legumes in northern pastures. Introduced species from South America and elsewhere have not only increased the nitrogen fertility of pastures but also provided a high-protein component to the ruminant diet. Depending on the region, a variety of legumes have risen to dominance and have greatly improved the nutritive value of the grass-dominated swards. Predominant among these legumes are the S*tylosanthes*, *Luecaena* and *Desmanthus* species. As with introduced grasses, legume species can become established outside of designated sown paddocks and become weedy e.g. leucaena (Campbell et al., 2019). Other species such as butterfly pea (*Clitoria* spp*.)*, lablab (*Lablab purpureus*), *Arachis pintoi* and *Macroptilium* are also grown generally in ley cropping systems farming as opposed to pastoral country.

With controlled management of woody weeds, appropriate utilisation rates and taking advantage of adapted exotic species, the production potential of the higher rainfall zones (+600 mm) can be optimised. Figure 5 shows data from an open woodland pasture aerial seeded with Seca and Verano stylo cultivars at least 30 years ago. Legume content varied between 10 and 30% over the season, being lowest in the wet season, and liveweight gain of steers averaged just over 200 kg/year or 63 kg/ha. Such data would be typical for large areas of Queensland with 600 to 700 m rainfall.

Doubling of animal gains can be achieved through intensive pasture management that includes legumes such as leucaena (Bowen et al., 2018), butterfly pea or desmanthus (Cox and Gardiner, 2013) or forage cereals such as forage sorghum (*Sorghum bicolor*) or maize (*Zea mays*). Higher productivity and nutritive value of pastures in the wet season can be exploited by implementing seasonal calving and pasture division to allow for appropriate spelling. The frequency and placement of watering and supplementation points can improve the evenness of grazing and rotational grazing systems may improve overall carrying capacity.

As with native pastures, effective management of improved pastures is tested by climate variability and successive drought periods. New management tools are needed if the industry is to continue to remain economic. In the past there have been benefits from improved cattle genetics and improved pasture species. Major advances in either of these aspects are unlikely in the middle term. It will be how the existing resources are managed that will make the difference. Technologies to assist reproductive performance, to aid management and to forecast weather and climate represent the opportunities that lie in the future.

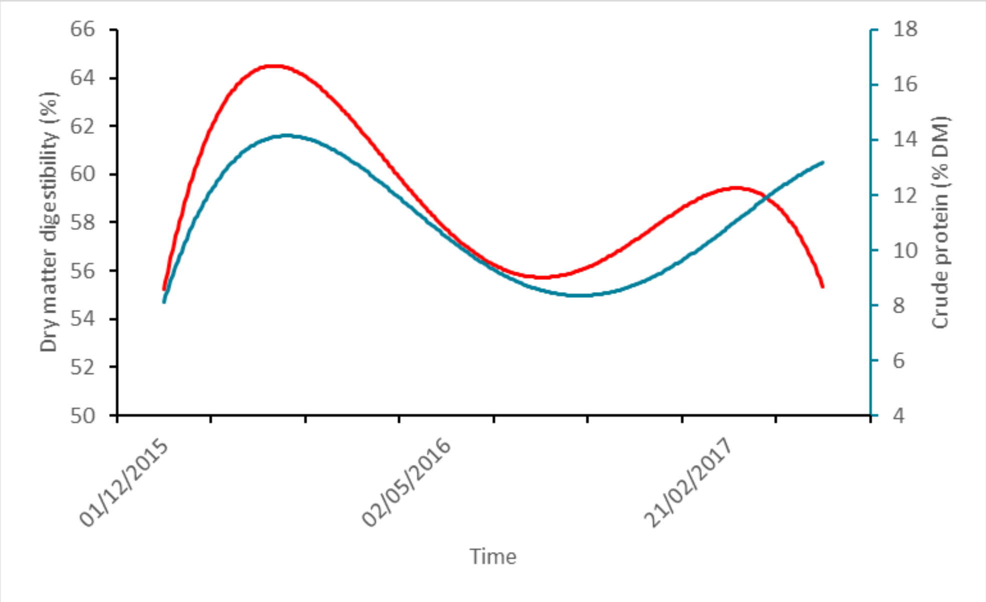

Figure 5 Typical dry matter digestibility (red) and crude protein (blue) variation over seasons for a tropical sward in northern Queensland
DM = dry matter.

There are environmental considerations with the use of improved pastures. Sown grass dominance raises concerns from production and environmental perspectives. If pastures are dominated by one species, production may be at risk, should pests or diseases hit that species. From an environmental perspective, there are concerns about the weed potential of some of these species, should they spread outside the areas where they are sown or where they are planted in unsuitable environments (Lonsdale, 1994). Exotic grasses can displace native species and are implicated in the loss of biodiversity (Grice, 2006; Smyth et al., 2009; Marshall et al., 2011).

7.4 Current opportunities to improve nutrition

7.4.1 Pasture Legumes

Tropical grasses in northern Australia are characterised by their low nutritive value, particularly in the dry season when grasses senesce into standing hay. One of the few opportunities to improve pasture nutritive value is through the introduction of legume species that are adapted to the soils and climate. Legumes typically are higher in nitrogen and can increase animal productivity by 50 to 100 kg/year. Many legume species are deep rooted and can withstand the dry season, often providing a higher proportion of the diet at this time of year. The introduction of legumes is not a new practice and the literature has many of examples of animal performance benefits from including legumes into pastures (e.g. Norton and Poppi, 1995).

Recent renewed interest in leucaena and desmanthus as two legumes suited to the higher and lower rainfall areas of Queensland have received renewed research interest. Leucaena species offer significant nutritive advantages for cattle because they are high in nitrogen and retain high nutritive value in the leaves. When grown in rows within grass pastures, growth performance of over 1 kg/day can be achieved with growing cattle. Historically, older cultivars were susceptible to psyllids but newer varieties are being developed that are psyllid resistant (Redlands) and high yielding. Leucaena can become a weed species as older cultivars are prolific seed producers (The Leucaena Network Committee, 2000). Research into developing sterile cultivars is ongoing and this breakthrough will have major positive implications for increasing the hectarage of leucaena planted.

Desmanthus species are better adapted to drier parts of northern Australia and can thrive on heavy, alkaline clay soils. Gardiner et al. (2012) evaluated the performance characteristics of desmanthus in contrasting tropical environments and found that it thrived and spread on heavier Vertosols. Hall and Walker (2005) conducted a study over a 15-year period in six different environments in the seasonally dry tropics of northern Queensland and found that on cracking clay soils, desmanthus and butterfly pea were the most persistent and productive legumes among 118 legume accessions.

Much of the investment in developing new legume species was made from the late 1960s through to the 1990s, with over 70,000 cultivars (about 950 species) at 567 sites evaluated (Bell et al., 2016). There is today relatively little investment in improved pastures research in northern Australia. The review by Bell et al. (2016) captured some of the highest priority legume evaluation data collected in northern Australia and provides a resource for refining or directing any future research. The review found that for many areas of northern Australia there were no options for improved pastures, and research to fill those gaps and overcome key limiting attributes would widen the success.

7.4.2 Mosaic irrigation

Irrigated forages are attracting increased interest in northern Australia as a means of increasing productivity and creating new market opportunities. There is a particular interest in mosaic irrigation (Chilcott, 2009; Grice et al., 2013; Monjardino et al., 2015; MacLeod et al., 2015; Ash et al., 2017), a concept that involves areas of special-purpose irrigated forages within a large extensive beef enterprise. The benefits of producing high-quality feed 'on farm' appear obvious and based on available groundwater mosaic irrigation could produce 2.4 million tonnes of forage to turn off over 200,000 head of cattle per year (Grice et al., 2013).

This wave of interest in establishing larger scale irrigated mosaics is most active in the Kimberley and Pilbara regions of WA. There is as yet little empirical data to determine the economic benefit of such large-scale capital developments. Experience to date has shown that the forages can be successfully established and the irrigation schemes implemented successfully. It is also clear that animal productivity can be increased significantly. Economic modelling of a range of irrigated forages across different regions of northern Australia has suggested that the projected economic advantage ranges from negative to only moderately positive (MacLeod et al., 2018). Returns that were projected to be quite high (internal rate of return of >15%) occurred under scenarios of high beef prices. Benefits from irrigated forages may be more easily attained through indirect whole-of-herd impacts (e.g. using irrigated forages for early weaning to improve the reproductive performance of breeders).

Currently there are no published studies that document the practical success or otherwise of integrating small-scale irrigation into northern Australia beef enterprises, despite the likely benefits of early weaning and the ability to market otherwise underweight cattle that would have otherwise been retained on property until the next season's muster. Further research is needed on tailored forage systems for a range of animal classes to determine which systems are most advantageous under different local conditions (e.g. feeding young growing animals versus feeding heifers to improve their body frame at first calving for long-term reproduction benefits). Grice et al. (2013) concluded that the following support from governments would be required to assist development of small-scale irrigation into northern Australia beef enterprises:

- streamlining of various approvals processes
- progressing water resource planning and ensuring that it allows for dispersed small water licences to be allocated
- supporting research, development and extension in farming and irrigation systems that are adapted to northern Australia
- investing in the acquisition and analysis of digital soils mapping and proving of groundwater resources and availability
- encouraging collaborative arrangements between commercial famers and graziers to overcome skills shortages from the latter
- facilitating connections with potential (third-party) investors
- improving within-government coordination and collaboration to support development.

7.4.3 By-Product feeding of vegetable wastes

High-rainfall coastal areas and large-scale irrigation systems produce a range of crops that have potential by-product value for beef production (Rogers and Poore, 2002). The nutritive value of waste from sugarcane (*Saccharum* spp.) (cane tops, molasses, bagasse), bananas (*Musa* spp.), cotton (*Gossypium* spp.) and other horticultural crops are well known and used extensively in other parts of the world. In northern Australia, uptake of by-product feeding has been limited due to inconsistency of supply and quality, the lack of suitable equipment, and the co-location of production systems and feedlots. However, with increasing pressure on traditional concentrate sources for beef finishing the opportunity for by-product use in northern Australia may increase in future (Leng et al., 2010).

7.4.4 Targeted supplementation

For decades, supplementation in northern Australia has been confined to dry-season supplementation of energy (molasses) and non-protein nitrogen (urea), and phosphorus supplementation in the wet season. Added to this is emergency feeding for extraordinary drought conditions. In more intensive ruminant industries such as dairy and feedlot, supplementation has evolved to become the addition of specific deficient macro and micro nutrients to address a deficiency in the basal diet. Thus rumen-protected amino acids and fatty acids are included in dairy rations and rumen-undegraded protein is included in feedlot rations. Cost and the logistics of supplement delivery has limited the uptake of more sophisticated feeding systems for grazing beef cattle. However, with improved understanding of the rumen microbiome, it is now possible to identify specific additives that elicit a production response. Bekker (2016) listed the following novel feed additives under development:

- probiotics (live cultures of bacteria introduced to the rumen to influence digestion)
- direct application of enzymes to improve digestion
- antioxidants to scavenge oxygen free radicals to maintain anaerobiosis in the rumen.

To this list the following can be included:

- additives to reduce methane production and capture hydrogen for productive purposes (Martinez-Fernandez et al., 2017)
- methyl-donor compounds (e.g. Pinotti et al., 2002) and co-factors to improve rumen efficiency and the metabolic and immune status of the cow resulting in an increase in re-conception, and productivity gains of offspring later in life.

Challenges around delivery of nutrients remain but micronutrients, when required in small quantities, can be incorporated into lick blocks, provided in the water, and perhaps in future delivered by drones. Another exciting development is the concept of pulse dosing to 'knock' the rumen onto an alternative pathway through epigenetic effects.

7.4.5 Revising feeding systems

Feeds, whether as pasture or concentrates, represent the highest single part of variable production costs in the beef industry. Yet optimisation of nutrients in diets for beef cattle is seldom a priority for the industry because feeding standards were developed in the 1990s and are out of date (Standing Committee on Agriculture, 1990). A 2007 update did not fundamentally change the underpinning science (CSIRO, 2007). Consequently, software packages are not widely used for optimising the nutrient management of ruminants. The standards do not acknowledge marked changes in genetic potential of ruminants; they are not responsive to diet/environment effects on body composition; they do not deliver market specifications, in particular Meat Standards Australia (MSA) grades; and they fail to predict intake and performance in northern grazing systems. Thus, the industry is ill-prepared to take advantage of new information-based feeding systems. Furthermore, the use of technical services, such as nutrition consultants, is unusual in the pastoral sector. Current MLA Donor Company research is tackling this issue with the view to bringing the feeding standards up to date and compatible with electronic media.

Aligned with updated feeding standards that use body composition as an input is the need to predict body composition. The New South Wales Department of Primary Industries has developed BeefSpecs (Walmsley et al., 2014), which generates updated information for more precise estimates of relationships between growth and carcass composition. A currently funded project through the MLA Donor Company is further developing BeefSpecs with the goal of a seamless user interface that integrates nutrition, growth body composition and lean meat yield (https://www.mla.com.au/about-mla/what-we-do/mla-donor-company/lpp/). This is complemented by the current Automated Livestock Measurement Technology (ALMTech) Rural Research & Development for Profit program, cofounded by Meat and Livestock Australia (MLA), to better predict yield in the processing sector (https://www.mla.com.au/research-and-development/automation-and-value-chain-technologies/).

7.5 Opportunity to unlock the potential of the rumen

7.5.1 Grazing efficiency

As 90% of cattle in northern Australia spend the majority of their lives grazing, any improvement in the efficiency with which the feed base is converted to meat will influence reproduction and growth through improved nutrient supply. While it is well known that not all individuals perform equally well on pasture, little is known about why this is so.

Efficiency has to be defined for any particular purpose. In this case, efficiency refers to feed efficiency. But this is a composite trait made up of:

- Grazing efficiency – the propensity to derive maximum biomass and nutrients per unit area of pasture. Often this is simply referred to as voluntary food intake. However, under grazing conditions feed intake may be restricted by availability and the nutritive value of ingested feed can be influenced by diet selection, as well as by what is on offer. So what constitutes an efficient grazer?
- Rumen efficiency – the conversion of ingested feed to nutrients for absorption or passage to the lower intestine. Here efficiency can be defined as the rate at which raw materials entering the rumen are processed and passed along to the next phase of digestion. This is characterised by a high digestive rate and high turnover driven by rapid particulate breakdown, and is a function of an active microbiome coupled with the host's ability to accelerate the process through eructation and rumen contractions.
- Post absorptive efficiency – the use of energy (mostly volatile fatty acids) to fuel maintenance and for growth and lactation and amino acids (mostly microbial in origin) for protein synthesis and turnover. The energetic efficiency is influenced by the chemical composition of the energy substrate and the purpose for which energy is used. Glucose is used with higher efficiency than acetate and efficiency of maintenance is higher than efficiency for gain. Lean gain (which is about 75% water) is more efficient that fat gain (no water and high energy content of lipid) when expressed in terms of body weight.

To adequately address the efficiency question, a knowledge of feed intake is essential (Figure 6). CSIRO Armidale has tackled this question with research spanning a 5-year period. Using detailed measures of intake under controlled grazing conditions and relating intake to behavioural measures, a preliminary relationship has been developed for very specific conditions (Greenwood et al., 2017).

In a longitudinal 2-year study at CSIRO Townsville these ideas were tested to determine the typical variation in efficiency within a herd and the critical factors that influenced efficiency. Because intake cannot currently be measured, performance was used as an inadequate proxy for efficiency.

Seasonal effects had by far the dominant impact on conditions in the rumen and performance. However, there were differences in performance among animals and this was manifested during the wet season. Higher performing animals appeared to select a higher quality diet, but at the same time total volatile fatty acids, ammonia and nitrogen in the rumen were reduced. This may indicate higher turnover rate and/or microbial protein synthesis, possibly a reflection of increased voluntary intake. The ability to measure intake in these animals is crucial if the dynamics of intake, diet quality, selection and digestion on animal performance are to be fully understood, and if these variables are to be manipulated to improve productivity and efficiency.

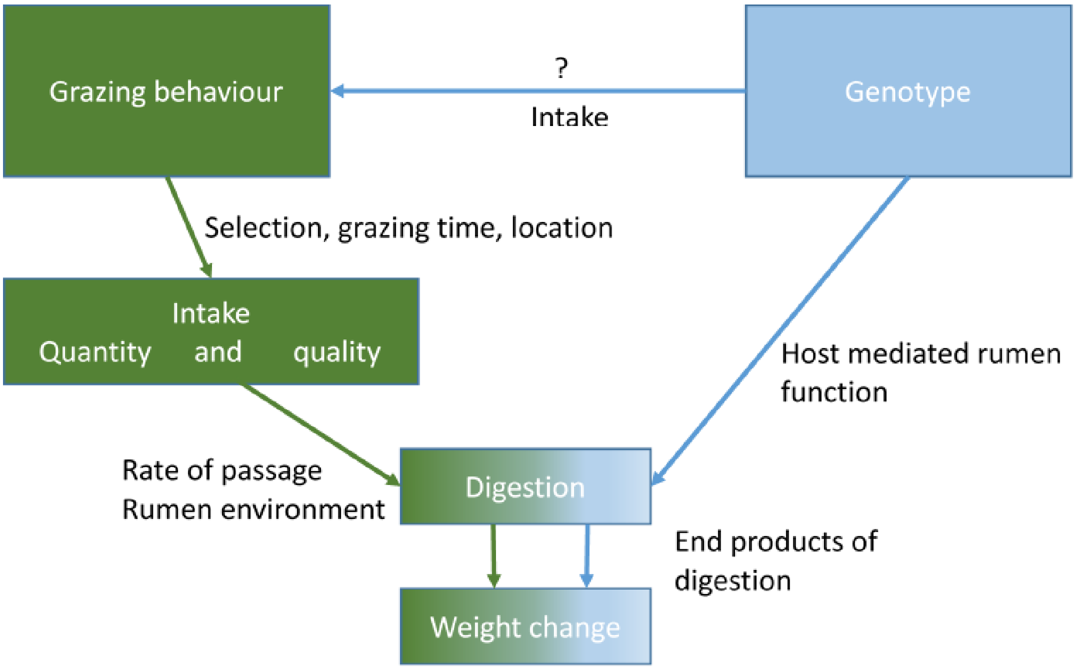

Figure 6 Factors driving ruminant efficiency

7.5.2 Unlocking the rumen

Recent developments based on an understanding of the rumen microbiome using genomic technologies is allowing specific microbial populations and biochemical pathways that result in changes in the efficiency with which the diet is utilised by the animal to be identified. These technologies offer the opportunity to tailor feeds to the microbiome or to adjust the microbiome to better exploit the feeds provided (Denman et al., 2018). The ability to rapidly describe rumen microbial populations and to track shifts in these populations in response to dietary manipulation heralds the possibility of actively shifting rumen metabolism towards more productive and less wasteful populations. Denman et al. (2015) demonstrated that it is possible to reprogram the rumen to improve digestive efficiency through a deep understanding of the rumen microbiome.

Variability in grazing efficiency and growth efficiency will be characterised within and between genotypes with the goal of identifying phenotypes for both traits. A molecular basis for these traits will be sought.

8 Identifying opportunities to lift enterprise productivity and profitability on property

8.1 Background

The northern Australia beef industry achieved impressive gains in productivity from the 1970s, particularly through the adoption of technological innovations, including the wide-scale replacement of British breed (Bos taurus) herds with Zebu (Bos indicus) cattle, improved animal health, nutritional supplements and infrastructure development (Bortolussi et al., 2005a). However, despite these gains, the industry has faced major economic challenges over the last decade. For example, the 'terms of trade' for beef production and marketing remain in decline (average trend is –2%), with a rapid escalation in production and marketing costs while beef prices declined in real terms by 15% from 2005 until 2014 (ABARES, 2014), before a return to more favourable prices from 2015 until 2017. The *Australian beef report* (Holmes et al., 2017), which surveyed family-owned beef operations across Australia, showed that the northern beef industry (Queensland, NT and the northern half of WA) had a net profit before interest of $210,000 over the period 2004–2005 to 2015–2016. Cost of production was $1.61/kg liveweight and operating return on assets was 1.4%. Cost of production in more recent years is mostly greater than $2.00/kg. For the top 25% of producers, cost of production was $1.21/kg liveweight over the 12-year period. Net returns before interest were $575,000 and operating return on assets was 3.3%.

Larger companies are often credited with achieving better economies of scale, which drives more efficient production. However, a recent analysis of six large corporate entities in northern Australia, which collectively manage 65 pastoral stations covering 176 million hectares, shows that financial performance is not significantly different from family-owned enterprises (McLean et al., 2018). Operating returns for the period 2012–2017 were around 2% averaged across all stations and as high as 5% for the top 25% of stations analysed. Company properties had higher returns per adult equivalent (AE) because of higher productivity but had higher operating expenses per AE. The cost of production was $1.44/kg liveweight.

Increasing profit can be achieved by higher prices, reducing costs, or increasing productivity (beef produced per animal unit and/or increasing sustainable carrying capacity). Producing animals that attract a premium is within the control of management but these premiums are usually small compared with market fluctuations in price that are outside the control of individual producers. Considerable effort has been put into reducing costs over the years and a major driver of the top 25% of producers achieving higher returns is their lower cost of production, achieved through better targeting of expenditure, labour efficiencies and scale of operations (Holmes et al., 2017). Further cost efficiencies may be achieved through new technologies that save labour costs or provide information to better manage herds (culling, target market groups, etc.). The *Australian beef report* (Holmes et al., 2017) indicates that industry-wide gains can be achieved by lifting the bottom 75% of the beef producers up to the levels of the current top 25%.

Technologies with potential to lift productivity in these extensive grazing lands includes better breeder management and herd disease control to reduce mortality rates, further genetic gains in cattle reproduction and growth efficiency (Johnston et al., 2014; Wolcott et al., 2014), nutrient and protein supplements (Poppi and McLennan, 2010), the use of superior pasture or fodder species and especially legumes (McIvor and Monypenny, 1995), and the use of high-quality forage crops in intensive animal feeding systems (Bell et al., 2014). The potential advantages of employing these technologies have been empirically evaluated on a relatively piecemeal basis, and rarely within a systems context that facilitates more comprehensive comparisons or allows combinations of technologies to be rigorously tested to see if the interactive effects are additive, synergistic or substitutional. Understanding the potential interactions of new technologies as part of an overall grazing system is essential because in practice livestock enterprises will usually implement more than one productivity improvement simultaneously (Ashfield et al., 2013; Clark, 2013).

The tropical rangelands of Australia are vulnerable to overgrazing and degradation and a key area of grazing management research and extension over many years has been the development of sustainable carrying capacities (Hunt et al., 2014). Introducing new technologies that allow more animals to be carried and/or to consume more pasture run the risk of overgrazing. It is therefore important to be able to appropriately assess the impacts of new technologies on key aspects of landscape health. A more recent environmental concern is the level of methane emissions from the extensive livestock sector, particularly in regions where pasture quality is low such as northern Australia (Cook et al., 2010). Introducing technologies that reduce emissions intensity and offer scope for reducing total methane emissions is therefore desirable.

In this section a property (enterprise) level analysis was undertaken, adopting a scenario approach where productivity and profit of baseline enterprises (current practice) were compared with a range of scenarios involving technologies to improve productivity. The effects of the technologies on production and profit were examined individually and then in combinations to determine the additive benefits of implementing a range of interventions to improve production. This scenario approach utilised simulation models to explore the benefits and consequences of different technology improvements.

8.2 Modelling rationale

Simulation models provide a cost-effective means of exploring the response of extensive livestock grazing enterprises to changes in herd and resource management practices as a result of technological advances (Tess and Kolstad, 2000; Crosson et al., 2006). These enterprises are characterised by complex herd structures and dynamics that are subject to interactions between a highly variable climate and pasture resource, which drives considerable production risk (Cacho et al., 1999). To adequately test these interventions, a model was required that could integrate the growth and quality of natural pastures under grazing; herd dynamics including reproduction, growth and mortality; genetic improvements in reproduction and growth efficiency; alteration of the pasture feed base; nutrient supplements; and rumen modification. This required an ability to model the energy and protein supply consumed by animals and its conversion into animal growth, body condition score (BCS) and reproductive state. With the emphasis of this project being on more forward-looking management changes, the North Australian Beef Systems Analyser (NABSA) was used (Ash et al., 2015).

8.2.1 Model Overview

NABSA is a whole-of-enterprise, multi-year, dynamic simulation model that assesses the production, environmental and economic consequences of a range of development options. It is broadly based on an approach developed to simulate smallholder crop–livestock systems in developing countries (Lisson et al., 2010). Puig et al. (2011) developed a systems-modelling approach to examine options and trade-offs for development, diversification and land-use change in the pastoral lands of northern Australia but they took a broader industry structural approach rather than a focus on 'within enterprise' herd productivity interventions.

The NABSA model was originally built on a Microsoft Excel platform using a monthly time step but it was re-compiled in 2015 to make it consistent with the Agricultural Production Systems Simulator (APSIM) crop modelling framework (Holzworth et al., 2014). NABSA integrates livestock, pasture and crop production with labour and land requirements, accounts for revenue and cost streams, and provides estimates of the expected environmental consequences of various management options (Figure 7).

In the model the type of enterprise is defined by the user based on the property size, the area that is used for grazing, soil type, starting land condition and approximate herd size. The structure of the beef herd and the main turn-off class of animals are stipulated based on a herd dynamics approach developed by MacLeod et al. (2004). Other input parameters associated with the herd operations include labour; direct costs (transport, veterinary, fuel, supplementary feeding, etc.); prices per kilogram of liveweight for different animal classes; rules for sale of animals and feeding; and disposal of animals when forage becomes limiting.

Forage production and quality

Once an enterprise has been set up, a model run is commenced using an historical climate file to drive the natural features of good and poor seasons to grow forages that supply the animals with nutrients. It was important to incorporate this large inter-annual climate variability and its influence on pasture and animal productivity and resource condition that characterises the northern Australian semi-arid tropics (Ash et al., 1997).

Historical records of daily climate were obtained from the SILO database (https://www.longpaddock.qld.gov.au/) based on the most relevant climate station within each region. Forage growth of native pastures was simulated using GRASP (Grass Production Model) (McKeon et al., 1990), which is a process-based model that uses daily climate, soil water holding capacity and soil nitrogen to drive pasture growth. The output from the GRASP model was imported into a database that the NABSA model called up to acquire monthly pasture growth. Given the objective of this study was to explore a range of productivity improvement options it was considered important to be able to explore other forage options, including sown pasture and the use of more intensive forage crops. The APSIM crop model (Keating et al., 2003) will be used to simulate forage crop growth using the same daily historical climate files as used in GRASP. Likewise, the output from APSIM will be imported into the NABSA model.

The amount of available forage is only one determinant of animal production from grazing ruminants. Forage quality is also a strong driver of animal growth and reproduction and is a particularly important issue in northern Australia due to the seasonal protein and energy deficiency that is typically associated with tropical grasses (McLean et al., 1983). The quality of forage from new growth, the decay rate through the season and the minimum quality can all be stipulated within the model. There are now sufficient data available on these parameters from near-infrared spectroscopy (NIRS) analysis of cattle dung from free-ranging cattle in different parts of northern Australia (e.g. Coates and Dixon, 2008).

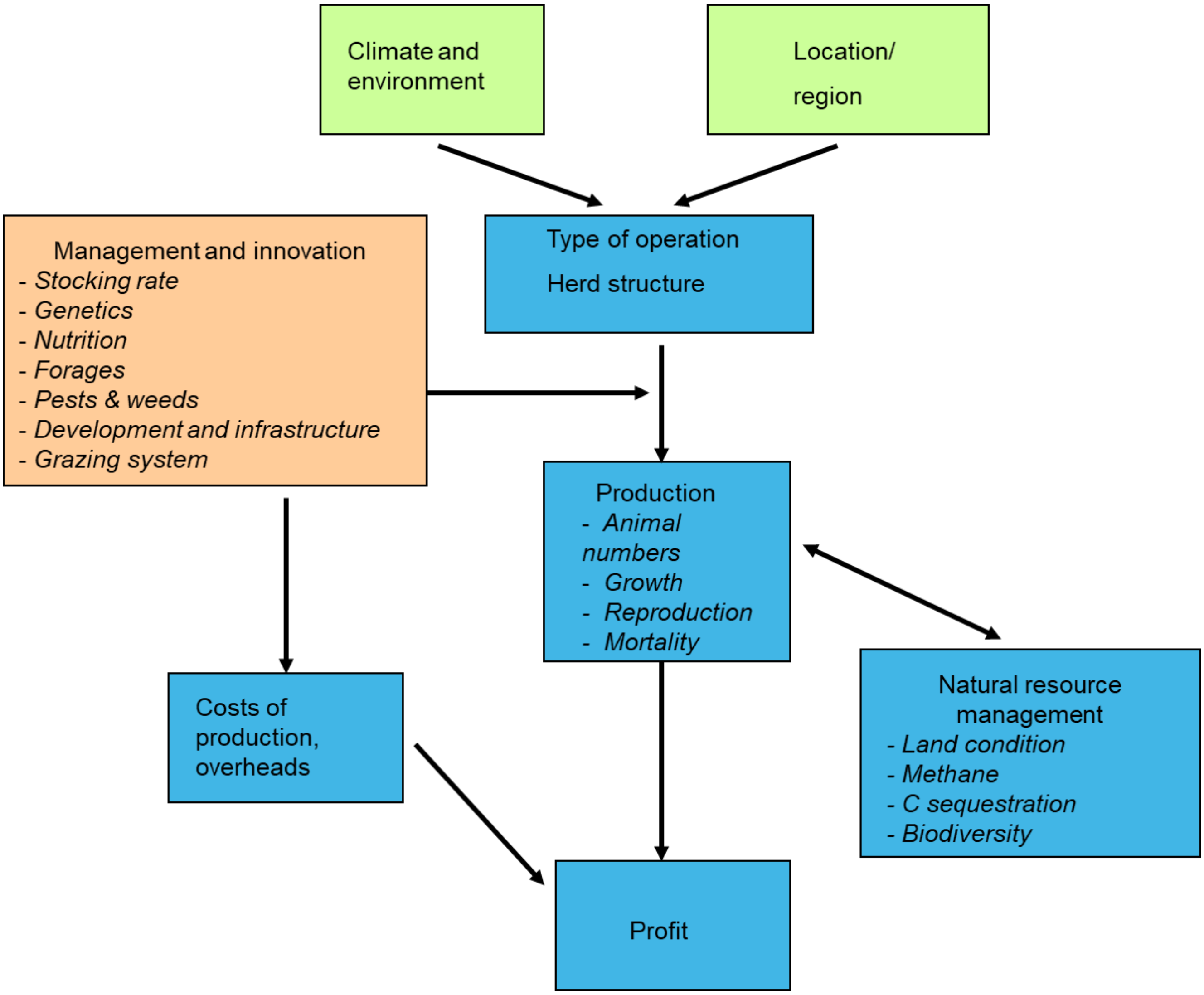

Figure 7 A schematic illustration of the structure of the northern Australia beef production system on which the NABSA enterprise model was based

Green boxes indicate environmental and geographic inputs that determine the type and scale of operation, the orange box represents technology and management interventions and the blue boxes represent how the enterprise (herd dynamics, productivity and economics) and resource base respond to the environment and management drivers.

To test adaptation scenarios involving special-purpose forage crops, the APSIM crop simulation model can be used to simulate production for a range of dryland or irrigated forage crops (e.g.

sorghum, lablab, lucerne (*Medicago sativa*)) and perennial pastures (Bambatsi (*Panicum coloratum*), one of the panic grasses) in a variety of environments. This forage could be made available to particular classes of animals (e.g. young growing animals) to allow enhanced growth on high-quality forage. As with native pasture, the quantity and quality of the forage crop will be used to drive animal intake and growth.

Animal growth

Simulation of animal growth from birth to turn off is based on energy and protein supply from forages and supplements using standard relationships for the nutrient requirements of domesticated ruminants (CSIRO, 2007; Feeding Standards of Australia). This is the first model of cattle growth for northern Australian forage conditions that takes this approach. Previously, models have used more simplistic relationships between feed availability, estimates of its quality and animal growth (e.g. McKeon et al., 1990). Calf growth is determined by the milk supply from cows which, in turn, depends on the nutritional conditions of lactating cows. Time of weaning can be varied within the model to allow testing of early weaning scenarios. Compensatory growth is not explicitly represented in the model, which means late dry-season losses and early wet-season gains in body weight are both underestimated with the expectation that these essentially negate each other.

The model can simulate situations where low forage availability (e.g. due to poor seasons or overstocking) limits animal intake. For example, the level of feed availability below which feed intake becomes limiting is greater for dense pasture swards in the subtropics (1000 kg/ha) than it is in more open extensive native pastures.

Enterprise economics

Enterprise economic outcomes (except for taxation) for different scenarios are simulated by assessing the revenues from animal turn off against direct costs of production (animal veterinary costs, transport, commission, etc.) to generate gross margins. In addition, overhead costs, labour and interest paid on debts are calculated to generate net profits. Capital costs associated with any development are included as a debt, but there is no annual depreciation charge included in overhead costs.

Natural resource condition

It is possible to simulate some key resource condition outcomes for modelled scenarios. The pasture utilisation rate (an estimate of total pasture growth that is consumed by animals) determines land condition, with high utilisation rates driving down land condition. Changes in land condition are reflected in altered pasture growth simulated in the GRASP model. How land condition improves or deteriorates in response to this utilisation rate can be altered for different climate–pasture systems. Qualitative indices that integrate the effects of livestock production across a range of resource condition criteria are also produced by the model. The approach used to produce these indices builds on some earlier work for extensive beef enterprises in northern Australia (MacLeod and McIvor, 2006).

Methane production

Methane production from cattle grazing pastures is closely related to dry matter intake (Kennedy and Charmley, 2012). Given the NABSA model predicts dry matter intake of cattle, it is a straightforward regression relationship to derive methane production. The relationship developed by Kurihara et al. (1999) for tropical pastures, which was amended by Hunter (2007), was used to estimate methane production as this relationship is used in Australia's greenhouse gas inventory of greenhouse gas emissions (AGO, 2005).

The interaction between adaptation options and methane production occurs via the herd numbers used in the different adaptation options and the methane intensity per unit of production (e.g. better quality diets can result in significant improvements in methane intensity but this can be offset by increases in herd numbers).

The relationship used in NABSA has been based on that developed by Kennedy and Charmley (2012). This equation is:

$$\text{methane}\left(\frac{\text{g}}{\text{day}}\right) = 19.6 \times \text{intake}\left(\frac{\text{kg dry matter}}{\text{day}}\right) \qquad (1)$$

8.2.2 Model assumptions and limitations

While the NABSA model has been developed to test scenarios at an enterprise scale, the current version cannot represent all of the operational diversity and complexities of real beef enterprises in their entirety. As with any model of a complex system, it has a number of limitations and simplifying assumptions. The important limitations include the following:

- Diseases are not explicitly represented in the animal production model, but efforts to minimise their effects are represented in veterinary costs (e.g. vaccines).
- The model does not allow for variation of individuals within a cohort or age class of animals. All of the animals within a given cohort or age class are subject to the same process rates (e.g. they grow at the same rate, consume supplement at the same rate).
- Where enterprises carry a financial debt, all profit is directed towards paying off the debt as soon as possible.
- The model does not allow for separate paddocks to be simulated and does not incorporate spatial issues such as uneven grazing distribution and its effect on intake, diet quality and production. It was also generally assumed that a single land type exists on a property.
- No additional capital costs beyond those required for technology development scenarios are included in the model. Maintenance and repairs are included as overheads but imputed costs for depreciation and replacement of capital items are not included.
- While some technology scenarios in reality would take many years to fully take effect (e.g. improved genetics), model runs will be taken without this ramp-up period, assuming that they have been fully implemented or established within the first 2 years of the simulation.

- A key aspect of implementing technology scenarios will be to ensure they can be implemented sustainably. Breeder numbers are adjusted in the model runs to maintain safe utilisation rates and to either maintain or improve land condition over the simulation period.

Despite these assumptions, the key processes in these beef production systems are well represented and the outputs that have been tested are realistic.

8.2.3 Interventions

Previous consultations with industry representatives and the scientific community revealed a variety of potential development opportunities suggesting productivity benefits for the northern Australia beef industry. Many suggestions related to improving the fundamental aspects of cattle production (e.g. livestock reproduction and growth), which receives ongoing research support from Meat and Livestock Australia (MLA).

Over the last decade the issues that have been most commonly raised by producers to improve productivity include:

- better pastures (to provide more protein in the late dry season)
- opportunities to incorporate intensive, irrigated forage into production systems
- improved breeder genetics (especially in relation to reconception rates)
- faster growth rates (through improved genetics and pastures)
- improved pasture utilisation through better grazing distribution
- reduced labour costs
- more effective options for managing weeds, pests and diseases.

The need for increased adoption of existing best practices is commonly raised as an ongoing challenge for industry. Although there has been investment in new processing facilities in recent years (Darwin and Derby), a lack of viable alternative markets and processing facilities in northern Australia are still perceived as impediments to the further development of the beef industry.

The primary technology scenarios that have been considered in this analysis are summarised in Table 11.

In this study the focus was on scenarios to increase productivity, although it is recognised that reducing cost of production is an important aspect of increasing profitability. Reducing cost of production through scenarios such as greater use of remote management technologies can be represented in the model through reduced labour inputs.

The first-pass analysis looked at different productivity improvement scenarios individually and then the most promising individual scenarios were combined to provide integrated productivity scenarios.

Table 11 An overview of the productivity improvements that were assessed for beef producing regions across northern Australia

TECHNOLOGY/DEVELOPMENT	SCENARIOS
Individual development scenarios	
Reduced mortality	Overall better herd management and disease control to reduce mortality rates and improve herd production efficiency
Better breeder genetics	Improved breeder conception rates at moderate BCS and while lactating, resulting in improved calving, branding and weaning percentages (5% unit improvement in branding rates)
Better genetics for growing	Improved efficiency of energy use for growth that results in annual liveweight gains increasing by around 10 kg/head/year
Improved pastures	Oversow native pastures with legumes to lift overall pasture production but particularly diet quality in the dry season to allow animals to grow instead of losing weight
Mosaic farming/irrigation	Steers or weaners grazed on good pasture in late dry season to bring to market sooner
More efficient rumen (better rumen microbes, modified rumen ecology)	Increase in pasture digestibility
Cheap protein	A cheap high-protein source that has both soluble and insoluble proteins
Integrated development scenarios	
Integrated genetics – improved reproduction and growth efficiency	These integrate genetic improvements without alteration to the feed base
Genetics + improved feed base	Improved genetics, as above, plus improved feed base through oversown legume
Genetics + improved rumen and protein	Improved genetics, as above, plus a cheap protein source and a rumen modifier that increases digestibility of base forage. No change to the feed base

Current technologies

Animal productivity

A significant factor in reduced productivity in northern beef herds is mortality. Herd mortality can be as high as 10% in low productivity areas in northern Australia, although more typical levels of mortality are in the region of 3 to 5% (Holmes et al., 2017). To test effects of reduced mortality, baseline mortality rates in the herd model were reduced.

The NABSA model has been set up to allow genetic gains in growth efficiency and in reproduction to be represented through modifying key equations relating to body condition and conception and the conversion efficiency of energy into growth. Through ongoing systemic improvements in genetic gain it was assumed for a 2030 scenario that a 5% unit increase in reproduction will be achieved, and an improvement in growth efficiency that delivers improved liveweight gains of around 10 kg/head/year. These scenarios are considered plausible given existing technologies (genetic improvement, nutrition) are capable of delivering such gains in animal production.

Legumes

Another way of adapting to declining pasture quality is to augment native pastures with an introduced legume. This technology has been available for a few decades and is able to substantially increase animal productivity. While there has been some adoption of this technology its application is not widespread, largely due to issues of reliable aerial establishment or regulatory constraints (e.g. WA pastoral lands). The cost of seed and application from planes or helicopters is expensive when done over large areas of land, and this combined with a lack of confidence in first-time establishment has constrained adoption. However, productivity and profitability are much increased where it is successfully established. There is renewed research activity in improving reliability of establishment and new plants are now available for a wider range of soils (e.g. commercial varieties of desmanthus are now available for Vertosols).

Oversowing of legumes (such as stylo) was simulated in NABSA by increasing the quality of the available pasture (higher protein content) and by slowing the typical seasonal decline in protein content. Oversowing with legumes also increases pasture quantity and this was simulated by increasing the basal area of pasture within the pasture model.

It should be noted that oversown legumes were assumed to be successfully established with a single application of seed. This cannot currently be guaranteed and research programs are under way to improve establishment.

Irrigated forage crops

In response to declining forage quality of native pasture (temperature and elevated carbon dioxide (CO_2)) and increased variability of pasture production (increased rainfall variability), irrigated forage crops provide an option to greatly increase forage quality and in providing a more stable feed base. Young animals can be held on irrigated pasture or fed harvested hay in holding yards to target market niches such as an increase in price late in the year when export numbers are dropping in response to the seasonal shutdown in mustering. Depending on the area of land that is feasible to irrigate there may also be opportunities to turn off whole cohorts of stock at a younger age and into a different market, for example slaughter export of ox rather than live export of lighter animals.

For this adaptation option, a mosaic irrigation system was assumed with water pumped from groundwater supplies or surface water (rivers/streams or ring tanks). Centre pivot irrigation systems on the grazing property were assumed. Forage was grown for direct grazing to create an alternative market for young sale animals. While a range of forage grasses are currently being used in pivot irrigation systems across northern Australia, for this analysis irrigated forage sorghum was chosen.

The forage crops were modelled within APSIM (Keating et al., 2003). Grazing was then simulated in NABSA by putting a class or a number of classes of animals onto the available forage and grazing it until animals were either finished or the forage supply was exhausted and they then returned to the native pasture. Input costs in growing and harvesting the forage crop were captured within NABSA as were the capital costs of establishing the irrigated forage system.

Future technologies

These technologies are not currently available but are likely future technologies.

Low-cost, high-quality protein supplements

One way of overcoming the seasonal deficit in pasture protein is to provide a high-quality protein supplement. All commercially available protein supplements are expensive and are not cost-effective to feed in extensive production systems. This scenario assumed new and alternative protein sources, such as algae, or locally available protein supplements (e.g. whole cottonseed from locally grown cotton in new irrigation developments). This was assumed to be available on property (e.g. on-farm algal ponds, for $250/tonne compared with existing costs of protein meals, for $500/tonne to $600/tonne). This option was simulated in NABSA by providing a cheap protein source to all stock as a routine supplement.

Improved rumen function

The technological challenges associated with modifying rumen function to improve digestibility of energy are significant because of the difficulties in permanently altering rumen microflora. However, even a small gain in digestive efficiency can have a large impact on animal production in these tropical pasture systems where dry matter digestibility of forage is very low for much of the year. If a small gain in digestibility of energy could be achieved, which is not guaranteed, this would be transformational. Improved rumen function was represented in NABSA through a slight lessening of the normal decay curve from high digestibility to low digestibility from the wet season to the end of the dry season. Minimum digestibility was simulated to increase by 2 percentage units (e.g. from 42 to 44%) at the end of the dry season.

8.3 Summary of results across regions

All development scenarios led to increases in beef produced, gross margin and profit in each of the five locations, but there were differences among regions and development scenarios in these responses (Table 12), with detailed results for the five study regions provided in Appendix A .

Overall, the integrated technology scenarios gave the greatest response in productivity and financial performance, followed by improved pastures > cheap protein supplements > improved rumen function > improved growth efficiency > improved reproduction. Although the trend in response to the development scenarios was largely consistent across the regions, the relative magnitude of the response compared with the baseline differed among regions. These differences appear to be related to the underlying productivity of each region. The north-east Queensland region was the most productive and profitable region in terms of individual animal performance and gross margin per AE but had the least response in relative terms to the different development scenarios. In contrast, the lower productivity regions (e.g. Kimberley) had the greatest relative response to the various technology interventions.

Table 12 Summary of production and financial outcomes from different technology intervention scenarios, averaged across five locations (Tropical Queensland, north-west Queensland, Barkly, Katherine–Victoria River Downs and Kimberley)

TECHNOLOGY/DEVELOPMENT	HERD SIZE (AE)	GROSS MARGIN ($/AE)	PROFIT ($)	WEANING RATE (%)	ANNUAL LIVEWEIGHT GAIN (kg/head/y)	BEEF SOLD (kg/AE)
Baseline	11,870	165	808,947	56	121	101
Reduced mortality	12,209	180	1,024,192	58	121	108
Improved reproduction	11,967	176	968,918	62	121	107
Increased growth efficiency	12,154	183	1,068,722	61	136	109
Oversown legume	13,796	203	1,573,272	64	147	116
Leucaena	12,132	217	1,383,311	57	209	128
Irrigated forage sorghum	12,406	198	1,149,207	57	191	123
Cheap protein	11,970	205	1,270,457	64	154	126
Rumen modification	12,001	186	1,104,886	64	140	115
Integrated genetics	12,512	194	1,308,425	66	135	112
Genetics + legume	14,095	235	2,154,299	69	161	124
Genetics + rumen modifier + protein	12,575	228	1,702,735	74	179	136

8.3.1 Reduced mortality

High mortality rates have a significant impact on profitability. This issue is often not visible to management because in extensive herds, record keeping required to accurately quantify mortality is often lacking. Reducing mortality by 2 to 4 percentage units results in more animals for sale and a slight increase in weaning rates with the loss of fewer breeders. Consequently, simulated profit can increase by 20% through a reduction in mortality. A combination of better disease management, nutrition and general herd management is critical to reducing mortality.

8.3.2 Genetics

Improved herd management (disease control, good weaning management, culling, etc.) that reduces mortality by 2 to 4 percentage units has a significant benefit on gross margin and profit despite only a modest increase in weaning rate and no direct impact on liveweight gain. Simply having more animals progressing to breeding and/or sale generates very positive outcomes. This ‘no regrets’ strategy can be implemented over a short period of time and usually does not require much in the way of capital investment.

The genetics scenarios (improved reproduction and growth efficiency) produced lower gains in productivity and financial performance than a number of the other development scenarios. This in part reflects a more modest intervention (e.g. for the improved reproduction scenario there was a 5-percentage point increase in weaning rate, with no change to growth of animals). Some of the other nutrition-based scenarios (e.g. protein supplementation) lifted growth of all animals, which led to higher weaning rates and increased growth. Nevertheless, increasing the weaning rate by 5 percentage points resulted in a ~20% increase in average annual net profit despite the growth rates of individual animals not being directly affected.

Increasing efficiency of growth through genetic gain resulted in a consistent increase of 15 kg/head/year in liveweight gain across the five regions, which also had some flow-on benefits for cow condition and calf weaning rates.

Genetic improvements in reproduction or growth efficiency take time to implement as it usually requires many generations to achieve the desired outcome. The results shown in this study represent indicative gains following this transition period. A distinct advantage of these 'within animal' improvement technologies is that capital investment is usually spread over time compared with an infrastructure development such as developing land for irrigation. Further, given the land is not being developed, there is no requirement for any approvals such as land-use/tenure change or environmental assessment, which can be both costly and time consuming.

8.3.3 Introduced pastures and irrigated forages

Improved pasture, whether it was oversown into rainfed systems, used dedicated areas of leucaena, or was special-purpose irrigated forage, resulted in significant gains in both animal productivity and enterprise profitability in all five regions. In the case of oversown forage legumes (e.g. stylo) which were available to the whole herd, these gains were a result of both improved liveweight gain per animal (average 38 kg/head/year increase over baseline) and increased weaning rate. An increased herd carrying capacity (average increase of 16%) facilitated by higher levels of pasture production also contributed significantly to the large increase in gross margin and profit in the oversown legume scenario.

Use of leucaena in special-purpose areas for fattening of growing animals for sale produced the highest productivity gains with annual liveweight gains of around 200 kg/animal. Unlike oversown forage legumes, which also improved reproductive performance, leucaena was only used for fattening and it consequently, on average, generated profits somewhat lower than oversown legumes. There was considerable regional variability in the financial outcomes for leucaena, which was related to its simulated productivity.

In the scenarios used for this comparative analysis, irrigated forages were grown over a substantial area and were used to fatten young animals to reach turn off at a young age, thereby providing different market opportunities to existing markets such as live export. The increase in net profit was not as great as for some other scenarios, mostly due to the large capital cost of irrigation development. Other irrigation scenarios are possible (e.g. growing a much smaller area of fodder requiring lower capital development costs and using the forage to feed early weaned calves, with excess forage available for sale).

In the recently completed Northern Australia Water Resource Assessment (NAWRA), this early weaning scenario was compared with a fattening scenario for a range of irrigated forages in the Mitchell catchment in Queensland and the Fitzroy catchment in WA. The results showed that using a smaller area of forage for early weaning and hay sales could generate better returns on capital than using larger areas for fattening (Table 13 and Table 14). For the grazed scenarios in the Fitzroy catchment, the marginal return on capital (increased income as a proportion of capital costs of development) ranged from 5 to 10% when capital costs were $12,000/ha and from 3 to 6% with higher capital costs of $20,000/ha. However, in the Mitchell catchment, profit increases were modest and returns on capital were low, generating negative net present values (NPVs). These scenarios used a sale price of $3.00/kg liveweight and if a $2.00/kg liveweight sale price was used, returns and NPVs were considerably lower.

However, for smaller areas of irrigation with high-quality hay used in the breeding herd to support feeding of early weaned calves, profits and NPVs were substantially higher in both the Fitzroy and Mitchell catchments. There was also less risk involved as the total capital outlays were substantially lower in the hay scenario because of the smaller areas of land needed for irrigation. The hay could be used either on farm for early weaning and/or for sale, providing a diversity of market opportunities.

Table 13 Simulated production and financial outcomes from investment in irrigated forages in a 450,000-ha beef enterprise in the Fitzroy catchment

	BASELINE	GRAZED FORAGE FOR STEER FATTENING			EARLY WEANING STRATEGY USING HAY + EXCESS HAY SOLD LOCALLY		
Forage	None	Forage sorghum	Rhodes grass	Lablab	Forage sorghum	Rhodes grass	Lablab
Area of irrigated forage (ha)	0	1,000	900	1,000	330	220	330
Herd size (AE)	26,686	27,255	28,088	26,602	26,724	27,109	26,999
Pasture utilisation (%)	15.3	15.2	15.4	15.2	14.8	15	15
Weaning rate (%)	55	59	57	55	62	62	62
Annual growth (kg/animal)	131	176	241	221	130	130	130
Beef produced (kg/AE)	79	107	109	101	98	98	98
Gross margin ($/ha)	9.2	12.1	10.9	11.2	12.9	13.2	13.1
Profit (EBITA) ($ million)	2.89	4.10	3.55	3.68	4.46	4.61	4.53
Net present value ($ million) – $12,000/ha capital cost	NA	3.15	6.33	–0.84	12.17	15.35	13.65
Net present value ($ million) – $20,000/ha capital cost	NA	–2.78	1.89	–6.78	10.91	14.05	11.69

NA = data not available.

Table 14 Simulated production and financial outcomes from investment in irrigated forages in a 60,000-ha beef enterprise in the Mitchell catchment

	BASELINE	GRAZED FORAGE FOR STEER FATTENING			EARLY WEANING STRATEGY USING HAY + EXCESS HAY SOLD LOCALLY		
Forage	None	Forage sorghum	Rhodes grass	Lablab	Forage sorghum	Rhodes grass	Lablab
Area of irrigated forage (ha)	0	250	185	400	110	80	200
Herd size (AE)	3677	3872	3876	3946	3778	3790	3778
Pasture utilisation (%)	20.6	20.3	20.2	20.1	20.3	20.4	20.3
Weaning rate (%)	55.0	58.0	58.0	59.0	65.0	65.0	65.0
Annual growth (kg/animal)	115	211	235	272	117	117	117
Beef produced (kg/AE)	96	128	131	136	109	109	109
Gross margin ($/ha)	13	16	15	17	15	15	17
Profit (EBITA) ($ million)	0.47	0.61	0.57	0.67	0.58	0.57	0.67
Net present value ($ million) – $12,000/ha capital cost	NA	–0.96	–0.85	–1.79	0.58	0.75	0.12
Net present value ($ million) – $20,000/ha capital cost	NA	–2.60	–1.95	–4.17	–0.07	0.28	–1.07

NA = data not available.

8.3.4 Cheap protein source

Providing a cheap high-quality protein supplement resulted in significant increases in productivity and profitability in all locations, which is not surprising given that a feature of production systems right across northern Australia is the seasonal deficiency in protein during the long dry season. The gains can be attributed to a combination of factors including being able to support a small increase in herd carrying capacity (average of 8% over the baseline), improved animal liveweight gains (33 kg/head/year average increase) and significant improvements in the weaning rate (5–12 percentage points). This scenario assumed ready availability of a cheap protein source (algal protein at $250/tonne on farm with a protein content of 40%). The challenges in attaining this technology breakthrough are discussed below.

8.3.5 Rumen modification to improve feed digestibility

Simulating a modest improvement in rumen function (rumen feed additives, rumen microbial modification) through reducing slightly the seasonal decline in dry matter digestibility and lifting the minimum digestibility by 3 percentage points (e.g. 42 to 45%) resulted in large gains in productivity and financial performance. The weaning rate increased by an average of 8 percentage points and liveweight gain by an average of 19 kg/head/year, which led to average increases in gross margin of $31/AE and an average increase in annual net profit of 50%. The modest increases in growth and weaning rate combined to provide this significant increase in financial return. Herd size increased modestly, which contributed to the positive financial outcome.

8.3.6 Combined technologies

The scenario of the combined technologies, genetic gains in reproduction and growth efficiency, genetics + oversown legume, and genetics + cheap protein, improved rumen function, and cheap protein supplementation, led to the greatest gains in productivity and profitability. For genetic improvements, weaning rates increased by 10 percentage units, liveweight gain by 11% and net profit increased by 70%. Combining these genetic gains with nutritional technologies such as oversown legume or protein supplementation combined with a rumen modifier led to much larger gains: weaning rate increased by 16 percentage units, weight gain lifted by 40% and profit was 150% higher. Regardless of the individual technology, this approach highlights the value in taking a systems approach and looking to lift productivity and profit through different parts of the production system, especially genetics and nutrition, rather than focusing on one or the other.

8.3.7 Methane

A general finding from the simulations that is consistent across all of the technologies and regional locations is that total production of methane per hectare increased slightly in scenarios with greater levels of animal productivity, kilograms of beef produced per hectare and profit (Table 15). This was particularly the case for the oversown legume treatment because it permitted significantly higher cattle numbers to be carried.

In contrast, the intensity of methane production (i.e. the amount of methane per kilogram of beef produced) decreased under scenarios of higher productivity and profit (Table 15). The simulated average reduction in methane intensity was less than 10% for genetic improvements and reduced mortality but was between 10 and 16% for the interventions that improved nutrition and consequently feed conversion efficiency. For the combined scenarios involving genetics and nutritional improvements, the improvement in methane emitted per unit of beef produced was around 30%, which is a very significant reduction.

Table 15 Effect of different technologies on amount and intensity of methane production

TECHNOLOGY	METHANE PRODUCTION (kg CO_2e/ha/day)	METHANE INTENSITY (kg CO_2e/kg beef)	CHANGE IN INTENSITY (%)
Baseline	0.12	17.3	0.0
Reduced mortality	0.12	16.5	–4.7
Improved reproduction	0.13	16.7	–3.5
Increased growth efficiency	0.12	15.9	–8.4
Oversown legume	0.14	15.2	–11.9
Leucaena	0.13	14.8	–14.7
Irrigated forage sorghum	0.12	14.5	–16.4
Cheap protein (algae, 40% protein)	0.12	15.3	–11.8
Rumen modification	0.12	17.3	0.0
Integrated genetics	0.12	13.8	–20.1
Genetics + legume	0.14	12.6	–27.3
Genetics + rumen modifier + protein	0.12	11.2	–35.1

8.4 Discussion

The simulation results for the two genetic gain scenarios (improved reproduction and growth efficiency) are generally consistent with published data based on experiments and data from commercial enterprises. For example, increasing weaning rate by 5 percentage points gave comparable results to that of Schatz (2011) who found that when average herd reproductive efficiency was increased by about 5%, the estimated gross margins increased by $6 to $8/AE. Larger economic gains have been demonstrated for cases in which more significant improvements in reproductive efficiency are achieved. For example, Burrow et al. (2003) found that by shifting breeds from pure or near pure Bos indicus to tropical composites (a mix of Bos indicus and Bos taurus breeds), weaning rates could be increased by 17 percentage points to yield a gain of approximately $17/AE.

The simulation trial results affirm that herd fertility is a significant profit driver of northern Australia beef enterprises (Burns et al., 2010). Accordingly, considerable effort has gone into improving the reproduction efficiency of the northern beef herd over the last several decades. This particular scenario has been focused on further improving average conception and weaning rates of breeding herds. Gains in overall reproductive efficiency can also be achieved through earlier puberty (Fordyce et al., 1994; Fortes et al., 2012); reducing pre-natal, peri-natal and post-natal mortality rates, which are currently high (and simulated accordingly in this modelling study) although the causes are not as yet well understood (Burns et al., 2010); and reducing losses from animal disease.

The genetic gains in growth efficiency simulated in this study are within the scope of what can be achieved over 20 years by selecting bulls with high estimated breeding values (EBVs) for 600-day weight (Burrow and Rudder, 1991). Growth rates are moderately heritable (Burrow, 2001; Burrow, 2012) indicating that there is good opportunity to achieve reasonable production gains through genetic improvement. However, heritability relating to weight is higher than that relating to weight gain, especially post-weaning (Davis, 1993). There is a risk that selecting for weight will simply result in an increase in the mature body size of animals rather than in growth efficiency, with commensurate increases in feed requirements. Notwithstanding these factors, the simulation results suggest that significant gains in productivity and profitability can be achieved in response to genetic gains in growth efficiency.

The simulated effects of increasing digestibility through improving rumen function were surprisingly large. A considerable research effort has been expended to develop novel technologies to improve the digestive efficiency of ruminants. This has included research on feed additives such as ionophores (e.g. monensin) to reduce methane production (Guan et al., 2006) and improve animal performance from grain diets (Goodrich et al., 1984), although the benefits of this approach for cattle consuming low-quality tropical pasture may be negligible (McLennan et al., 1995). Research has also been focused on altering the rumen ecology in order to improve digestion, although fundamental understanding of rumen processes still limits any significant practical breakthroughs (Klieve, 2009). While the simulation trial results clearly highlight the benefits that increasing energy efficiency may achieve, there are no immediate prospects of a practical breakthrough in technology. As a consequence, overcoming nutritional constraints in northern Australia has been focused on addressing protein and other mineral and trace element deficiencies because these have been the more tractable problems to address.

The addition of legumes to tropical pastures has been demonstrated to greatly improve animal productivity by overcoming seasonal protein deficiencies. The increase in annual liveweight gain of 25 to 30 kg/head simulated in the improved pasture scenario is consistent with results from grazing trials (Coates et al., 1997). Similarly, the use of leucaena-produced weight gains is broadly consistent with published literature (Bowen et al., 2015; Bowen et al., 2018), although gains on leucaena are highly variable depending on the area planted, the productivity of edible leucaena and the number of available grazing days per year. Given the large positive impact of this legume-augmentation scenario on productivity and net profit, the question is necessarily raised as to why legumes are not more widely used in areas for which suitable species are currently available. High costs and poor reliability of establishment have in the past been put forward by producers as significant constraints to wider adoption (Clements, 1996). Miller et al. (1993) showed that the financial payback period was 8 years if it took 5 years for the oversown legume pasture to reach full productivity, and the NPV was greatly reduced under that scenario compared with reaching full productivity within one year. Similarly, the payback period for leucaena production can be quite long (8–14 years) even with the most favourable finishing scenarios (Bowen and Chudleigh, 2017).

In considering a possible expansion in the use of oversown legumes or leucaena, attention must also be given to the potential environmental consequences. For example, stylo, which is presently the most successful pasture legume used in northern Australia, is not without potential negative consequences. These largely relate to legume dominance, which can result in soil acidification, reduced cover levels and increased erosion risk, and biodiversity impacts (Noble et al., 2000). Nevertheless, these risks can be managed in part through strategic use of fire, grazing management and targeted fertiliser use (Noble et al., 2000). In the analysis used in this study, only the establishment costs were considered and the costs of additional management or inputs to manage legume dominance would need to be considered. There are weed risks associated with the use of leucaena (Shelton and Dalzell, 2007) and recent efforts to minimise this risk have included developing a code of practice for use, and through breeding to reduce the levels of viable seed (Shelton and Dalzell, 2007).

There is renewed interest in developing northern Australia for more intensive forms of agriculture (Ash and Watson, 2018). Use of irrigated forages to improve productivity of extensive grazing enterprises is receiving considerable attention. The analysis undertaken in this study shows that significant increases in productivity can be achieved when irrigated forage is produced at scale. However, even though annual returns can be improved under irrigation, the longer-term return on investment is not always favourable. Achieving a positive outcome is dependent on location and production system, capital costs of development and prices received, with a significant degree of risk involved, which was a message conveyed in the analysis of MacLeod et al. (2018). There are currently large-scale pivot irrigation developments in the Kimberley and Pilbara regions producing forage for grazing or hay. The lesson learned from those developments is that it takes a number of years to scale up and achieve target production outcomes, which is a consistent message from agricultural development in northern Australia more broadly (Ash and Watson, 2018).

These results also highlight the importance of undertaking a full investment analysis to determine the likely returns on capital from different forage options. An NPV or a similar return on investment type analysis is usually undertaken by large companies while smaller investors, such as individual farmers or small to medium companies, may use other criteria for reaching decisions on the value of an investment. For example, returning a reasonable net profit, even where there is a negative NPV, may suffice for some investors who might rely on medium-term increases in the capital value of the land to justify their investment.

Another option for improving nutrition of cattle, especially during the dry season, is through protein supplementation. Lick blocks, mostly based on urea but with some including small amounts of protein, are widely used in the northern Australia cattle industry. Use of high-quality protein supplements such as cottonseed meal or copra meal are not routinely used because they are uneconomical, even though the productivity benefits have been proven.

Potential sources of a novel high-protein supplement available at low cost could include algal biodiesel residue (Bryant et al., 2012) or on-farm algal protein production (Holman and Malau-Aduli, 2013). The simulated liveweight gains found in this study, assuming a cheap algal protein source is available, are broadly consistent with experimental data for similar quality protein meals such as cottonseed meal (e.g. Addison et al., 1984), although the gains achieved are somewhat lower than might be predicted by empirical relationships between the amount of protein supplied and the liveweight gain response (McLennan et al., 1995). The lesser response in the simulated liveweight gains (c. 200 g/day) compared with the expected response from the empirical data sources (c. 300 g/day) is, in part, likely due to years in the simulation where green pasture was available through the dry season as a result of autumn or winter rainfall.

Combining a range of different production technologies and practices rather than focusing effort in one or two particular areas resulted in large increases in productivity and profitability, suggesting these technologies act in a synergistic way. The magnitude of the projected liveweight gain advantages would suggest that for some of the regions in the study, the herd structure and business operation could profitably be changed to finishing turn-off cattle to a heavier weight for slaughter rather than producing lighter animals that are traded in order to be finished in environments with better quality pastures. Given the size of the productivity gains projected for this scenario, the number of breeding animals had to be actively reduced to prevent the total herd size from increasing to levels that negatively affected land condition. However, only a relatively small proportion of the gain in profitability could be attributed to the increase in the average herd size – most of it resulted from gains in individual animal productivity.

Introducing new technologies that increase the productivity of extensive beef enterprises can pose a risk to sustainable grazing land management because the productivity gains are often associated with higher animal numbers and degradation of the resource base (Gardener et al., 1990). Each of the technologies that were assessed in this study tended to result in the herd size increasing through the duration of the simulation trials. This was in part because the individual animals generally became more productive and their higher average weight contributed to a larger herd size, as measured by AE. However, the total size of the herds also increased in response to technologies that increased weaning rates and/or decreased mortality rates. While the pasture improvement scenario of legume oversowing also resulted in increasing animal productivity and total numbers carried, it does this through an increased total level of pasture productivity (biomass and quality), which also increases the effective carrying capacity of the enterprise. To avoid overstocking and utilisation of pasture increasing beyond sustainable levels, herd numbers in this study were not allowed to increase significantly and if necessary, breeding cow numbers were reduced to ensure this outcome. By adopting this particular herd management strategy in the simulations, land condition could be maintained while at the same time permitting improved financial outcomes.

Given the extensive nature of beef production and the low-quality pastures in northern Australia, methane output per unit of product was high, as was methane output per unit of dry matter intake (Charmley et al., 2008). Increasing the intensity of production in beef systems generally increased total methane emissions (White et al., 2010), while lowering methane per kilogram of beef produced. However, management decisions can be made along the intensification spectrum as to how much to increase productivity and profitability versus reducing the environmental footprint.

8.4.1 Other analyses

Chudleigh et al. (2018) undertook a detailed enterprise analysis of a range of herd and pasture improvement options in central Queensland, the northern Gulf and Katherine regions. Unlike NABSA, Chudleigh et al. used a static herd model that does not capture climate variation and its flow-on impacts on forage supply, forage quality and herd dynamics and the feedbacks of grazing on the pasture resource. However, by adopting a simple pasture and herd dynamics model, the Breedcow and Dynama modelling approach used by Chudleigh et al. (2018) allows much more specific enterprise interventions to be examined and to more effectively examine ramp-up phases in investment and outcomes. The financial analysis is also more comprehensive than in NABSA.

For the northern Gulf and Katherine regions the findings of Chudleigh et al. were broadly consistent with the results from NABSA. Improvements in breeder fertility did not provide the same level of benefit as investments in perennial legumes such as stylo. However, the gains through genetics in the Chudleigh et al. study were generally less than those reported in the NABSA results above, even though the gains in branding rates were similar between the two studies. The cattle prices used by Chudleigh et al. (2018) were generally lower than in the NABSA results (e.g. in Katherine $2.00/kg versus $2.50/kg liveweight), which can explain some but not all of the differences in gain from genetics compared with a baseline scenario. The benefits from using stylo were also less in the Chudleigh et al. study due to targeting only the steer population (versus steers and breeders in NABSA) and the higher costs of sowing that were used.

Similar to the NABSA results, Chudleigh et al. (2018) found reducing mortalities had a significant benefit for a modest cost outlay ($5/head ongoing or an upfront capital cost of $50,000).

8.4.2 Future R&D implications at the property scale

The results from this simulation modelling and analytical study suggest that ongoing research investment in component technologies will continue to deliver benefits in productivity and profitability. The risk–return spectrum of where research investments are made in individual technologies offers some interesting trade-offs. Continued investment in genetic technologies will likely offer fairly certain but incremental gains in productivity and profit. This analysis suggests that larger productivity gains can be achieved by improving the feed base. However, the technological and/or cost barriers are higher. For example, oversowing a legume can offer significant returns but the long-known technology challenge in achieving reliable establishment still remains a significant barrier to wider adoption. Also, identifying existing species that are suited to a wider range of environments is still needed. Using special-purpose forages such as leucaena or irrigated forage crops is capital intensive and returns on capital can take many years. Further, there are more regulatory (e.g. land tenure) and environmental issues associated with developing native pasture and this can add significant time and costs to development (See Section 10). Increased effort could focus on how to lower these barriers to investment without compromising environmental or social outcomes.

Even in the absence of new technologies, it can be argued that significant gains in industry profitability could be achieved through adoption of better herd management practices, better financial management, and more sustainable grazing management practices. Holmes (2015) identified this as a critical issue for the northern Australia beef industry. Despite significant effort over decades in extension, there are still many underperforming enterprises. The entry of private companies and individual consultants with a focus on lifting business and environmental performance has had some positive impact. However, innovative approaches are needed to stimulate the rate of change in what remains a conservative industry. In contrast, other agricultural sectors (e.g. cotton industry, broadacre cropping in southern Australia) would appear to have been more prepared to embrace innovation (use of genetic modification, integrated pest management, precision agriculture).

Given the results suggest a significant increase in productivity and profitability can be achieved by taking a systems approach to integrating individual technologies, there is a need to invest in whole-of-enterprise technology innovation that can exploit synergies from deploying a range of technologies. Current research efforts continue to overwhelmingly focus on specific issues or component technologies. This is evident from an analysis of on-farm projects funded by MLA. Table 16 shows a listing of projects relevant to northern Australia funded by MLA since the early 2000s. It also classifies projects into whether they were undertaken in and/or directly relevant to the area of interest to the CRCNA, versus more generic projects that are still relevant to northern Australia but not specific to the north, and a listing of more recent digital agriculture projects. A full listing of projects is provided in Appendix B . There are few projects exploring how technologies can be integrated at a whole-of-enterprise scale. Projects that would fit into this classification would have been allocated to property management but there were only eight projects in this area, and all but one relates to digital aspects of property management.

Managers must operate at the enterprise scale and make decisions where animal health, reproduction, nutrition, herd management, pastures, and resource management all interact. This area of whole-enterprise technology management appears to be neglected at the expense of the component areas of research.

Table 16 Number of on-farm MLA projects funded since the early 2000s with relevance to northern Australia
Project areas are classified according to whether they were: (i) undertaken in tropical Australia and/or focused directly on issues in the tropics, (ii) projects that are more generic in nature but with relevance to tropical Australia, and (iii) also generic projects relevant to tropical Australia but with a digital technology focus. The database of projects was provided by MLA. All short-term projects (reviews, specific consultancies, coordinator roles, priority setting activities, scholarships, workshops, travel grants, etc.) were excluded from the analysis. GHG = greenhouse gas.

AREA OF RESEARCH	TROPICAL	GENERIC	DIGITAL	TOTAL
Animal health	2	2	0	4
Beef genomics	3	5	0	8
Capacity building	4	5	1	10
Climate change and variability	0	8	0	8
Economics	3	1	0	4
Environment	0	3	0	3
Feral management	1	2	0	3
Grazing management	5	2	0	7
Herd management	10	4	10	24
Mitigation of GHG emissions	3	24	0	27
Nutrition	19	19	0	38
Occupational health & safety	0	2	0	2
Pastures/fodder	8	13	2	23
Plant breeding	3	2	0	5
Plant toxins	1	0	0	1
Property management	0	1	7	8
Reproduction	13	8	1	22
Rumen function	1	5	0	6
Weed management	8	1	1	10
TOTAL	**84**	**107**	**22**	**213**

GHG = greenhouse gas.

9 Performance of the northern Australia beef industry and opportunities for improvement

Ian McLean (Bush AgriBusiness Pty Ltd) and Phil Holmes (Holmes & Co) were engaged by CSIRO to undertake this section in the form of a short analytical report. This section draws on the data and findings from the *Australian beef report* (Holmes et al., 2017), an independent publication prepared by the authors, as well as knowledge and experience of the authors from their work in northern Australia.

9.1 Introduction

Previous situation analyses of the northern Australia beef industry have found that the 'the northern beef industry is generally in a very unprofitable and unsustainable state' (McCosker et al., 2010) and that 'the majority of Northern Beef producers are not economically sustainable' (McLean et al., 2014). These reports also identified a large variation in industry performance. This was evaluated further in the *Australian beef report* (Holmes et al., 2017), which found no improvement in the financial performance of the industry, but identified and detailed the barriers to profit for beef producers, which are:

- operating scale
- operating efficiency.

Presented here is a more detailed analysis of the performance of beef producers in the regions of interest to this review, detailing the tropical region of northern Australia, evaluating the difference between the top performers and the rest of the industry and identifying issues to improve long-term performance.

9.2 Industry performance

9.2.1 Geographic Scope

The regional segmentation of the *Australian beef report* data is by Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) regions, as shown in Figure 8 below.

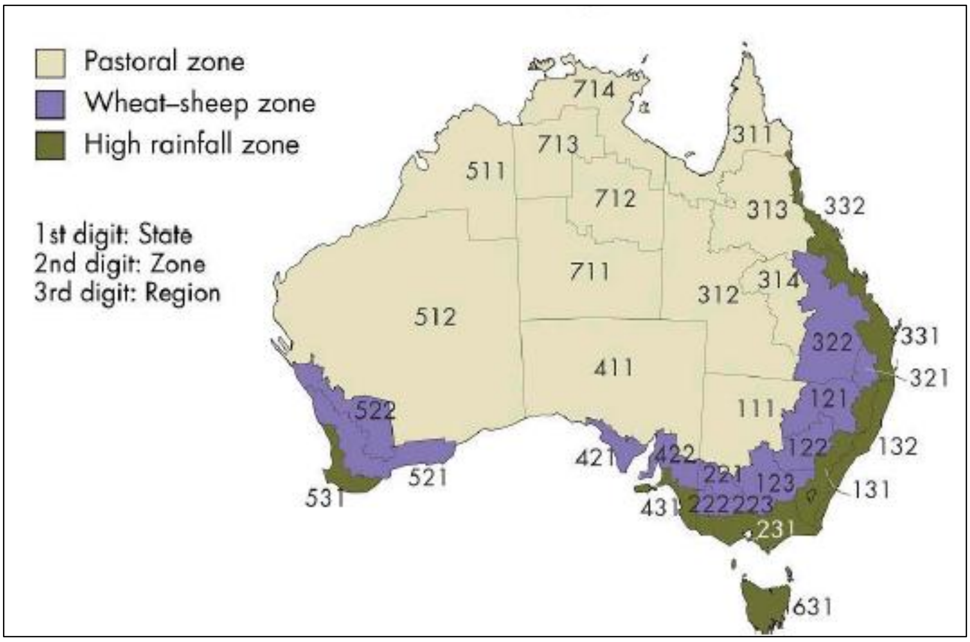

Figure 8 Australian broadacre zones and regions
The regions in this analysis are: 511 WA The Kimberley, 713 NT Victoria River District and Katherine, 311 Queensland Cape York and Gulf, 313 Queensland Central North. Regions 712 and 714 are not included as there are insufficient data within those regions to separate the top 25% performers. ABARES numbering code: first digit represents state; second digit represents zone (1, pastoral zone; 2, wheat–sheep zone; 3, high-rainfall zone); third digit represents region within state and zone.

9.2.2 Analysis methodology and interpretation

Management accounting principles were applied in order to conduct the analysis. This involved applying market values to land and livestock and placing a reasonable market value on unpaid family labour.

Table 17 and Table 18 are the whole business income statement and herd income statement. The whole business income statement calculates the total profit (or loss) of the cohort on average for the period. The herd income statement expresses the performance of the cohort on an adult equivalent (AE) basis. This standardises the performance and allows different herd sizes and areas to be analysed on a like-for-like basis.

Table 17 and Table 18 below summarise the long-term financial performance across the four regions above. The data are the average of the 12 financial years from 2004 to 2016 and is expressed in 2016 dollars. The population is non-corporate owned beef businesses with more than 200 head of cattle, where those businesses derive the majority of their income from beef production.

The data are segmented into average (average of all), top 25% (average of the top 25% of population segmented by return on assets) and bottom 75%. Segmenting the bottom 75% and top 25% of the population allows them to be analysed as two distinct groups, which comparison of average and top 25% does not.

That the bottom 75% report an average loss does not mean that all producers within the bottom 75% cohort are operating at a loss, rather the average of all producers in the cohort is a loss. Those producers, within the bottom 75% cohort that are operating at a profit, are outnumbered by those operating at a loss, hence the cohort average is negative. That the average operating profit (as earnings before interest and tax (EBIT)) of each of the four regions is positive indicates that the majority of producers are operating at a profit, if it assumed that the population is normally distributed.

Readers should note that these data are statistics and not parameters; that is, they are derived from samples of the population, rather than a census of the entire population. While the primary data source is the best available at whole-of-industry level, Australian Agricultural and Grazing Industries Survey data (ABARES, 2017) are not perfect. The average data are arguably the most reliable as they have the most weight.

Table 17 Performance data for the four regions – whole business income statement

ANNUAL AVERAGE (2004–2016)	WA KIMBERLEY			NT VICTORIA RIVER DOWNS & KATHERINE			QUEENSLAND CAPE YORK & GULF			QUEENSLAND CENTRAL NORTH		
	Bot. 75%	**Average**	**Top 25%**	**Bot. 75%**	**Average**	**Top 25%**	**Bot. 75%**	**Average**	**Top 25%**	**Bot. 75%**	**Average**	**Top 25%**
	$000	**$000**	**$000**	**$000**	**$000**	**$000**	**$000**	**$000**	**$000**	**$000**	**$000**	**$000**
INCOME												
Sales – beef	1,070.0	1,446.1	1,761.6	427.4	1,563.8	3,766.0	502.2	672.1	1,058.9	467.0	653.9	1,169.3
Purchases – beef	(12.6)	(122.0)	(213.8)	(110.9)	(324.0)	(737.0)	(27.1)	(54.5)	(116.8)	(47.3)	(74.9)	(151.1)
Inventory change – beef	(381.9)	(149.5)	45.2	(4.6)	137.7	413.5	(110.7)	121.9	651.2	(75.2)	(47.9)	27.5
GROSS PROFIT – BEEF	675.5	1,174.5	1,593.0	311.9	1,377.5	3,442.5	364.4	739.5	1,593.3	344.5	531.2	1,045.7
Other enterprises gross profit	0.2	4.8	8.7	5.2	3.8	1.1	12.0	8.4	(0.0)	2.4	4.6	10.9
Other income	31.2	41.8	50.7	45.7	75.9	134.3	18.2	25.7	42.8	35.9	46.0	73.7
GROSS PROFIT	706.9	1,221.2	1,652.4	362.8	1,457.2	3,577.9	394.6	773.5	1,636.0	382.8	581.8	1,130.3
ENTERPRISE EXPENSES	280.8	334.5	379.6	162.9	312.3	601.8	171.8	216.7	318.9	128.6	159.9	246.4
Beef	280.7	333.9	378.6	160.9	310.1	599.3	169.1	214.8	318.7	124.6	155.4	240.3
Other enterprises	0.1	0.6	1.1	2.0	2.2	2.6	2.6	1.9	0.2	4.0	4.6	6.1
GROSS MARGIN	426.1	886.6	1,272.8	199.9	1,144.9	2,976.1	222.9	556.9	1,317.1	254.3	421.9	883.9
OVERHEAD EXPENSES												
Administration	25.2	34.2	41.7	19.6	30.7	52.3	13.1	13.5	14.5	20.0	23.8	34.0
Depreciation	87.2	104.6	119.2	48.5	92.2	177.0	69.6	77.7	96.3	41.7	48.8	68.3
Electricity & gas	0.2	0.9	1.5	0.4	1.4	3.4	3.6	4.1	5.2	5.1	6.3	9.6
Fuel & lubricants	63.4	96.8	124.8	56.4	98.0	178.7	36.6	50.6	82.7	25.5	30.9	45.8
Insurance	15.1	21.4	26.7	10.1	23.8	50.2	7.3	7.6	8.3	9.0	10.9	16.2
Materials	4.3	6.4	8.2	6.0	11.1	21.1	4.9	5.3	6.1	4.0	4.3	5.2
Motor vehicle expenses	7.5	21.3	32.9	8.2	11.8	18.8	9.1	9.0	8.5	7.0	7.5	8.9
Rates & rents	31.0	47.0	60.3	10.1	32.2	74.9	24.3	32.1	49.8	17.4	22.0	34.6
R & M general	75.5	110.8	140.4	68.2	107.5	183.7	42.9	58.8	95.0	41.6	48.7	68.3
Wages (inc. stores & rations)	96.8	158.9	210.9	52.1	164.6	382.6	35.1	73.2	159.9	27.3	37.7	66.6

ANNUAL AVERAGE (2004–2016)	WA KIMBERLEY			NT VICTORIA RIVER DOWNS & KATHERINE			QUEENSLAND CAPE YORK & GULF			QUEENSLAND CENTRAL NORTH		
Wages (owner)	106.3	100.5	95.7	109.7	119.1	137.3	118.2	112.2	98.7	119.0	122.0	130.1
TOTAL OVERHEAD EXPENSES	512.8	702.9	862.3	389.4	692.5	1,279.9	364.7	444.1	624.9	317.6	362.9	487.7
TOTAL OPERATING EXPENSES	793.6	1,037.4	1,241.9	552.3	1,004.8	1,881.7	536.5	660.8	943.9	446.2	522.8	734.1
EARNINGS BEFORE INTEREST & TAX	(86.7)	183.7	410.4	(189.5)	452.4	1,696.2	(141.8)	112.7	692.1	(63.3)	59.0	396.2
Interest	24.1	44.5	61.7	82.2	166.6	330.3	52.8	51.3	48.0	58.9	93.1	187.4
EARNINGS BEFORE TAX	(110.8)	139.2	348.8	(271.7)	285.8	1,365.9	(194.6)	61.4	644.2	(122.2)	(34.1)	208.8
OPERATING RETURN	(0.9%)	1.5%	2.7%	(2.2%)	2.4%	4.4%	(1.4%)	0.9%	4.0%	(0.9%)	0.6%	2.8%

Table 18 Herd income statement for the four regions

ANNUAL AVERAGE (2004–2016)	WA KIMBERLEY			NT VICTORIA RIVER DOWNS & KATHERINE			QUEENSLAND CAPE YORK & GULF			QUEENSLAND CENTRAL NORTH		
	Bot. 75%	**Average**	**Top 25%**	**Bot. 75%**	**Average**	**Top 25%**	**Bot. 75%**	**Average**	**Top 25%**	**Bot. 75%**	**Average**	**Top 25%**
	$/AE	**$/AE**	**$/AE**	**$/AE**	**$/AE**	**$/AE**	**$/AE**	**$/AE**	**$/AE**	**$/AE**	**$/AE**	**$/AE**
Sales	187.08	166.57	157.76	151.65	164.50	167.62	117.49	103.19	91.21	170.11	176.48	184.07
Purchases	(2.20)	(14.06)	(19.15)	(39.35)	(34.08)	(32.80)	(6.35)	(8.37)	(10.06)	(17.22)	(20.22)	(23.79)
Inventory change	(66.77)	(17.23)	4.05	(1.63)	14.49	18.41	(25.89)	18.71	56.09	(27.39)	(12.92)	4.33
GROSS PROFIT (INCOME)	**118.11**	**135.29**	**142.66**	**110.67**	**144.90**	**153.23**	**85.25**	**113.53**	**137.24**	**125.50**	**143.35**	**164.61**
ENTERPRISE EXPENSES												
Animal health	0.78	0.56	0.47	0.40	0.54	0.58	0.05	0.45	0.78	0.73	0.63	0.51
Contracting & mustering	12.08	9.25	8.03	9.52	6.11	5.28	7.32	6.17	5.21	4.44	4.45	4.46
Fodder & supplements	12.88	10.00	8.77	24.06	12.24	9.37	13.92	10.32	7.29	22.83	20.10	16.86
Freight	12.98	9.09	7.42	6.83	6.57	6.51	11.44	10.29	9.33	8.94	8.72	8.46
Insurance & materials	5.23	5.69	5.88	8.68	3.98	2.84	3.61	3.45	3.31	3.80	3.64	3.46
Selling costs	5.12	3.87	3.34	7.60	3.17	2.10	3.22	2.30	1.53	4.64	4.38	4.07
TOTAL	49.08	38.46	33.90	57.09	32.62	26.67	39.56	32.97	27.45	45.37	41.93	37.82
GROSS MARGIN	**69.03**	**96.82**	**108.76**	**53.58**	**112.28**	**126.55**	**45.68**	**80.56**	**109.79**	**80.13**	**101.42**	**126.78**

ANNUAL AVERAGE (2004–2016)	WA KIMBERLEY			NT VICTORIA RIVER DOWNS & KATHERINE			QUEENSLAND CAPE YORK & GULF			QUEENSLAND CENTRAL NORTH		
OVERHEAD EXPENSES												
Administration	4.23	3.78	3.59	6.37	3.05	2.24	2.90	1.98	1.22	6.61	5.85	4.95
Depreciation	14.56	11.58	10.30	15.68	9.15	7.56	15.38	11.41	8.08	13.77	12.02	9.94
Electricity & gas	0.04	0.10	0.13	0.12	0.14	0.15	0.79	0.60	0.44	1.70	1.56	1.40
Fuel & lubricants	10.59	10.67	10.70	18.26	9.70	7.62	8.02	7.43	6.94	8.41	7.61	6.67
Insurance	2.54	2.37	2.30	3.24	2.36	2.15	1.62	1.12	0.70	2.95	2.68	2.36
Materials	0.70	0.71	0.71	1.95	1.10	0.90	1.09	0.78	0.52	1.32	1.06	0.75
Motor vehicle expenses	1.23	2.34	2.82	2.67	1.17	0.80	2.04	1.32	0.71	2.32	1.85	1.29
Rates & rents	5.13	5.17	5.18	3.18	3.19	3.20	5.35	4.72	4.19	5.73	5.42	5.05
R & M general	12.54	12.21	12.06	22.16	10.64	7.84	9.39	8.62	7.98	13.71	11.99	9.94
Wages (inc. stores & rations)	16.30	17.64	18.22	16.15	16.32	16.36	7.50	10.73	13.44	8.94	9.29	9.71
Wages (owner)	17.70	11.10	8.26	36.45	11.83	5.85	26.21	16.47	8.30	39.35	30.02	18.91
TOTAL	85.56	77.67	74.28	126.23	68.64	54.65	80.30	65.18	52.50	104.81	89.37	70.98
TOTAL OPERATING EXPENSES	134.64	116.13	108.18	183.32	101.27	81.32	119.86	98.15	79.95	150.18	131.30	108.80
EARNINGS BEFORE INTEREST & TAX	**(16.53)**	**19.16**	**34.49**	**(72.66)**	**43.64**	**71.91**	**(34.61)**	**15.38**	**57.28**	**(24.68)**	**12.05**	**55.81**
HERD KPIs												
Income ($/kg LW)	$2.18	$1.90	$1.82	$1.92	$2.11	$2.14	$1.86	$1.84	$1.83	$1.78	$1.84	$1.89
Cost of production ($/kg LW)	$2.48	$1.63	$1.38	$3.18	$1.47	$1.14	$2.61	$1.59	$1.07	$2.13	$1.68	$1.25
Operating margin ($/kg LW)	($0.30)	$0.27	$0.44	($1.26)	$0.63	$1.00	($0.75)	$0.25	$0.77	($0.35)	$0.15	$0.64
Kg beef/AE	54.2	71.0	78.3	57.6	68.8	71.6	45.9	61.6	74.9	70.4	78.0	87.1
Labour efficiency (AE/FTE)	1,584	1,863	2,016	1,069	1,744	2,061	1,581	1,904	2,296	1,127	1,351	1,770
Enterprise size (annual avg. AE)	5,719	8,682	11,166	2,818	9,507	22,467	4,275	6,513	11,610	2,745	3,705	6,352

9.3 Discussion of industry issues

9.3.1 Top 25% versus the rest

It can be seen in Table 18 that the factors determining the difference between the bottom 75% and the top 25% are stark. They are:

- Better herd productivity –The top performers have much higher herd productivity per animal unit (expressed as kg of beef produced/AE/year or kg beef/AE). The drivers of herd productivity are not shown in this segmentation, but they are reproductive rate, mortality weight and sale weight. It is known from past analyses that these drivers explain over three-quarters of the difference in productivity between herds (McLean et al., 2014; Holmes et al., 2017; McLean et al., 2018). Put simply, the top performers are much more effective than the rest at converting grass into beef.
- Targeted herd expenditure – The top performers spend less on their herd in enterprise or direct expenditure than the rest. When considered in conjunction with their superior productivity, this indicates that their expenditure is more targeted and therefore more effective, rather than that they simply spend less. The areas of higher enterprise (herd) expenditure differ across the regions; however, fodder and supplements are higher for the bottom 75% across all regions analysed.
- Efficient use of labour – The labour efficiency of a business has a major influence on its overhead cost structure. Top performers are typically more efficient in their use of labour than the rest, as is the case in the regions analysed. The labour efficiency measure for the top 25% is close to or more than 2000 AE managed per full time equivalent (FTE) across the four regions, whereas the bottom 75% is around 1500 AE/FTE or less. This difference is reflected in not only the wages cost per AE (Table 18), but also in other labour-related overheads, such as depreciation, fuel, motor vehicle expenses, and repairs and maintenance.
- More operating scale – Operating scale impacts a business in a number of ways, as discussed further below, but a major effect of scale is its influence on overhead costs per AE. The top performers have considerably more scale than the rest.

The above factors combine to reduce income (gross profit) and increase operating expenses per animal equivalent for the bottom 75%. Herd income (on an AE basis) is driven primarily by herd productivity. Price received is not a significant driver in long-term data. The poorer herd productivity of the bottom 75% mean they generate less income per AE than the top performers. The higher herd expenditure, poorer labour efficiency and lower operating scale all compound to increase the operating expenses per animal unit for the bottom 75%. Therefore, each animal unit run earns less and costs more for the bottom 75%, when compared to the top performers, resulting in lower (negative) profits per animal equivalent. These differences in operating costs and productivity also combine to cause a significant difference in cost of production between the bottom 75% and the top 25%, with it costing the top performers around half of what it costs the bottom 75% to produce a kilogram of beef.

It should be noted that neither the bottom 75% or the top 25% are homogenous groups. In reality there is a wide range in performance against all of the above measures across each region and the industry as a whole. Each top 25% producer would not necessarily achieve top 25% against each of the above measures if looked at in isolation. However, the importance of these factors means that the differences between the top and bottom performers is considerable.

Table 19 highlights the differences between the top 25% and the bottom 75% figures with the performance of the top 25% expressed relative to the bottom 75% for each measure.

Table 19 Top 25% performance relative to bottom 75% on key measures

MEASURE	WA KIMBERLEY	NT VICTORIA RIVER DOWNS & KATHERINE	QUEENSLAND CAPE YORK & GULF	QUEENSLAND CENTRAL NORTH
Herd productivity (kg beef/AE)	144%	124%	163%	124%
Enterprise expenditure ($/AE)	69%	47%	69%	83%
Labour efficiency (AE/FTE)	127%	193%	145%	157%
Operating scale (AE)	195%	797%	272%	231%
Income (gross profit) per AE ($/AE)	121%	138%	161%	131%
Operating expenses per AE ($/AE)	80%	44%	67%	72%
Cost of production ($/kg LW)	56%	36%	41%	59%

The quantitative characteristics of top performers are clear and consistent across datasets; they have better operating efficiency (a combination of better herd productivity, targeted enterprise expenditure and good labour efficiency) and sufficient operating scale (Holmes et al., 2017; McLean et al., 2018; McLean et al., 2014). The qualitative characteristics are also important, but not as easily expressed and are discussed in Section 9.3.7 below.

That the average profit (EBIT) of the bottom 75% for all four regions is negative (Table 17), means that effectively all of the industry profits are coming from the top 25% producers. The top 25%, due to their larger scale and better performance, generally produce the majority of beef and manage the majority of animals. This is shown graphically in Figure 9, Figure 10 and Figure 11 below, which shows that across the four regions analysed, the top 25% producers produce 59% of the beef from 54% of the herd across 48% of the landscape. This is a practical demonstration of the Pareto principle. This is a practical demonstration of the Pareto principle, commonly known as the 80:20 rule, which states that 80% of the consequences or effects come from 20% of the causes.

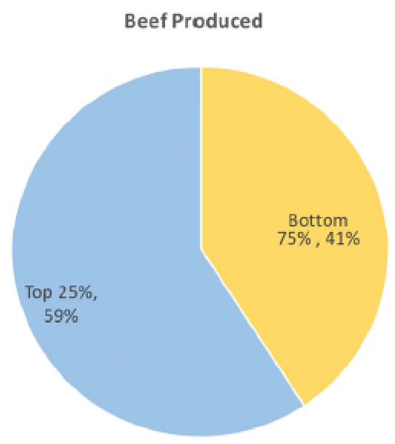

Figure 9 Beef produced by performance for northern regions that were analysed

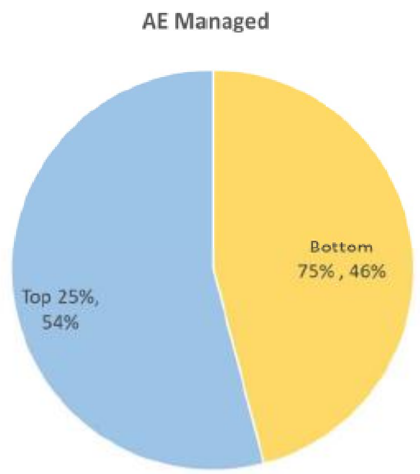

Figure 10 AE managed by performance for northern regions that were analysed

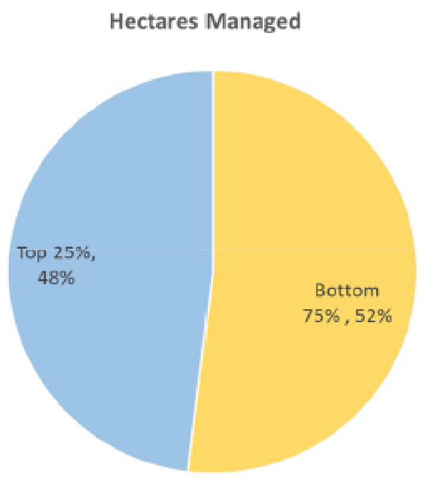

Figure 11 Land area managed by performance for northern regions that were analysed

While some of the findings with regard to the performance of the bottom 75% cohort as a whole may be confronting, a positive is that it can be concluded from this analysis that the majority of the herd, and land, is managed by producers who are generating profits from doing so.

9.3.2 Profitability Requirements

This discussion on profitability should begin with some context on what profitability is, and what level of profitability is required. First, it should be made clear that profitability here refers to the ratio of profit to capital employed (i.e. return on assets). Profitability for beef businesses comes in two forms, operating return (returns from running the business, calculated by dividing the operating profits into the total assets of the business) and capital return (increase in land value over time). Historically, capital returns have been the main contributor to total returns over time in the beef industry. The focus of this analysis is on the operating return because this is a function of management and represents the generation of earnings that can be put towards the long-term funding needs of a healthy business (provisioning for succession and retirement, debt reduction, capital expenditure, expansion, etc.), whereas capital appreciation can only be realised on sale of the asset.

Ultimately, it is up to individual owners to determine what is a satisfactory return on their capital. The approach taken here is to look beyond a number target initially and look at what the business needs to fund in the long term, and then work back to a profit and profitability target. In the *Australian beef report* (Holmes et al., 2017), the basic financial requirements of a beef business were listed, which are a list of criteria for businesses to be economically sustainable. The application of these requirements will be unique to each business, and clients are encouraged to apply them to determine what profits, and profitability, are required to achieve their long-term aims. From experience, an operating return of at least 4% is required for businesses to meet these criteria.

9.3.3 Productivity versus Profitability

Excellent herd productivity will not necessarily result in excellent profitability because all of the above characteristics (herd productivity, targeted herd expenditure, efficient use of labour and sufficient operating scale) are required. If a business does not perform well across all of these, then excellent productivity alone will not be sufficient to achieve reasonable profitability.

However, an increase in productivity will, all things being equal, increase the profitability of individual producers. Any increase in productivity will need to be cost-effective, that is the returns from the additional productivity will need to exceed the costs of achieving the additional productivity.

Detailed analysis across multiple datasets (Holmes et al., 2017; McLean et al., 2018; McLean et al., 2014) has shown that reproductive rate, mortality rate and sale weight are the key drivers of productivity and that these three measures explain nearly all of the variation in productivity between herds.

From these analyses the following response in productivity (expressed as kg of beef produced/AE/year) can be expected as a result of incremental changes in the productivity drivers:

- 0.7–1.5 kg beef/AE for a 1% increase in reproductive rate
- 2–4 kg beef/AE for a 1% decrease in mortality rate
- 1.5–2.2 kg beef/AE for a 10 kg increase in sale weight.

Which of the measures should be targeted, and how they are best addressed will be unique to each business. These measures can be addressed in most cases without significant capital investment or increases in operating expenses.

Analysis of these data has shown that income is more of a determinant of profit than costs, and that increasing income is usually the most effective way to increase profits. Income is a function of productivity and price received is not a driver than can be effectively addressed to increase income. Price received is largely a function of the general market and, being a commodity, there is little that producers can effectively do to differentiate their product within the market.

Costs are important in profit, insofar as a competitive cost base is required to be profitable, however superior income is more of a factor in superior performance than low costs. Low costs alone will not deliver superior performance.

Kilograms of beef per AE is a measure of efficiency of production; it is effectively a measure of the efficiency of conversion of grass into beef. The focus with regard to productivity should be on the conversion of grass into beef, or per animal performance, and not the number of animals. An extensive analysis of large northern Australia herds (McLean et al., 2018) has demonstrated that per animal performance is more important that the number of animals in determining return on assets.

Across the industry, increasing per animal productivity (kg beef/AE) should be the priority for most producers and, if done in a cost-effective manner, will improve the performance of most producers. However, as stated above, if the businesses have an uncompetitive cost base or insufficient operating scale, increasing productivity in isolation is unlikely to result in satisfactory profitability for underperforming businesses.

9.3.4 Operating Scale

As discussed in the *Australian beef report* (Holmes et al., 2017), there are two considerations with regard to operating scale, one relative and one absolute. The relative consideration relates to economies of scale in that there must be sufficient scale (number of AE) for overhead costs to be competitive. For family operations, this scale is around 3000 to 5000 AE. Sufficient scale, coupled with good labour efficiency, will provide a business with a competitive overhead cost base.

The benefits of additional scale are not ongoing, in that once sufficient scale is achieved costs will increase proportionally with herd size. The analysis has shown that overhead costs per AE do not fall below $50/AE, regardless of scale. If a business has sufficient scale, there is likely to be more benefit from focusing on per animal performance at that scale than there is from increasing scale further.

The absolute consideration with regard to scale relates to the needs of the owners, in that there are sufficient numbers to provide for their needs, which is also a function of the profit per animal.

While the perception may be that northern Australia operations are all large operations with sufficient scale, Section 9.2.2 above shows that the bottom 75% cohorts for the Katherine–Victoria River Downs region and the Central North Queensland region average less than the 3000 AE scale threshold mentioned above. This means that a large number of producers in these regions, and a small number in the other regions, are faced with a significant scale constraint.

Lack of scale is not an insurmountable obstacle, but it is important that business owners be aware of whether scale is a constraint for them, and if it is, have strategies to address it. Two suggested strategies are listed below:

- Treating the operation as a part-time pursuit – This is effectively employed by a number of producers who offer contracting services or have off-farm jobs. The benefit of this strategy is twofold: first, it increases household income, and second, it reduces the overhead costs of the business through improved labour efficiency, as when people are not on the farm they are not incurring costs by driving vehicles, using equipment, etc.
- Have outstanding operating efficiency – Operating efficiency is essentially herd productivity, targeted herd expenditure and efficient use of labour detailed above. It also relates to land productivity, which is discussed further below. Excellent operating efficiency will allow businesses to partly overcome the operating scale constraint (see analysis by herd size in the *Australian beef report*).

9.3.5 Diversification

Another strategy that is often suggested to address lack of scale, or to generally reduce risk in an agricultural enterprise, is diversification. It is suggested that this be approached with caution as specialist producers usually outperform diversified operations in the long term.

The main challenges to diversification are required management expertise, required scale, risk, and the economics of the enterprise in question.

- Required management expertise – Outstanding performance in any enterprise or venture requires specialist skills. If an enterprise is considering diversifying, then a consideration should be whether they have, or can obtain (themselves or by bringing in outside expertise), the specialist skills required for the enterprise. They also need to be able to ensure their existing enterprise is given the attention and specialist skills it needs.

- Scale – If an underscale business diversifies as a strategy to address that scale then a consideration needs to be whether it can achieve sufficient scale in the new enterprise. What sufficient scale is will be dependent on the enterprise, but if it cannot reach sufficient scale it may end up with two underscale enterprises instead of one, which is unlikely to improve the overall result.
- Risk – Rather than reduce the overall risk of the operation, the introduction of a new enterprise will likely change the risk profile as it will introduce risks of its own, while potentially reducing some of the existing risks.
- Economics – The new enterprise needs to stack up economically, contributing to business profit each year as well as recouping the upfront investment costs. There are known examples of agricultural developments in northern Australia that, due to high freight costs for inputs and outputs, high pumping costs, significant upfront capital and limited regional services (e.g. harvesters, spraying contractors), are white elephants.

This should not be interpreted as saying that diversification will not work for some businesses and should not be considered; it will and it should. However, if it is not approached with a clear understanding of the key success factors for the enterprise(s) in question, as well as consideration for what effect it will have on the existing business, then it is unlikely to be a successful strategy.

9.3.6 Land Condition

Individual AE performance in northern Australia is largely a function of nutrition, other management issues aside. It is possible to achieve average performance from a northern beef herd with 'below-average' management and genetics if enough dry matter is available to mask the deficiencies. The problem is that producers need all elements to be additive, rather than compensatory, if a top 25% result is the goal. Therefore, land condition is critical; it has to be managed at least as well as the herd for optimal performance. Land condition is all about the dry matter production response to any individual rainfall event per unit area.

The benefits of good land condition are not just from increased productivity per animal or being able to run more animals. Good land condition in combination with good management will result in more stable herd numbers through seasonal variations, which is linked to superior performance. A recent study of large northern stations (McLean et al., 2018) identified that better performing breeding operations had lower sales (per AE) than the average. This does seem counter-intuitive, but they had higher net herd income (sales adjusted for purchases and changes in inventory) due to their herd inventory being more stable and turn off consisted mainly of produced animals, rather than animals being moved on and off through seasonal variations.

The importance of land condition and its impact on long-term business performance is an area that is not currently well understood, requiring more work. What is currently known needs to be better understood by industry and this is an area where there are genuine R&D

gaps that should be addressed. For the beef industry to be truly sustainable in the long term, the management of land condition within the context of effective overall business management needs to be improved and knowledge of this area needs to be better understood.

There would appear to be a very strong case for the following:

- accreditation for lessees of government-owned land, based on having attended at least a grazing land management course, or recognised equivalent
- sanctions on lessees who fail to comply with basic standards.

There is little objective advice on the cost of comprehensive remediation on degraded landscapes, mostly limited to the cost of ponding banks, without reference to a stocking rate decrease and its associated costs. If an individual station has the majority of its land condition in grazing land management classes C and D (some B), this has an enormous impact on its intrinsic economic value. This is not well recognised by market forces, hence perpetuation of land condition decline continues.

Too many stations have little intrinsic economic value if valued on a return on assets approach. This creates a situation where a property purchased at a very high price will strive to create a decent return, which could result in overstocking (despite evidence to the contrary that a conservative stocking regime will produce a better financial result).

This view will only unfold with a combination of serious financial analysis outcomes, including remediation costs, and government willingness to apply regulations relating to land conservation. Otherwise an uninformed market will make irrational decisions, and inflated property prices will lead to degradation.

There is a need for a comprehensive picture of current land condition, how it varies across the landscape and how it has changed over time. This is an essential resource for the effective management of the pastoral estate at property and industry level. And with this the application of existing regulation that govern appropriate land management. There may be industry resistance to do this, but in the long term the industry will be better for it.

9.3.7 Adoption of R&D

R&D has, and does, provide means for industry to increase productivity and profit. However, the current bottleneck to improved performance is not lack of R&D, particularly for the bottom 75%, but rather lack of adoption of existing R&D. Adding to the R&D information that is 'sitting on the shelf' will do little for the majority of the industry if improvements are not made in the adoption and extension of R&D. The whole approach to adoption and extension needs a rethink, because the existing model is not effective.

There are issues both on the supply and demand sides of extension and adoption. On the supply side, there are a number of specialists that are very knowledgeable in their area of expertise and the research done in that area. However, there are few multidisciplinary generalists with sufficient knowledge of both the pastoral production system (land, livestock and labour), the pastoral business and the established science. This knowledge needs to be complemented by the ability to identify the high priority issues to be addressed, distil the science so it can be practically understood by producers and then determine if and how it can be applied in a cost-effective manner. Managing a pastoral business is a multidisciplinary occupation, and the good producers are skilled at understanding and managing the disciplines. However, the R&D and the technical specialists are usually focused on a particular aspect of the system, and often rightly so, but it is left up to the producer to balance the often-conflicting aspects of the business in deciding if and how to apply R&D, which limits its uptake.

The links between most R&D results and outcomes, especially financial and environmental, are rarely explained well enough to be able to be used in a practical sense.

On the demand side, poor understanding of business performance, satisfaction with low return and ability to run down capital over time (all discussed in market forces below), mean that there is not the drive from a lot of producers to want to improve. They are either content with where they are at or do not see a way to improve their performance through management (also discussed further below).

It is suggested that future R&D be more targeted, especially in line with financial and environmental outcomes. Too often R&D is conducted because it can be, rather than because there is a critical need. As an example, satellite-based technology to monitor the movements of individual animals in paddocks is interesting but is unlikely to improve profitability of beef enterprises. Research workers may be passionate about their particular area of expertise, but it may not be a major industry profit driver. Similarly, committees of producers who do not fully understand the profit drivers of their businesses are not in a strong position to choose the most appropriate R&D programs. While there will always be a need for 'pure' research, the parlous state of the Australian beef industry, as quantified and described in the *Australian beef report*, would best be currently served by more R&D selectivity.

Producer financial literacy and business focus

Producers should have a good understanding of their actual performance if their intent is to improve it. For example, producers' estimates of their reproductive rate and mortality rate are typically in the range of 70 to 80% and 2 to 3% respectively. However, when these measures are properly calculated over a longer time frame, they are usually closer to 50% and 5 to 10% (McGowan et al., 2014; Henderson et al., 2013; McLean et al., 2014; Holmes et al., 2017).

The result is that producers are not aware of the extent of their herd and business performance and therefore not motivated to address it.

The major features of the profile of the cohort of top producers can be described as follows:

- they value the importance of intellectual property (i.e. the business, financial and strategic skills required to run a business)

- their decisions are always evidence based
- their primary focus is business performance. The detail of what happens in the paddocks and yards is secondary
- mostly, they would put the acquisition of financial literacy and business skills ahead of practical and in-paddock skills, because they are more aware of the ramifications.

9.3.8 Market Forces

The market (international and domestic) perceives Australian agriculture as being a ‘safe’ investment, largely as a result of historical capital gains on assets (capital return), political stability and increasing demand for protein. As a result, a lot of domestic and international capital has shown interest in Australian rural assets. Most of that interest is not cognisant of the inherent risk embedded in the operating return, which can erode the capital return to zero and below at times. Although, the returns and risks do seem to be recognised by the superannuation industry in Australia, as they invest very little in Australian agriculture, and pastoral properties in particular.

A fund analyst or domestic producer, looking at available data, may conclude that a particular purchase is prudent, but any due diligence may not have considered land condition for the property or region. While there is information on the financial returns this can suffer from optimism bias, a function of increasing food demand leading to a belief they will outperform against the current industry standards.

It depends on what view is taken, caveat emptor, or science-based transparency. In the absence of transparency, bad decisions are likely to be made, adding to the overall problem. This will not change until science comes to the fore. If an investment in a publicly-listed Australian company is being considered, there is a plethora of information available.

It is a given that despite transparency, analysts and investors will make wrong calls – that is a feature of capitalism. The issue is that all potential information has to be transparent and, at the moment, the environmental data are not.

At the micro level, market forces do not force inefficient businesses out of the industry as quickly as it does in many other industries, which impedes evolution. This applies across agriculture, not just the northern regions that are the focus of this section, and has a number of facets:

- **Large capital base**

Pastoral operations have a significant amount of financial and environmental capital in the land asset. An inefficient or unprofitable operation can gradually run down these capital reserves, through increasing debt, running down and not reinvesting in infrastructure and declining land condition through overstocking. Depending on the starting position, the business can operate like this for 30+ years before it is noticed in financial or land management accounts. This means that it can occur across more than one generation. Over this time significant capital gains are likely to have occurred, in spite of any decline in land condition. There are few other industries where these inefficient operators would not have been forced out of business in this time frame.

- **Poor understanding of business performance**

Many producers do not have a good understanding of business performance. Cash in the bank, number of cattle, (perceived) branding rate and perhaps a few others, are the main performance indicators that producers have to assess their performance by. Very few calculate their actual operating profit – their accountant will calculate a profit figure for the purpose of determining tax. However, this is not the actual operating profit of the business and the industry's aversion to paying tax means that a lower profit is considered better, which conspires against long-term profitability. Again, the economic realities of many other businesses mean that they are forced out of operation if they are not on top of profits, cash flows and margins. This does apply to pastoralism, but the pressure is not as great.

Understanding business performance for pastoral producers is made difficult because the feedback loops on management decisions are weak and can take a long time. For example, if a dairy farmer changes their grazing management or animal health regime, any impact on production can be picked up by the amount of milk in the vat very quickly. Also, if a cropping business changes varieties, fertilisers or pesticides, then the result can usually be observed and measured quite quickly. Whereas if a pastoral business introduces new genetics, an animal health regime or reduces their grazing pressure, the results may not be seen for a number of years, and there are many other factors that can mask the impact (positively or negatively). This means that the effectiveness of the change is often harder to objectively assess than it is for the dairy farmer or the cropper.

This may be the reason that there is an attitude, among some producers, that their long-term performance is largely at the whim of cattle prices, seasons and government policy. In reality, long-term performance is a function of management, and the attitude and aptitude of the manager(s).

- **Quality of life is affected**

This point is linked to the two points above. Because often in family pastoral businesses the home and the business are inseparable, both the cost of living and the psyche, or sense of self-worth, of the owners are rooted in the business. This can mean that when things are financially tight, it is the quality of life expenditures (stores, repairs and upgrades of household facilities, holidays, education, etc.) that are sacrificed to make ends meet

- **Low required return on capital**

The prices paid for rural property can mean that long-term operating returns of around 1% or less are all that is possible. Producers not putting a value on their time, not requiring a reasonable return on the capital they have invested, and reliance on capital gains for long-term returns are the main reasons for this.

9.4 Conclusion

There is a significant variation in industry performance generally, and across the regions analysed above. The factors separating the top performers from the rest are operating scale and operating efficiency.

Effective improvement will require significant changes across the industry, and individual producers will have to want to change before performance will improve. There needs to be a good understanding of what are, and what are not, the profit drivers by producers and the R&D community. Increasing demand for protein, R&D breakthroughs or new technologies cannot be relied on to improve industry performance. A good understanding of, and clear focus on, the fundamentals of profitable beef production will improve performance regardless, as well as position producers to benefit from any advances that may occur.

The adoption of existing R&D is arguably more of a bottleneck to industry performance than R&D gaps are. One area where there is a genuine R&D gap is the understanding of land condition, what it is, how it is changing and its interrelation with business performance. This area has significant implications for the long-term sustainability of the industry.

10 Legal and policy constraints

As part of a broader analysis for the CRCNA, CSIRO commissioned The Australian National University (ANU) to conduct an institutional analysis of the regulatory barriers to the expansion of northern Australia's beef industry. The scope of the project covered the main institutional and regulatory regimes that apply to the production, processing and marketing of beef in northern Australia.

To undertake the analysis, beef production and marketing was divided into five relevant stages: production, road transport, processing, live export and foreign investment. An analysis was then undertaken of the main institutional and regulatory regimes that apply to these five stages in the supply chain. The review covered relevant institutional arrangements that apply under Commonwealth law, as well as those under Western Australian, Northern Territory and Queensland law.

It is difficult to empirically evaluate the economic costs associated with the identified regulatory processes or the extent to which they create uncertainty in the minds of investors. The aim was to identify and describe the nature of the main institutional and regulatory regimes that apply to the industry and to conduct a first-pass assessment of the associated regulatory barriers, relying on an analysis of the applicable regimes and, where available, government reviews of the regulatory systems.

Ten main categories of institutions and regulations were identified that intersect with the five stages. Table 20 provides a summary of the relevant intersections between the institutional categories and the five stages in the supply chain. The analysis of these institutions identified seven areas that warrant further investigation in relation to their capacity to impede development in the industry:

- land title and native title
- interests in and access to water
- planning, environment and heritage laws
- vegetation management laws
- road transport-related biosecurity, animal welfare and heavy vehicle laws
- live export laws
- foreign investment laws.

Table 20 Relevance of institutional categories to the five stages in the supply chain

	Production	Road transport	Abattoirs	Live export	Foreign investment
Land tenure and native title	Relevant	Not relevant	Relevant	Not relevant	Not relevant
Interests in and access to water	Relevant	Not relevant	May be relevant	Not relevant	Not relevant
Planning, environment and heritage laws	Relevant	Not relevant	Relevant	Not relevant	Not relevant
Vegetation management laws	Relevant	Not relevant	May be relevant	Not relevant	Not relevant
Biosecurity laws	Relevant	Relevant	Relevant	Relevant	Not relevant
Animal welfare laws	Relevant	Relevant	Relevant	Relevant	Not relevant
Soil conservation laws	Relevant	Not relevant	Not relevant	Not relevant	Not relevant
Heavy vehicle laws	Not relevant	Relevant	Not relevant	Not relevant	Not relevant
Food safety – meat processing	Not relevant	Not relevant	Relevant	Not relevant	Not relevant
Foreign investment	Not relevant	Not relevant	Not relevant	Not relevant	Relevant

Colour codes:

Relevant
May be relevant, depending on nature of project/activity
Not relevant

10.1 Context

This section of the report presents an analysis of the current legislative and regulatory barriers to the northern Australia beef industry. This analysis will allow identification of the relative contribution of policy, legislation and regulation (and the manner that it is applied) in shaping, supporting and constraining the current status of the industry. This will involve an institutional-based analysis of regulatory barriers to the expansion of the northern Australia beef industry, focusing on the regulatory regimes that apply to beef production and export, including biosecurity, land clearing, biodiversity, transport, animal welfare, water access and soil conservation, and the operation of abattoirs.

10.2 Introduction

Over the past decade, a number of government agencies at the federal and state levels have raised concerns about the regulatory and institutional impediments to the development of the beef industry in northern Australia. The sources of these concerns have been wide ranging covering, among other things, the land tenure arrangements for pastoral businesses, planning and environmental regulations that restrict vegetation clearing, native title, and animal welfare laws. In recent years, steps have been taken to address some of these issues. However, industry stakeholders continue to raise concerns about regulatory processes increasing the cost of production and creating uncertainty for investors.

Most cattle in northern Australia are produced in extensive production systems on unimproved pastures in semi-arid tropic regions where average rainfall is around 450 mm. Where feedlots are used, it is primarily for finishing, which often occurs in the southern areas in Queensland, northern NSW and southern WA (Bortolussi et al., 2005a).

Queensland is the largest beef producer of the three northern jurisdictions, accounting for almost 70% of the northern herd and approximately 80% of the gross value of cattle production. The NT is the second largest, with around 25% of the herd and 15% of the gross value of production, followed by WA (ABS, 2019).

A significant proportion of the cattle produced in northern Australia is for the live export trade. These cattle are produced in extensive systems across the region and then exported for finishing and slaughter in foreign markets, particularly in South-East Asia (Meat and Livestock Australia, 2018a; MLA, 2017a; MLA, 2016a). The majority of the cattle that are exported live are shipped from Darwin, Townsville, Broome and Fremantle. Reasonable numbers are also exported through Wyndham, Geraldton and Karumba (Meat and Livestock Australia, 2018a; MLA, 2017a; MLA, 2016a).

To undertake the institutional and regulatory analysis, beef production and marketing was divided into five relevant stages: production, road transport, processing, live export and foreign investment. An analysis was then undertaken of the main institutional and regulatory regimes that apply to these five stages in the supply chain. The review covered relevant institutional arrangements that apply under Commonwealth law, as well as those under WA, NT and Queensland law. The review was not exhaustive. Due to time and resource constraints, some regulatory regimes were omitted, for example, work health and safety laws, competition laws and the regulation of the management and access to travelling stock reserves (for example, see the *Stock Route Management Act 2002* (Qld)). The analysis also did not cover self-regulation and accreditation initiatives like the National Feedlot Accreditation Scheme, Livestock Production Assurance On-Farm Quality Assurance program and National Saleyard Quality Assurance program. The results presented in this section reflect the state of relevant laws at 30 June 2019. As such, names of Commonwealth, state and territory departments and portfolios may have changed since the publication of this report.

The remainder of this section is set out as follows. Section 10.3 presents the analysis of the regulatory systems that apply to broadacre grazing and feedlots. Section 10.4 presents the results concerning the regulatory regimes that apply to the transport of cattle by road. Section 10.5 provides the analysis of the regimes that apply to the processing of cattle in abattoirs. Section 10.6 presents the analysis of the live export regulations. Section 10.7 covers the foreign investment rules, Section 10.8 covers barriers related to foreign investment laws and Section 10.9 provides a short conclusion.

10.3 Institutional and regulatory regimes that apply to production processes

As noted in the introduction, cattle production in northern Australia is dominated by broadacre grazing, with feedlots used mainly for finishing and the housing of animals awaiting live export. For the purposes of the analysis, the main institutional and regulatory regimes that apply to these production systems were grouped into seven categories based on the listing in the introduction. A notable feature of these institutions is that some regulate the conduct of existing operations, while others apply predominantly to new developments, including the expansion, intensification and diversification of existing operations. For example, biosecurity and animal welfare regulations restrict the conduct of existing grazing operations and the transport and slaughter of animals, imposing obligations on pastoralists to manage livestock in particular ways. In contrast, planning regulations mainly operate to restrict new developments. Existing activities are covered by what are known as 'existing use rights', meaning planning approvals are generally not required to continue the activities. This difference in scope is important when evaluating the nature and magnitude of relevant regulatory impediments, as one can reduce the profitability of existing operations, while the other acts as a barrier to new investment.

10.3.1 Land tenure and native title

Nature of pastoral interests in land

Pastoralists and feedlot owners operating in northern Australia generally access and use land under one of three forms of legal instrument:

- Crown leases, being leasehold interests issued over Crown land by the state or territory government
- freehold title, in the form of a fee simple estate
- grazing licences issued in relation to Crown land.

The form and nature of these interests is largely the domain of the state and territories. The Commonwealth plays almost no role in land tenure arrangements. It has a more prominent role in the NT in relation to Indigenous land and across all jurisdictions in relation to native title.

Crown leases

Most of the land that is used for pastoral purposes in northern Australia is held under leases issued by the state or territory government over Crown land. The nature of these Crown leases varies between jurisdictions. In WA and the NT, pastoral leases dominate. In Queensland, most of the Crown leases used for pastoral purposes are either term or perpetual leases. Crown leases are an incomplete form of land tenure, in that they are generally subject to restrictions on use, do not necessarily confer the right to exclusive possession and, in many cases, have limited terms. A summary of the types of Crown leases that can be issued in the three jurisdictions, and the restrictions that apply under these leases, is provided in Table 21, Table 22 and Table 23.

Table 21 Types of leasehold interest in Crown land in WA

INTEREST TYPE	COMMENT
General leases	Under s 79 of the *Land Administration Act 1997* (WA) (LA Act), the Minister for Lands has broad powers to grant leases for any purpose and any term, and may impose whatever conditions are deemed appropriate. These general leases may give the lessee the option of converting the estate to freehold if specified conditions are satisfied.
Conditional purchase leases	Under s 80 of the LA Act, the minister is given the power to grant conditional purchase leases of any Crown land, under which the lessee is able to convert the leasehold interest to a fee simple estate when specified conditions are met and the purchase price paid.
Aboriginal leases	Under s 83 of the LA Act, the minister has the power to grant leases of Crown land, for a fixed term or in perpetuity, 'for the purposes of advancing the interests of any Aboriginal person or persons'. These leases can be granted to an individual, group of people, or an approved body corporate, on such conditions as the minister believes are appropriate.
Government leases	Section 86 of the LA Act gives the minister the power to lease Crown land to the Australian Government, Australian Government agencies, state agencies and local governments.
Pastoral leases	Under s 101 of the LA Act, the minister has the power to grant pastoral leases, provided the Pastoral Land Board (a statutory committee established under the LA Act) is satisfied the land, when fully developed, will be able to carry 'sufficient authorised stock to enable it to be worked as an economically viable and ecologically sustainable pastoral business unit'. The leases can be issued for terms of up to 50 years, although in practice, some are as short as 18 years. Pastoral leases do not necessarily confer an absolute right to exclusive possession; Indigenous people are entitled to enter unenclosed and unimproved parts of all pastoral lease land 'to seek their sustenance in their accustomed manner' (LA Act, s 104). Conditions can also be imposed that give other parties the capacity to occupy the land for specific purposes. Pastoral leases can be subject to a range of conditions, including as to what activities can be undertaken on the land and what products can be sold from the land. Generally, unless authorised by the Pastoral Land Board, pastoral lease land can only be used for 'pastoral purposes' (the commercial grazing of authorised stock and ancillary activities), no native vegetation can be cleared on the land, and no non-indigenous pasture can be sown or cultivated on the land. Pastoral leases are also subject to other restrictions imposed under the LA Act, including relating to minimum and maximum stock numbers, the distribution of stock, management of pests, and the management of native vegetation. The Pastoral Land Board is empowered to enter onto pastoral lease land to investigate compliance with the conditions of the lease, and can authorise others to do the same. The Pastoral Land Board can also issue permits authorising non-pastoral uses and the sowing and cultivation of non-indigenous pasture.

Table 22 Types of leasehold interest in Crown land in the NT

INTEREST TYPE	COMMENT
Fixed-term lease	Under part 3 of the *Crown Lands Act 1992* (NT) (CL Act), the minister may issue fixed-term leases, which are subject to conditions and reservations specified in the CL Act. The minister can also impose any other conditions or reservations considered necessary in the circumstances. Lessees must obtain ministerial approval for a number of dealings with the leases, including transfers, mortgages, subdivisions, subletting and the creation of easements and covenants. The leases can contain provisions relating to the exchange of the leasehold interest for a fee simple estate.
Perpetual lease	Under part 3 of the CL Act, the minister may issue leases in perpetuity (for an indefinite term). Perpetual leases are subject to similar statutory conditions as those applying to term leases, including in relation to the need to obtain ministerial approval for various dealings and the capacity for leases to include conditions in relation to their surrender in exchange for fee simple estates.
Pastoral lease (PL Act, Pt 4)	Section 31 of the *Pastoral Land Act 1992* (NT) (PL Act) gives the minister the power to issue pastoral leases, being leases for 'pastoral purposes'. Pastoral purposes are defined as 'pasturing of stock for sustainable commercial use of the land on which they are pastured or agricultural or other non-dominant uses essential to, carried out in conjunction with, or inseparable from, the pastoral enterprise, including the production of agricultural products for use in stock feeding and pastoral based tourist activities such as farm holidays'. Pastoral leases do not confer an absolute right to exclusive possession; they must contain a mandatory reservation 'in favour of the Aboriginal inhabitants of the Territory' (s 38). This reservation entitles the Indigenous people of the area to occupy the land, take water from natural water bodies and springs on the land, hunt wild animals and take food and vegetable matter grown naturally on the land. Fee simple estates can also be excised out of pastoral leasehold land on the application of Indigenous people for community living areas. In addition, the Pastoral Land Board is entitled to establish monitoring stations on pastoral lease land and enter on the land to investigate compliance with the conditions of the lease. Generally, pastoral leasehold land can only be used for pastoral purposes unless a permit authorising a non-pastoral use has been issued by the Pastoral Land Board. Permits can be issued for up to 30 years and, once issued, become attached to the lease and must be registered under the *Land Title Act 2000* (NT). Hence, if the pastoral leasehold interest is transferred to another party, the permit passes with the lease. Pastoral leases are subject to a number of other mandatory statutory reservations and conditions, including that the lessee take all reasonable measures to conserve and protect features of environmental, cultural, heritage or ecological significance, and that vegetation cannot be removed without the consent of the Pastoral Land Board, or in accordance with clearing guidelines issued by the board. The minister can also impose such other conditions as he or she thinks fit, and the Pastoral Land Board can issue notices directing lessees to take measures to address land management issues, including feral animals. Pastoral leases can be issued for a fixed term of not more than 25 years or in perpetuity.
Special-purpose lease	Section 4 of the *Special Purposes Leases Act 1953* (NT) (SPL Act) gives the responsible minister the power to grant special-purpose leases over any unleased Crown land. Special purposes are defined as any purpose other than residential, pastoral, agricultural or mining. 'Agricultural' does not include horticultural for these purposes. Special-purpose leases can be granted over areas reserved for other purposes. However, special-purpose leases can only be granted if the proposed use or development is consistent with the development provisions of the *Planning Act 1999* (NT). Further, foreign companies cannot hold a special-purpose lease, a sublease of a special-purpose lease, or be a mortgagee over a special-purpose lease without the approval of the responsible minister. Special-purpose leases can be subject to a wide range of terms and conditions, and be for a term of years or in perpetuity. The SPL Act contains specific provisions concerning the resumption of special-purpose lease land, and the payment of compensation in these circumstances.

Table 23 Types of leasehold interest in Crown land in Queensland

INTEREST TYPE	COMMENT
Term leases	Under chapter 4 of the *Land Administration Act 1994* (Qld) (LA Act), the minister can issue fixed-term leases for specific purposes for up to 100 years. Generally, the term will be limited to a maximum of 50 years but longer terms can be issued for significant developments, timber plantations and projects involving a high level of investment (s 155). Leases over state reserves are limited to a maximum of 30 years (s 32). Term leases can only be used for the specific purposes identified in the lease, although there is the capacity for the minister to approve additional purposes. Term leases are also subject to a range of mandatory conditions relating to the management of the land, including a general duty of care. For agricultural, grazing and pastoral purpose term leases, the duty of care explicitly includes the obligation to take all reasonable steps to, among other things, avoid causing dryland salinity, conserve soil, protect riparian vegetation, maintain native grassland free of encroachment from woody vegetation, manage declared pests and conserve biodiversity (s 199). Term leases can be subject to other conditions at the discretion of the minister. In addition, term leases cannot be transferred, sublet, subdivided or amalgamated without government approval (ss 322, 332, 175 and 176J). In addition to allowing for the creation of new term leases, the LA Act provides for the continuation of four types of pastoral leases that existed under the previous regime (pastoral holdings, pastoral development holdings, preferential pastoral holdings and stud holdings) as term leases. Term leases can be rolling term leases, in which case the term of the lease can be extended at any time for the same length as the original term. Leases for agriculture, grazing or pastoral purposes covering more than 100 hectares are treated as rolling term leases. There is also scope for leaseholders to apply to the minister for their lease to be declared a rolling term lease.
Perpetual leases	Chapter 4 of the LA Act gives the minister the power to lease unallocated Crown land for specific purposes in perpetuity. With the exception of their term, perpetual leases are subject to similar statutory reservations and conditions as those applying to term leases. Like term leases, they must be for a specific purpose and the lessee can only use the land for that purpose. Perpetual leases are also subject to mandatory statutory conditions, can be subject to other conditions imposed by the minister, and they cannot be transferred, sublet, subdivided or amalgamated without government approval. The fact perpetual leases do not expire makes them similar to a freehold estate, only they are subject to more reservations and conditions, a requirement to pay rent, and, like all leases, they can be terminated on account of failing to pay rent or non-compliance with conditions. Several types of leases that existed under the previous regime are continued as perpetual leases, including grazing homestead perpetual leases.
Freeholding leases	Under section 15 and section 166 of the LA Act, the Governor in Council can issue freeholding leases; leases that convert to freehold after the satisfaction of conditions and the payment of the purchase price over a term of years. In addition, under chapter 8, several types of leases that existed under the previous regime are continued as freeholding leases, including grazing homestead freeholding leases. Freeholding leases are subject to similar statutory reservations and conditions as those applying to term and perpetual leases, including in relation to use, management, transfer, subletting, subdivision and amalgamation.

Freehold

Freehold, in the form of a fee simple estate, is the most complete legal interest in land under Australian law. The estate is generally held in perpetuity and without conditions on title concerning the use and development of the land. For this reason, it is considered the most secure form of title and superior to other interests, including Crown leases.

While coming close to absolute ownership, freehold title does not give the holder of the estate the right to use the land as they please. The estates are almost always subject to reservations (e.g. the Crown reserves the rights to minerals and petroleum in the land) and the privileges inherent in ownership concerning the use and development of the land are usually curtailed through planning, environment and other similar regulations (see below).

Grazing licences issued in relation to Crown land

In addition to leasehold and freehold title, some pastoral activities are conducted under grazing licences issued in relation to Crown land. The nature of these licences differs depending on the jurisdiction and whether the Crown land is unallocated or reserved for specific purposes. Generally, grazing licences (or permits) authorise entry onto, and use of, Crown land for grazing purposes where it would otherwise be unlawful. They do not give the holder any proprietary rights or interests in the relevant land. Consistent with this, they can generally be readily amended or cancelled, usually without a need for the government to pay compensation.

Native title

Native title is a unique form of property interest under Australian law consisting of a bundle of rights defined by the laws and customs of the relevant Indigenous community. This concept is reflected in the *Native Title Act 1993* (Cth), which defines native title, and native title rights and interests, as:

> … the communal, group or individual rights and interests of Aboriginal peoples or Torres Strait Islanders in relation to land or waters, where:
>
> (a) the rights and interests are possessed under the traditional laws acknowledged, and the traditional customs observed, by the Aboriginal peoples or Torres Strait Islanders; and
>
> (b) the Aboriginal peoples or Torres Strait Islanders, by those laws and customs, have a connection with the land or waters; and
>
> (c) the rights and interests are recognised by the common law of Australia.[1]

Native title was first recognised in 1992 in the High Court of Australia's decision in *Mabo v. Queensland* [No.2]. Following the decision, the Native Title Act was passed in order to provide a statutory scheme for determining native title claims, and a national system for the recognition and protection of native title. There are four main relevant elements of the native title regime: application and registrations, determinations, compensation for acts that adversely affect native title, and the process for ensuring the validity of 'future acts' and payment of associated compensation.

Application and registration of native title claims

There are two main types of native title applications: claimant and non-claimant. Claimant applications are made by persons from, and authorised by, the Indigenous group who, according to their traditional laws and customs, hold the claimed native title. Non-claimant applications can be made by the Australian Government, the relevant state or territory

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[1] *Native Title Act 1993* (Cth), s 223

government, or a person who holds a non-native title interest in the area over which the determination is sought.

Applications for the determination of native title claims are made to the Federal Court. After an application is lodged, the Federal Court is required to notify the National Native Title Tribunal (NNTT), an administrative agency of the Australian Government established under the Native Title Act. The NNTT is required to notify specified parties of the application and, if particular conditions are satisfied (known as the 'registration test'), the Registrar of the NNTT must register the application on the Register of Native Title Claims. While registration does not determine a claim, it confers on the claimant group the status of a 'registered native title claimant', meaning they obtain procedural rights, including the right to negotiate on proposed 'future acts' that could adversely affect their claimed native title.

Native title determinations

Applications are determined by the Federal Court through the making of orders. These orders determine whether the native title is recognised, the nature of the native title rights, and the geographic boundaries within which the title applies. Two types of native title are recognised:

- exclusive possession, which gives the holders a bundle of rights that stem from traditional Indigenous laws and customs, including the right to control access so as to exclude all others
- non-exclusive possession, which gives the holders a bundle of rights that stem from traditional Indigenous laws and customs but not the right to control access.

All native title determinations are recorded on the National Native Title Register, regardless of whether the Federal Court finds in favour of or against the claimant. The details that must be recorded include the determination date, the area it covers, and whether native title is recognised. Where native title is recognised, the entry on the register must include details of who the common law holders of the native title are, a description of the nature and extent of the native title rights and interests, and the name and address of the prescribed body corporate assigned to hold or manage the title for the Traditional Owners. As part of the determination process, the native title group must nominate a prescribed body corporate to hold the native title on trust for, or manage the native title as an agent of, the group. After the determination is made, and the prescribed body corporate is recorded on the National Native Title Register, it becomes known as the 'registered native title body corporate'.

Compensation

The Native Title Act provides for the payment of compensation to native title holders for acts that adversely affect their title. For these purposes, acts that affect native title are those that extinguish the native title rights and interests or are wholly or partly inconsistent with their continued existence, enjoyment or exercise. These acts can include the making or amendment of legislation, the granting of property interests, the issuance of government approvals, the reservation of land for public purposes and 'the exercise of any executive power of the Crown in any of its capacities, whether or not under legislation'.[2]

The operation of the compensation regime hinges on a distinction between past acts, intermediate past acts and future acts. Past acts are acts involving the making, amendment or repeal of legislation (legislative acts) that occurred before 1 July 1993 and any other acts (non-legislative acts) that occurred before 1 January 1994.[3] Intermediate period acts are particular non-legislative acts that occurred between 1 January 1994 and 23 December 1996, consisting of such things as the grant of property interests and conduct of public works that were carried out on the assumption native title had been extinguished by the issuance of prior interests (especially leases).[4] Future acts are legislative acts that occurred or occur after 1 July 1993 and non-legislative acts that occurred or occur after 1 January 1994, other than intermediate period acts.[5]

At a high level, compensation is payable for:

- past legislative (31 October 1975 to 1 July 1993) and non-legislative (31 October 1975 to 1 January 1994) acts
- intermediate period acts (particular acts that occurred between 1 January 1994 and 23 December 1996)
- future legislative (after 1 July 1993) and non-legislative (after 1 January 1994) acts.

No compensation is payable in relation to acts that occurred prior to 31 October 1975.

Future acts regime

Pastoral and feedlot developments that affect native title could involve 'future acts' that are rendered invalid by the operation of the Native Title Act, or trigger a right to compensation. In this context, relevant 'future acts' could consist of the issuance of property interests and approvals to support the development, special legislative amendments that are made to facilitate the development, and the conduct of related public works. There are three aspects of the Native Title Act that are critical to the conduct of such future acts concerning these developments:

- Validity – Part 2, division 3 of the Native Title Act contains 11 grounds that ensure the validity of certain future acts, summarised in Table 24. These grounds are intended to operate as a cascade, meaning the validity of a future act will be governed by the first applicable ground. For example, if a future act is validated by the operation of an

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[2] *Native Title Act 1993* (Cth), s 226

[3] To be a past act, the act must also have been invalid (i.e. by virtue of the *Racial Discrimination Act 1975* (Cth)) but would have been valid but for the existence of the native title.

[4] To be an intermediate period act, among other things, the act must have been invalid (i.e. by virtue of the Native Title Act or Racial Discrimination Act) but would have been valid but for the existence of the native title.

[5] To be a future act, the act must not be a past act and, apart from the Native Title Act, it must either: (i) validly affect native title in relation to land or waters; or (ii) be invalid but for the existence of native title (i.e. by virtue of the Racial Discrimination Act) and, if it were valid, it would affect the native title.

Indigenous Land Use Agreement (ILUA), it cannot be validated by any subsequent provision. If a future act does not satisfy one of these grounds, it will be invalid to the extent it affects native title.

- Procedural requirements and rights – The Native Title Act requires certain procedures to be followed when conducting valid future acts. It also confers procedural rights on representative Indigenous bodies, registered native title bodies corporate and registered native title claimants in relation to the conduct of valid future acts. These include rights to notice, comment, consultation and negotiation (see Table 24).
- Compensation – While part 2, division 3 of the Native Title Act ensures the validity of certain future acts, it also provides rights to compensation for affected Traditional Owners. Generally, liability for compensation formally attaches to the government responsible for the future act. However, private parties can be liable to pay compensation, particularly via governments wholly or partially passing liabilities onto private entities undertaking developments through contracts or other legal means.

Table 24 Grounds for validity of future acts affecting native title under the Native Title Act

LEGISLATIVE REFERENCE (PT 2, DIV 3)	GROUNDS FOR VALIDITY	COMMENT
Subdiv B–E	Indigenous Land Use Agreements (ILUAs)	Future acts will be valid if done in accordance with a registered ILUA. ILUAs are agreements between native title holders or claimants and other interested parties concerning the use of land and management of native title. The agreements are voluntary and can provide for a wide range of terms.
Subdiv F	Non-claimant application	Future acts will be valid if done in an area covered by a non-claimant application (native title application by a government or a person who holds a non-native title interest in the area) so long as, at the time the act occurs: (i) the notice period for the application has ended; (ii) no native title claim was made covering the area during the notice period; and (iii) no entry has been made on the National Native Title Register that native title exists in relation to the area.
Subdiv G	Acts related to primary production on non-exclusive leases	Subdivision G ensures the validity of future acts involving primary production in three circumstances. A. Where the future act authorises or requires the conduct of a primary production activity, or an activity incidental to a primary production activity, on an area subject to a non-exclusive agricultural or pastoral lease granted before 24 December 1996. However, this does not apply where: (i) the future act has the effect of allowing or requiring the majority of the area of greater than 5000 ha to be used for purposes other than pastoral purposes; or (ii) the future act involves the conversion of the non-exclusive possession lease into a freehold estate or exclusive possession lease. Further, where the primary production activity involves forestry, horticulture or aquaculture, or an agriculture activity on a non-exclusive pastoral lease, relevant representative Indigenous bodies, registered native title bodies corporate and registered native title claimants must be notified and given an opportunity to comment. B. Where the future act permits or requires the carrying on of grazing, or an activity relating to gaining access to water for primary production, that takes place in an area adjoining or near the area covered by a freehold estate, agricultural lease or pastoral lease that is used for primary production that was granted on or before 23 December 1996, provided the act does not prevent native title holders having reasonable access to the area, then the future act will be valid. Prior to the future act being undertaken, relevant representative Indigenous bodies, registered native title bodies corporate and registered native title claimants must be notified and given an opportunity to comment. C. Where the future act, not involving the grant of a lease, confers on a person a right to cut timber or to engage in mining activities from an area covered by a non-exclusive agricultural or pastoral lease granted on or before 23 December 1996, the future act will be valid, provided notice has been given to representative Indigenous bodies, registered native title bodies corporate and registered native title claimants and they have been provided an opportunity to comment on the act.
Subdiv H	Management and regulation of water and airspace	Future acts consisting of the making, amendment or repeal of legislation, or grant of a lease, licence or permit, in relation to the management or regulation of surface and subterranean water, living aquatic resources or airspace will be valid. The management or regulation of water includes granting access to water and taking water. Prior to the future act being

LEGISLATIVE REFERENCE (PT 2, DIV 3)	GROUNDS FOR VALIDITY	COMMENT
		undertaken, relevant representative Indigenous bodies, registered native title bodies corporate and registered native title claimants must be notified and given an opportunity to comment.
Subdiv I	Pre-existing rights and renewals and extensions of leases, licences and permits	Subdivision I ensures the validity of two types of future acts. A. Pre-existing right-based acts, being acts done: (i) in exercise of a legally enforceable right created by an act done on or before 23 December 1996; or (ii) in good faith in giving effect to, or otherwise because of, an offer, commitment, arrangement or undertaking made or given in good faith on or before 23 December 1996. If the future act consists of the grant of a freehold estate, or the conferral of a right of exclusive possession, over particular land or waters, relevant representative Indigenous bodies, registered native title bodies corporate and registered native title claimants must be notified and given an opportunity to comment. B. Permissible renewals and extensions, being the renewal or extension of a lease, licence or permit that satisfies particular requirements in section 24IC, including that it does not confer a right of exclusive possession, does not enlarge a pre-existing proprietary interest, and (if the area is greater than 5000 ha and the original interest was a non-exclusive pastoral lease) does not have the effect of allowing the majority of the area to be used for purposes other than pastoral purposes. If the original interest contained a reservation for the benefit of Indigenous people, the renewal or extension must be subject to the same reservation. If the act is done by the Australian Government, or a state or territory government, and it creates a right to mine, it will give rise to a subdivision P 'right to negotiate' (see below). If the future act involves the renewal of a non-exclusive agricultural or pastoral lease, and the term of the lease is longer than the original or the new lease is a perpetual lease, the relevant representative Indigenous bodies, registered native title bodies corporate and registered native title claimants must be notified. If a claimant or body corporate objects to the act, the government or third party must consult with them and, if they request, ensure the matter is heard by an independent person.
Subdiv JA	Public housing and other facilities for the benefit of Indigenous people	Future acts involving the provision of public housing and other public services by a government entity for the benefit of Indigenous people on land held for the benefit of the Indigenous people conducted within a prescribed period will be valid, provided there are laws in place for the protection and preservation of places of Indigenous significance on the site. Relevant representative Indigenous bodies, registered native title bodies corporate and registered native title claimants must be notified and given an opportunity to comment by the responsible government entity. If a registered native title claimant or registered native title body corporate requests it, the government entity must also consult them about ways of minimising impacts on the native title rights and interests, access to the land or waters, and the way the activities authorised by the act are done.
Subdiv J	Future acts arising on lands reserved for public purposes prior to 23 December 1996	Subdivision J ensures the validity of future acts done on land reserved or leased for particular purposes on or prior to 23 December 1996. Where legislation was made, amended or revoked on or prior to 23 December 1996, and the legislative change conferred a reservation, condition, permission or authority under which the whole or part of the land or waters was to be used for a particular purpose, a future act taken under or in accordance with the reservation, condition, permission or authority will

LEGISLATIVE REFERENCE (PT 2, DIV 3)	GROUNDS FOR VALIDITY	COMMENT
		be valid. Examples given in the act of what the future acts might consist of include the making of a management plan for a national park reserved prior to 23 December 1996, and the issuance of a forestry licence on land reserved for forestry purposes prior to 23 December 1996. The lease provisions provide that, where a lease was granted by the Australian Government, or a state or territory government, to a statutory authority for a particular purpose on or prior to 23 December 1996, a future act consisting of the use of the land or waters for the specified purpose will be valid. There are notification requirements that apply to public works and the creation of management plans for conservation reserves. In both instances, relevant representative Indigenous bodies, registered native title bodies corporate and registered native title claimants must be notified and given an opportunity to comment.
Subdiv K	Acts involving facilities for services for the general public	Future acts involving the authorisation of the construction, operation, maintenance or use of facilities for services for the general public, or the construction, operation, maintenance or use of these facilities by a government entity, will be valid, provided there are laws in place for the protection and preservation of places of Indigenous significance on the site and the future act does not prevent native title holders from having reasonable access to the area. Native title holders and registered native title claimants have the same procedural rights (e.g. to be notified and have the chance to comment) as they would have if they instead held ordinary title to the land or, if the land is subject to a non-exclusive agricultural or pastoral lease, a lease of the same kind.
Subdiv L	Low impact future acts	Subdivision L ensures the validity of low impact future acts, being acts that: (i) take place before, and do not continue after, native title is determined to exist in relation to the relevant area; and (ii) the act does not involve the grant of a freehold or leasehold estate, conferral of a right of exclusive possession, excavation or clearing of the area (other than for public health, public safety, environmental assessment and other specified purposes), mining, construction of a fixture (something affixed to the land), or waste disposal.
Subdiv M	Legislative and non-legislative acts passing the 'freehold test'	Subdivision M ensures the validity of future acts that pass the 'freehold test', which in broad terms requires native title interests to be treated the same as other property interests. There are two tests: one for legislative acts, one for non-legislative acts. A. For legislative acts (making, amending or repeal of legislation) to be valid, the act must apply in the same way to the native title holders as it would if they held ordinary title to the land and the effect of the act on the native title must not cause the native title holders to be in a more disadvantageous position at law than they would be if they held ordinary title to the land. B. For non-legislative acts, the act will be valid if the act could be done if the native title holders instead held ordinary title to the area and there are laws in place for the protection and preservation of places of Indigenous significance on the site. Native title holders and registered native title claimants have the same procedural rights (e.g. to be notified and have the chance to comment) as they would have if they instead held ordinary title to the land or land adjoining the area concerned. If the act involves the compulsory acquisition of native title so as to enable a government to confer rights and interests on a third party, or

LEGISLATIVE REFERENCE (PT 2, DIV 3)	GROUNDS FOR VALIDITY	COMMENT
		the creation or variation of a right to mine to facilitate the construction of mining infrastructure, relevant representative Indigenous bodies, registered native title bodies corporate and registered native title claimants must be notified. If a claimant or body corporate objects to the act, the government or third party must consult with them and, if they request, ensure the matter is heard by an independent person. In addition, if the future act is done by the Australian Government, or a state or territory government, and it creates or varies a right to mine (except one created for the sole purpose of the construction of an infrastructure facility associated with mining) or involves the compulsory acquisition of native title rights and interests (unless the acquisition is to confer rights on the government or is for the purpose of an infrastructure facility), it will give rise to a subdivision P 'right to negotiate' (see below).
Subdiv N	Acts affecting offshore places	Future acts involving offshore places will be valid. Native title holders and registered native title claimants have the same procedural rights (e.g. to be notified and have the chance to comment) as they would have if they instead held any other corresponding non-native title rights and interests.
Subdivision P 'right to negotiate'		
In specified instances, including where a future act involving the compulsory acquisition of native title rights and interests passes the freehold test (subdiv M), native title parties are given a subdivision P 'right to negotiate'. Where this applies, the future act will be invalid to the extent it affects native title unless specified procedures are followed. Native title parties are defined for these purposes as registered native title bodies corporate, registered native title claimants and relevant representative Indigenous bodies. Where the right applies, the government party must provide public notice of the proposed act and give potential claimants three months to become native title parties. The government party also must give existing native title parties notice of the proposed act and provide them with an opportunity to make submissions on it. After satisfying the notice requirements, the government party must negotiate with the native title parties in good faith with a view to obtaining agreement to the doing of the future act. During the course of the negotiations, any of the parties can request mediation from the relevant arbitral body (e.g. National Native Title Tribunal (NNTT) or other specified state/territory bodies). Further, after six months from the notification day specified in the public notice, any negotiating party can make a future act determination application to the relevant arbitral body. Where an application is made, the arbitral body is empowered to make a determination, as soon as practicable, having regard to the statutory criteria contained in section 39. Decisions of the arbitral bodies can be overruled by relevant federal, state or territory ministers (the federal minster can overrule if the arbitral body is the NNTT and a state/territory minister can overrule where the arbitral body is a state/territory body). While the normal procedure requires adherence to the good faith negotiation process, there is an expedited procedure that bypasses these requirements (see section 32 and section 237). For the expedited process to apply, the act must be unlikely to: (i) interfere directly with the carrying on of the community or social activities of the native title holders; (ii) interfere with areas or sites of particular Indigenous heritage significance; (iii) involve major disturbance to any land or waters concerned; and (iv) create rights whose exercise is likely to involve major disturbance to any land or waters concerned. In addition, the government party must include a statement in the notice of the future act to the effect that it considers the act attracts the expedited procedure. Native title parties can object to the application of the expedited procedure to a relevant arbitral body, who can determine whether or not it applies.		

Barriers related to land tenure and native title

For decades, voices within and associated with the pastoral industry have raised concerns about the security of the land tenure arrangements for graziers in northern Australia. The main points of contention concern the restrictions that relevant Crown leases impose on non-pastoral uses and development, the term-limited nature of many Crown leases, and the uncertainty and costs associated with the resolution of native title issues.

In recent years, a number of reforms have been introduced to address some of these concerns, particularly the impediments to undertaking non-pastoral uses on pastoral leasehold land. These include the 2014 amendments to the *Pastoral Land Act 1992* (NT) (PL Act) that enabled the issuance of 30-year permits for non-pastoral uses on pastoral leasehold land. To provide increased certainty for investors, these permits attach to title, meaning subsequent purchasers of the lease can continue to use the land for the authorised use without having to apply for a new permit (Table 22). In Queensland, the *Land Act 1994* (Qld) was also amended to allow for rolling term leases with terms of up to 50 years for pastoral and other agricultural purposes.

The Western Australian Government is currently in the midst of a pastoral lands reform process. The proposals that are being considered in this process include allowing permits for non-pastoral uses on pastoral leasehold land to attach to title, giving pastoralists who have complied with the conditions of their lease a statutory right to renewal, and extending the term of existing pastoral leases to 50 years.[6] In a related initiative, in 2018, the Western Australian Government gave 'in-principle support' for the commencement of carbon sequestration projects on pastoral leasehold land under the federal *Carbon Credits (Carbon Farming Initiative) Act 2011* (Cth) (CFI Act). At the time of writing, the Western Australian Government had not given the final required formal consent to the registered carbon projects but the announcement serves as a signal of its desire to promote diversification and investment in pastoral enterprises.

For its part, the Australian Government has signalled its support for the efforts to reduce the land-use restrictions on pastoral leases and to increase the security of tenure. It has also indicated a desire to make changes to native title processes to reduce the uncertainty over claims and facilitate the more efficient negotiation of agreements concerning native title.

The efforts to reform land tenure arrangements are complicated by a number of factors. Most notably, any changes to Crown leases must adhere to the requirements in the Native Title Act, including in relation to consultation, compensation and the steps required to ensure the legal validity of future acts. Changes to native title processes to reduce uncertainty and facilitate investment are also likely to take a considerable period of time and require sensitive negotiations with Indigenous communities.

In addition to these practical issues, there is conflicting evidence about the extent to which land tenure and land-use restrictions imposed under Crown leases are holding back investment. Past inquiries into land tenure arrangements have also found problems with the trends in the ecological condition of pastoral leasehold land. There are differing views on whether the

[6] See: http://www.drd.wa.gov.au/Publications/Documents/Ministers update -Pastoral Lands Reform - 8 June.pdf (22 June 2019)

liberalisation of the conditions on land use could exacerbate this problem, leading to an intensification of unsustainable practices.

Given the conflicting evidence, further research is warranted to investigate the specific nature and magnitude of the barriers associated with pastoral interests and native title, and to identify the most cost-effective solutions to the issues that are identified. This research should look at whether there is validity to the claim that changes to the land tenure requirements could lead to a deterioration in the condition of pastoral leasehold land. Conceptually, the reverse is more likely to be true – increasing security of tenure should provide landholders with a greater incentive to manage the land sustainably. However, there may be circumstances associated with northern Australia pastoral enterprises that nullify this incentive.

10.3.2 Interests in and access to water resources

Nature of interests in water

WA, NT and Queensland have water statutes that control access to, interference with and use of ground and surface water within their territorial boundaries. As with interests in land, the Australian Government plays only a limited direct role in water governance in northern Australia.

The WA, NT and Queensland water statutes contain processes for water planning, the regulation of taking water (with and without government authorisation), and statutory requirements to obtain government approval for works related to water infrastructure (e.g. dams, bores, levees and pipes). In Queensland, the regulation of the construction and operation of water infrastructure is done through the *Planning Act 2016* (Qld) and *Water Act 2000* (Qld). The main elements of the water governance regimes in each jurisdiction are summarised in Table 25, Table 26 and

Table 27.

Table 25 Main elements of the water governance regime in WA

ELEMENT	COMMENT
Main statute	*Rights in Water and Irrigation Act 1914* (WA) (RiWI Act)
Water planning	Water resource management plans can be prepared at regional, subregional and local scales. Regional plans define the available water resources in a region. Subregional plans guide the water minister on water resource management issues for the specified subregion, including in relation to the allocation of water between competing uses. Local area management plans guide the management of water resources at a local level, including water allocations, how water can be taken and used, and matters that should be taken into consideration in licensing decisions.
Approvals for taking water	Under the RiWI Act, activities involving taking water are divided into two categories: (i) those that can occur without authorisation; and (ii) those that can only occur with authorisation. The nature of the approval requirements depends on whether the water resource is proclaimed. Generally, water can be taken from a proclaimed or unproclaimed surface water resource for stock without approval. Activities involving taking water for irrigation purposes will typically require a water licence under section 5C of the RiWI Act.
Water-related works approvals	A licence or a permit under the RiWI Act is usually required to interfere with a watercourse, wetland or underground waters. There are four main types of approvals: (i) section 26D licences (construction or alteration of a well or bore); (ii) section 11 permits (construction of works to take water where access is via a public road or reserve in a proclaimed area); (iii) section 17 permits (construction of works to take water in a proclaimed area); and (iv) section 21A permits (construction of works to take water via access from a public road or reserve in an unproclaimed area).

Table 26 Main elements of the water governance regime in the NT

ELEMENT	COMMENT
Main statute	*Water Act 1992* (NT) (Water Act)
Water planning	The Water Act contains two main mechanisms to support water planning: (i) water control district declarations; and (ii) water allocation plans. In declared water control districts, the priority water uses are identified and sustaining these uses forms the basis for the preparation of water allocation plans. Water allocation plans describe the sustainable yield for the area and water allocation for beneficial uses.
Approvals for taking water	Activities involving taking water are divided into two categories: (i) those that can occur without a water licence; and (ii) those that can only occur with a water licence. Water licences are not required to take water from a waterway or aquifer for stock, provided they have lawful access to the water. Most irrigation developments will require a water licence. The amount of water taken under a licence can be limited by annual announced allocations, which are guided by water allocation plans or default rules. Water licences tend to be issued for 10 years, with an option for renewal.
Water-related works approvals	Permits or licences under the Water Act are generally required to undertake water-related works. Specifically: (i) a permit is required to construct a water storage in a waterway, or in such a way as to affect the flow of water in a waterway; (ii) a permit is required to construct works to take groundwater; and (iii) a licence is required to recharge groundwater.

Table 27 Main elements of the water governance regime in Queensland

ELEMENT	COMMENT
Main statute	*Water Act 2000* (Qld) (Water Act)
Water planning	The Water Act's planning process involves the preparation of statutory water plans, which provide the basis for 'water entitlements' (water allocations, interim water allocations and water licenses).
Approvals for taking water	Activities involving the taking or interference with water are divided into two categories: (i) those that can occur without an authorisation; and (ii) those that can only occur under an authorisation. Generally, landholders adjoining a watercourse, or that have dams on their property, can take water for watering stock without authorisation. The Water Act provides for six main types of authorisations: (i) water licences; (ii) water allocations; (iii) water permits; (iv) resource operations licences; (v) distribution operations licences; and (vi) operations licences. Beef-related developments involving significant water extraction and use will typically be authorised under a water licence or allocation.
Water-related works approvals	Generally, the construction of water-related facilities requires development approval under the *Planning Act 2016* (Qld), as well as authorisations under the *Water Act 2000* to engage in the actual taking or interference. The details of the development approval requirements are spread across the *Planning Act 2016* and *Planning Regulation 2017* (Qld), and the *Water Act 2000* and *Water Regulation 2016* (Qld). A riverine protection permit may also be required under the Water Act to excavate or place fill in a watercourse, lake or spring.

Native title and water

In principle, native title applies to water in the same way as it does to land. A notable aspect of water-related native title is that the law will not recognise native title rights involving the *exclusive possession* of water. However, non-exclusive possession native title rights that entitle the holder to access and use water can exist. A similar situation exists in relation to tidal waters; the common law does not recognise exclusive possession native title rights and interests in relation to these waters but there can be non-exclusive possession native title.

Like all native title, the precise nature of the native title rights in water will depend on the traditional Indigenous laws and customs of the community involved, and whether the laws, and relevant connection to water and land, have been sustained. Where native title in relevant waters is claimed or has been determined to exist, proponents of developments that affect these interests are required to engage with Traditional Owners and the federal native title process.

Barriers related to rights to access water

In 2004, the Commonwealth and all states and territories agreed to the National Water Initiative (NWI). One of the key objectives of the NWI was to separate rights to water from land, and to establish nationally consistent and secure statutory water access entitlements. The NWI specifies the characteristics that these water access entitlements should have, and the need for rights and obligations of entitlement holders to be clearly specified. The NWI envisaged these water entitlements would be similar to property rights on land, in that they would be exclusive, tradable, and enforceable, and be backed by a system of registration similar to Torrens Title land. The NWI also outlines, among other things, the need for statutory-based water planning that reflects regional variability in water supply, and the importance of recognising Indigenous needs in relation to water access and management.

The NWI has prompted important reforms in water management across Australia that have improved water planning and the security of water entitlements in many areas. These reforms have resulted in the emergence of significant water markets, particularly in the Murray–Darling Basin, that are helping to reallocate water to the most productive uses.

In northern Australia, the process of incorporating the NWI requirements into the state and territory frameworks has been variable. Queensland has made the most progress, with its Water Act providing the statutory basis for responsive water planning and the creation of secure water entitlements. In contrast, the NT and WA are still in the preliminary stages of the reform process. As the Productivity Commission's 2017 water reform report states:

> The NWI envisages clear and secure water rights that are separate from land, readily tradeable and defined as a perpetual or open-ended share of the resource. However, Western Australia and the Northern Territory have not yet introduced legislation to create the statutory-based entitlement and planning arrangements that provide for these features. Delay in adopting legislative reforms is likely to constrain economic activity in these jurisdictions, as investors will not have certainty about water rights and allocation arrangements. This may also undermine long-term environmental outcomes.[7]

At the time of writing, both the WA and NT governments had initiated reform processes, with the aim of incorporating key elements of the NWI. In WA, the *Water Resources Management (Administration) Bill 2003* (WA), if passed, will consolidate the six existing state water statutes into one and create a two-tiered risk-based management framework involving:

- a simplified licensing and management regime for water resources that have low levels of allocation and are deemed to be a low management risk
- statutory water allocation plans and water access entitlement arrangements for high-risk and fully or over-allocated water resources where competition for water is high.[8]

The Bill is expected to be put before the Western Australian Parliament in 2019.

The Northern Territory Government is considering a suite of reforms include the following:[9]

- Extending the tenure of water licences – They are currently issued for a term of 10 years with the option of renewal. The government is considering issuing longer-term licences for significant developments.
- Changing the processes for the allocation of water licences to promote the efficient use of water – Water licences are currently issued on a first-come-first-served basis, which can result in inefficient water use in catchments with high water demand. To address this, the government is considering introducing a more strategic water allocation process, along with changes in the conditions of water licences to encourage development (e.g. the need for licence holders to meet development milestones) and statutory amendments to enable water trading outside of areas with water allocation plans.
- Creating tradable water entitlements that are separate from interests in land – water licences in the NT are currently tied to land and are term limited. The government is considering creating

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[7] Productivity Commission, *National Water Reform* (Australian Government, 2017), p 12

[8] See: http://www.water.wa.gov.au/legislation/water/water-resource-management-legislation (accessed 25 June 2019)

[9] Northern Territory Government, *Northern Territory Water Regulatory Reform: Directions Paper* (Northern Territory Government, 2018)

new tradable perpetual water entitlements, at least for some catchments (e.g. where there is high demand and water is fully allocated).

- Changing the NT Water Allocation Planning Framework to promote more consistent decision making in relation to water allocations – the framework guides the determination of the 'estimated sustainable yield' under water allocation plans. The sustainable yield determines the volume of water that can be allocated for consumptive use. The changes would provide a more robust framework for decision making on these core issues.

The slow rate of progress with water reform, particularly in WA and the NT, could potentially be holding back development in the northern Australia beef industry, especially in relation to irrigation development on pastoral lands. This is the case in the Pilbara and Kimberley, where navigating the regulatory requirements for water developments can take many years. The risk here relates predominantly to new developments. The day-to-day operations of most pastoral enterprises are unlikely to be materially affected by the uncertainties associated with the water planning and access regimes. Generally, pastoralists will have rights of access to the water resources on or adjoining their properties, other than groundwater. Where groundwater is relied on for stock watering, pastoralists should already hold relevant licences. While not posing a material challenge to the continuation of most existing operations, the institutional uncertainties potentially create obstacles to new investment that may be limiting the capacity of pastoral enterprises to diversify, intensify and expand their operations.

Although this issue is a risk, it is not clear how material the relevant barriers are to cattle-related developments. In many northern pastoral areas, the demand for water is limited. In contrast to the situation in much of southern Australia, there are few pastoral catchments in northern Australia where water resources are over-allocated. Due to the underutilisation of the available resources, governments have been actively encouraging water-related developments in many regions. This dynamic suggests the barriers posed by the uncertainties surrounding water planning and water entitlements may not be overly material relative to other issues, particularly the availability of productive land, distances from markets, production costs and access to capital. Further research is warranted to evaluate the extent of any water-related regulatory barriers and investigate the most cost-effective solutions to any identified problems.

10.3.3 Planning, environmental protection and heritage

Overview of regulatory regimes

Land-use planning is primarily the responsibility of the states and territories. The states and territories also have environment and heritage laws that seek to manage the externalities associated with the use and development of land and water resources. The Commonwealth shares the responsibility for environmental and heritage matters with the states and territories but it has no direct role in the regulation of land-use planning. The sections below provide a brief overview of the main planning, environment and heritage regimes at the federal and state/territory levels.

Commonwealth

The principal federal environment and heritage statute is the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act), which contains an environmental impact assessment (EIA) regime that regulates actions that have significant impacts on protected matters, being:

- the Matters of National Environmental Significance
- the environment on Commonwealth land
- the environment generally where the relevant action is carried out by a Commonwealth agency or on Commonwealth land.

There are currently nine Matters of National Environmental Significance: world heritage values of World Heritage Areas; national heritage values of National Heritage;[10] ecological character of Ramsar-listed wetlands; listed threatened species and ecological communities; listed migratory species; the impacts of nuclear actions on the environment; the environment in Commonwealth marine areas and Commonwealth managed fisheries; the environment in the Great Barrier Reef Marine Park; and coal seam gas and large coal mining developments.[11]

Where a proposed action could have a significant impact on a protected matter, the proponent is required to refer details of the action to the federal Environment Minister (via the Department of the Environment and Energy), who then makes a determination on whether significant impacts are likely (known as a 'controlled action decision'). If a project is deemed to be a controlled action, the project must be formally assessed and approved under the legislation. To reduce duplication, EPBC Act assessments can be undertaken through state/territory assessment processes, under Commonwealth–state/territory bilateral agreements. The federal Environment Minister can also accredit state/territory processes on a one-off basis for the same purposes.

Every year, in the order of 300 to 400 projects are referred under the EPBC Act. Approximately 30% of these are deemed to be controlled actions, with the remainder being allowed to proceed without formal assessment and approval. Very few projects are refused approval through the process. However, proponents of controlled actions are generally required to make adjustments to their projects to mitigate and offset impacts on protected matters.

The EPBC Act allows the Environment Minister to initiate strategic assessments with the agreement of a state or territory government. Strategic assessments are a form of EIA, only they focus on plans, policies and programs rather than individual projects. Where they are undertaken, they can result in individual actions being exempt from the requirement to make referrals provided they are carried out in accordance with the terms of the assessed and endorsed plan, policy or program.

The EPBC Act contains the Commonwealth's primary heritage regulations. The EPBC Act protects world, national and Commonwealth heritage places, imposes restrictions on Commonwealth agencies in relation to their dealings with heritage issues and requires management plans to be prepared for most listed heritage sites. In addition to this, the Commonwealth also has a stand-alone Indigenous heritage protection statute, the *Aboriginal and Torres Strait Islander Heritage*

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[10] The *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) contains a Commonwealth Heritage List for places of heritage significance in Commonwealth areas, which are protected through the Commonwealth areas provisions of the Environmental Impact Assessment and Approval (EIAA) regime and Part 15 (the Commonwealth reserves regime).

[11] Coal seam gas and coal mine projects are only a matter of national environmental significance if they could have material adverse impacts on a water resource.

Protection Act 1984 (Cth) (ATSIHP Act). Declarations can be issued under the ATSIHP Act to protect significant Aboriginal areas and objects from injury or desecration. These declarations are rarely made but they can be powerful, forcing the cessation of projects affecting the relevant area.

In recognition of the complexity of the applicable approval requirements, the Commonwealth has established a Major Projects Facilitation Program that provides information and approval facilitation services to projects that are given major projects status. The program is run by the Major Projects Facilitation Agency. There is no equivalent program for smaller projects. However, information on the EPBC Act is available through the Department of the Environment and Energy, which actively encourages proponents to consult with it on project proposals to clarify referral, assessment and approval requirements.

Western Australia, Northern Territory and Queensland

Land-use planning

The three northern jurisdictions have established regulatory processes to manage the impacts of projects on planning, environment and heritage issues. These regulatory regimes share some common features but there are material differences in their structure, when and how they apply, and the nature of their assessment and approval processes.

In WA, the NT and Queensland, the main planning statutes are the *Planning and Development Act 2005* (WA), *Planning Act 1999* (NT) and *Planning Act 2016* (Qld). These planning statutes have two main components: processes for the preparation of policies and plans, which set the policy and regulatory framework governing the use and development of land; and development approval processes, which govern the issuance of approvals for specific projects.

Under the planning statutes, there is a hierarchy of planning instruments that cascade down from state, to regional, then local level. These instruments contain relevant planning objectives and strategies, as well as detailed and often spatially based planning regulations that specify the range of land uses and development allowed or prohibited in certain areas. Local planning schemes are usually the principal planning instruments that regulate land use and development. They contain regulations that control the use and development of land, and high-level objectives, strategies and principles to guide the exercise of approval powers and performance of strategic planning functions. The regulations are usually based on spatially explicit zoning, which specifies the permissible uses of the land and restrictions on development. In Queensland, overlays are also used to control development. Through zones and overlays, local planning schemes generally divide development (where development is defined as including changes in uses) into three categories: prohibited development (cannot be carried out on the subject land); assessable development (can only be carried out with planning approval); and accepted or permitted development (can be carried out without approval).

Where a development is assessable, an application must be made to the relevant consent authority. Depending on the nature and location of the development, the consent authority for these purposes can be the local government, a government agency or the planning minister. Government agencies and ministers also often play a role in decision making as a referral authority, either providing advice or direction to the consent authority on the determination of the development application.

Significant beef-related developments will often require approval under the planning regulations. However, this will not always be the case. Typically, activities involving broadacre grazing operations will not require planning approval, unless they involve the clearance of native vegetation, installation of new water infrastructure, or a change in land use (e.g. establishment of irrigated cropping to help diversify the enterprise). This is largely because of the existence of ‘existing use rights’, an issue that is discussed further below. In contrast, new feedlot developments will almost always require planning approval. The nature of the planning requirements can vary significantly between regions, and will often depend on the content of the applicable local planning scheme. Proponents of new developments should always seek advice on planning issues before commencing operations.

Environment protection

The environment protection regimes in WA, the NT and Queensland have a number of similar features. In particular, they all contain two main elements: an EIA regime for assessing and regulating projects that could have material impacts on the environment,[12] and a regulatory regime that controls activities that could cause pollution or other significant environmental harm.

EIA regimes

In WA and the NT, the EIA processes work through the *Environmental Protection Act 1986* (WA) and *Environmental Assessment Act 1982* (NT). In these two jurisdictions, the EIA regimes follow a standard format, containing referral, screening, assessment and approval phases. Proposals likely to have a significant effect on the environment are required to be referred to the relevant Environmental Protection Authority (EPA) for assessment. Having received a referral, the EPA must decide whether to assess the proposal (the screening decision) and, if so, what level of assessment applies and the scope of the assessment. The assessment document is generally prepared by the proponent in accordance with guidelines set by the EPA, after which it is published for public comment. After the public comment period has ended, the assessment documentation is finalised and the EPA prepares an assessment report.

In WA, after the EPA assessment is complete, and it has made its recommendation on whether the proposal should be allowed to proceed, the responsibility for approving the project passes to the Environment Minister. The Environment Minister is required to consult with the other ministers or government agencies that have decision-making responsibilities in relation to the proposal to determine whether the proposal should be allowed to proceed, and if so, on what conditions. In the NT, the EPA’s assessment report is provided to the Environment Minister but their role is advisory. The Environment Minister is required to provide the EPA’s assessment report to the ‘responsible minister’ for decision, with additional comments if they consider they are necessary. In this context, the responsible minister is another minister with statutory decision-making responsibilities in relation to the project (e.g. the Planning Minister).

[12] The EIAA regimes in WA, NT and Queensland are linked to the federal EPBC Act through assessment bilateral agreements. Assessment bilateral agreements allow state/territory assessments to substitute for federal assessments under the EPBC Act’s EIAA regime.

In Queensland, the environmental impact assessment and approval (EIAA) requirements are contained in three main statutes: the *Planning Act 2016*, the *State Development and Public Works Organisation Act 1971* (Qld) and the *Environmental Protection Act 1994* (Qld). Most environmental assessments conducted in relation to the beef industry are likely to be carried out under the Planning Act or State Development and Public Works Organisation Act. There is also the prospect of environmental assessments being triggered by an 'environmentally relevant activity' that could cause significant environmental harm within the terms of the Environmental Protection Act (see below).

Activities causing significant environmental harm

WA, NT and Queensland all have environmental protection statutes that require environmental approvals to be obtained for activities that could cause serious or material environmental harm. However, the scope of these differs. In WA, environmental harm is defined broadly under the *Environmental Protection Act 1986*, and includes the removal of, or damage to, native vegetation or the habitat of native vegetation or indigenous aquatic or terrestrial animals, alteration of the environment to its detriment or degradation or potential detriment or degradation, and alteration of the environment to the detriment or potential detriment of an environmental value.

In the NT, the equivalent statutory provisions are found in the *Waste Management and Pollution Control Act 1998* (NT). However, the scope of the environmental harm obligations is narrower, being confined largely to activities 'likely to cause pollution resulting in environmental harm' or that 'is likely to generate waste'. Proponents of Schedule 2 activities are also required to obtain environmental approvals or licences under the Act. However, the listed Schedule 2 activities mainly relate to waste facilities, the burial of waste and the processing and storage of petrol and other hydrocarbons.

In Queensland, under the *Environmental Protection Act 1994*, it is an offence to carry out an 'environmentally relevant activity', or to cause material or serious environmental harm, without an environmental authority. Environmentally relevant activities are defined for these purposes as activities that could contaminate and harm the environment that are prescribed under the regulations. The *Environmental Protection Regulation 2008* (Qld) contains a list of prescribed environmentally relevant activities, which includes intensive animal feedlots.

Heritage

The institutions governing the protection of heritage values and places in WA, NT and Queensland are spread across a number of statutes, including those concerning land-use planning, environment protection and national parks and reserves. However, each jurisdiction has heritage-specific statutes. In all three jurisdictions, the heritage protection regimes under these statutes have two components: a general heritage regime and a regime specifically for places and objects of Indigenous heritage significance.

In WA, the general heritage regime is contained in the *Heritage Act 2018* (WA). The centrepiece of the regime is the State Register of Heritage Places. Protection of places on the register from the impacts of development activities is provided through the *Planning and Development Act 2005* and related advisory processes under the Heritage Act. WA's Indigenous heritage protection regime is governed by the *Aboriginal Heritage Act 1972* (WA). Prior to carrying out any development, proponents are legally obliged to take reasonable measures to assess whether the subject land is, or contains, sites or objects of Indigenous heritage significance.

There are two specific heritage statutes in the NT: the *Heritage Act 2011* (NT) and the *Northern Territory Aboriginal Sacred Sites Act 1989* (NT). The Heritage Act protects three classes of places and objects: places and objects declared to be heritage places and objects under part 2.2 of the Act, places and objects declared to be protected classes of places and objects of heritage significance under part 2.3, and Aboriginal and Macassan archaeological places and objects. Parts 2.2 and 2.3 of the Act contain the NT's 'general heritage regime'. The NT's Indigenous heritage protection regime is contained in the Heritage Act and Northern Territory Aboriginal Sacred Sites Act. The Heritage Act protects Aboriginal archaeological places and objects, while the Northern Territory Aboriginal Sacred Sites Act protects sites that are sacred to Indigenous people or of significance according to Indigenous tradition. Generally, in order to carry out development on a heritage place covered by the Heritage Act, including Aboriginal archaeological places, it is necessary to obtain a work approval, or enter into a heritage agreement, under the Act. Under the Northern Territory Aboriginal Sacred Sites Act, in order to enter onto, carry out work on or use a sacred site, it is necessary to have a certificate under the Act from the Aboriginal Areas Protection Authority or responsible minister.

In Queensland, there are three main heritage statutes: one governing non-Indigenous cultural heritage, the *Queensland Heritage Act 1992* (Qld) (the general heritage regime); and two governing Indigenous cultural heritage, the *Aboriginal Cultural Heritage Act 2003* (Qld) and the *Torres Strait Islander Cultural Heritage Act 2003* (Qld). The Queensland Heritage Act establishes the Queensland Heritage Register to record places of state cultural heritage significance, with the exception of places of Indigenous heritage significance. The Act also requires local governments to identify and record places of local heritage significance, either through local heritage registers or their local planning schemes. Protection of places of state or local heritage significance is afforded through the Planning Act. The two Indigenous heritage statutes establish a regime for the protection and conservation of Aboriginal and Torres Strait Islander cultural heritage across Queensland. Among other things, they impose a general 'cultural heritage duty of care' not to harm Aboriginal or Torres Strait Islander cultural heritage. This duty of care requires a person who carries out an activity to take 'all reasonable and practicable measures to ensure the activity does not harm Aboriginal cultural heritage'.[13]

Major projects

All three jurisdictions have processes to help major projects. In WA, this is the Lead Agency Framework policy. The NT has a similar Major Project Status Policy Framework. There are two relevant processes in Queensland: the State Development and Public Works Organisation Act process for coordinated projects; and the State Assessment and Referral Agency (which forms part of the Queensland Department of Infrastructure, Local Government and Planning) process for projects requiring assessment under the Planning Act that affect state interests. All of these

[13] *Aboriginal Cultural Heritage Act 2003* (Qld), s 23

processes are intended to lower transaction costs for major project proponents by streamlining government approval requirements.

Barriers related to planning, environment and heritage laws

State and territory planning regulations have 'existing use' provisions that generally ensure landholders can continue to undertake existing lawful uses (e.g. continue to graze cattle on pastoral leases or operate intensive feedlots), even if the planning requirements are subsequently changed. The WA and Queensland planning statutes also have 'injurious affection' provisions that provide landholders with a right to compensation if planning instruments are changed in a manner that prevents the continuance of a previously lawful use or curbs the development opportunities associated with land for public purposes.[14] There are similar provisions in the federal EPBC Act that ensure pastoralists and feedlot owners do not need to seek approval for activities that were being undertaken, or that were approved, prior to July 2000 (when the EPBC Act commenced).

The presence of these protections for existing uses means the main barriers associated with planning, environment and heritage laws relate to new developments, including projects involving the intensification, extension or diversification of existing operations. Depending on where new projects are undertaken, the nature of the project and its potential environmental impacts, proponents may be required to obtain planning, environmental and/or heritage approvals, and undergo environmental assessment. These approvals can be (and often are) required to be obtained from multiple state/territory agencies, as well as the federal Department of the Environment and Energy.

The barriers that stem from these approvals relate to the limitation of development options, and the costs, delays and uncertainty associated with relevant assessment and approval processes. Planning, environment and heritage laws can restrict the use and development of land, thereby preventing proposed developments from proceeding or limiting their scope. However, even when they do not directly limit development options, they can still create material barriers to investment. Proponents have to expend resources in obtaining approvals, generally through the devotion of staff time and engagement of external consultants. The process of applying for approvals, getting projects assessed, and negotiating the conditions of approval is time consuming and can delay the commencement of projects. The delays create additional costs, in the form of hold up costs and by delaying project returns. The final element is regulatory uncertainty – proponents often do not know what the assessment and approval requirements are, and how long the process will take, and these uncertainties can deter investment.

Industry concerns about planning, environment and heritage regulations tend to focus on five main issues:

- Uncertainty about when approvals are required – At times, the regulatory triggers for approvals are vague or ambiguous, which can make it difficult for proponents to determine whether approvals are required and evaluate investment risks.
- Uncertainty about what information must be submitted during assessment and approval processes – There are often disagreements between proponents and regulators about the

[14] In the NT, the planning minister has reasonably broad powers to revoke and modify development permits issued under the *Planning Act*. However, compensation is payable for wasted expenditure incurred in reliance on a development permit that is revoked or modified.

information that must or should be submitted in assessment and approval processes, which can increase costs and cause delays.

- Uncertainty about the design, mitigation and environmental offset requirements that must be met to secure approvals – The regulatory regimes often give decision makers broad discretions concerning the granting of approvals and attachment of conditions, a downside of which is that it can make it difficult for proponents to anticipate the requirements that must be satisfied to secure approvals.
- Complexity associated with the satisfaction and negotiation of multiple state/territory and federal approvals – The overlapping nature of the regulatory regimes can complicate approval processes, forcing proponents to negotiate and satisfy different approval requirements.
- Project delays that stem from the above – The literature suggests that the main costs associated with assessment and approval processes relate to delays rather than direct outlays and other resource costs.

The length of the assessment and approval processes is variable, and depends on the nature of the regulatory regime, the project impacts and how the process is run by the proponent and regulator. For example, between 2010 and 2018, 189 projects were approved under the EPBC Act in WA, the NT and Queensland. The length of time it took to secure these approvals ranged from 71 to 2662 days. Almost 40% of these approvals took less than 365 days, while 13% took more than 1000 days (Macintosh et al., 2018).

There is a need for further research to evaluate the extent to which planning, environment and heritage regulations are deterring investment in the northern Australia beef industry. As noted above, broadacre grazing operations rarely require approvals, unless they involve the establishment of new water infrastructure or significant clearing of native vegetation. Arguably, the restrictions on non-pastoral uses on Crown leases are more important and have a greater impact on the stability and profitability of pastoral enterprises. Additional research on the perceptions of pastoralists and operation of the relevant regulatory regimes could help to isolate the nature and magnitude of the applicable barriers and potential solutions.

Feedlot developments will typically require planning and environmental approvals. However, it is unclear whether proponents see these requirements as a material obstacle to investment. There is a reasonable likelihood that market-related issues are the primary barriers and that any issues associated with planning, environmental and heritage approvals are of secondary importance. To clarify this, further information should be collected from beef industry stakeholders on the nature of the barriers, including regulatory barriers, to feedlot developments.

10.3.4 Vegetation management

Overview of vegetation management laws

Commonwealth

The clearing and management of native vegetation is regulated by both the federal and state/territory governments. Federal regulation of vegetation management occurs through the EPBC Act EIA regime. Where the clearing of native vegetation could have a significant impact on a matter protected under the Act, the proponent must refer details of the action to the Department of the Environment and Energy. The failure to refer an action that has a significant adverse effect on a protected matter can result in the imposition of fines of up to $1.05 million for individuals and $10.5 million for corporations, and jail terms of up to 7 years.

Most of the vegetation clearing that is undertaken for agricultural purposes in Australia is not referred under the EPBC Act, either due to the absence of protected matters in relevant areas or non-compliance. Between January 2010 and March 2019, there were only 32 agricultural-related project referrals under the Act, and only 20 of these were declared to be controlled actions. The 20 controlled actions involved the clearing of a total of 28,565 ha, 10,291 ha of which was from Queensland (Department of Environment and Energy, 2019a). In comparison, over the same period, 563,000 ha of remnant forest was cleared across Australia, including 347,000 ha from Queensland (Department of Environment and Energy, 2019b).

The small amount of clearing referred under the EPBC Act does not necessarily mean the legislation is not deterring investment. There have been a number of high-profile incidents over the past decade involving alleged breaches of the legislation by graziers, which have prompted compliance actions. These incidents may be influencing investment decisions in the industry, particularly in Queensland. Immediately prior to publication, the Australian Government published a commissioned report on the impacts of the EPBC Act on agriculture (Aither, 2018). Further research may be warranted to supplement the material contained in the review report.

Western Australia

Agriculture-related native vegetation clearing in WA is primarily regulated under part V, division 2 of the Environmental Protection Act. Under section 51C, it is an offence to clear native vegetation without a clearing permit under the Environmental Protection Act or other 'prescribed approval',[15] unless it is low impact clearing authorised under the *Environment Protection (Clearing of Native Vegetation) Regulations 2004* (WA). Broadly, the low impact clearing exemptions allow landholders to clear up to 5 ha/year for specified purposes (e.g. to facilitate the construction of a building, to reduce fire hazards, for fencing, vehicle and walking tracks and to clear regrowth for agricultural purposes) or under a code of practice, providing the clearing is not in an environmentally sensitive area. The native vegetation clearing provisions of the Environmental Protection Act are administered by the Department of Environment Regulation.

In addition to the restrictions that apply under the Environmental Protection Act, native vegetation clearing on pastoral land is generally prohibited, unless it is done under a permit issued under the LA Act. The recently commenced *Biodiversity Conservation Act 2016* (WA) also imposes further requirements that can regulate the clearing of native vegetation. The Act provides for the listing of threatened species and ecological communities and then imposes a collection of obligations in relation to the species and communities that are listed. These include a prohibition on actions that modify the occurrence of a listed threatened ecological community or involve the taking of threatened flora on Crown land, other than in accordance with an authorisation from the Environment Minister under the Act. In granting such an authorisation, the minister can require

[15] Prescribed approvals are listed in schedule 6 of the *Environmental Protection Act 1986* (WA) and include an approval, works approval or licence issued under the Act.

the proponent to offset the associated environmental harm, including by conserving other land or making a monetary contribution towards the purchase of land of conservation value. The Act also provides for the registration and protection of habitat that is critical to the survival of listed threatened species and communities, including through the issuance of habitat conservation notices that can restrict the clearing of vegetation and require landholders to repair habitat damage that has already occurred.

Northern Territory

Native vegetation clearing in the NT is regulated through the Planning Act and PL Act. Which statute applies depends on the tenure of the land. If the land is freehold, the Planning Act will apply, and a development permit will generally be required to be obtained, either from the planning minister or Development Consent Authority. If the clearing involves pastoral leasehold land, approval is required under the PL Act from the Pastoral Land Board

The Planning Act establishes the Northern Territory Planning Scheme (NTPS), which formally recognises policy, guidelines or assessment criteria to assist the consent authority to assess development applications. The *Land clearing guidelines*, a referenced document in the NTPS, sets out in detail the circumstances in which land clearing may be undertaken in the NT.[16] Generally, a permit is required for the removal of native vegetation if the clearing involves more than one hectare on a single parcel of land. This general rule does not apply if:

- the native vegetation was cleared prior to the introduction of controls and has been continually maintained free of native vegetation
- the native vegetation was previously cleared in accordance with the terms and conditions of a development permit (i.e. a landholder can re-clear vegetation continually to control regrowth)
- the proposed clearing works are subject to an exemption outlined in clause 1.3 of the NTPS (such as for the purpose of a public road).

The PL Act prohibits the clearing of any pastoral leasehold land without the written consent of the Pastoral Land Board. There are only a limited number of exemptions to this broad prohibition. These include the clearing of declared weeds, lopping of a tree, incidental tree death through grazing or fire, and clearing in the course of traditional Indigenous land uses. The breadth of the requirement means that most developments on pastoral land that involve the clearing of native vegetation will require approval from the Pastoral Land Board.[17]

Queensland

Native vegetation clearing in Queensland is regulated through two largely separate regimes: the planning-based system, which involves the Planning Act and *Vegetation Management Act 1999* (Qld);[18] and the ‘protected plants’ regime, which applies under the *Nature Conservation Act 1992* (Qld).

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[16] See: https://nt.gov.au/__data/assets/pdf_file/0007/236815/land-clearing-guidelines-2019.pdf (30 June 2019)

[17] For the *Northern Territory Pastoral Land Clearing Guidelines*, see: https://nt.gov.au/__data/assets/pdf_file/0003/236865/pastoral-land-clearing-guidelines-march-2019.pdf (30 June 2019).

[18] See also the *Vegetation Management Regulation 2012* (Qld), particularly schedule 10, part 3.

Under the planning-based regime, agriculture-related clearing can occur via one of four avenues:

- exempt clearing work (does not require approval or notification)
- clearing under an accepted development vegetation clearing code (requires notification and adherence with applicable code)
- clearing under an area management plan (requires notification and adherence with plan)
- clearing under a development approval.

Like other parts of the planning system, the operation of the regime is based on spatially explicit restrictions which, in this case, are articulated through vegetation maps. Through these maps, land is assigned to one of five categories: Category A (areas subject to compliance notices, offsets and voluntary declarations); Category B (remnant vegetation); Category C (high-value regrowth, being vegetation that has not been cleared in the last 15 years on freehold or leasehold land); Category R (regrowth within 50 m of watercourses in priority reef catchment areas); and Category X (areas exempt from regulation under the Act). Which avenue a proposed clearing development must follow depends on what category of land is involved, as expressed in the applicable vegetation maps.

Generally, clearing for agriculture and grazing purposes on Category X land is exempt from the Planning Act requirements. In these areas, the main potential restrictions stem from the Nature Conservation Act. Importantly, the Vegetation Management Act allows property owners to 'lock in' Category X classifications through property maps of assessable vegetation (PMAV) (property-scale maps that identify protected and clearable vegetation).

Outside of Category X lands, vegetation clearing can only occur if it is covered by a specified exemption (e.g. for fencing, roads or fire), is carried out under an applicable accepted development vegetation clearing code or area management plan, or is approved under the Planning Act. Amendments to the Vegetation Management Act that took effect on 8 March 2018 narrowed the grounds on which development approvals can be issued for agriculture-related land clearing. Prior to the amendments taking effect, it was possible to obtain approval for 'high-value irrigated agriculture'. This option no longer applies. However, approvals can still be given in relation to coordinated projects under the State Development and Public Works Organisation Act and for fodder harvesting, managing thickened vegetation, and clearing encroachment. Decisions on development applications concerning native vegetation clearing are made in accordance with the State Development Assessment Provisions: State Code 16: Native vegetation clearing.[19] In many cases, proponents are required to develop offsets to gain approvals, meaning they may need to purchase and covenant and/or revegetate other land to compensate for the impacts of the clearing.

The protected plants regime under the Nature Conservation Act is intended to protect particular native plants from taking or clearing. Broadly stated, the general rule under this regime is that it is an offence to clear endangered, vulnerable or near threatened plants in a high-risk area, other than in accordance with a clearing permit issued by the Department of Environment and Heritage Protection. High-risk areas are identified in so-called 'trigger maps'. Prior to carrying out clearing,

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[19] See: https://dsdmipprd.blob.core.windows.net/general/sdap-2-5-state-code-16.pdf (30 June 2019)

proponents must check the flora survey trigger map to determine if any part of the subject land is within a high-risk area. Where the subject land is within a high-risk area, the proponent must undertake a flora survey in accordance with the Flora Survey Guidelines. If the survey does not detect endangered, vulnerable or near threatened plants, the clearing can occur, provided notice is provided to the department at least one week prior to commencement and the proponent does not otherwise become aware of the presence of endangered, vulnerable or near threatened plants. If endangered, vulnerable or near threatened plants are detected, the clearing can only occur under a clearing permit.

Barriers related to vegetation management laws

The regulatory barriers related to the vegetation management laws are similar to those concerning other planning, environment and heritage regulations. They can limit land use and development options and the assessment and approval processes can deter investment by increases costs, delaying projects and creating uncertainty.

A defining feature of the vegetation management laws over the past two decades has been instability, particularly in Queensland. Major changes to Queensland vegetation management laws were made in 2004, 2009, 2013 and 2018. In addition to these scheme-wide changes, there have been significant changes in relevant maps and regulations, including to the trigger maps issued under the Nature Conservation Act. The policy instability in the area increases the costs of compliance and magnifies the uncertainty in the eyes of investors. Further research is warranted to quantify the extent to which vegetation management laws are obstructing investment in the northern Australia beef industry.

10.3.5 Biosecurity

Overview of biosecurity laws

The regulation of the biosecurity risks associated with broadacre grazing and the operation of feedlots is largely the responsibility of states and territories. The Commonwealth's role in biosecurity management is largely confined to the control of organisms, diseases and potential carriers entering and leaving Australia. Set out below is a brief summary of the relevant Commonwealth, state and territory biosecurity regimes.

Commonwealth

For cattle producers, the most relevant federal restrictions concern the importation of live cattle, cattle semen and cattle embryos from other countries. The importation of these and other similar materials is regulated under the *Biosecurity Act 2015* (Cth) and part 13A of the EPBC Act.

The Biosecurity Act is the principal statute under which Australia's biosecurity interests are protected at a national level. The Biosecurity Act creates three classes of goods:

- prohibited goods – goods that the Director of Biosecurity and the Director of Human Biosecurity have determined must not be brought or imported into Australian territory
- conditionally non-prohibited goods – goods that may only be brought or imported into Australian territory if certain specified conditions are complied with

- suspended goods – goods that the Director of Biosecurity has determined may not be brought or imported into Australian territory for a specified period.

The classification of goods into these categories is undertaken by the Director of Biosecurity and Director of Human Biosecurity. Prior to making a decision on how to classify a good, the Director of Biosecurity generally undertakes a biosecurity risk analysis (BIRA). A BIRA is an evaluation of the level of biosecurity risk associated with particular goods, or a particular class of goods, that may be imported, or are proposed to be imported, into Australian territory. Typically, it will involve the assessment of the risks associated with the importation of the good and the identification of conditions that must be met to manage the level of biosecurity risk associated with the goods, or the class of goods.

Where goods are classified as conditionally non-prohibited goods, their importation will typically only be allowed if it is covered by an import permit issued by the Director of Biosecurity under part 3 of the Biosecurity Act. In making a decision to issue a permit, the Director is required to apply the prescribed 'appropriate Level of Protection for Australia', which is 'a high level of sanitary and phytosanitary protection aimed at reducing biosecurity risks to a very low level, but not to zero'.

At present, the importation of live cattle is prohibited under the Biosecurity Act. However, cattle embryos and semen can be imported from a selection of countries, provided certain conditions are met. Relevant countries include Canada, the Member States of the European Union, New Caledonia, New Zealand, Norway, Switzerland and the United States. Details of the import restrictions can be viewed through the Biosecurity Import Conditions system (BICON): http://www.agriculture.gov.au/import/online-services/bicon.

Part 13A of the EPBC Act contains a regulatory regime that governs the import and export of wildlife, which is linked to the Convention on International Trade in Endangered Species (CITES). Part of this regime regulates the importation of live specimens, being live plants and animals. It does this through a list of specimens that are suitable for live import. Where a specimen is on the list, it can be imported without restriction under the EPBC Act. If a specimen is not on the list, it can only be imported with a permit. At present, the list includes both Bos indicus and Bos taurus, meaning there are no EPBC Act-related restrictions on the importation of live cattle. The impediment to these imports is the Biosecurity Act.

In addition to the above issues, it should be noted that the Biosecurity Act provides for the declaration of a biosecurity emergency (i.e. one that poses an immediate and severe threat to animals, the environment, or economic activities so related). If such a declaration is made, the Commonwealth can take over control of internal biosecurity regulation from the states and territories. To date, this power has not been exercised.

Western Australia

In WA, there are two main biosecurity statutes: the *Biosecurity and Agriculture Management Act 2007* (WA) (BAM Act) and *Exotic Diseases of Animals Act 1993* (WA).[20] The BAM Act regulates the importation of organisms into WA and the management of biosecurity issues within the state. This

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[20] Other relevant legislation includes the *Emergency Management Act 2005* (WA), *Agricultural Produce Commission Act 198*8 (WA) and *Health Act 1911* (WA).

is achieved by assigning organisms to one of three categories under the Western Australian Organism List (WAOL): permitted, prohibited or unlisted. Which category an organism is assigned to determines the regulatory restrictions that apply to the importation of the organism into WA and whether a person in charge of a place or thing is required to take any measures to control the organism within the state. In addition to the regulation of organisms, the BAM Act also regulates dealings with 'prescribed potential carriers' of organisms that pose biosecurity risks. Relevantly, these prescribed potential carriers include agricultural machinery, animals and animal products, plants, soil, and containers used to transport animals.

The general rules regarding the importation of organisms and prescribed potential carriers into WA under the BAM Act are that:

- it is an offence to import a prohibited organism except in accordance with an import permit and the *Biosecurity and Agriculture Management Regulations 2013* (WA) (BAM Regulations)
- it is an offence to import an unlisted organism except in accordance with an import permit and the BAM Regulations
- it is an offence to import prescribed potential carriers except in accordance with the BAM Regulations
- it is an offence to import a permitted organism that is classified as requiring a permit other than in accordance with an import permit.

Jail terms of up to 12 months and fines of up to $100,000 can be imposed for the unlawful importation of materials into WA.

Relevantly, beef cattle are a permitted import, subject to import conditions. Bison cross-breeds (or 'beefalo' constituting more than 37.5% bison) are registered as a declared pest for the whole of the state and are prohibited.

The regulation of biosecurity-related activities within the state hinges on whether the relevant organism is a declared pest. All prohibited organisms on the WAOL are declared pests, along with any other organism specified in a pest declaration made by the responsible minister. Organisms can be made declared pests for the whole or part of the state. Where pests are declared, they are also assigned to control and keeping categories, which dictate the regulatory measures that apply to relevant dealings.

The inclusion of organisms within the list of declared pests is the central tool through which measures are taken in respect of internal state biosecurity risks. The BAM Act prohibits a range of dealings with declared pests, including keeping, breeding or cultivating them, and moving or releasing them into the environment. A person wanting to deal with a declared pest must be authorised under the Act and act in accordance with the terms of the authorisation. Further, if a person finds a declared pest, they are required to report it to the state agriculture department. In areas where an organism is a declared pest, landholders can be required to take 'prescribed control measures' to control its spread. These can include the isolation of an infected thing or organism and the taking various measures (e.g. poisoning, fumigation, chemical treatment, mustering, shearing and shooting) to eradicate or control the pest. The department and inspectors can also issue pest control and quarantine notices to landholders requiring them to adhere to specified conditions, prescribed codes of practice or applicable management plans. Management plans are issued by the minister and set down required pest control measures for identified areas.

Another key element of the BAM Act is the stock registration and identification requirements, which are related to the National Livestock Identification System (NLIS). The NLIS established a cooperative national scheme for the registration, identification and tracking of lifetime movements of livestock, including cattle. The traceability established through the scheme allows for the efficient management of biosecurity and food contamination issues. To give effect to the NLIS, under the BAM Act and accompanying regulations, there are mandatory requirements for stock owners to be registered, processes for the allocation and transfer of property identification codes (PICs) and buyer identification codes (BICs), requirements for stockowners to identify stock through the use of earmarks or brands (typically, for northern Australia producers, before the stock are moved or reach 18 months of age), and processes for the approval of the use of specific identifiers.

The Exotic Diseases of Animals Act imposes regulatory requirements concerning listed 'exotic' diseases. In relation to such diseases, quarantine officers have a suite of powers, including to stop the movement or order the movement of any animal or animal product and to disinfect or fumigate any land, place, premises or vehicle. An officer who suspects any animal, land, place, premises or other thing is infected may require any owner or person apparently in charge or control to, among other things, carry out disinfection or fumigation (including of himself or herself) and confine or move any animal.

Northern Territory

Unlike most other Australian jurisdictions, the NT does not yet have a comprehensive biosecurity act. The regulation of biosecurity issues associated with the cattle industry is accomplished via provisions within the *Livestock Act 2008* (NT) and accompanying *Livestock Regulations 2009* (NT), and the *Weeds Management Act 2001* (NT).

Central to the regulatory framework established under the Livestock Act is power of the Chief Executive of the Department of Primary Industry and Resources to classify a disease or pathogen into one of four categories:

- notifiable – a disease or pathogen that poses a threat to the livestock industry
- emergency – a disease or pathogen specified under an agreement between Australian states and territories
- endemic – a notifiable disease endemic to Australia
- exotic – a notifiable disease not endemic to Australia.

The classification of a disease or pathogen into one of these categories triggers a number of control powers and gives rise to several obligations on landholders with livestock that are infected with the disease or pathogen. Relevantly, these include obligations to notify the Chief Inspector of the existence of infected livestock and to isolate livestock from relevant pathogens. Stock owners are also prohibited from selling infected livestock or products from livestock that were infected before their death without authorisation from the Chief Inspector.

Quarantine orders can be issued by biosecurity inspectors if they reasonably suspect a disease is present on a property. These orders can limit the movement of livestock and equipment. Broader protection orders can also be issued that require management actions to be taken or involve the seizure and destruction of livestock and equipment. Offence provisions apply for failing to comply with such an order.

In terms of further broad-ranging and permanent control measures (such as for cattle tick (*Rhipicephalus microplus*)), the responsible minister may establish a 'disease control program' for control of a specified disease. Such a program may involve orders including containment of relevant livestock, or movement or restriction of movement of relevant livestock. In the case of a control program for an emergency disease (such as foot-and-mouth disease), the minister may declare an area to be a standstill zone, and restrict the movement of relevant livestock and things into, out of or within the zone. For a notifiable disease (which includes tick-borne viruses and Johne's disease), the Chief Inspector has the power to declare an area a control area or restricted area, and may restrict the movement of persons, vehicles, livestock and other things entering, leaving or within an area.

As is the case in WA, the NT Livestock Act provides the statutory framework for the implementation of the NLIS. Under the applicable rules, stockowners must ensure that permanent identification devices are attached to cattle before they are moved from their property.

The Weeds Management Act provides for the declaration and classification of weeds and potential weeds, and imposes general duties on landholders to, among other things:

- take all reasonable measures to prevent the land being infested with a declared weed
- take all reasonable measures to prevent a declared weed or potential weed on the land spreading to other land
- notify a relevant government officer within 14 days after first becoming aware of a declared weed
- comply with the terms of an applicable weed management plan if their land contains a declared weed or potential weed.

The Act also prohibits a range of dealings (e.g. import to the NT, propagation, sale or purchase) with declared weeds without a permit.

A key element of the framework established under the Weeds Management Act is the process for the preparation and implementation of weed management plans. These plans are made by the minister and are intended to set out the required actions and strategies to manage weed risks and the environmental, social and economic impacts of weeds. The plans can include details on how declared weeds can be used, the processes for the identification and control of weeds and the criteria for obtaining government assistance to carry out the obligations imposed under the plan and the extent of the assistance. If a landholder fails to comply with the terms of a weed management plan, the minister can issue directions to force them to comply and/or to prepare and implement a remedial weed management plan. Failure to comply with a remedial weed management plan is an offence. Where a landholder fails to comply with a direction, the department can also undertake the required actions and recover the costs as a debt from the landholder. Similar to the arrangements under the Livestock Act, quarantine areas and 'cleaning areas' can be established under the Weeds Management Act to control the spread of weeds.

Queensland

The primary biosecurity statute in Queensland is the *Biosecurity Act 2014* (Qld). It is an extensive legislative instrument dealing with an array of biosecurity matters. The legislation is intended to embody a risk-based approach to biosecurity regulation, where resources and regulatory effort is allocated on the basis of an objective assessment of the relevant biosecurity risks. The goal of such an approach is to allow greater flexibility and more responsive approaches to managing biosecurity risks. The Biosecurity Act facilitates this risk-based approach by imposing on all persons a general biosecurity obligation to prevent or minimise the impact of biosecurity risks. It also explicitly provides that risk-based decision making is to be adopted in administering the Act.

The Biosecurity Act manages biosecurity risks through a combination of the general biosecurity obligation and specific provisions to manage particular biosecurity matters that pose a particular risk to the state's biosecurity. The general biosecurity obligation requires any person who deals with a 'biosecurity matter', or who carries out an activity and knows (or ought reasonably to know) that the matter or activity is likely to pose a 'biosecurity risk', to 'take all reasonable and practical measures to prevent or minimise the biosecurity risk' (a summary of key defined terms is provided in Table 28). Additionally, the obligation entails a duty to prevent or minimise adverse effects on a 'biosecurity consideration' when dealing with the biosecurity matter (or carrying out the activity), together with an obligation to minimise the likelihood of causing a 'biosecurity event' (or limiting its consequences).

Table 28 Key defined terms under the *Biosecurity Act 2014* (Qld)

DEFINED TERM	MEANING
Biosecurity consideration	The impact of biosecurity risks on human health, social amenity, the economy and the environment
Biosecurity event	An event that has (or may have) a significant adverse effect on a biosecurity consideration and is caused by, or may be or may have been caused by, a biosecurity matter
Biosecurity matter	Includes a living thing (other than a human), or a pathogenic agent that can cause disease; or a contaminant
Biosecurity risk	Any adverse effect on a biosecurity consideration caused by a biosecurity matter
Contaminant	Includes anything that may be harmful to animal or plant health or pose a risk of any adverse effect on a biosecurity consideration

A person who fails to discharge their general obligation is guilty of an offence (subject to a statutorily defined due diligence defence). Further, anyone who keeps or holds a biosecurity matter, including cattle, is classified as a 'registrable biosecurity entity'. As registrable entities, graziers, owners of feedlots, abattoirs and holding yards must apply for registration under the Biosecurity Act. Registration facilitates the implementation of the NLIS and imposes certain responsibilities on registered entities beyond the general obligation. These include requirements to earmark or brand cattle before they are moved.

In addition to the general obligation, the Biosecurity Act contains specific biosecurity provisions that regulate the management of certain biosecurity risks. The Biosecurity Act divides these risks into the control and management of 'prohibited matter' and 'restricted matter'. Prohibited matter is matter that is not present (or not known to be present in Queensland) where it is believed on reasonable grounds that if the biosecurity matter was to enter the state it may have a significant adverse effect on a biosecurity consideration. Restricted matter is biosecurity matter that is currently present in Queensland, where it is believed on reasonable grounds that if conditions are not imposed to reduce, control or contain the matter it may have an adverse effect on a biosecurity consideration. Schedules in the Biosecurity Act set out a list of diseases and pathogens that constitute prohibited matter and restricted matter.

Once a person becomes aware that biosecurity matter is prohibited matter, the person must report the presence of that matter to an inspector immediately. It is an offence to fail to report the presence of prohibited matter under a person's control if the person becomes aware of the presence of such matter, or if that person believes or ought reasonably to believe it to be prohibited matter. It is also an offence to deal with prohibited matter, unless the person has been issued with a permit. Similar offence provisions apply for restricted matter that affects animals, including beef cattle, subject to the requirement to report within 24 hours (rather than immediately).

There is a further catch-all obligation on individuals to advise an inspector of a 'notifiable incident'. A notifiable incident means a biosecurity event but also includes the appearance of blisters on the mouths or feet of cattle, an abnormally high mortality rate or morbidity rate, a sudden and unexplained fall in production or the appearance of other symptoms or conditions prescribed under the regulations that may indicate the presence of biosecurity matter which may cause adverse effects on a biosecurity consideration. Unlike the general obligation, there is no due diligence defence that applies to the offence provisions relating to prohibited matter or restricted matter.

Various orders can be issued under the Act to manage biosecurity incidents. These include the issuance of biosecurity emergency and movement control orders. These orders are primarily designed as interim measures. Regulations can be made under the Act to impose more permanent restrictions, including through the establishment of biosecurity zones and surveillance programs. By way of example, Queensland currently has in place biosecurity zones and a surveillance program to address cattle tick.

Barriers related to biosecurity laws

There is little evidence of major problems with the form of Australia's biosecurity laws. The introduction of the federal Biosecurity Act in 2016 was widely supported by industry and, on the basis of the available evidence, there do not appear to be major shortcomings in the form of the applicable WA, NT or Queensland biosecurity laws. The differences that exist in state and territory biosecurity regulations have been a source of some frustration among agricultural stakeholders. However, there are often good reasons for the adoption of alternative approaches. Further, the Intergovernmental Agreement on Biosecurity, which was signed by all states and territories except Tasmania and came into effect in 2016, is encouraging greater cooperation between jurisdictions on the management of biosecurity risks and the harmonisation of relevant laws.

While the form of the applicable laws does not appear to be a source of material barriers for the beef industry, there are resourcing problems that are undermining the effectiveness of the biosecurity arrangements. There are significant weed and pest problems across large parts of northern Australia that landholders and other stakeholders are struggling to manage. The spread of gamba grass (*Andropogon gayanus*) across northern Australia is illustrative of the problem and suggests there may be a case for increased targeted investment on behalf of the Commonwealth, state and territory governments.

10.3.6 Animal welfare

Overview of animal welfare laws

Responsibility for the regulation of the treatment of cattle is divided between the federal and state/territory governments, depending on the point in the supply chain. At the point of production, primarily responsibility lies with the states and territories. There can also be some local government involvement in animal cruelty regulation; for example, where they own or manage saleyards.

At the urging of industry stakeholders, efforts have been made to standardise the applicable animal cruelty laws across the country. This started with the development of 'model codes of practice' in the 1980s, which laid down desired standards for different livestock, including cattle. The aim in developing the codes was that the states and territories could then incorporate them into their animal welfare laws, resulting in a nationally consistent regulatory approach. However, the levels and modes of incorporation differed, with most jurisdictions adopting them as voluntary (rather than mandatory) codes.

In 2005, the Commonwealth, state and territory governments agreed to convert the model codes of practice for livestock into Australian Animal Welfare Standards and Guidelines. Under the agreed 'standards and guidelines' approach, the standards would set down mandatory welfare requirements, while the guidelines would provide recommendations on good practice. One of the aims of this tightening and standardisation process was to ensure Australia's livestock industry could meet the growing animal welfare expectations in domestic and international markets.

Progress on developing and implementing the standards and guidelines has been slow. It was not until 2016 that the Australian Animal Welfare Standards and Guidelines for Cattle were agreed, and their subsequent adoption has been patchy. At the time of writing, only SA and NSW had translated the national standards for cattle into operative law. WA, NT and Queensland were all in the process of making the required changes to their regulatory regimes.

Western Australia

At present, the welfare of cattle is governed through the *Animal Welfare Act 2002* (WA) and *Animal Welfare (General) Regulations 2003* (WA). The Act creates a general offence of 'cruelty to animals', breach that attracts a minimum penalty of $2000 and a maximum penalty of $50,000 and imprisonment for 5 years. Corporations are exposed to much larger fines, up to a maximum of $250,000. The officers of corporations that have engaged in animal cruelty can also be held personally liable for offences and courts have the power to impose a wide range of orders on offenders, including prohibitions on animal ownership and the forfeiture of property.

The Act sets out a number of defences to the offence of cruelty, one of which is that the 'person was acting in accordance with a relevant code of practice'. Under the 2003 regulations, the Model Code of Practice for the Welfare of Animals: Cattle (2nd edition, 2004), a voluntary code, is a recognised 'code of practice' for the purposes of the Act. Breach of this code provision does not alone constitute proof of the commission of an offence of animal cruelty. However, compliance with it provides a defence to the offence of animal cruelty.

Section 94 of the Animal Welfare Act was recently amended to facilitate the incorporation of the Australian Animal Welfare Standards and Guidelines into law. However, to date, no standards have been incorporated. Consultation with stakeholders on the proposed form of these Regulations is scheduled to commence in mid-2019.

Northern Territory

The NT is currently in the process of overhauling its animal welfare laws. In November 2018, the NT's Legislative Assembly passed the *Animal Protection Act 2018* (NT), with the intention that it will ultimately replace the existing regime that operates under the *Animal Welfare Act 1999* (NT). At the time of writing, the 2018 Act had not yet come into operation and it will not do so until regulations to accompany the Act are prepared and approved. The latter process is under way and the Department of Primary Industry and Resources advises that it is being pursued as a priority.

Under the existing Animal Welfare Act, there are three primary offences relating to animal mistreatment. Section 8 provides that a person 'in charge of an animal owes a duty of care to it' and that breach of that duty is an offence. A separate offence of 'cruelty' to an animal is established by s 9, with a further offence of 'aggravated cruelty' in s 10. The penalties that apply in relation to these offences range from a maximum of 100 units (currently $15,500), in the case of breach of a duty of care, up to a maximum of 200 units ($31,000) or 2 years imprisonment, for aggravated cruelty. A range of additional orders can be made where a conviction has been secured, including orders for the seizure of animals and orders prohibiting future ownership of animals.

Under the Animal Welfare Act, the minister can endorse a voluntary code for the NT. Compliance with codes can also be made mandatory. Relevantly, the Model Code of Practice for the Welfare of Animals: Cattle is currently endorsed as a voluntary code. This means that compliance with the code can be used as a defence in proceedings brought under the Act.

The Northern Territory Government has endorsed the Australian Animal Welfare Standards and Guidelines for Cattle. The intent is that these will be adopted as a compulsory code under the new regime currently being prepared around the Animal Protection Act.

Queensland

In Queensland, the treatment of animals in broadacre grazing and feedlot systems is regulated under the *Animal Care and Protection Act 2001* (Qld). The Animal Care and Protection Act imposes a general 'duty of care' on those in charge of animals to provide for their basic needs, breach of which exposes a person to penalties. In addition to this, it creates separate offences relating to, among other things, animal cruelty, unreasonable abandonment or release of an animal, and tail docking. These offences attract maximum fines of between $39,165 and $261,100, and jail terms of up to 3 years can be imposed. Other types of orders can also be made following a conviction, including an order prohibiting a person from owning or possessing animals. Where a corporation is found to have committed any of these offences, each of its officers can be deemed individually criminally responsible.

Under chapter 2 of the Animal Care and Protection Act, 'codes of practice' can be incorporated into law through the making of regulations. Codes of practice have three relevant effects. First, compliance with a relevant code provision provides an exemption to the Act's offence provisions, shielding a potential offender against liability. Second, codes of practice can be used as evidence in court, where relevant to an alleged offence. For example, they could be used to provide guidance on what constitutes cruelty or unreasonable abandonment of an animal. Third, under the Act, certain code provisions can be designated as 'compulsory code requirements', breaches of which can attract significant fines.

The *Animal Care and Protection Regulation 2012* (Qld) designates, as voluntary codes, four model code documents concerning beef production:

- the Australian Code of Practice for the Welfare of Cattle in Beef Feedlots
- the Australian Model Code of Practice for the Welfare of Animals – Cattle
- the Model Code of Practice for the Welfare of Animals – Animals at Saleyards
- the Model Code of Practice for the Welfare of Animals – Livestock at Slaughtering Establishments.

At the time of writing, there were no compulsory code requirements in relation to cattle, other than in the specific context of livestock transportation (see below). Biosecurity Queensland has indicated that the drafting of regulations to adopt the Australian Animal Welfare Standards and Guidelines for Cattle into Queensland law, including the designation of some compulsory code requirements, is currently under way and that the changes should be in place by the end of 2019.

Barriers related to animal welfare laws

Animal welfare regulations bring costs and benefits for the beef industry. Compliance with animal cruelty requirements can increase costs in cattle production systems. However, they also ensure the industry meets community and market animal welfare expectations. In the absence of standards, there is the potential for the industry to encounter market access problems and to face unexpected and unstructured regulatory interventions in response to animal welfare incidents, as has occurred with live exports. The drive for national standards also minimises the risk of free riding and reduces the complications that arise from producers having to comply with different requirements in different jurisdictions.

Although there is a sound rationale behind the regimes, there are several areas where improvements could be made to lessen the impacts on industry. The most pressing is the incorporation of the Australian Animal Welfare Standards and Guidelines for Cattle into law across northern Australia, and preferably the entire country. As the Productivity Commission's 2016 agriculture regulation review identified, there is also scope for improvements to be made in the evidence base behind, and the processes for developing, the standards and accompanying regulations. Additional work is required in relation to animal welfare standards to ensure there are appropriate processes to generate and capture relevant evidence on the impacts of industry practices on animals and community and market expectations regarding the treatment of animals.

10.3.7 Soil conservation

Overview of soil conservation laws

The first coordinated regulatory response to soil degradation was prompted by Australia's 'dust bowl crises' of the 1930s and 1940s. At a conference of Commonwealth and state agricultural ministers in 1936, it was resolved that each state would form a committee, in cooperation with the then Council for Scientific and Industrial Research (now CSIRO), to assess the extent and nature of soil erosion problems and make recommendations on how to address the issue. Legislation addressing soil conservation grew out of this investigatory process, including specific soil conservation laws in the northern Australian jurisdictions of WA (1945), Queensland (1951) and the NT (1970) (McKenzie, 2018). Historically, these statutes have adopted a cooperative, bottom-up approach to regulation that seeks to address soil conservation issues through education, awareness-raising and cooperative efforts rather than through the enforcement of strict behavioural standards. This regulatory style remains the defining feature of the current soil conservation statutes, including in WA, the NT and Queensland.

The soil conservation statutes in the three northern jurisdictions are the *Soil and Land Conservation Act 1945* (WA), *Soil Conservation and Land Utilisation Act 1969* (NT) and *Soil Conservation Act 1986* (Qld). All three are reasonably similar, in that they are intended to provide a supporting framework for the resolution of soil conservation issues, while having 'reserve powers' to force landholders to take remedial actions in certain circumstances. Under WA and NT laws, designated soil commissioners have the power to issue soil conservation notices or orders that can direct landholders to undertake remedial works and to adopt or refrain from adopting specified practices, including in relation to the grazing of livestock. These notices can be registered on title, meaning they will bind successors in title. While breaches of these notices and orders is an offence, the penalties are small, with maximum fines generally less than $3000.

The equivalent powers under the Queensland Soil Conservation Act stem from the development of project plans by the Director-General of the Department of Natural Resources, Mining and Energy. These plans are required to be prepared in consultation with affected landholders, after which they are approved by the Governor in Council. Once an approved project plan is made, the Director-General can give soil conservation orders to landholders in the project area requiring them to take specified soil conservation measures. These orders bind the owners and occupiers, including subsequent owners and occupiers if the land is transferred. Failure to comply with an order is an offence, although, again, the maximum fines are modest (up to $2611). The Act also makes provision for cost-sharing between affected landowners and the state of Queensland.

In addition to these soil conservation statutes, pastoral and other Crown leases that are used for grazing and other agricultural purposes, and grazing licences that allow cattle to be run on Crown land, include obligations concerning the prevention of land degradation, including soil erosion and soil salinity. For example, under the Queensland Land Act, all leases, licences and permits that are issued in relation to Crown land 'are subject to the condition that the lessee, licensee or permittee has the responsibility for a duty of care for the land'. The duty of care that applies to leases that are issued for pastoral purposes includes a requirement to, among other things, conserve soil and avoid causing or contributing to land salinity. If the minister is satisfied a lessee and licensee has breached their duty of care, or is otherwise using the land in a way that is or could cause land degradation, they can issue a remedial action notice requiring the landholder to take specified corrective actions. Failure to comply with a remedial action notice is an offence and, if the landholder fails to take the required actions, the Queensland Government can recover the associated costs as a debt from the landholder. In a similar vein, under the NT PL Act, the Pastoral Land Board can require a lessee to prepare and implement a remedial plan to deal with land degradation. The minister can also take such action as they think fit to deal with land degradation and recover the costs of the action from the lessee.

The states and territories have almost exclusive responsibility for the regulation of activities related to soil erosion and conservation. The only relevant federal statute that has the potential to apply to soil issues is the EPBC Act. Other than the incidental involvement in soil conservation regulation through the EPBC Act, the Commonwealth's involvement in soil issues is largely confined to the coordination of research and policy development, and the funding of voluntary programs. In recent years, most Commonwealth funding for soil conservation and broader natural resource management issues has been through the National Landcare Program.

Barriers related to soil conservation laws

There are few, if any, regulatory barriers that arise as a consequence of soil conservation laws. As discussed, a cooperative approach is taken to the management of soil conservation issues, where the emphasis is on education, awareness and capacity building. Due to this, the coercive powers of regulators are generally reserved for cases of manifest neglect, where landholders have egregiously failed in their duty of care to manage the land. In other cases, where interventions are necessary, a cooperative approach tends to be taken, where government authorities work with and support landholders, including through the provision of funding, to address the identified issues.

10.3.8 Control-of-use Legislative Frameworks for agricultural and veterinary chemicals

Overview of agricultural and veterinary chemical legislation and regulation

Under the National Registration Scheme (NRS), the Commonwealth (through the Australian Pesticides and Veterinary Medicines Authority (APVMA)) regulates agricultural and veterinary chemicals up to the point of sale, while the states and territories are responsible for regulating the use of those chemical products after sale, including use by beef producers. The assessment and registration scheme operates in a uniform fashion throughout Australia via a cooperative scheme, under which all states and territories have adopted the Agricultural and Veterinary Chemicals Code (Agvet Code).[21]

The control-of-use regulations of the states and territories cover:

- the use of agricultural and veterinary chemicals
- the licensing and use of high-risk products
- the licensing of professional operators (including veterinarians)

[21] As set out in the Schedule to the *Agricultural and Veterinary Chemicals Code Act 1994* (Cth).

- the monitoring and auditing of the use of relevant chemicals and their effects on human health and the environment.

The state and territory regulatory regimes have different architectures but similar operative provisions. The Western Australian control-of-use regulations are spread across several statutes, most notably, the *Veterinary Chemical Control and Animal Feeding Stuffs Act 1976* (WA), *Biosecurity and Agriculture Management Act 2007* (WA), *Agriculture and Related Resources Protection Act 1976* (WA), *Health (Miscellaneous Provisions) Act 1911* (WA) and *Dangerous Goods Safety Act 2004* (WA). In the NT, the use of agricultural and veterinary chemicals is primarily regulated through the *Agricultural and Veterinary Chemicals (Control of Use) Act 2004* (NT). In Queensland, the main legislation is the *Chemical Usage (Agricultural and Veterinary) Control Act 1988* (Qld). The regulatory regimes established under these statutes are supported by an array of delegated legislation. For example, in WA, the primary regulations include the *Veterinary Chemical Control Regulations 2006* (WA), *Biosecurity and Agriculture Management (Agriculture Standards) Regulations 2013* (WA), *Biosecurity and Agriculture Management (Aerial Application) Regulations 2018* (WA), *Agriculture and Related Resources Protection (Spraying Restrictions) Regulations 1979* (WA) and *Health (Pesticides) Regulations 2011* (WA).

The main regulatory provisions that are of relevance to the production of beef cover:

- bans on the use of unregistered chemicals
- restrictions on the people who can use registered chemicals (e.g. veterinary chemicals can only be used by registered veterinarians)
- requirements for registered chemicals to be used in accordance with the specifications on the approved label
- the approval of 'off-label' uses in certain circumstances.

There are particular requirements that are of relevance to the cattle industry. For example, under the Chemical Usage (Agricultural and Veterinary) Control Act and accompanying *Chemical Usage (Agricultural and Veterinary) Control Regulation 2017* (Qld), an agricultural chemical containing tebuthiuron that is used in cattle grazing can only be used by a person who has prescribed qualifications or is under the direct supervision of another person with the prescribed qualifications. The regulations also impose restrictions on the use and distribution of chemicals containing tebuthiuron for grazing purposes, including through aerial spraying, so as to prevent runoff into the Great Barrier Reef.

Barriers related to control-of-use legislative frameworks

The primary concerns that have been raised about the control-of-use regimes in the states and territories are complexity and a lack of harmonisation. The regulatory regimes that apply across the states and territories are complex, particularly in relation to off-label uses. There are also differences in the regulations between the jurisdictions that can increase compliance costs and make it harder for the APVMA to assess the risks associated with registration and use. In its submission to the Productivity Commission review on the regulation of agriculture, CropLife Australia summarised the concern when it stated that the regulatory differences at the state/territory level made compliance 'difficult, confusing and costly' (Productivity Commission, 2016). There have been attempts to address these concerns, including through the Council of

Australian Governments (COAG). However, progress on the design and implementation of harmonisation measures has been slow and remains a work in progress.

It is unlikely that the complexity and a lack of harmonisation of the control-of-use regulations is a major development barrier among northern beef producers. However, there is little empirical evidence on the issue. Consideration should be given to undertaking research on the extent to which the complexity and inconsistencies in control-of-use regulations increase production costs and undermine safe practices among cattle producers. This information could be useful in providing new impetus for regulatory reforms.

10.4 Regulatory regimes that apply to the transport of cattle by road

There are three main types of regulatory regimes that apply to the transport of cattle by road: biosecurity, animal welfare and heavy vehicle. All three are primarily the domain of the states and territories.

10.4.1 Biosecurity

As discussed above in Section 10.3.5, the NLIS has created a nationally consistent scheme for the registration and recording of livestock movements. Under these processes, which are found in the state and territory biosecurity laws, all cattle must be registered and fitted with an NLIS device. The NLIS system uses radio frequency identification (RFID) to identify stock from birth to slaughter. The device records the PIC from which the livestock are being moved and an individual animal identifier. Because cattle must be identified with an NLIS device before leaving the property on which they are kept, the attachment of an NLIS device is typically the responsibility of pastoralists. Operators of destination properties (e.g. feedlots and abattoirs) must notify the NLIS database when cattle are moved from a source property to those destinations. As noted above, the NLIS is an important element of the framework for the management of biosecurity threats across jurisdictional borders.

The NLIS registration and recording system is supplemented with waybill or ‘movement records’ requirements. These requirements dictate that a waybill/movement record must accompany all travelling stock. The waybill/movement records are required to be issued by the owner of the cattle (the registrable biosecurity entity in Queensland) before stock can begin travelling. The person in charge of the stock while travelling (such as drivers) must sign the waybill at the commencement of the movement. At the conclusion of the movement, the person in charge must then endorse and sign the waybill to show the number of stock that were lost during the journey. The person to whom the stock are to be delivered, which will typically involve feedlot operators and abattoirs, must not take delivery of the travelling livestock and the waybill, unless the waybill contains accurate details of the livestock and has been properly signed by the owner and person in charge of the livestock.

In addition to these issues, there are additional, often more specific, regulatory requirements that apply under state and territory processes. For example, in WA, there are requirements to:

- make notifications prior to livestock movements – in the case of transport by land, whoever is transporting the animals must notify the inspector at an entry inspection point at least 72 hours before the estimated time of arrival
- presentation of a valid health certificate – typically, the health certificate makes provision for cattle tick treatment and Johne's disease mitigation
- measures to control Johne's disease – beef cattle entering WA to move directly to export facilities or to abattoir facilities must:
  - not be from a herd infected or suspected to be infected with Johne's disease for the last 5 years
  - be from a property of origin that has the requisite Johne's Beef Assurance Score (e.g. a J-BAS 6 or higher if from WA or J-BAS of 7 or higher if born and grazed in the NT or Queensland).

These types of restrictions are not uniform across jurisdictions. In Queensland, the general biosecurity obligation applies to the movement of livestock, meaning appropriate measures must be put in place to manage relevant risks. Consistent with this, the applicable requirements are less prescriptive, which provides owners and others with greater flexibility. The differences in approach can be illustrated using cattle ticks as a case study.

Case study on biosecurity regulations concerning cattle ticks

Cattle ticks (*Rhipicephalus microplus*) are an external parasite favouring cattle as their hosts. Critical parts of the tick's life cycle (including the duration of the life cycle itself and number of eggs laid by female ticks) is optimised when relative humidity and ambient temperature are high. Northern Australia's climate conditions, especially during the wet season, provide cattle tick with ideal environmental conditions to thrive. Due to this, the control of cattle tick and tick-borne diseases is a high priority in biosecurity regulation in northern Australia.

In each jurisdiction, movement of cattle is controlled within by reference to 'tick-free' or 'infested' zones, or demarcated via 'tick lines' in maps. Both Queensland and WA are divided into two cattle tick zones, demarcated by a single tick line. The NT has four zones. Queensland recently abandoned a three-tiered system (infected zone, a free zone and a control zone) due to concerns it was causing confusion among key stakeholders.

It might be thought that the same biosecurity threat (in terms of pathogen and geographical spread) would be met with the same regulatory response across the jurisdictions. This is true but only to an extent. Each jurisdiction places restrictions on stock movements travelling from tick-infested areas to other parts of the state or territory. However, there are material differences in regulatory approach, including in relation to how the demarcation lines are set.

In WA, cattle tick is classified as a declared pest for the purposes of s 22(2) of the BAM Act and is subject to prohibition (and therefore import restrictions) in relation to the cattle tick-free area. Its chemically resistant form is a prohibited import for the whole of the state. In addition to the general movement and import requirements:

- cattle moving to the tick-free area of WA, except for immediate slaughter or export, must have an approved plunge treatment for tick and, within three to seven days, a clean inspection and a treatment supervised by an inspector immediately (24 hours) before movement

- cattle moving to the tick-free area direct to holding pens for immediate slaughter must have either a clean inspection followed by a supervised plunge treatment immediately (24 hours) before movement or a supervised plunge treatment followed within one to three days by a clean inspection immediately (24 hours) before movement
- cattle moving to the tick-free area direct to wharf for export must have either a clean inspection followed by a supervised treatment immediately (24 hours) before movement or a supervised plunge treatment followed within one to three days by a clean inspection immediately (24 hours) before movement.

Cattle from the NT not under movement restrictions due to chemically resistant tick may be moved into the cattle tick infected area of WA without treatment or inspection for tick.

Under the NT regime, the NT is divided into four zones: Parkhurst Infected Zone (Red); Infected Zone (Pink); Control Zone (Yellow); and Free Zone (Green). Movement from the Parkhurst Infected Zone (Red) to or through the Infected Zone (Pink), Control Zone (Yellow) or Free Zone (Green) requires a clean inspection, together with specific treatment. Movement from an infected zone requires clean inspection and a prescribed tick treatment. Proof of treatment must be on the endorsed waybill, health certificate and waybill, or movement permit. Under NT regulations, a distinction is made between tick-free and tick-infested areas of other jurisdictions. Cattle moving from a tick-infested area in Queensland or WA must satisfy the same requirements as set out above for movement from the infected zones for entry into any part of the NT.

In Queensland, the general biosecurity obligation requires those responsible for the movement of cattle to take appropriate precautions to address tick-related risks. In addition, the movement of stock from a cattle tick zone in Queensland requires a travel permit issued by a biosecurity inspector; cattle tick preliminary treatment owner declaration; and a cattle tick certificate of inspection or treatment, which is also issued by a biosecurity inspector. A certificate of inspection will be issued only once an inspector is satisfied the appropriate risk-minimisation procedures, as set out in the *Queensland biosecurity manual*, have been complied with. These include, if moving from an infested zone (except feedlots) to a free zone, a tick-free manual inspection and supervised treatment.

Additionally, cattle held in a feedlot in the infested zone must be held under prescribed conditions to meet the risk-minimisation requirements, including that:

- the entire feedlot must be separated from surrounding pasture paddocks by a minimum 10-metre buffer zone that is maintained free of cattle tick carriers at all times
- feedlot pens and associated handling facilities are kept free of vegetation at all times
- if the feedlot accepts cattle from the Queensland cattle tick-infested zone, the owner must be able to show procedures that detail how cattle in the feedlot are protected from the risk of cattle tick infestation.

10.4.2 Animal welfare

In Australia, all jurisdictions except WA have given legal force to the core requirements of the Australian Standards and Guidelines for Welfare of Animals – Land Transport of Livestock (widely referred to as the 'LTS'). This set of national standards concerning livestock transportation was agreed and endorsed by all Australian governments in 2014. In Queensland, the standards component of the LTS is transposed into schedule 3 of the Animal Care and Protection Regulation and designated as a wholly compulsory code for purposes of the Act. In the NT, the LTS has been adopted under part 4A of the *Livestock Regulations 2009* (NT). In the NT, the LTS takes its original form of a mixture of 'standards' (compulsory) and 'guidelines' (recommended but not enforced).

The LTS standards apply to participants at every stage of the process of transporting livestock within Australia by road and rail (and, within Queensland, also by sea) and so implicate persons consigning, transporting and receiving stock. The compulsory standards are, in both their Queensland and NT versions, divided into two parts: the first part specifies general standards applying to all species of livestock, while the second part adds species-specific standards (including for cattle).

The standards address many aspects of the livestock transportation process in considerable detail. In general terms, the standards extend to: the selection of livestock to be transported, the provision of feed and water before and during journeys, how densely animals can be packed into trucks and trailers, rest spells during long journeys, and inspection of livestock undergoing transportation. In relation to cattle specifically, a key feature of the LTS is their differentiation according to age and condition (e.g. very young (bobby) calves, pregnant or lactating cows, etc.) with different requirements imposed for each class in relation to such things as feed, water and rest spells during journeys.

In WA, the transportation of cattle is governed only by the general terms of the Animal Welfare Act and the *Animal Welfare (General) Regulations 2003* (WA). Schedule 1 to the regulation lists as a 'code of practice', for purposes of the Act, the Code of Practice for the Transportation of Cattle in Western Australia. While this code addresses many of the same matters as the LTS, it remains a wholly voluntary code with no directly enforceable provisions.

10.4.3 Heavy vehicles

In 2009, COAG agreed to establish a single national heavy vehicle regulatory regime to harmonise the regulation of heavy vehicles across the states and territories. This regime, embodied in the Heavy Vehicle National Law, commenced in 2014 and is administered by the National Heavy Vehicle Regulator (NHVR). The Heavy Vehicle National Law contains detailed regulations governing, among other things, heavy vehicle registration, heavy vehicle standards, operating standards concerning loading and weight, driving licence requirements, and regulations designed to minimise risks associated with fatigue management.

A key element of the law is the creation of a principle of shared responsibility, under which the responsibility for ensuring the safe operation of heavily vehicles is shared between each party in the chain of responsibility for the vehicle, not merely the owner and driver of the vehicle. This means that the consignors and receivers of goods transported by heavy vehicles have a responsibility for ensuring the vehicle is loaded and operated in a safe manner. Formally, the Heavy Vehicle National Law creates a primary duty, under which each party in the chain of responsibility must 'ensure, so far as is reasonably practicable, the safety of the party's transport activities relating to the vehicle'. This requires each party to eliminate or minimise public risks and to ensure they do not directly or indirectly cause or encourage the driver to contravene the law.

Executives of responsible entities must exercise due diligence to ensure the entity complies with its safety duties. Contravention of the duty is an offence, carrying penalties of up to $3 million.

The anticipated harmonisation benefits associated with the Heavy Vehicle National Law have been partially undermined by the fact that neither WA nor the NT have adopted it. Queensland adopted the law through the *Heavy Vehicle National Law Act 2012* (Qld), meaning heavy vehicle regulation in the state is now largely administered by the NHVR. In WA and the NT, there are similar but separate regulatory systems administered by the Western Australian Department of Main Roads and Northern Territory Motor Vehicle Registry. In WA, the operative laws are spread across a suite of statutes and regulations, including the *Road Traffic Act 1974* (WA), *Road Traffic (Vehicles) Act 2012* (WA) and *Road Traffic (Vehicle) Regulations 2014* (WA). The regulatory framework includes the Western Australian Heavy Vehicle Accreditation Scheme, a mandatory audit scheme that applies to all operators of restricted access vehicles. The equivalent regulations in the NT are found mainly in the *Motor Vehicles Act 1949* (NT), *Motor Vehicles Regulations 1977* (NT), *Motor Vehicles (Standards) Regulations 2003* (NT), and *Motor Vehicles (Standards) Regulations – Australian Vehicle Standards Rules* (NT).

10.4.4 Barriers related to cattle transport laws

Transport costs are a significant barrier to the development of the northern Australia beef industry. The remoteness of many, if not most, pastoral enterprises means cattle must be transported long distances to abattoirs or export facilities. The costs associated with this transport adversely affects the profitability of pastoral enterprises and reduces their competitiveness in relevant markets.

Given the materiality of transport costs to the competitiveness of pastoral enterprises, there is a risk the applicable transport-related regulations concerning biosecurity, animal welfare and the operation of heavy vehicles may be acting as a deterrent to development. These regulations undoubtedly increase costs. The complexity and lack of harmonisation across the northern jurisdictions could be acting as magnifiers of these costs, particularly by limiting competition. As with the other types of regulations, there is no doubt regulations are needed to manage biosecurity, animal welfare and vehicle-related risks. The question is whether they are as efficient and cost-effective as possible.

In April 2019, the federal Treasurer asked the Productivity Commission to undertake an inquiry into national transport regulatory reform. The scope of the inquiry requires the Productivity Commission to 'investigate the long-run economic impacts of transport regulatory reforms agreed by COAG in 2008–2009 relating to heavy vehicle safety and productivity, rail safety and maritime safety and to make recommendations for further reforms towards a more integrated national market for transport services'.[22] This review provides an immediate opportunity for further investigation of the cost-effectiveness of existing heavy vehicle regulations and how they affect the northern Australia beef industry. The fact that both WA and the NT have not implemented the Heavy Vehicle National Law should allow these jurisdictions to be used as quasi-controls, allowing for comparisons to be made about the impacts of the law. It could also enable analysis to be done

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[22] See: https://www.pc.gov.au/inquiries/current/transport/terms-of-reference (accessed 30 June 2019)

on the effectiveness of recent reforms to, among other things, increase the gazettal of heavy vehicle routes to reduce the need for road permits. On the back of the Productivity Commission inquiry, decisions can be made about the need for further research on the extent and causes of any relevant problems related to the regulation of the transport of cattle by road, including in relation to biosecurity and animal welfare laws.

10.5 Regulatory regimes that apply to the processing of cattle in abattoirs

There are three principal institutional and regulatory regimes that apply to the operation of abattoirs for the processing of cattle that are relevant for current purposes: land tenure and native title, pollution control, and biosecurity and food security regulations. The land tenure issues are the same as those covered in Section 10.3.1, only most abattoirs are typically located on freehold land, meaning there are fewer land tenure-related complications, including native title (because the issuance of freehold title extinguishes native title). The other two are discussed below.

10.5.1 Pollution control

The regulation of pollution from abattoirs is regulated through planning and environmental laws, discussed in Section 10.3.3. Where a new abattoir is proposed, the developer will generally need to obtain a planning permit that authorises the use and development of the site for the slaughter of animals and a pollution licence from the state or territory EPA for the discharge of waste water and operation of effluent ponds (where relevant). Depending on the location of the facility and the proposed waste discharge practices, referral under the federal EPBC Act may also be necessary. Compliance with the conditions of relevant planning permit and EPA licences will be necessary, even for pre-existing abattoirs.

10.5.2 Regulation of the slaughter of animals

Responsibility for the regulation of the slaughter of animals is shared between the Commonwealth, states and territories. Abattoirs that service export markets are regulated under federal law, while those servicing domestic markets are regulated under state and territory laws.

10.5.3 Regulation of slaughter for export

The primary statute governing the slaughter of livestock for export markets is the *Export Control Act 1982* (Cth). The Export Control Act provides for the implementation of ‘approved export programs’ to oversee the slaughter of livestock for export. The regulations made under the Act, as they relate to slaughtering practices, require that veterinarians must be present to oversee animal health and welfare at abattoirs from their arrival at the facility up until the slaughter is complete. Both designated veterinarians and other authorised officers are empowered give operational directions at abattoirs in relation to animal handling and slaughtering practices, including in the case of halal slaughter.[23] Various offence provisions penalise the failure to satisfy approved export program requirements or to cooperate fully with regulatory personnel.

The *Export Control (Prescribed Goods – General) Order 2005* (Cth), which was made under the Act, provides for the registration of premises at which export preparation is to take place, the issuing of export permits, certification of goods and the use of official marks. These controls are generally applicable to operators engaged in slaughter for export. Any costs incurred by the Commonwealth in overseeing these regulatory programs can be passed on to abattoir operators via the *Export Control (Fees) Order 2015* (Cth).

10.5.4 Regulation of slaughter for domestic markets

Regulatory control of slaughter is a state and territory responsibility. Under the applicable regulatory regimes, operators of abattoirs are required to hold licences, the conditions of which are principally intended to manage biosecurity and food security risks.

In WA, the licensing and inspection of abattoirs is provided for in the *Western Australian Meat Industry Authority Act 1976* (WA) and accompanying regulations, as well as in regulations made under the *Food Act 2008* (WA) and *Food Regulations 2009* (WA). These provisions are generally directed to food hygiene and biosecurity objectives, with one exception. Regulation 32 of the *Western Australian Meat Industry Authority Regulations 1985* (WA) requires stock agents and livestock owners to ensure appropriate care (as to food, water, etc.) of stock housed at saleyards and to obey related directions from authorised officers, or be liable to a penalty of $5000. That same provision empowers officers of the WA Meat Industry Authority to provide directly for the needs of livestock and to pass costs on to the responsible stock agents or livestock owners, recoverable as a debt in court.

In the NT, licences to slaughter meat for domestic consumption are required to be obtained under the *Meat Industries Act 1996* (NT) and accompanying *Meat Industries Regulations 1997* (NT). The licences issued under these instruments are subject to an enforceable condition that abattoirs must comply with certain national standards. These standards are directed to food safety objectives. Under the *Animal Welfare Regulations 2000* (NT), there are also restrictions on the ways in which electrical stunning devices can be used in abattoirs. The new regulations being prepared under the not-yet-operating Animal Protection Act, and imminent regulatory reform that is planned in relation to the Livestock Act, are expected to augment the NT's existing commitment to nationally agreed standards for livestock welfare in all contexts, including slaughter.

In Queensland, the main statute is the *Food Production (Safety) Act 2000* (Qld). The *Food Production (Safety) Regulation 2014* (Qld) made under the Act establishes a 'meat scheme' that is directed solely to food hygiene.

In all three northern jurisdictions, there has been some form of legal endorsement given to a common voluntary code concerning the welfare of animals prior to and during slaughter. This code, commissioned and endorsed by the national Primary Industries Standing Committee, is called the Model Code of Practice for the Welfare of Animals – Livestock at Slaughtering

[23] See *Export Control (Meat and Meat Products) Orders 2005* (Cth), which prescribes meat derived from 'bovine species' as a prescribed good, thereby enabling the issuance of relevant directions.

Establishments.[24] In Queensland, this code is referenced in schedule 4 of the Animal Care and Protection Regulation. In WA, it is referenced in the Animal Welfare (General) Regulations. In the NT, the minister has endorsed that same model code via the powers conferred under the Animal Welfare Act.

An additional set of standards and guidelines relevant to livestock slaughtering practices is maintained by the peak industry body, the Australian Meat Industry Council (AMIC). AMIC administers a voluntary industry code called the Industry Animal Welfare Standards for Livestock Processing Establishments Preparing Meat for Human Consumption.[25] Together with an accompanying, independently audited, certification program commenced in 2013, this set of voluntary code standards addresses many aspects of abattoir operating procedures, facility design and staff competence from the perspective of animal welfare. Participation in the certification system is voluntary and entitles participants to use scheme logos and make associated claims about animal welfare in relation to their meat products.[26]

10.5.5 Barriers related to cattle processing laws

The barriers that stem from the application of pollution control laws to abattoirs are similar to those discussed in Section 10.3.3. They can limit development options, deter investment by increasing costs, causing delays and creating uncertainty, and decrease profitability by increasing operating costs. Some of these costs are unavoidable –few would argue abattoirs should not be subject to environmental and planning regulations. The relevant issue is not whether the regulations should exist but whether the regulatory systems are as efficient as possible, and whether they provide certainty for proponents in relation to assessment and approval requirements. There is little relevant information available on this issue. Further inquiries should be made to determine whether these regulatory systems pose a material barrier for new abattoir developments.

A similar situation applies in relation to the food safety and biosecurity regulations that apply to the operation of abattoirs. The 2016 Productivity Commission review of agriculture regulation raised concerns about the overlapping nature of federal and state regulations at individual abattoirs, which arises as a consequence of export and market access requirements. One of the main issues that arises from the duplication is the need for dual audits, one for the federal requirements and another for state/territory purposes. Many abattoirs are also required to undergo private food safety audits by large customers. These requirements increase costs for abattoirs, reducing their profitability. Federal and state/territory regulators have taken steps to streamline audit requirements, including through bilateral agreements that eliminate the need for separate federal and state audits (one audit is done for both purposes). However, in the time available, additional reliable information on the success of these types of measures and the extent

[24] Prepared for the Standing Committee on Agriculture and Resource Management. Published by CSIRO, 2001, SCARM report No 79

[25] Australian Meat Industry Council, first published in 2005. See: https://amic.org.au/policy-agenda/animal-welfare/ (30 June 2019)

[26] See: Australian Livestock Processing Industry Animal Welfare Certification System (AAWCS) website https://www.ausmeat.com.au/services/list/meat/aawcs/ (30 June 2019)

to which biosecurity and food safety regulations continue to impose unnecessary burdens on abattoirs was unable to be found.

10.6 Regulation of live cattle exports

10.6.1 Overview of live export laws

The export of live cattle from Australia is an industry that has experienced robust growth over the last three decades, with a more than a tenfold increase in head of cattle exported from Australia since 1988. Unlike other aspects of livestock regulation, live export is subject to extensive federal control. Federal regulation is facilitated, in this domain, by the Commonwealth Parliament's express legislative power over 'trade and commerce with other countries'.[27] The livestock export trade has long been controversial, with suggestions of regulatory failure and incidents of animal cruelty prompting investigations and, in some instances, temporary cessation of the trade.

Federal regulatory control over live export is constructed around a complex, multi-tiered licensing regime. The *Australian Meat and Live-stock Industry Act 1977* (Cth) is the head Act governing the issue of licences to livestock exporters. Two sets of regulations are maintained under that Act: the *Australian Meat and Live-stock Industry Regulations 1998* (Cth) and the *Australian Meat and Live-stock Industry (Export Licensing) Regulations 1998* (Cth). A third tier of legislative instrument, in the form of orders, nests under these regulations. Of particular interest here is the *Australian Meat and Live-stock Industry (Standards) Order 2005* (Cth), which prohibits livestock export by licence holders other than in conformity with a further document, the Australian Standards for the Export of Livestock (ASEL). These standards set out detailed requirements on a number of matters, including the preparation and loading of vessels for livestock export and the on-board management of livestock.

In 2018, in response to concerns about the welfare of livestock exported from Australia, the federal Minister for Agriculture and Water Resources instigated a review of the ASEL. The ASEL Review Technical Advisory Committee report on the standards for the export of livestock by sea was submitted to the minister on 14 December 2018 and the report has since been publicly released (ASEL Review Technical Advisory Committee, 2018). The government supported all of the report's recommendations and these are being gradually incorporated into law and practice via a revised version of the standard, to be called ASEL version 3, expected to be finalised in mid-2019. Relevantly for the cattle industry, the review report's recommendations relating to livestock density during transport have already been implemented as of 1 June 2019. A separate review, also in 2018, of the regulatory capability of the Department of Agriculture and Water Resources to safeguard animal welfare in the context of live export (the Moss review) recommended the re-introduction of an independent overseer for live export regulatory arrangements (Moss, 2018). The Australian Government agreed to adopt this recommendation and an Interim Inspector-General of Live Animal Exports was appointed under executive arrangements on 18 March 2019.

A parallel federal regulatory regime exists under the Export Control Act, section 9A, which provides for the implementation of 'approved export programs' in respect of livestock being

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[27] *Australian Constitution*, s 51(i)

prepared for export. Approved export programs cross-reference and incorporate the matters dealt with in the various orders, made under the Act, as described below. In terms of animal health and welfare, the Act requires that veterinarians or other authorised officers must be present to oversee both preparation and journey. The costs incurred by the Commonwealth in administering an approved export program can be passed on to exporters. Various offence provisions penalise the failure to satisfy approved export program requirements or to cooperate fully with regulatory personnel.

The *Export Control (Animals) Order 2004* (Cth) sets out in detail the process governing the issuance of export permits. Importantly, exporters must have in place a conforming Exporter Supply Chain Assurance System (ESCAS) to address animal welfare concerns during the livestock's journey and also following arrival at the destination country. Independent auditors monitor and evaluate each ESCAS against animal welfare standards devised specifically for the ESCAS process. Premises (including ships) to be used in connection with live export must maintain current registration under the *Export Control (Prescribed Goods – General) Order 2005* (Cth). The Export Control (Fees) Order authorises the imposition of various fees upon live animal exporters to cover the Commonwealth's costs in undertaking inspections, audits, and other regulatory activities.

10.6.2 Barriers associated with live export laws

The regulations on live cattle exports increase the costs of supplying cattle to foreign markets, thereby reducing the northern industry's competitiveness and profitability. In making its recommendations for increasing the stringency of export regulations, and particularly lowering stocking densities on vessels, the ASEL Review Technical Advisory Committee did not shy away from this fact, stating:

> There is no escaping the fact that the changes proposed by the committee will increase costs, and that there are only a few outcomes that can follow:
>
> - the exporter is able to pass on the costs in the form of higher prices in the destination market
> - the exporter passes the costs back to farmers in the form of a reduced purchase price
> - the exporter absorbs the cost increases and accepts a lower profit
> - a combination of the first three
> - the exporter exits the market. (ASEL Review Technical Advisory Committee, 2018)

The competitiveness of export markets prevents exporters from passing costs on to consumers. Due to this, the costs associated with the animal welfare requirements must be borne by exporters and cattle producers. This can render some operations unviable. Again, as the ASEL Review Technical Advisory Committee report states bluntly:

> The consequent reduction in the margin of both the exporter and farmers may well result in the least efficient industry participants exiting the market, with only the most efficient remaining. (ASEL Review Technical Advisory Committee, 2018)

Given the recent history in the industry, there is unlikely to be an appetite in the short term, either among producers or governments, to re-evaluate the costs and benefits of existing regulatory requirements. There is likely to be a need for a period of stability, after which there may be scope for revisiting the existing (and still emerging) regulations.

10.7 Foreign investment

10.7.1 Overview of foreign investment laws

Foreign investment in Australia is regulated under the *Foreign Acquisitions and Takeovers Act 1975* (Cth) and *Foreign Acquisitions and Takeovers Fees Imposition Act 2015* (Cth). Under this regulatory regime, the federal Treasurer can impose conditions and even block foreign investment proposals in Australia.

Specified proposed foreign investments are required to obtain approval under the Foreign Acquisitions and Takeovers Act. The approval requirements hinge on the definition of a 'foreign person', which for these purposes is defined as including a non-resident, foreign government, foreign government investor or a corporation in which two or more foreign persons hold an aggregate substantial interest of at least 40% or an individual foreigner holds a substantial interest of at least 20%. The most relevant general rules are that approval is required where a foreign person intends to acquire:

- a substantial interest (at least 20%) in an Australian entity that is valued above $266 million
- a direct interest (generally at least 10%, or the ability to influence, participate in or control) in an agribusiness where the value of the investment is more than $58 million (regardless of the value of the agribusiness)
- an interest in agricultural land where the cumulative value of agricultural land owned by the foreign person (and any associates), including the proposed purchase, is more than $15 million
- vacant commercial land, regardless of the value of the land
- an interest in developed commercial land if the value of the interest is likely to exceed $266 million.[28]

Foreign government investors are also required to obtain approval before acquiring a direct interest in Australia (generally at least 10%, or the ability to influence, participate in or control), starting a new business or acquiring an interest in Australian land regardless of the value of the investment. Foreign government investors are defined for these purposes as a foreign government or an entity in which:

- a foreign government holds a substantial interest of at least 20%
- more than one foreign country (or parts of more than one foreign country) hold an aggregate substantial interest of at least 40%.

[28] Different thresholds apply where the foreign investors are from countries that have a free trade agreement with Australia (e.g. United States, China, New Zealand, Singapore, Japan, Mexico and South Korea). For details, see Australia's Foreign Investment Policy, at: https://cdn.tspace.gov.au/uploads/sites/82/2018/12/1-January-2019-Policy_.pdf (30 June 2019).

Where approval is required, the proposal is first assessed by the Foreign Investment Review Board (FIRB). FIRB is a non-statutory advisory committee, which analyses foreign investment proposals and advises the Treasurer. As a matter of practice, all proposals are assessed by FIRB and its recommendations carry considerable weight in the making of approval decisions.

In addition to the foreign investment regulations under the Foreign Acquisitions and Takeovers Act, under the *Register of Foreign Ownership of Water or Agricultural Land Act 2015* (Cth), foreign interests in water and agricultural land are required to be registered with the Australian Taxation Office. Under the Act, two separate registers are maintained: the Register of Foreign Ownership of Agricultural Land and the Register of Foreign Ownership of Water Entitlements. The Commissioner reports annually to the Treasurer on the operation of the Register of Foreign Ownership of Water or Agricultural Land Act.[29]

10.8 Barriers related to foreign investment laws

While serving an important purpose, Australia's foreign investment laws may deter investment and increase the costs of capital, including in the agricultural sector. The extent to which this is a material barrier for the northern Australia beef industry is unclear. In its 2016 review of agriculture regulation, the Productivity Commission raised concerns about the Australian Government's 2015 decision to lower the approval thresholds that apply to agricultural investments. In relation to this issue, the Productivity Commission concluded that:

> the lower thresholds (combined with different thresholds depending on the country of origin of the investor) increase the cost and complexity of investing in Australian agriculture and ultimately risk deterring foreign investment in the sector without offsetting public benefits. It is unclear what additional public benefits will be derived from the lower thresholds, particularly given that other measures (such as the Register of Foreign Ownership of Agricultural Land) are in place to increase transparency and public confidence of foreign investment in Australian agriculture. (Productivity Commission, 2016)

The risks to foreign investment are real. However, relevant empirical evidence on the nature and extent of the impacts of the foreign investment regulations on agricultural investment in Australia was unable to be identified. The data published by the Commissioner of Taxation show no clear trends since the thresholds were lowered, with an increase in foreign ownership of agricultural land in WA offset by declines in Queensland and the NT. Given the importance of foreign investment to the future of the northern Australia beef industry, further investigations into the impacts of these regulations is warranted.

10.9 Conclusion

The object of this report was to provide a first-pass assessment of the potential regulatory barriers to the expansion of the northern Australia beef industry. Ten main categories of institutions and regulations were identified that apply to the northern beef industry. The analysis of these

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[29] For the most recent report, see: https://firb.gov.au/about-firb/publications/register-foreign-ownership-water-entitlements-report-registrations-30-june (30 June 2019).

institutions identified seven areas that warrant further investigation in relation to their capacity to impede development in the industry:

- land title and native title
- interests in and access to water
- planning, environment and heritage laws
- vegetation management laws
- road transport-related biosecurity, animal welfare and heavy vehicle laws
- live export laws
- foreign investment laws.

11 Biosecurity

11.1 Introduction

Biosecurity has been, and will remain, a critical component of the northern Australia beef industry. The industry has faced notable biosecurity challenges in the past, such as the arrival of the cattle tick and the eradication of bovine tuberculosis (TB). Today it faces biosecurity challenges from multiple fronts, including the re-emergence of threats already here (endemics), possible incursions of threats not previous recorded (exotics) and the emergence of previously unknown or 'new' threats. An escalation in biosecurity challenges is projected, especially as the development of Australia's north is likely to result in increased movement of goods and people to and from the region. Consequently, there is a need to raise biosecurity awareness, surveillance and response capability to ensure that current and future biosecurity risks are managed.

11.2 Current biosecurity status of the northern Australia beef industry

11.2.1 Geography and climate

Northern Australia, with its extensive coastline and small, sparse population is a complex environment in which to monitor and manage biosecurity. This, combined with its close proximity to Australia's northern international neighbours, makes it particularly vulnerable. An incursion from further north may occur via currents and tides, wind dispersion (particularly in the wet season) or international vessels using northern ports (Livestock Biosecurity Network, 2019). Australia's northern neighbours, Indonesia, Malaysia and Papua New Guinea (PNG), have many pests and diseases that are not yet present in Australia and have been identified as a significant biosecurity risk pathway. For example, the geographical closeness of countries to the north of Australia where Old World screw-worm fly (*Chrysomya bezziana*) is endemic and the amount of goods and people moving through Australian ports, particularly the northern ports, has been identified as a risk pathway for this species (Welch et al., 2014) possibly entering through either the Torres Strait or with returning livestock export vessels (Animal Health Australia, 2019a).

The tropical climate of northern Australia is another biosecurity risk facing the region. A larger array of insect pests are found in the tropics that can act as disease vectors, particularly in the wet season (Livestock Biosecurity Network, 2019). The tropical climate also provides for fewer natural breaks to the life cycle of many pests and diseases, adding to their potential impact. Furthermore, there is less information about tropical diseases compared with those found in the southern regions (Commonwealth of Australia, 2015b).

11.2.2 Production system

The production system of the northern Australia beef industry offers both strengths and weaknesses in terms biosecurity risks. First, the extensive grazing system is one of its greatest strengths in that it lowers stock contact and hence potential spread of weeds, pests and diseases

(Livestock Biosecurity Network, 2019). However, this does create a challenge in the ability to closely monitor stock and the environment for biosecurity concerns. This may result in a delay of detection, allowing for weeds, pests and diseases to spread more widely before discovery. Second, livestock movements in northern Australia occur across much larger distances. While the quantity of stock moved may be lower than that of southern regions, the distances they travel mean that if an incursion were to occur, such movements could aid in a more rapid spread across a wider area (Livestock Biosecurity Network, 2019). Third, the region faces long distances for veterinary assistance and laboratory facilities. This may cause a delay in detection and provides an additional challenge in collecting and testing viable samples (NABSnet, 2019).

11.2.3 Exotics

Diseases

Currently, the northern Australia beef industry enjoys a key competitive trade advantage because of its relative freedom from infectious animal diseases, such as foot-and-mouth disease (FMD), bovine spongiform encephalopathy (BSE) and TB. Any change in this freedom status would greatly impact on the trade abilities of not only the region but of the whole national industry.

Table 29 lists the exotic animal diseases relevant to the northern Australia beef industry that are currently recognised in the Emergency Animal Disease Response Agreement.

Table 29 Exotic animal diseases relevant to the northern Australia beef industry

DISEASE	SPECIES
Bovine brucellosis (*Brucella abortus*)	Cattle, buffalo
Bovine spongiform encephalopathy	Cattle, buffalo
Bovine tuberculosis (*Mycobacterium bovis*)	Cattle, buffalo
Bovine virus diarrhoea Type 2	Cattle, buffalo
Contagious bovine pleuropneumonia (*Mycoplasma mycoides* subsp. *mycoides* SC)	Cattle, buffalo
East Coast fever (*Theileria parva*)	Cattle, buffalo
Mediterranean theileriosis (*Theileria annulata*)	Cattle, buffalo
Haemorrhagic septicaemia	Cattle, buffalo
Jembrana disease	Cattle, buffalo
Lumpy skin disease	Cattle, buffalo
Malignant catarrhal fever (wildebeest associated)	Cattle, buffalo
Aujeszky's disease	Multiple
Bluetongue (clinical disease)	Multiple
Borna disease	Multiple
Chagas disease (*Trypanosoma cruzi*)	Multiple
Crimean–Congo haemorrhagic fever	Multiple
Encephalitides (tick borne)	Multiple
Epizootic haemorrhagic disease (clinical disease)	Multiple
Foot-and-mouth disease	Multiple
Heartwater (*Ehrlichia ruminantium*)	Multiple
Japanese encephalitis	Multiple
Rabies	Multiple
Rift Valley fever	Multiple
Rinderpest	Multiple
Screw-worm fly New World (*Cochliomyia hominivorax*)	Multiple
Screw-worm fly Old World (*Chrysomya bezziana*)	Multiple
Surra (*Trypanosoma evansi*)	Multiple
Transmissible spongiform encephalopathy	Multiple
Trypanosomiasis (tsetse fly associated)	Multiple
Tularaemia	Multiple
Vesicular stomatitis	Multiple
Warble fly infestation	Multiple
West Nile virus infection (clinical disease)	Multiple

Source: Animal Health Australia (2018a)

Foot-and-mouth disease

Incursions of exotic animal diseases have not been frequently detected in Australia. The most recent nationally noteworthy animal disease outbreak was equine influenza in 2007, which cost approximately $522 million in direct and indirect losses (Australian Horse Industry Council, 2008). An outbreak of FMD would be far worse and is considered to be one of the biggest biosecurity risks to Australia. Buetre et al. (2013) estimated that the economic impact of a small FMD outbreak within an extensive rangeland grazing system in northern Queensland would be close to $6 billion over 10 years, due to lost markets and eradication efforts. It was estimated that the economic impact of a large multi-state FMD outbreak in Australia would be up to $50 billion over a decade (Buetre et al., 2013).

An FMD outbreak in the northern Australia beef industry is likely to experience lower rates of disease spread due to its extensive grazing system; however, the size of the outbreak would depend on time elapsed before detection and the availability of resources to address the outbreak. Such an outbreak is also likely to require fewer control resources, but may experience higher animal culling rates as vaccination would likely have little effect in reducing cull numbers or eradication time and only add to the total cost of the outbreak (Buetre et al., 2013). The regional economic impact of an outbreak in northern Australia is also likely to be greater due to the limited capacity of the region's economy to restructure following an external shock such as closure of a major industry and export market. The lack of alternative job opportunities for displaced workers could lead to a loss of people and skills from the region, having long-term consequences for regional communities (Buetre et al., 2013). Furthermore, an FMD outbreak in northern Australia may be further complicated by the wider range of feral animals present, possibly causing a delay in the detection of an outbreak, increasing disease spread, raising the cost of control, and delaying disease eradication and proof of disease-free status.

The most significant risk pathway of entry of FMD into Australia is through the illegal importation of meat and dairy products. The sheer volume of international visitors, shipping containers and mail items entering Australia each year, and the inability to inspect them all, makes it the most significant risk pathway. Between December 2018 and February 2019, there were two confirmed detections of FMD in meat products declared and seized at Australian airports, highlighting the risk (Long and Sullivan, 2019). The disease could also be introduced by international visitors accidentally bringing it in on their boots or clothing.

Bovine tuberculosis

The northern Australia beef industry has had experience in a major eradication program with the Brucellosis and Tuberculosis Eradication Campaign (BTEC). This was one of the largest and most expensive animal disease control programs undertaken in Australia, costing an estimated $850 million by its completion in December 1997 (Cousins and Roberts, 2001). Challenges faced by this campaign in northern Australia are still relevant to disease control and surveillance today, including geography and distance, climate conditions, lack of infrastructure (although this has greatly improved since the 1970s), large-scale mustering and testing, and reservoir infection within feral pests (buffalo in the case of TB) (Cousins and Roberts, 2001). See Box 1 for key lessons learned by the BTEC. The prevention of the re-entry of TB into Australia's livestock is now of important concern.

Screw-worm fly

Old World and New World screw-worm fly (SWF) have the potential for spread across the tropical and subtropical areas of Australia, with potentially significant impacts on livestock production and public health (Commonwealth of Australia, 2019d; Animal Health Australia, 2007; Animal Health Australia, 2019a). SWF is endemic across all of Australia's northern neighbours, including PNG, Indonesia, Malaysia, the Philippines and Timor-Leste. The highest risk pathways of SWF entering Australia are considered to be through the Torres Strait, the northern Australian coastline and ports, or with returning livestock vessels (Animal Health Australia, 2007; Animal Health Australia, 2019a). An active surveillance program is conducted through the Northern Australia Quarantine Strategy (NAQS) and the Ports Surveillance Program, using sentinel animals/herds, adult trapping and SWF-specific surveillance at all northern export abattoirs and livestock export facilities (Animal Health Australia, 2019a).

An uncontrolled incursion of SWF is likely to greatly impact the northern cattle industry. Climate modelling has shown that most of tropical northern Australia and the eastern seaboard offer a suitable climate for SWF survival (Sutherst et al., 1989). If SWF were to become endemic in Australia, the direct production losses have been estimated to be in order of $500 million per year, and the total economic impact, accounting for indirect and public health costs, to be in the order of $900 million (Urech et al., 2008). Extensive grazing systems would suffer the highest losses (73% of total producer losses) (Animal Health Australia, 2007). This would come in the form of increased labour costs, projected lower turn-off rates due to higher mortalities, and higher treatment costs. A major social impact could also be expected, especially in extensive cattle areas where, in many cases, economic viability is currently both variable and marginal (Animal Health Australia, 2007). The large feral animal populations present in northern Australia may also add significant concern. Little impact is expected on exports.

Box 1. Key lessons learned from Australia's eradication of bovine tuberculosis

A nationally coordinated bovine tuberculosis (TB) eradication campaign of Australia's national cattle herd began in 1970 in response to concern of its threat to international beef exports and human health (Cousins and Roberts, 2001; More et al., 2015). The program ran for 27 years, costing approximately $850 million (Cousins and Roberts, 2001), and has since been followed by ongoing abattoir surveillance. Eradication of TB in the extensive pastoral areas of northern Australia proved more challenging than that of southern Australia, but Australia's TB freedom was declared in 1997.

There are a number of key lessons from the TB eradication campaign that should be remembered when considering current and future biosecurity responses:

1. strong partnership and clear cost-sharing between government and industry
2. a clear and agreed upon final outcome with both government and industry commitment to the common goal
3. compelling reasons for eradication, both nationally and for individuals – the threat of the loss of international trade and individual farm-based trading restrictions
4. industry's commitment to the TB eradication program – maintaining a strong voice and involvement in the campaign's management, developing a strong and constructive relationship between government and industry
5. a business model for program planning, implementation and review
6. consistent and transparent technical standards, underpinned by a regulatory regime and applied research
7. critical role provided by abattoir surveillance
8. effective elimination of residual infection
9. objective and readily understood measures of program progress
10. willingness to incorporate new technologies and innovative approaches into the program.

The eradication program resulted in substantial additional benefits to cattle productivity in northern Australia, achieved through improved husbandry, mustering, bloodlines, reproductive rates, decreased mortality, controlled livestock movements, and improved infrastructure (water points, yards, fencing).

Pests

Generally, the intentional introduction of exotic vertebrate species has declined in Australia. However, with ever-increasing international trade, people movements, and faster transit (allowing more species to survive transport), the risk of incursion events also increases (Henderson et al., 2011). Exotic pest species incursions may result from escapes from captivity, deliberate releases, smuggling and unintentional stowaways on transport vehicles, containers, people or luggage. They may become pests due to being predators, competitors, or become a pathway and/or reservoir for animal diseases.

Henderson and Bomford (2011) investigated some 1753 reports of illegal and accidental imports, and seizures and surrenders of illegally kept exotic vertebrates in Australia from 1999 to 2010. From these reports one exotic species, the blackbuck (*Antilope cervicapra*), could reportedly pose a risk to the northern Australia beef industry via grazing competition, weed spread and possible disease reservoir. The blackbuck was identified as a significant pest concern, with a serious risk of establishment and a high climate match to northern Australia. A small number of illegally released blackbuck (1980s or 1990s) were known to persist in Cape York, Queensland, before being eradicated (Henderson and Bomford, 2011).

Weeds

Invasive weeds are among the most serious threats to Australia's natural environment and primary production industries. They have major economic, environmental and social impacts in Australia, causing damage to natural landscapes, agricultural lands, waterways and coastal areas.

Research by Randall, Mitchell and Waterhouse (1999) reported that 574 weed species not known in northern Australia were found in near northern neighbours such as Timor, West Papua, Papua, PNG and various smaller Indonesian islands. Most of these species would require some human assistance to enter Australia (Randall, 2014) and the extent of their impact is not fully understood. Table 30 lists some of the exotic weeds species of concern to the northern Australia beef industry, detailing areas of possible distribution and risk posed.

There are number of key biosecurity risk pathways for weeds to spread into or within northern Australia. The level of risk they pose may vary regionally, they may be regulated or unregulated, and there may be border or post-border concerns, but the pathways are generally:

- interstate movement of livestock
- transportation of agricultural produce
- movement via clothing, machinery and vehicles, construction materials or waste disposal
- weed escapes from adjacent locations
- natural spread by animals, wind and water
- spread via other industries (such as the mining, tourism, nursery, grain or fodder seed industries).

Table 30 Some of the exotic weeds species of concern to the northern Australia beef industry

NAME	POSSIBLE DISTRIBUTION	RISK
Bitter weed (*Helenium amarum*)	Prefers open fields, roadsides and disturbed areas in subhumid, warm temperate and subtropical areas where annual rainfall does not exceed 1000 mm Known to exist at a single location near Mount Tarampa in Lockyer Valley	Potential weed of pastures Poisonous to stock, including sheep, horses and cattle Taints milk of dairy cattle
Burning bush (*Kochia scoparia* syn. *Bassia scoparia*)	Tolerates drought Prefers most soil types Found along railway lines and roadsides It is a serious weed of crops in North America	Potential to invade crops and pastures Has the potential to become a serious pest if it is ever introduced
Cha-om (*Senegalia pennata* sp. *insuavis*)	Prefers disturbed habitats, generally near rainforests Sparingly naturalised in northern Queensland	Invades natural ecosystems Invades pastures and reduces beef production
Christ's thorn (*Ziziphus spina-christi*)	Found in areas of low rainfall Capable of growing in desert or semi-desert areas where soils are often silty	Forms dense thickets, displacing native vegetation Dominates grazing land in arid/semi-arid areas
Harrisia cactus (*Harrisia* spp. syn. *Eriocereus* spp. other than *H. martinii*, *H. tortuosa* and *H. pomanensis* syn. *Cereus pomanensis*)	Occurs in Brigalow woodlands and associated softwood country Infestations also found in eucalypt and pine forests Tolerates shade and reaches maximum development in shade and shelter of Brigalow scrub, though established infestations can persist once scrub is pulled	Forms dense infestations that choke out other pasture species when left unchecked Spines interfere with stock mustering and movement, and cause injuries and lameness
Honey locust (*Gleditsia* spp. other than *G. triacanthos*)	Grows in most soil types, especially on alluvial floodplains along river systems Heavy infestations occurred on the Darling Downs in the Clifton-Allora area and at Toogoolawah	Out-competes and replaces native vegetation Provides haven for introduced pests Sharp spines can injure livestock and damage equipment and vehicles

NAME	POSSIBLE DISTRIBUTION	RISK
	Scattered infestations are found around Monto, on the eastern Darling Downs from Toowoomba to NSW and in the Arcadia, Stanley, Bremer and Logan valleys	Forms dense thickets, particularly along waterways, preventing stock access to water
Karroo thorn (*Vachellia karroo*)	Prefers a range of soil types, generally in areas of rangelands in sub-coastal, semi-arid and arid southern Queensland Two recorded infestations on the Darling Downs	Invades large areas, particularly where land has been overgrazed Resists fire and is well-suited to rangelands and open grasslands Reduces agricultural productivity by suppressing grass growth Prevents stock movement and can restrict watering
Piper, spiked pepper (*Piper aduncum*)	Prefers rainforests, roadsides, waterways, plantations and pasture	Forms infestations that exclude all native vegetation Poisonous to cattle
Prickly pear (*Opuntia* spp. other than *O. aurantiaca*, *O. elata*, *O. ficus-indica*, *O. microdasys*, *O. monacantha*, *O. stricta*, *O. streptacantha* and *O. tomentosa*)	Prefers subhumid to semi-arid areas in warm temperate and subtropical regions Varies depending on species and can range from streams, banks, and roadsides to woodlands	Vigorous in hot, dry conditions, causing other plants to lose vigour or die Competes and invades pastures Impedes stock movement and mustering Can harm animals and prevent them from eating
Siam weed (*Chromolaena* spp. other than *C. odorata* and *C. squalida*)	Suited to highly productive land types Grows easily along watercourses, foreshores and swamps Generally found in areas with rainfall over 600 mm per year Found in council areas of Townsville City, Charters Towers, Cassowary Coast, Cairns and Tablelands Target of a national eradication program since 1994. However, an assessment of the program by a nationally appointed scientific advisory panel concluded that it was no longer technically feasible to eradicate	Quickly invades and smothers native vegetation Out-competes native vegetation Increases frequency and intensity of bushfires Out-competes pastures and crops Poisonous to stock Causes skin problems and asthma in allergy-prone people
Tropical soda apple (*Solanum viarum*)	Prefers open, disturbed sites, especially pastures and areas around cattle yards Prefers coastal, high-rainfall habitats in tropical and subtropical areas Small number of isolated infestations in Queensland	Invades and replaces pasture, including improved pasture Leaves are unpalatable to livestock (although fruit are readily eaten) Provides an alternative host for at least six viruses that affect various vegetables
Yellow fever tree (*Vachellia xanthophloea*)	Prefers riparian and other low-lying habitats in tropical and subtropical savannas Only found in gardens but could spread over large areas of central Queensland if escapes into wild A similar species to prickly acacia	Forms dense thickets that could replace native plants and pastures Long-lived seeds would be difficult to control once established Dominates grazing land along banks of waterways

Sources: Department of Agriculture and Fisheries (2018); Northern Territory Government (2019a)

11.2.4 Endemic

Diseases

Endemic diseases are those that are constantly present within a region or population. They may occur only sporadically and only in specific regions, making them endemic in one part of Australia but notifiable in another. These tend to be managed through regional biosecurity programs, such as cattle tick, buffalo fly (*Haematobia exigua*), and 3-day sickness. Other reasons for endemic diseases being notifiable include their potential to cause significant production loses (e.g. cattle tick), the resistance of parasites to chemical treatments (e.g. Parkhurst strain of cattle tick), or their zoonotic potential (e.g. Q fever, leptospirosis). Some endemic diseases have only been present in Australia for a short time and are referred to as emerging diseases (e.g. bovine Johne's disease) (MLA, 2019a).

Cattle tick

Cattle tick is the most significant endemic disease faced by the northern Australia beef industry. It has been estimated that cattle tick has an economic impact to the industry of around $156 million, the majority of which can be attributed to production losses (MLA, 2015). Fortunately, these high economic costs are offset somewhat by the high level of industry knowledge and management tools available. Regional biosecurity programs for cattle tick in northern Australia aim to contain ticks to within specific zones and lower the risk of spreading to areas that are not yet infected. Maintaining the tick control zones is imperative to halt the spread of this endemic species.

A significant problem facing the industry is the development of acaricide-resistant tick populations (Kearney, 2013). The development of acaricide resistance results in the chemical being ineffective in killing and controlling cattle ticks, reducing the number of available effective treatments on the market. Currently, resistant tick strains are present in the Queensland central highlands and northern NT, with minimal resistance found in the northern gulf and western regions of Queensland, and no known acaricide resistance in WA (Kearney, 2013). Further spread outside the tick control zones will have significant impacts on the Bos taurus sector of the industry.

Feral pests

Northern Australia has a wider range of feral animals compared to those found in southern Australia. This larger range provides for a greater potential source or reservoir of disease, both endemic and exotic, as well as an increased variety of disease types and likelihood of a disease impacting one or many of the feral animal species in the region (Livestock Biosecurity Network, 2019). The transmission of pathogens between wildlife and livestock is a globally recognised threat to the livestock industry (Cripps et al., 2018), although there is an incomplete understanding of feral population connectivity and disease transmission under Australian conditions (Caley and Perry, 2018).

Northern Australia's wider range of feral animals also adds to cost and complexity of any surveillance, eradication or control plan. The establishment of an exotic disease, such as FMD, rabies or SWF, in wild animal populations (e.g. pigs, buffalo, deer) (Commonwealth of Australia, 2019f), may present a significant threat to both livestock production and markets. Further adding to the risk is that there are limited surveillance programs currently operating for some feral species (e.g. deer) (Cripps et al., 2018).

Feral animals of concern to the northern Australia beef industry include feral pigs, wild dogs, water buffalo, deer, camel, donkey, horses, goats, rabbits and feral cattle. Table 31 provides a summary of the distribution, biosecurity concerns and controls for feral animals impacting the northern Australia beef industry.

Feral pigs

Feral pigs are considered a major biosecurity threat to livestock due to the range of endemic and exotic livestock diseases for which they are a potential host. Also, there are concerns that they may play a role in spreading and complicating efforts to eradicate exotic diseases, such as FMD. Epidemiological modelling of the spread of FMD by feral pigs in Australia suggests that very high culling rates would be required to achieve eradication (Doran and Laffan, 2005). Feral pigs are also a host endemic disease such as the bacteria *Leptospira* spp. and *Brucella* spp. (causes of infertility in livestock), and contribute to the spread of cattle tick.

Apart from the regular sampling as part of NAQS, all other sampling and disease testing of the feral pig population is opportunistic, which can make disease detection unreliable (Caley and Perry, 2018). There is also a poor understanding regarding disease transmission between pigs under Australian conditions and the connectivity between pig populations (Caley and Perry, 2018). Together these limit the capacity to definitively quantify the risk of feral pigs as disease vectors.

Estimates of the feral pig population in Australia vary greatly, partly because of the difficulty in estimating their numbers, but also because populations change extensively in response to variations in environmental conditions and the availability of food and water. The tropics of Queensland have the highest feral pig densities due to a very suitable combination of water availability, shelter and food resources (Commonwealth of Australia, 2017).

Wild dogs

Wild dogs, which includes the dingo, the feral domestic dog, and hybrids of these, are a declared pest and are subject to management programs due to their impacts on livestock. Wild dogs can have major economic impacts on cattle production enterprises under the right conditions, particularly on calf production, although this may be influenced by the availability of prey and other food sources (Northern Territory Government, 2019b; Wicks et al., 2014). Wild dogs also transmit parasites and diseases to cattle (e.g. hydatidosis, *Neospora caninum*) (Northern Territory Government, 2019b; Wicks et al., 2014), which was estimated to cost the Queensland cattle industry around $2 million in 2008–2009 (AgForce, 2009) Wild dogs could also pose a serious risk if the exotic disease rabies was introduced to Australia. Controls for wild dogs include exclusion fencing, 1080 baiting, shooting, trapping and livestock guardian dogs (minor use in sheep and goats). Having dingoes within the definition of wild dogs does complicate wild dog management across northern Australia as they are considered a native species and as such are protected to varying degrees by the different state legislation.

Table 31 Feral animals of concern to the northern Australia beef industry

FERAL PEST	DISTRIBUTION	BIOSECURITY CONCERN	MANAGEMENT
Pigs (*Sus scrofa*)	Highest densities in the tropics of Queensland Growing populations in NT and Kimberley, WA	Potential carrier of endemic and exotic diseases Biggest concern being their role as a reservoir for foot-and-mouth disease Hosts for the bacteria *Leptospira* spp. and *Brucella* spp.	Trapping, poisoning, aerial and on-ground shooting National threat abatement plan (currently being reviewed)
Wild dogs (*Canis* spp.)	Throughout Queensland, NT and WA Approx. 90% of NT wild dogs are pure-bred dingo	Predation of livestock Transmission of parasites and diseases to livestock Potential carrier of exotic diseases (e.g. rabies)	Control impacted by having dingoes within the definition of wild dogs Effective control requires integrated, collaborative approach Shooting, trapping, fencing and baiting *National Wild Dog Action Plan* *WA Wild Dog Action Plan 2016–2021* Queensland *Wild Dog Management Strategy 2011–16*
Buffalo (*Bubalus bubalis*)	NT only (areas of rainfall >1000 mm/year)	Potential reservoir of livestock diseases Environmental damage Weed spread	Aerial and on-ground shooting Limited active control
Deer (*Cervus* spp.)	Queensland – scattered populations across northern Queensland, larger population of chital deer around Charters Towers NT – Coburg Peninsula, Western Arnhem Land, Groote Eylandt and smaller islands in the Gulf of Carpentaria	Potential reservoir of livestock diseases Environmental damage Weed spread	Fencing, ground and aerial culling, commercial hunting (small) Queensland *Feral Deer Management Strategy 2013–18* National threat abatement plan currently being developed
Camels (*Camelus* spp.)	Over 1 million camels in Australia, largely in central Australian desert regions Size of the population in the NT is thought to have doubled between 1990 and 2000	Potential reservoir of livestock diseases (e.g. TB and brucellosis) Compete with domestic cattle for resources Environmental damage Weed spread	Fencing, live harvest and export, on-ground and aerial shooting NT – aerial shooting done by Parks and Wildlife contractors with land managers paying costs of helicopter hire and ammunition *National Feral Camel Action Plan*
Horses (*Equus caballus*)	Common across northern Australia's extensive cattle production areas	Potential reservoir of livestock diseases Compete with domestic cattle for resources Environmental damage Weed spread	Mustering, trapping, aerial and on-ground shooting
Donkeys (*Equus asinus*)	Arid central Australia, the Kimberley in WA, and the Top End in NT	Potential reservoir of livestock diseases	Mustering, trapping, aerial and on-ground shooting ('Judas' technique used successfully in both cases)

FERAL PEST	DISTRIBUTION	BIOSECURITY CONCERN	MANAGEMENT
		Compete with domestic cattle for resources Environmental damage Weed spread	Local control program on some pastoral leases in the Kimberley, WA
Goats (*Capra hircus*)	Minor populations found in northern Australia	Potential reservoir of livestock diseases Environmental damage Weed spread	Harvesting, mustering, aerial and on-ground shooting, trapping National threat abatement plan (currently being reviewed)
Rabbits (*Oryctolagus cuniculus*)	Above the Tropic of Capricorn is considered to be the edge of their range	Compete with domestic cattle for pasture resources Environmental damage	Biological control, on-ground shooting Integrated control approach, combining different control methods (e.g. destroying rabbit warrens, baiting, rabbit-proof fencing, fumigation, trapping and shooting) with land management practices is most effective National threat abatement plan
Feral cattle	Across northern Australia's extensive cattle production areas	Potential reservoir of livestock diseases Compete with domestic cattle for resources Complicate disease control operations Environmental damage Weed spread	Mustering, trapping, aerial and on-ground shooting

Sources: Business Queensland (2019a); Northern Territory Government (2019d)

Buffalo

Buffalo are only a pest within the NT. They can cause huge environmental damage through their movement and feeding, helping spread weeds (e.g. *Mimosa pigra*), and are a potential reservoir for livestock diseases (e.g. TB and brucellosis). Generally, buffalo herds on pastoral lands are managed but there has been no consistent management of feral buffalo in the NT since the BTEC concluded in 1995 (Saalfeld, 2014). Since then, only smaller scale (property or part catchment) control has been undertaken on both pastoral and Indigenous lands, but these programs have not been coordinated or integrated at the broader regional scale (Saalfeld, 2014). There is a small commercial buffalo industry in northern Australia exporting buffalo to South-East Asia (Indonesia and Vietnam) which is currently not able to meet demand.

Deer

Deer are considered one of Australia's worst emerging pests (Invasive Species Council, 2019). Their importance as a feral pest in northern Australia is not as high as that in southern regions but due to their ability to carry the same diseases that can infect domestic stock they should not be dismissed. The main biosecurity concerns are the cost in lost livestock production, the spread of disease and as a reservoir of disease. Evidence from New Zealand suggests that wild deer could play a role in initiating new outbreaks of TB through dispersal or reinitiate infection post-elimination by acting as a reservoir of infection (Ryan et al., 2006; Nugent et al., 2015; Nugent, 2011; Cripps et al., 2018).

Deer have a potential role in the epidemiology of multiple diseases, both endemic and exotic. Cripps et al. (2018) found that of 38 pathogens reviewed, five of these classified as a high risk for transmission by deer to livestock, including TB, FMD, malignant catarrhal fever, surra and SWF. Feral deer are also susceptible to several diseases and parasites currently in Australia including cattle tick, leptospirosis, and ovine and bovine Johne's disease (Cripps et al., 2018).

Currently, feral deer in northern Australia are largely found in Queensland, with confirmed populations of deer in the Cobourg Peninsula, Western Arnhem Land, Groote Eylandt and smaller islands in the Gulf of Carpentaria of the NT (Davis et al., 2016). However, modelling shows that their potential distribution may greatly expand in northern Australia (Davis et al., 2016). Currently, feral deer are a declared pest in all three states across northern Australia, although the pest class (and thus control requirements) may vary depending on the species. Control measures include shooting (ground and aerial), recreational hunting, trapping and exclusion fencing. The literature (see Cripps et al., 2018; Davis et al., 2016) suggests that there is a limited level of understanding or discussion of disease risks in deer within Australia. The Centre for Invasive Species Solutions is currently conducting research on the risk posed by deer to the livestock industry as hosts for exotic diseases (Centre for Invasive Species Solutions, 2019).

Camels

Camels have encroached into the drier pastoral areas of northern Australia, with the population estimated to be over one million (Edwards et al., 2008; Northern Territory Government, 2019c). Camels have several impacts on agriculture and the environment, particularly the desert environment, including browsing several native shrub and tree species, competing with livestock for water and fodder, contributing to erosion, and damaging stock fences and infrastructure (Edwards et al., 2008). They are a biosecurity issue to the industry largely through their ability to carry and spread weeds and diseases. They also cause problems during disease control operations (e.g. brucellosis and TB) (Edwards et al., 2008). However, Australia's camel population is largely disease free, a status that greatly enhances the suitability of Australian feral camel populations for commercial use, particularly domestic but also for live export (Commonwealth of Australia, 2010). Current methods of camel management are largely ad hoc and include fencing off key areas, live harvest for commercial sale, and ground-based and aerial shooting. Live harvest and export for commercial sale has become (with potential to grow) an important management component for camels.

Feral cattle

Feral cattle are an issue in the more extensive grazing lands of northern Australia. They can affect productivity of properties because feral bulls have inferior genetic characteristics and can dilute efforts to improve herd productivity through selected bulls. They can also cause damage to the environment through soil compaction and erosion near waterways, increased nutrient loading and spread of weeds. Feral cattle can carry and spread disease and may cause problems when undertaking whole herd disease control operations. They are of particular concern as a potential reservoir for disease if major diseases such as FMD arrive in Australia.

Weeds

Weeds are estimated to impose an overall average cost of nearly $5 billion across Australia each year. The majority of these costs are associated with the agricultural industries (average costs of $3.927 billion/year), of which the livestock industries are associated with the higher portion (estimated $2.409 billion/year) (McLeod, 2018). There are currently over 2500 endemic weed species that impact the Australian environment and the primary production industries. They displace native species, contribute to land degradation, reduce grazing and water resources, impede stock management and feral animal control, and consume considerable amounts of time and money for their control, thus reducing agricultural productivity and increasing production costs. Control measures are centred on chemical control, physical removal, the use of fire, disturbance management and biological control, with the last two methods being the most cost-effective in extensive grazing systems. The application of new genetic approaches such as CRISPR-based gene drive technology may offer an effective alternative control method in the future (Webber et al., 2015).

There are several priority weeds that already have an impact on the northern Australia beef industry and their further spread is a risk to the industry, including parkinsonia, prickly acacia, rubber vine, mimosa pigra, bellyache bush, mesquite, gamba grass and parthenium. Table 32 lists some of the endemic weeds of importance to the northern Australia beef industry, their distribution and biosecurity risk.

Table 32 Endemic weeds of concern to the northern Australia beef industry

NAME	DISTRIBUTION	BIOSECURITY RISK
Parkinsonia (*Parkinsonia aculeata*) **(WoNS in Queensland, NT and WA)** **Class B, NT**	Coastal, central and western Queensland; central and northern parts NT; and the Pilbara and Kimberley regions WA Regional priority weed – Alice Springs region, NT	Potential to invade more than three-quarters of mainland Australia Forms dense impenetrable thickets on rangelands and wetlands, making areas of land inaccessible for people and animals Impedes mustering, access to watering points, out-competes pastures, provides refuges for feral animals (especially pigs) Economic costs of control are high once established
Rubber vine (*Cryptostegia grandiflora*) **(WoNS in Queensland, NT and WA)** **Class A, NT**	Widely naturalised in the north-eastern parts of Australia, particularly widespread in northern Queensland	Potential distribution covering all of northern Queensland, the northern parts of NT, and most of the Kimberley and Pilbara regions in WA Infests creek banks and other waterways (i.e. riparian zones), open woodlands, grasslands, closed forests, forest margins, pastures, roadsides and disturbed sites Smothers all other vegetation Economic costs of control are high once established
Mimosa pigra (*Mimosa pigra*) **(WoNS in Queensland, NT and WA)** **Class A/B, NT**	Mostly confined to the NT; has been recorded in northern WA near the NT border; a small infestation near Proserpine, Queensland (removed and managed)	Potential to dominate wetlands across the whole of northern Australia Smothers and replaces grasslands, blocks access to stock watering points and hinders mustering
Prickly acacia (*Vachellia nilotica*) **(WoNS in Queensland, NT and WA)** **Class B, NT**	Over 6.6 million ha of arid and semi-arid Queensland are infested Scattered infestations have been found along the Queensland coast between Bowen and Maryborough, the Barkly Tablelands and Arnhem Land in the NT, west of Wyndham in WA	Potentially infest vast tracts of grasslands and woodlands throughout Australia Economic impacts of prickly acacia on Queensland's grazing industry are estimated at $3 million to $5 million per year Even at medium densities, it halves the primary productivity of grasslands, interferes with stock mustering and restricts stock access to water
Mesquite (*Prosopis* spp.) **(WoNS in Queensland, NT and WA)** **Class B, NT**	Worst infestations are on pastoral land in the Pilbara in WA; the Barkly Tablelands in the NT; and in north-western, central and south-western Queensland	Potential distribution across much of northern Australia Forms dense, impenetrable thickets which, combined with its large thorns, prevent stock accessing watering holes and make mustering difficult, out-competes pasture and reduces pastoral productivity Seedpods poisonous to livestock if consumed in large amounts Harbours feral animals
Bellyache bush (*Jatropha gossypiifolia*) **(WoNS in Queensland, NT and WA)** **Class A/B, NT**	Widespread but scattered distribution throughout northern Australia; common in the northern parts of Queensland, NT and WA, but is also present in central and south-eastern Queensland and in other parts of the NT	Forms dense thickets that interfere with pasture growth, obscure fence lines, interfere with mustering and displace native vegetation Poisonous to livestock Harbours feral animals

NAME	DISTRIBUTION	BIOSECURITY RISK
Parthenium (*Parthenium hysterophorus*) **(WoNS in Queensland, NT and WA)** **Class B, NT**	Widespread and seemingly entrenched in central Queensland Outbreaks have occurred (and controlled) in NT	Major problem in rangeland of Queensland, costing farmers and graziers over $22 million a year in reduced production and increased management costs Colonises disturbed and heavily stocked areas, reduces both pasture establishment and potential, and invades native vegetation Somewhat toxic to livestock and taints meat Spread via vehicle, farm machinery, grain and livestock movements
Lantana (*Lantana camara*) **(WoNS in Queensland, NT and WA)** **Class B, NT**	East of the Great Dividing Range to Cape Melville in northern Queensland; isolated infestations in the Top End of the NT	Potential to spread further west of the Great Dividing Range, across the northern part of the NT and into areas of northern WA Forms dense, impenetrable thickets that take over native bushland and pastures Most variants are toxic to cattle to some degree
Athel pine (*Tamarix aphylla*) **(WoNS in Queensland, NT and WA)** **Class B, NT**	Widely distributed in the inland areas of Australia; naturalised in areas in the NT, Queensland and WA Regional priority weed – Alice Springs region, and Barkley Tablelands, NT	Potential distribution across much of the NT, except the Top End Displaces eucalypts and native vegetation, may alter fire regime, raises localised salinity Impedes mustering and decreases pasture production, competes for water resources
Gamba grass (*Andropogon gayanus*) **(WoNS in Queensland, NT and WA)** **Class A/B, NT**	Naturalised in the east Kimberley region of WA, in the northern parts of the NT (primarily Darwin and Katherine regions), and in coastal and sub-coastal areas of northern Queensland	Potential to spread from current distribution Impact on savanna biodiversity, loss in tree cover, increased fire intensity and alters soil nitrogen availability
Pond apple (*Annona glabra*) **(WoNS in Queensland, NT and WA)** **Class A, NT**	Currently distributed in the coastal districts of northern and central Queensland	Potential to spread throughout estuaries and floodplains of much of northern Australia Mainly an environmental weed at present, it may have impacts on the cattle industry in the future

WoNS = Weeds of National Significance
Source: Commonwealth of Australia (2019a)

Some plant species have been identified as of concern due to their impact on the industry but may or may not be declared weeds. Their impact may cause a reduction to pasture productivity, reduce stocking rates, impede mustering or are suspected of being poisonous to stock. These include candle bush (*Senna alata*), castor oil plant (*Ricinus communis*), chinee apple (*Ziziphus mauritiana*), fountain grass (*Cenchrus setaceus*), grader grass (*Themeda quadrivalvis*), Mexican feather grass (*Nassella tenuissima*), Noogoora burr (*Xanthium strumarium* or *X. occidentale*), Bathurst burr (*Xanthium spinosum*), rubber bush (*Calotropis procera*), para grass (*Urochloa mutica*), olive hymenachne (*Hymenachne amplexicaulis*), and perennial (*Cenchrus polystachios*) and annual mission grass (*C. pedicellatus*) (Business Queensland, 2019b; Northern Territory Government, 2019e). Box 2 describes methods being used to help eradicate several key weeds from western Queensland.

Box 2 . The War on Western Weeds (WoWW)

The War on Western Weeds (WoWW) initiative contributed to reducing the incidence and spread of prickly acacia and bellyache bush in western Queensland through improved weed management, research and training. WoWW was a 5-year, $1.88 million Queensland Government initiative managed by the Queensland Department of Agriculture and Fisheries. It commenced mid-2013 and concluded in mid-2018. The WoWW initiative focused on three key areas: (i) refining new tools and approaches, (ii) improving biosecurity systems, and (iii) exploring biological control opportunities. The WoWW initiative increased the capacities, skills, tools and motivation of land managers to help achieve practical and cost-effective outcomes for prickly acacia management. The key outcomes included:

- improved understanding of prickly acacia ecology to better manage the problem
- refinement of herbicide application techniques, especially spray misting, heli-drop and scattergun methods
- development of community-based case studies, particularly Good Neighbour Programs, to pilot new weed control approaches
- identification and testing of potential biological control agents, including insects and pathogens
- development of biosecurity systems and guidelines to reduce the spread of weeds within and between properties
- improved planning and management for prickly acacia control at all levels (from individual properties to cross-regional scale)
- promotion of best-practice weed management through field days, workshops and forums.

Source: Business Queensland, 2019c

11.2.5 Antimicrobial resistance (AMR)

Antimicrobial resistance (AMR) is no longer an emerging issue, but a current threat to human and animal health (DAWR, 2019). It is a significant threat to Australian animal industries through its potential impacts on public health, animal health and welfare, and trade. In animals, AMR infections result in reduced animal health, welfare, biosecurity and production outcomes. Additionally, the resistant bacteria may be transferred to people either via contact with infected animals or via food where infected animals are destined for human consumption (DAWR, 2019). There is increasing recognition that AMR will affect exports of food animals and food animal products to international markets. To address concerns, Australia, in a partnership between government and stakeholders, has developed the National AMR Strategy 2015–2019 and the Animal Sector National AMR Plan 2018 (DAWR, 2019).

The extensive grazing systems that make up much of the northern Australia beef industry have little call for the use of antimicrobials. It is the feedlot sector of the industry where AMR concerns are centred; however, this is not a large component of the northern Australia beef industry. In

Australian feedlots, antimicrobials play an indispensable role in helping manage the health and welfare of cattle in the system, but they may also be added to feed to improve animal growth and feed conversion. In December 2017, the livestock, veterinary pharmaceutical and animal feed industries voluntarily agreed to the removal of label claims for growth promotion from antimicrobials of importance to human health (DAWR, 2019). There is an opportunity for further development of prevention strategies other than antibiotics (e.g. vaccines, eradication and biosecurity) for the control of bacterial disease (Commonwealth of Australia, 1999).

11.2.6 Surveillance programs

There are numerous surveillance programs tasked with specific biosecurity issues currently utilised to protect the interests of the northern Australia beef industry. Including:

1. *Northern Australia Quarantine Strategy (NAQS)* – aims to provide an early warning system for exotic pests, weed and disease incursions across northern Australia and to help address unique biosecurity risks of the region. It undertakes a vast range of biosecurity activities including:
   - surveillance of targeted pests, diseases and weeds in coastal areas across northern Australia
   - biosecurity operations to address risks associated with movements of people, cargo, aircraft and vessels into and between biosecurity zones in Torres Strait, and to mainland Australia
   - public awareness activities (Top Watch)
   - collaborations with external stakeholders, particularly Aboriginal and Torres Strait Islander communities and state and territory agencies
   - participation in surveillance and monitoring activities in neighbouring countries.

   Source: (Commonwealth of Australia, 2019c), see: http://www.agriculture.gov.au/biosecurity/australia/naqs
2. The *Northern Australia Biosecurity Framework (NABF)* – builds on NAQS, which was established in 1989 to undertake surveillance for exotic pests and diseases across northern Australia. This new framework encourages collaboration between communities, industries and governments to safeguard the new and growing biosecurity risks in northern Australia. The program will include:
   - increasing biosecurity work for rangers; more community information and engagement
   - supporting biosecurity surveillance in neighbouring countries
   - improving collection, storage and reporting of tropical biosecurity data
   - strengthening the diagnostic capacity for tropical biosecurity
   - expanding biosecurity surveillance in several areas including marine environments and Indian Ocean territories.

   The NABF will be guided by a Reference Group comprising senior representatives from Australian, WA, NT and Queensland governments, Plant Health Australia and Animal Health Australia (AHA). The involvement of scientists and communities (especially Aboriginal and Torres Strait Islander communities) will play a key role.

Source: (Commonwealth of Australia, 2019b), see: http://www.agriculture.gov.au/biosecurity/partnerships/northern-australia-biosecurity-framework/

3. *Northern Australian Biosecurity Surveillance project (NABS)* – the project has been funded under the *Developing northern Australia white paper* and the *Agricultural competitiveness white paper* to manage new and growing biosecurity risks in northern Australia. It is funded by the Australian Government and supported by the WA, NT and Queensland jurisdictions and AHA. It aims to build effective and sustainable surveillance systems to enhance the early detection of exotic disease incursions and to provide surveillance information to underpin proof of freedom from trade-sensitive diseases in northern Australia. Activities under this project includes the distribution of post-mortem sampling consumables kits distributed to major cattle properties across northern Australia. The kits are designed to be kept on-hand by properties, to assist vets and others performing disease investigations in remote areas.

   Source: (NABSnet, 2019), see: http://nabsnet.com.au/

4. *National TSE Surveillance Project (NTSESP)* – is part of the surveillance component of the larger *TSE Freedom Assurance Program (TSEFAP)*, which is responsible for delivery of nationally integrated transmissible spongiform encephalopathy (TSE) risk-minimisation measures to keep Australian animals and their products free from TSEs. The TSEFAP is jointly funded by industry and governments and is managed by AHA. The NTSESP purpose is to enhance market confidence that Australian animals and animal products are free from TSEs (BSE and scrapie). It involves testing of samples from cattle with clinical signs consistent with BSE, as well as from fallen and casualty slaughter cattle. The program's objectives include:
   - maintain Australia's TSEs freedom status
   - conduct surveillance to meet international requirements and assure trading partners of Australia's TSEs freedom
   - demonstrate that no restricted animal material is fed to ruminants
   - manage risks posed by animals imported from countries that have had cases of TSE
   - provide an early detection mechanism should the disease even occur.

   Source: (Animal Health Australia, 2019b), see: https://www.animalhealthaustralia.com.au/what-we-do/disease-surveillance/tse-freedom-assurance-program/

5. *National Arborvirus Monitoring Program (NAMP)* – is an ongoing collaboration between the cattle, sheep and goat industries; the livestock export industry; and the state, territory and Australian governments. It monitors the distribution of economically important arboviruses (insect-borne viruses) of ruminant livestock and associated insect vectors, including Akabane, bovine ephemeral fever (BEF) and bluetongue viruses. NAMP data are gathered throughout Australia by serological monitoring of cattle in sentinel herds and strategic serological surveys of other cattle herds (serosurveys), and trapping of insect vectors. The programs objectives include:
   - market access – to facilitate the export of live cattle, sheep and goats, and ruminant genetic material, to countries with concerns about bluetongue, Akabane and BEF viruses

- bluetongue early warning – to detect incursions of exotic strains of bluetongue virus and vectors (*Culicoides* spp. biting midges) into Australia by surveillance of the northern bluetongue virus epidemic area
- risk management – to detect changes in the seasonal distribution in Australia of endemic bluetongue, Akabane and BEF viruses and their vectors, to support livestock exporters.

  Source: (Animal Health Australia, 2019c), see: https://animalhealthaustralia.com.au/what-we-do/disease-surveillance/national-arbovirus-monitoring-program/

6. *Screw-Worm Fly Surveillance and Preparedness Program (SWFSPP)* – is managed by AHA in consultation with a committee of industry and government stakeholders. It is a surveillance program for both Old World and New World SWF, aiming to safeguard early detection of any incursion to ensure eradication success. Old World SWF is considered a greater threat to Australian livestock industries than New World SWF due to the proximity of its distribution to Australia and traffic of livestock export vessels returning from Asia to Australian ports (Commonwealth of Australia, 2019a). The program comprises four work areas:
   - surveillance by: (i) fly trapping in WA (four locations), the NT (two locations) and Queensland (two locations); and (ii) targeted livestock wound surveys for myiasis in WA (two locations), the NT (three locations) and Queensland (four locations)
   - entomology training and development of reference resources
   - awareness promotion to increase general surveillance for myiasis
   - monitoring of the risk profile for SWF in Australia.

   Source: (Animal Health Australia, 2019a), see: https://www.animalhealthaustralia.com.au/what-we-do/disease-surveillance/screw-worm-fly/

7. *National Significant Disease Investigation (NSDI) Program* – facilitates investigations of significant disease events by non-government veterinary practitioners that would generally not occur due to competing priorities and commercial realities, such as the low economic value of individual animals relative to the cost of veterinary services. In 2016 the program expanded to include training of private veterinary practitioners in disease investigation, to increase the level of knowledge, skill and confidence to investigate and report on disease events. Subsidies are available through the program for field work, laboratory diagnostic work and a follow-up field investigation, if required.

   Source: (Animal Health Australia, 2019d), see: https://www.animalhealthaustralia.com.au/what-we-do/disease-surveillance/national-significant-disease-investigation-program/

8. *Endemic Disease Information System* – an AHA program that collects data from national programs that monitor endemic animal diseases found in Australia. It includes a public register of properties currently listed with the Australian Johne's Disease Market Assurance Program and National Sheep Health Monitoring Project information. Summary information from this program and other sources is used to support trade in animal commodities and meet Australia's international reporting obligations.

Source: (Animal Health Australia, 2019e), see:
https://www.animalhealthaustralia.com.au/what-we-do/disease-surveillance/endemic-disease-information-system/

9. *National Animal Health Information Program (NAHIP)* – is a collaboration between governments, livestock industries, AHA and Wildlife Health Australia to collate surveillance and monitoring data and provide an overview of animal health in Australia. The program maintains a database, the National Animal Health Information System (NAHIS), and produces the *Animal health surveillance quarterly report* and *Animal health in Australia annual report*. Objectives of the program are to:
   - collect summary data on animal health status and surveillance from the Australian, state and territory governments, and selected non-government agencies
   - manage, analyse and report data on Australia's animal health status as well as its surveillance and disease control activities and capabilities
   - identify needs and priorities for collating and reporting summary animal health information and required enhancements to the NAHIS.

   Source: (Animal Health Australia, 2019f), see:
   https://www.animalhealthaustralia.com.au/what-we-do/disease-surveillance/national-animal-health-information-system-nahip/

11.3 Biosecurity megatrends

Australia's biosecurity system is under growing pressure due to increased global trade and travel, agricultural expansion and intensification, urbanisation, changing consumer expectations, biodiversity pressures, and declining resources (Craik et al., 2017; Simpson and Srinivasan, 2014). In 2014 CSIRO released a report (see Simpson and Srinivasan, 2014) looking at these pressures and identified five global biosecurity megatrends for Australia. A megatrend is a significant shift in environmental, economic, social, technological or geopolitical conditions with the potential to reshape the way an organisation, industry or society operates over the coming decades (Hajkowicz et al., 2012; Simpson and Srinivasan, 2014). The megatrends identified by Simpson and Srinivasan (2014) indicate that Australia is likely to face a shift in the types of biosecurity risks and the way they will need to be managed. The identified megatrends from the report are:

1. *An Appetite for Change*: Rising global food demand is resulting in agricultural expansion and intensification. This demand brings opportunities for agricultural growth in Australia, and northern Australia has been identified as a possible key component of meeting that demand.

   Key implications that may be relevant to the northern Australia beef industry:
   - new biosecurity risks (via new pathways or new hosts) may be created by agricultural expansion and land-use change
   - increased vertical integration may leave only a small number of producers responsible for biosecurity across the entire supply chain
   - foreign investment associated with agricultural expansion has the potential to increase Australia's biosecurity risks through the introduction of new crops or animals)

- Australia's 'pest and disease-free' status could rise in importance in a growing and highly competitive global market. Maintaining that status will be essential to retain any competitive market advantage

2. *On the Move*: Australia's comparative isolation that once provided some biosecurity benefits has been reduced by the increased movement of goods, vessels and people around the world. Travel is faster and more accessible, allowing for a more interconnected world. This creates more opportunities for pests and diseases to enter and spread across Australia such that it is no longer a case of 'if' but 'when' a new threat will arrive.

   Key implications that may be relevant to the northern Australia beef industry:

   - increased movement of people and goods may help to bring new pests or diseases
   - the development of more and/or stronger regional and global biosecurity standards will be required
   - increased global trade will require Australia to protect its biosecurity status to maintain its competitive advantage in export markets, while at the same time avoid being seen as protectionist
   - the importance for interstate surveillance will grow due to greater domestic freight and people movements increasing the risk of pests and diseases being spread across Australia
   - rising online retailing may create new opportunities for the introduction of pests and diseases through illegal fauna and flora trade
   - the need for offshore biosecurity investment will remain and may need to be increased as a means of preventing biosecurity risks reaching Australian shores

3. *The Urban Mindset*: Growing urbanisation of society is leading to urban encroachment on some agricultural areas, an increasingly disconnected urban population from primary industries (and hence biosecurity issues) and changing consumer expectations relating to food production. New and adaptive biosecurity capabilities will be required to adapt to these changing expectations.

   Key implications that may be relevant to the northern Australia beef industry:

   - increased disconnection of urban populations and changing consumer expectations (e.g. regarding production methods, animal welfare, chemical use) could place increasing demands on primary production without fully considering the biosecurity or food safety implications
   - an increase in peri-urban/amateur producers who may tend to be less connected to the biosecurity network will require improved engagement to improve their understanding of biosecurity risks and adoption of biosecurity practices
   - peri-urban producers may be relatively close to major ports of entry for pests and diseases, which may help facilitate the establishment of certain pests and diseases
   - ongoing urban expansion could change interactions between people, wildlife, agriculture and disease vectors, increasing risks such as zoonotic disease

4. *The Efficiency Era*: There is a general trend in Australia towards declining biosecurity resources, both in terms of investments and experienced biosecurity specialists and producers. In response, the use of, and reliance on, technology occurs to fill the gaps.

   Key implications that may be relevant to the northern Australia beef industry:

- declining resources, investments in biosecurity, and biosecurity specialists could limit the support in identifying and responding to a pest or disease outbreak
- traceability solutions (not just livestock but also inputs) will play an increasing and invaluable role in day-to-day biosecurity management, allowing outbreaks and contaminants to be traced, contained and eradicated faster, minimising costs and protecting market access
- rise in the use of behavioural and social sciences to better understand biosecurity stakeholders, and the development of improved communication tools, may aid the flow of information and increase engagement in biosecurity management across all sectors
- improved surveillance and diagnostic techniques in the area of genetics may allow for better detection and understanding of pests and diseases, as well as opportunities to breed resistant species (e.g. gene-driven technology)
- improvements to technology, data modelling and increased data availability may lead to improved long-term decision making, risk pathway identification, and better detection and identification of pests and diseases
- conversely, if issues of reduced resourcing and poor data integration are not overcome it could reduce the potential for technological solutions to address current and future biosecurity challenges

5. *A Diversity Dilemma:* Declining biodiversity has been happening over the past 200 years. While it is known that this will have detrimental impacts, the exact scale and severity will likely become clearer in the coming decades.

   Key implications that may be relevant to the northern Australia beef industry:

   - a changing climate may allow the spread of pests, diseases and disease vectors into new areas
   - the loss of agricultural biodiversity may lead to reduced resilience to pest and disease outbreaks.

11.4 Risks and gaps in the biosecurity system

Past research has identified risks and gaps in Australia's biosecurity system that could be improved. Although the research is often concerned with the Australia-wide system, much is still relevant to the northern Australia beef industry.

11.4.1 Shared responsibility

The concept of 'shared responsibility' has been an important component of Australia's biosecurity system for some time. However, there is a general lack of understanding about what it means and how it impacts on roles and responsibilities for biosecurity. There has been significant progress towards the 'shared responsibility' model in some areas of Australia's biosecurity system, such as the roles of AHA and Plant Health Australia in bringing together industry engagement with biosecurity awareness and delivery (Craik et al., 2017; Simpson and Srinivasan, 2014). However, further improvements may be achieved by providing a clearer definition of 'shared responsibility', as well as better defined, and agreed upon, roles and responsibilities of participants across the national biosecurity system (Craik et al., 2017). Industry and producers may also need improved legislation to effectively increase their roles in biosecurity management (MLA, 2016b).

Additionally, the ‘shared responsibility’ model is frequently reported as being seen as a euphemism for cost shifting or a devolving of responsibilities by the government sector onto industry and producers (Simpson and Srinivasan, 2014; Craik et al., 2017; Loechel et al., 2018). This attitude may result in resentment and poor responses to biosecurity risks and/or incursions.

11.4.2 Impacts of agricultural expansion

Agricultural expansion in northern Australia may introduce new biosecurity threats through new pathways or new hosts for pests and diseases (Simpson and Srinivasan, 2014). Growth will result in increased movements of livestock, goods, vessels and people. They may travel further, be transported faster, and arrive from a vast array of locations, all of which may result in increased biosecurity risks that will have implications for producers, industry and government. Increased border interceptions of items that could harm Australian agriculture has already occurred as international movement of people and goods has grown (Livestock Biosecurity Network, 2019). Therefore, biosecurity considerations will form an important component when considering any expansion of the beef industry, or any other agricultural sector, in northern Australia.

The agricultural expansion and intensification of northern Australia may also pose a biosecurity risk to southern Australia by serving as a ‘green bridge’ for exotic pests to enter the southern region of Australia (Commonwealth of Australia, 2015a). An example of such an incident in the cropping industry was the arrival of sugarcane smut in the Ord, WA, in 1998 via wind spores from South-East Asia, which spread to Queensland in 2006, eventually resulting in a 10 to 30% reduction in gross margins because of yield losses, and the cost of planting resistant varieties (Fitt, 2016)

Expansion of the feedlot industry in northern Australia is favoured by availability of land and water, and the location of the tick zone, eliminating the need to dip cattle en-route from northern regions. However, it is limited in some regions by the lack of access to abattoirs, the strong competition for cattle from the live export trade, and the lack of adequate quantities of feed grain grown in the region (MLA, 2009). Any expansion of the feedlot sector would favour large, vertically integrated companies already involved in the live export industry (MLA, 2009). Such an expansion may heighten biosecurity risks as increased vertical integration reduces the number of companies responsible for biosecurity across the entire supply chain, which may allow for the rapid spread of a biosecurity issue throughout the entire supply chain (Simpson and Srinivasan, 2014).

11.4.3 Impacts of agricultural expansion by neighbouring countries

Like agricultural expansion in northern Australia, any expansion of the agricultural sector in neighbouring countries may also have biosecurity implications that need to be considered when managing biosecurity risks for northern Australia (Simpson and Srinivasan, 2014). For example, increasing domestic beef production for self-sufficiency continues to be a major priority for the Indonesian government. As part of that policy, they have opened trade with FMD countries (Meat and Livestock Australia, 2018b).

If agricultural expansion and intensification in nearby countries creates increased biosecurity risks abroad, it will be important to remain aware of the potential for these risks entering Australia. Industry and government will need to work cooperatively, sharing information and expertise with Australia's northern neighbours to help prevent biosecurity risks before they arrive (Commonwealth of Australia, 2015a). This points to the need for government to retain, and possibly increase, offshore biosecurity investments as a means of preventing biosecurity risks reaching Australian shores (Simpson and Srinivasan, 2014).

11.4.4 Climate change

A changing climate may allow the spread of pests, diseases and disease vectors into new areas (Simpson and Srinivasan, 2014). The successful establishment of an invasive species requires specific environmental and ecological conditions to be met. However, a changing climate may create conditions favourable for the establishment or spread of invasive species. For example, cattle tick is predicted to spread south with increased temperatures (White et al., 2003) and the distribution of the insect vector of bluetongue virus is projected to expand (Sutherst, 2001).

Additionally, changes in Australia's climate are having a profound impact on biodiversity, including causing the disappearance of environments as well as the creation of novel environments (Dunlop et al., 2012). Changing migratory bird patterns and the movement of plant and animal species into new areas have already been witnessed (Simpson and Srinivasan, 2014).

The combination of altered environments, due to changes in biodiversity and climate, increased urbanisation and growing international and interstate trade, vessel and people movements (therefore creating greater opportunities) could see the establishment and spread of invasive species not previously seen (Fitt, 2016).

11.4.5 Increased vertical integration

Greater vertical integration in agriculture both locally and globally may mean that only a small number of companies become responsible for biosecurity across the entire supply chain (Simpson and Srinivasan, 2014). If an incursion of some kind happens at one point along a company's supply chain, it could result in a rapid spread across the entire system if detection is delayed. If these integrated organisations do not prioritise biosecurity in their operations problems could emerge (Simpson and Srinivasan, 2014). However, such integration may facilitate collaboration with government agencies, resulting in the industry supply chain making investments in education and training, sustainable processes, coordination, and science and technologies that reduce biosecurity threats (Simpson and Srinivasan, 2014).

11.4.6 Antimicrobial resistance (AMR)

To address concerns regarding AMR, the Australian Government, in partnership with stakeholders, has developed the National AMR Strategy 2015–2019 and the Animal Sector National AMR Plan 2018 (DAWR, 2019). This is in response to the animal sector recognising that it has a shared responsibility in the appropriate use of antimicrobials to address resistance. Improving antibiotic stewardship must go hand-in-hand with improved infection control (human and veterinary) and improved animal management and biosecurity on farms (APVMA, 2017). While progress has occurred, the Animal Sector National AMR Plan 2018 (DAWR, 2019) identified gaps and challenges remain, for example:

- improving AMR-related education of animal health professionals
- developing options to ensure farmers and community have access to relevant, reliable and targeted information about AMR
- improving infection prevention and control and biosecurity measures across components of the animal sector to help prevent infections and the spread of antimicrobial resistance
- collecting additional data to provide evidence of activities the Australian animal sector is undertaking to address AMR.

11.4.7 Existing surveillance programs

Surveillance activities need to be strengthened, and technological development and improved stakeholder engagement are key to achieving this. Science and technology can help to create greater levels of efficiency in biosecurity surveillance and monitoring. This will be particularly important for remote locations, like northern Australia, where management occurs over vast distances (requiring long travel times) or when inspection is labour intensive (Simpson and Srinivasan, 2014). Enhanced incentives are also required to encourage producers to participate in on-property surveillance to improve detection and response. Industry may also need supporting legislation if it is to effectively take on a stronger role in biosecurity management (ACIL Allen Consulting, 2016). Without sufficient resources and surveillance technologies, the greater movement of goods and people has the ability to increase the level of risk for Australia. Technological development and improved stakeholder engagement will help to address any shortfalls in resourcing.

The large national or the whole of northern Australia focus of some surveillance programs has shortcomings due to the size of the region. The priorities of these programs are not always the same as those of state authorities or of what is required in a particular area, while any other sampling and disease testing that does occur tends to be more opportunistic. This approach has the potential to not detect all biosecurity concerns. For example, while NAQS does survey into WA, the survey may have different priorities and could overlook infestations of species of significance to WA such as gamba grass or prickly acacia (Randall, 2014). Recognition and identification of shortfalls in existing surveillance programs is important so they can be addressed or supplemented.

11.4.8 Interstate borders

The actual incursion rates across state boundaries for organisms with a biosecurity risk remains unknown. Information on detections at quarantine checkpoints make only a fraction of all incursions, with most being declared species that are reasonably well known to staff at the border and in the region (Randall, 2014). However, many of the roads crossing state borders are unregulated, having no permanent quarantine checkpoint and instead relying on people knowing, understanding and upholding biosecurity regulations. There is little data available on what and how much movement of livestock, goods or vehicles occurs along these more remote transport routes. Although anecdotal evidence suggests there are risks associated with these pathways, no data on truck or stock numbers are currently available. (Randall, 2014).

Greater domestic freight and people movements within Australia will result in an increased risk of pest and disease spread across Australia. Hence the importance for interstate surveillance will grow to protect against both the spread of endemic species and to limit the impact of exotic species that arrive through increasing international travel, trade, vessel movements and even parcel post (Simpson and Srinivasan, 2014).

11.4.9 Traceability

Accurate livestock traceability systems are imperative in any disease outbreak and are expected to play an increasing and invaluable role in day-to-day biosecurity management (Simpson and Srinivasan, 2014). This is not just for livestock traceability but also includes information on inputs, treatments and actions (e.g. vaccination records). Further development of traceability solutions will help to increase the capacity for the industry to trace outbreaks and contaminants, and contain and eradicate issues faster; minimise costs; and help to prove eradication and regain market access (Simpson and Srinivasan, 2014).

11.4.10 Data

Greater sharing and availability of large datasets could help to enhance multidisciplinary biosecurity research, integrating resources and information across plant, animal, environment and human health disciplines, as well as climate change, economics, systems modelling and social sciences (Simpson and Srinivasan, 2014).

11.4.11 Reducing resources and investment

Declining biosecurity and agricultural resources and investment have the potential to create significant gaps in biosecurity capability (Simpson and Srinivasan, 2014). The agricultural sector generally is experiencing an ageing of its population, with fewer young people entering agriculture, large-animal veterinary sciences and, more specifically, the biosecurity disciplines. There are concerns that this will cause a decline of knowledge and specialists across the sector and changes will need to occur to ensure the ongoing improvements of biosecurity prevention, management and response activities (Simpson and Srinivasan, 2014).

Along with the personnel and knowledge shortfalls, a tight fiscal environment for governments has placed significant pressure on biosecurity budgets (Craik et al., 2017; Simpson and Srinivasan, 2014). While investment improved after the 2008 *Beale review*, the general sentiment within the biosecurity community is that investment has not kept pace with the growing challenges (Simpson and Srinivasan, 2014). Technological developments in surveillance, data capture and analysis, communication and engagement, and genetics may help improve future biosecurity capacity. It will also be important to manage investment of resources in the *known* biosecurity threats versus the *unknown* when developing biosecurity strategies that aim to protect the future of Australia's livestock-related industries (Simpson and Srinivasan, 2014). In a globalised world this will be crucial in helping these industries remain competitive, and to retain and gain access to international markets (Simpson and Srinivasan, 2014).

11.4.12 Infrastructure

Expansion of the northern Australia beef industry is likely to require additional infrastructure and investment. A 2015 review of the infrastructure available to the northern beef industry in WA found that there was a requirement for more efficient biosecurity infrastructure in the region (ACIL Allen Consulting, 2016). Specifically:

- improved truck wash-down facilities – to wash down trucks prior to vessel loading as required by some overseas markets
- AQIS-accredited holding yards – to allow cattle with different market requirements to be held separately and to also serve as a quarantine facility in the event of a biosecurity outbreak.

The identified infrastructure is required to meet market standards and to strengthen biosecurity preparedness within the Broome, Pilbara and Kimberley regions.

11.4.13 Communication and Engagement

Communication and engagement strategies will play an important role in making biosecurity a priority for everyone. There is a need for biosecurity engagement programs that are participatory, targeted, and allow for evaluation and monitoring (Kruger et al., 2009). There has been a rise in the use of behavioural and social sciences to better understand biosecurity stakeholders. There has also been the development of improved communication tools (Simpson and Srinivasan, 2014). This may aid the flow of information and increase engagement in biosecurity management across all sectors and is something that industry can especially harness. Science-based biosecurity information should be disseminated to relevant individuals or communities; this can now happen via a variety of platforms (e.g. apps, newsletters, social media, etc.).

Enhanced incentives are also required to encourage producers to participate in on-property surveillance to improve detection and response (Simpson and Srinivasan, 2014). The peri-urban/amateur producers are a group that this particularly relates to as they tend to be less connected to the biosecurity network. Improved engagement with this sector is required to improve their understanding of biosecurity risks and adoption of biosecurity practices (Simpson and Srinivasan, 2014).

11.4.14 Market Access

Australia's 'pest and disease-free' status is likely to rise in importance in a growing and highly competitive global market. Maintaining that status will be essential to retain any competitive market advantage. Government and industry will need to protect the industry's biosecurity status while at the same time avoid being seen as protectionist (Simpson and Srinivasan, 2014). This will require the development of more and/or stronger regional and global biosecurity standards.

11.5 Current biosecurity research and innovation activities

Biosecurity initiatives in northern Australia have been funded under the *Agricultural competitiveness white paper*. The activities have centred around:

- improved animal, plant and aquatic surveillance (e.g. using new technology)

- modern diagnostics (using new equipment, modern methods and highly skilled diagnosticians from around Australia)
- better data (moving from manual to digital systems – even in remote areas)
- community engagement (sharing information and listening to what people need)
- Indigenous rangers (recognising the skills and knowledge of Aboriginal and Torres Strait Islander rangers to undertake a wide range of biosecurity work across northern Australia, especially in remote areas) (Commonwealth of Australia, 2019e).

Table 33 provides a list of some of the activities across northern Australia as the result of collaborations between the NT, WA and Queensland governments; AHA; Plant Health Australia; and other Australian Government stakeholders (Commonwealth of Australia, 2019e).

Table 33 Biosecurity activities in northern Australia

PROJECT	WHO	HOW THIS WILL MAKE A DIFFERENCE
Projects benefitting farms/farmers/aquaculture and other industries		
New 'sentinel' herds in Merapah (Queensland), Gunbalanya (NT), Papua New Guinea (PNG), Timor-Leste	Department of Agriculture, Water and the Environment (DAWE)/Queensland/NT/PNG/Timor-Leste	More sites to regularly test blood of cattle to prove absence of livestock diseases and detect any new local and exotic diseases
New arbovirus (molecular) testing	DAWE/CSIRO (Australian Centre for Disease Preparedness)/NSW Elizabeth MacArthur Agricultural Institute/NT (Berrimah Labs)	New molecular/DNA testing technology will allow detection and identification of viruses (such as bluetongue) in animal blood or insects in hours rather than days
Rabies preparedness	University of Sydney, Charles Darwin University	Preparing material, and practices for immediate and effective community response to rabies if it arrives in Australia
Plant, aquatic and animal biosecurity Industry Liaison Officers	Plant Health Australia/Animal Health Australia	Liaison officers will translate effective biosecurity practice into daily operations in industries across northern Australia
New diagnostic laboratory facility	DAWE NT (Berrimah Labs)	Local, timely and expert tropical biosecurity diagnosis of pests and diseases should be locally available in northern Australia
Projects increasing awareness/scientific knowledge		
Community-based education and awareness	DAWE/media/community groups	Offers practical information for farmers, the general public and other targeted groups on ways to help reduce biosecurity threats
Web-based information	DAWE	Producers, rangers and the general public can report (and get feedback) more easily and more accurately about high-risk pests and diseases
Digital photo imaging of tropical biosecurity pests	DAWE, CSIRO, WA/NT/Queensland	Online identification of tropical pests and diseases should be available anywhere in the world rather than relying on physical insect collections
Projects benefitting communities through better biosecurity		
28 more Aboriginal & Torres Strait Islander ranger groups working in biosecurity (total now 68 groups)	DAWE/WA/NT/Queensland, Kimberley, Northern, Carpentaria Land Council Aboriginal Corporation	More biosecurity surveillance across northern Australia, particularly in remote areas
Equipment for ranger biosecurity work including weed spraying units, water tanks, satellite phones, vehicle recovery kits, computers and surveillance drones	DAWE	Field equipment allows greater access to more remote areas, more varied work, better quality samples, etc.

PROJECT	WHO	HOW THIS WILL MAKE A DIFFERENCE
Training syllabus for rangers in tropical biosecurity	North Australian Indigenous Land & Sea Management Alliance/Batchelor Institute of Indigenous Tertiary Education (NT)	Offers more technical skills to rangers and showcases the quality training capability of a number of Indigenous organisations
Virtual reality tool for biosecurity awareness and training	EnViZion (Queensland)	Increases awareness of biosecurity, engages communities in practical biosecurity actions and illustrates various career and skills opportunities
Upgrade Torres Strait communication and office infrastructure	DAWE/Torres Strait Regional Authority/Telstra/Torres Strait Island Regional Council	Mobile telephone/data and office refresh across Torres Strait Islands to improve biosecurity coverage across Australia's closest frontline border
Aboriginal & Torres Strait Islander traineeships (currently five trainees at Seisia/Bamaga and Thursday Island)	DAWE/Queensland Department of Agriculture and Fisheries	On the job and formal training in biosecurity with collaboration across Australian, state and local government agencies to encourage school retention, provide careers and support economic development, particularly in remote locations

Source: Commonwealth of Australia (2019e)

11.5.1 Senate Standing Committees on Environment and Communications

The committee is currently looking into the impact of feral deer, pigs and goats in Australia. Submissions closed in November 2018 with the final report due in September 2019 (Commonwealth of Australia, 2019f). The review is looking into:

- the current and potential occurrence of feral deer, pigs and goats across Australia
- the likely and potential biosecurity risks and impacts of feral deer, pigs and goats on the environment, agriculture, community safety and other values
- the effectiveness of current state and national laws, policies and practices in limiting spread and mitigating impacts of feral deer, pigs and goats
- the efficacy and welfare implications of currently available control and containment tools and methods, and the potential for new control and containment tools and methods
- priority research questions
- the benefits of developing and fully implementing national threat abatement plans for feral deer, pigs and goats.

11.5.2 Northern Australian Biosecurity Surveillance significant disease investigation workshops for northern cattle producers

One of the initiatives of the NABS project has been the establishment of the Significant Disease Investigation (SDI) Network. This is a network of private veterinary practices, veterinary laboratories and government veterinarians who work in northern Australia. The SDI Network aims to increase the number of investigations, as well as improve sampling and reporting outcomes, of SDIs in cattle (NABSnet, 2019). It offers vets access to subsidies to undertake eligible SDIs, post-mortem kits, case assistance, and professional development and networking opportunities. NABS launched the network in February 2018, with 14 veterinary practices in northern Australia joining its ranks in 2018 (NABSnet, 2019).

Producers are recognised as a key component of the SDI Network, being on ground and responsible for starting any investigation via the initial contact. The program acknowledges the importance of producers in knowing when and who to contact, in seeing the value in investigations and importance of surveillance, and in knowing and trusting the vets in their area (NABSnet, 2018). Additionally, having producers who are able to collect good quality samples before the vet arrives, or from ensuing cases, may significantly improve diagnosis. As part of building these connections and skills, workshops are being offered to producers on investigating cattle disease and post-mortem techniques, as well as providing producers with post-mortem kits so they can collect samples if livestock are sick or die (NABSnet, 2018).

11.5.3 FMD Ready

The FMD Ready project is piloting farmer-led partnerships for improved animal health surveillance (CSIRO, 2019). It is looking at ways to strengthen animal health surveillance partnerships at local, state and national levels. The aim is to promote trusting and respectful relationships that will enhance animal health management and early detection of disease introduction and spread, resulting in fewer, less damaging, and more readily controlled disease outbreaks and an earlier return to trade and market access. In order to be ready for an outbreak of FMD (or other significant diseases), livestock industries, government and researchers are looking at a variety of ways to be better prepared. The FMD Ready project includes several sub-projects: (i) ensuring rapid diagnosis and vaccine stores are ready; (ii) farmer-led surveillance partnerships; (iii) improving outbreak decision support tools; and (iv) tracking of disease for rapid response to outbreaks (CSIRO, 2019). The project is supported by MLA, through funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural Research and Development for Profit programme, and by producer levies from Australian FMD-susceptible livestock industries and Charles Sturt University (CSU). The research partners include CSIRO, the Graham Centre for Agricultural Innovation, CSU, the Bureau of Meteorology (BOM) and the Australian Department of Agriculture, supported by AHA (CSIRO, 2019). See https://research.csiro.au/fmd/

11.5.4 Grazing Beef Cattle Industry Structured Surveillance Study

The Grazing Beef Cattle Industry Structured Surveillance Study is managed by AHA and supported by the Cattle Council of Australia (CCA). It will trial a new approach to collecting data on animal health to support trade and production in the grass-fed beef sector (Animal Health Australia, 2018b). Data will be collected to identify which diseases are having the greatest impact in a given region and will involve inspecting cattle processed at participating abattoirs for evidence of endemic disease. The data will inform the delivery of tailored biosecurity information and resources, thus enabling producers to focus their biosecurity plans on their greatest risks (Animal Health Australia, 2018b). The study will run until the end of 2019, when it will be assessed for its suitability as an ongoing program.

11.5.5 LookCheck App

AHA has developed the LookCheck app to keep producers informed about livestock health risks and to help make it easy to initiate conversations with the right vet (MLA, 2019b). This is in recognition that private vets are the most trusted advisors in livestock health and their involvement is fundamental to prompt disease outbreak detection. The app aims to help facilitate producer–vet conversations regarding livestock health by:

- vets can post de-identified cases to the app's 'Newsfeed', which producers can then browse, informing them of who to contact when an expert is needed
- vets can handle enquiries through the app as they see fit
- producers can capture case detail and send a vet a case message via the app (MLA, 2019b). See: https://www.animalhealthaustralia.com.au/lookcheck/

11.5.6 The role of wild deer in the transmission of diseases of livestock

The Centre for Invasive Species Solutions is currently conducting research on the risk posed by deer to the livestock industry as hosts for exotic diseases such as FMD (Centre for Invasive Species Solutions, 2019). A spatially explicit, multi-species model has been developed (Australian Animal

Disease Spread Model; AADIS) to predict the movement of FMD virus through various Australian agricultural industries. However, this model currently does not include virus transmission between livestock and wildlife populations, such as deer. The project will also evaluate the effectiveness of possible mitigation strategies should an outbreak occur. The project partners include the Arthur Rylah Institute; Victorian Government Department of Economic Development, Jobs, Transport and Resources; NSW Department of Primary Industries; and La Trobe University (Centre for Invasive Species Solutions, 2019). See: https://invasives.com.au/research/role-wild-deer-transmission-diseases-livestock/

11.6 Conclusion

The northern Australia beef industry has, does, and will into the future, face notable biosecurity challenges. The future is projected for an escalation in these challenges, especially as the development of northern Australia is likely to result in increased movement of livestock, goods and people to, from and within the region – all of which create heightened opportunities for the introduction and spread of weeds, pests and diseases (Fitt, 2016). An increase in host densities with intensification may also increase the chance of pest or disease establishment and spread. A warming climate may further increase the potential for the spread of pests, diseases and disease vectors into new areas (Simpson and Srinivasan, 2014). Adding to these challenges, the biosecurity sector is experiencing a decline in investment and resources, which may limit the ability to prevent and respond to the biosecurity needs of the industry (Simpson and Srinivasan, 2014).

Therefore, biosecurity must be explicitly considered in any plan to expand the northern Australia beef industry, and agriculture in general, so that threats can be addressed where possible. Surveillance activities need to be strengthened through technological development and stakeholder engagement, while the biosecurity capacity of producers, industry and in state jurisdictions should be improved (Fitt, 2016). Biosecurity risks are present and are expected to grow but they can be managed to support the industry's development, market access and economic future. The following recommendations could be considered for the development of the northern Australia beef industry:

- Interest in promoting regional growth in northern Australia is presently strong. There should be recognition that with growth there will be increased biosecurity risks and therefore biosecurity is a critical issue for northern Australia. Biosecurity should be at the forefront of the research agenda for the northern beef industry with Meat and Livestock Australia (MLA), states and the NT, the Commonwealth and the CRCNA all important stakeholders in setting priorities. Key issues to be pursued include:
  - Biosecurity challenges will escalate with increased development, increased movements of livestock, goods and people, a warming climate altering pest and diseases ranges– all of which create heightened opportunities for the introduction and spread of weeds, pests and diseases. Thus, biosecurity must be explicitly considered in any plan to expand the northern Australia beef industry, and agriculture general, so that threats can be addressed where possible.
  - Surveillance activities across northern Australia need to be strengthened. This can be supported via technological development, increased investment personnel and skills, and improved stakeholder engagement. As producers and industry take on increased roles in

biosecurity, there may be a need for improved ways of engaging with stakeholders, and for supporting legislation for industry.

– Increased agricultural expansion and intensification in nearby countries may create increased biosecurity risks abroad, and as such industry and government must remain aware and vigilant of the potential for these risks to enter Australia. Working cooperatively and sharing information and expertise with Australia's northern neighbours may help prevent biosecurity risks before they arrive.
– Better communication and engagement strategies are required to make biosecurity a priority for everyone. There is a need for biosecurity engagement programs that are participatory, targeted, and allow for evaluation and monitoring. This could include enhanced incentives to encourage producers to participate in on-property surveillance to improve detection and response. The dissemination of biosecurity information needs better targeting to relevant individuals or communities and can now happen via a variety of platforms (e.g. apps, newsletters, social media, etc.).

12 Climate change and variability

12.1 Existing climate variability

Northern Australia's climate is characterised by distinct wet seasons that occur from December to April and mild, long dry seasons from May until October. Summers are hot and, except for the more central arid environments, humid.

The strong seasonality of rainfall generally results in good pasture growth and beef growing conditions for a few months of the year, and a long dry season where pasture is mostly dormant and the grazing value is low, and as a consequence beef production is also low. A key challenge for beef production in northern Australia is not so much the seasonality of this rainfall and its constraints on pasture quality and beef production, which can be managed, but rather the large inter-annual variability in rainfall and its unpredictability. Runs of dry years are common and this makes it difficult to balance forage supply with animal demand (O'Reagain et al., 2011).

Petheram et al. (2008) has observed that for a given mean annual rainfall total, the inter-annual variability of rainfall in northern Australia is higher than that observed at rainfall stations from southern Australia (Figure 12) and the rest of the world. For the same annual rainfall amount the variability is higher in northern Australia, which makes managing agriculture and pastoral businesses more challenging.

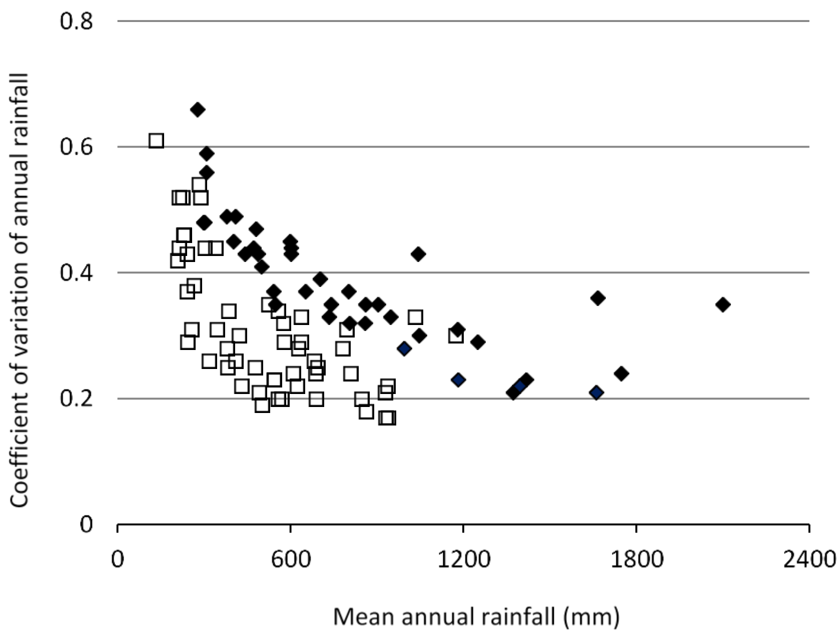


Figure 12 Inter-annual variability in rainfall, expressed as coefficient of variation (CV), in northern Australia compared to southern Australia (adapted from Charles et al., 2017)

Open squares are southern Australia climate stations while closed diamonds are from northern Australia.

The higher variability in rainfall is mostly attributed to the large impact of the El Niño Southern Oscillation (ENSO). ENSO is a coupled oceanic–atmospheric process originating in the equatorial Pacific. ENSO is commonly quantified as the strength of atmospheric pressure gradients across the

Pacific (e.g. Southern Oscillation Index, SOI, which is the difference in air pressure between Darwin and Tahiti) or by sea surface temperature anomalies in certain regions of the equatorial or near-equatorial Pacific. Its three dominant phases are El Niño phase (drier than average in Australia), cold La Niña phase (wetter than average in Australia) and a neutral phase. ENSO has the strongest impact on rainfall in northern Australia during September to December. This relationship is strongest in north-eastern Australia rather than in the NT or WA (Risbey et al., 2009) (Figure 13).

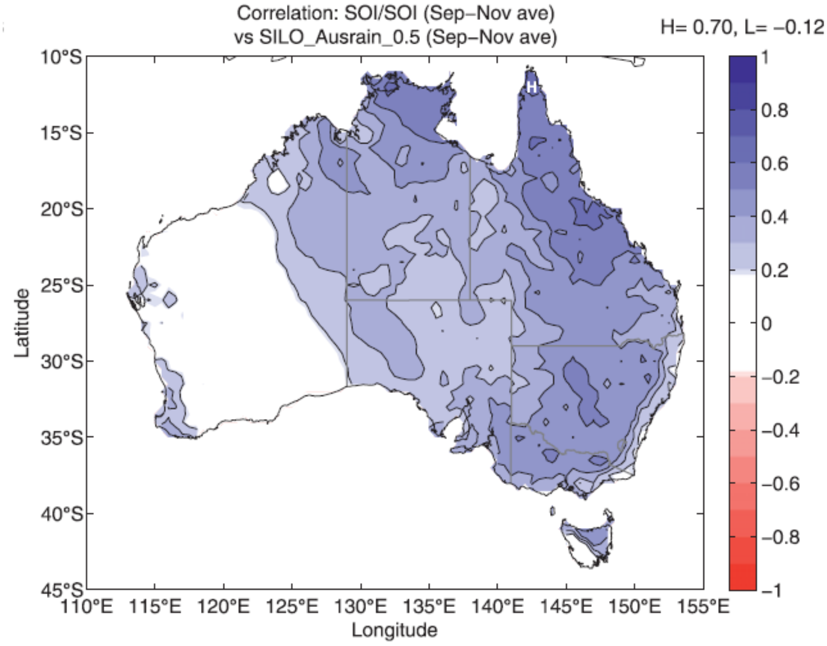


Figure 13 Correlation between the SOI and rainfall in Australia during the period September to November, data period 1889-2006
Source: Adapted from Risbey et al. (2009)

ENSO can interact with other climate drivers such as the Indian Ocean Dipole (Saji et al., 1999) to create runs of wet and dry years (Figure 14 and Figure 15). Runs of wet years are generally positive for pastoral production, though they can be associated with damaging flood events. It is the runs of dry years that can create challenges for northern beef production because forage shortages often occur and decisions need to be made on stocking strategies.

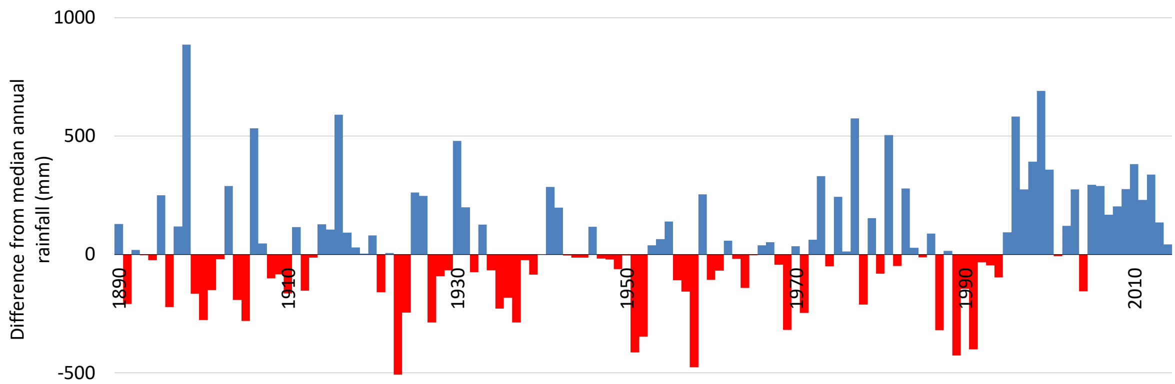


Figure 14 Runs of wet (blue columns) and dry (red columns) years at Derby, WA
Source: Adapted from Charles et al. (2017)

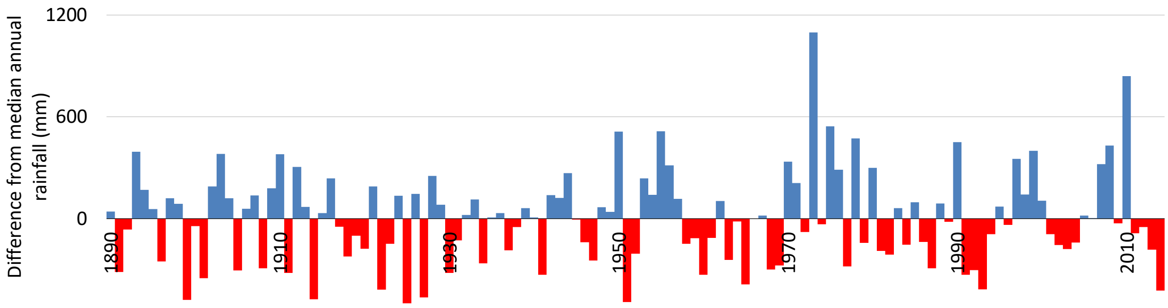


Figure 15 Runs of wet (blue columns) and dry (red columns) years at Chillagoe, Queensland
Source: Adapted from Charles et al. (2017)

In response to this large variability in rainfall, pastoralists in northern Australia can adopt a range of longer-term stocking strategies:

- Stock at a moderate to high stocking rate with more or less continuous grazing. This stocking strategy is widely practised throughout northern Australia. In times of drought the herd is fed supplements and/or parts of the herd are agisted in areas where forage supply is more plentiful, and/or animals are sold to reduce grazing pressure. Grazing trials throughout Australia and overseas (e.g. Ash and Smith, 1996b; Burrows et al., 2010) show that production per hectare can be maximised at high stocking rates in the short to medium term (3–15 years). By adopting such a strategy many producers perceive that maintaining high stock numbers is also financially rational, even taking into account the costs of supplementation and/or agistment, and there is some experimental evidence to support this practice (Burrows et al., 2010). However, economic analysis that considers all the penalties of heavy stocking (O'Reagain et al., 2011) and more reflective and analytical producer experience (Landsberg et al., 1998) suggests that high stocking rates are uneconomic in the medium to longer term and can place strains on producer wellbeing.
- Stock conservatively with more or less continuous grazing. This strategy aims to utilise some safe amount of the average forage growth by stocking with a more conservative number of cattle. This strategy accepts that overutilisation and feed shortages will occur in extreme years but it is assumed that such seasons will be sufficiently infrequent to keep pasture degradation and/or economic loss to a minimum. Although production per unit area may be low relative to the heavier stocking strategy, conservative stocking has the advantage of maintaining or improving the resource base (Ash et al., 2011), minimising production costs and maximising individual animal performance (Foran and Stafford Smith, 1991; Pratchett and Gardiner, 1993; O'Reagain et al., 2011). An added advantage of this strategy is that there will be increased opportunities for fire to be used to control unwanted increases in woody plants due to increased fuel loads.
- Flexible management of stock numbers through proactive flexible stocking. This stocking strategy typically involves assessing the availability of forage at some fixed point in the season when further rainfall is unlikely, for example at the end of the wet, and adjusting stock numbers according to feed availability. This strategy requires considerably better herd management and marketing skills as it is inherently riskier. An error in judgment with this strategy could have more sudden and serious consequences for farm finances and the resource base (O'Reagain et al., 2011).

- Rotational grazing systems. Rotational grazing systems are designed to provide strategic rest to the pasture during critical times for vegetative growth and to allow recovery from grazing. Rotational grazing systems can take the form of less intensive systems such as wet-season spelling (Ash et al., 2011) or higher intensity, short duration grazing systems (e.g. McCosker, 2000; Cowley et al., 2017). Although these rotational grazing systems are primarily aimed at either maintaining or improving land condition, they interact strongly with year-to-year variability in rainfall.

12.2 Future climate risks

12.2.1 Projected changes in climate

There is high confidence in the science that the Earth is warming and that future temperature increases and other climate changes at the global scale are highly likely. Temperatures in Australia are projected to increase by 1 to 5 °C (1.8 to 9 °F) by the end of the century, depending on the location and emissions scenario. For the near future (2030), mean warming is around 0.5 to 1.3 °C above the climate of 1986–2005, with only minor differences between emissions scenarios (Moise et al., 2015). For late in the century (2090), the projected warming is 1.3 to 2.7 °C for a moderate emissions scenario and 2.8 to 5.1 °C for a high emissions scenario. A substantial increase in extremely hot days is projected with high confidence. For example, for Broome, the number of days above 40 °C nearly triples in the mid to long term (Moise et al., 2015).

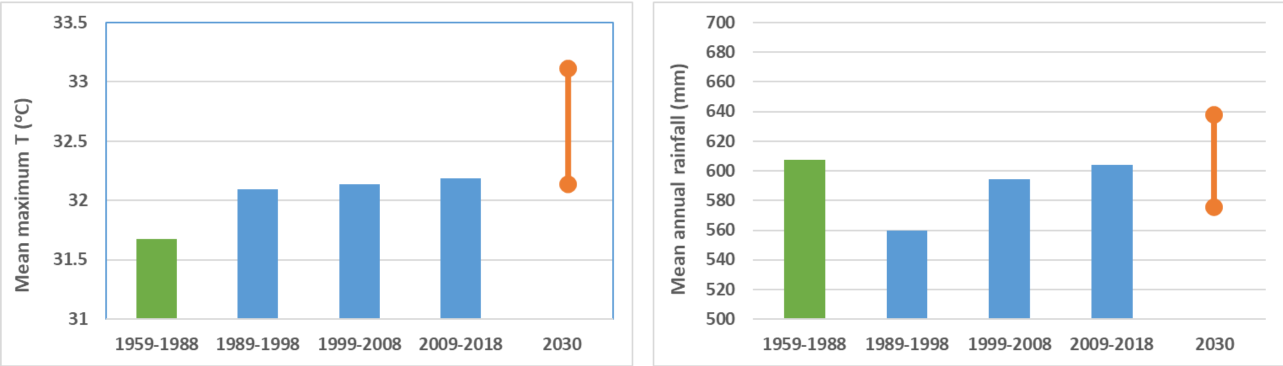
There is high confidence that natural climate variability will remain the major driver of annual rainfall changes over the near term (until 2030). Unlike temperature, where there is high confidence in the projections, there is low confidence in rainfall projections. This is because the main drivers of rainfall in northern Australia (tropical monsoon and Madden–Julian Oscillation) can have opposite impacts on rainfall in different climate models (Moise et al., 2015; Hennessy et al., 2010). In the near term (2030) the magnitude of possible summer rainfall changes is around ±10%. By 2090 it is around
–15 to +10% under moderate emissions and around –25 to +20% under high emissions (Moise et al., 2015), with the mean being a slightly drier future. In terms of extreme rainfall, high-rainfall events are expected to increase in magnitude as part of a broader picture of increased variability in rainfall (Ummenhofer et al., 2015). Changes in variability of rainfall are associated with possible changes in the frequency and intensity of ENSO events (Cai et al., 2015).

12.2.2 Are changes in climate already being observed?

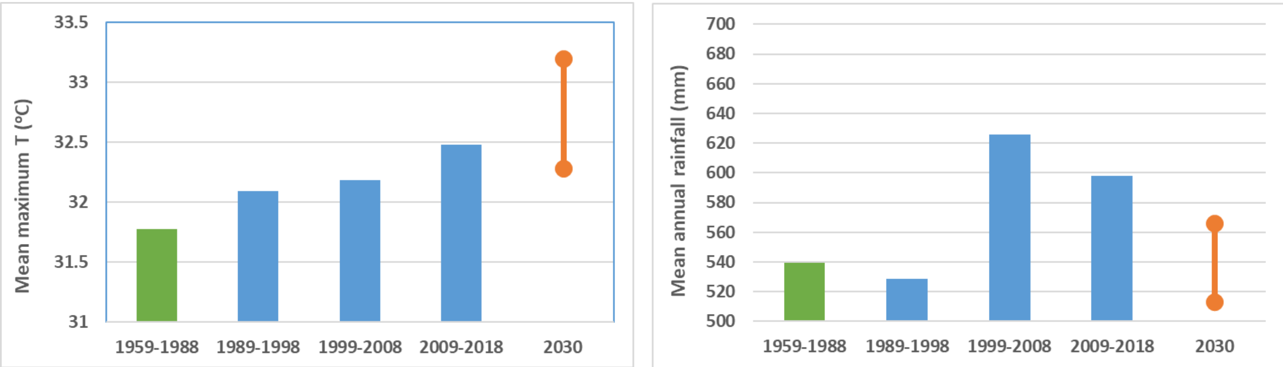
The common baseline climate period for climate projections is the 30-year period from 1961 to 1990. Given it is nearly 30 years past the end of the base climate period, can any of the projected changes be detected in recent observations?

Figure 16 shows the changes in temperature (mean maximum) and annual rainfall in each decade since 1998, compared with the climate change projections for 2030. The results shown are for four stations in Queensland (Longreach, Richmond, Charters Towers, Georgetown), three stations in the NT (Barkly Homestead, Alice Springs, Katherine) and three stations in WA (Halls Creek, Broome, Wittenoom). It shows that temperatures have increased since 1988 and are on track to fall within the modelled projected temperatures for 2030.

(a) Queensland



(b) Northern Territory



(c) Western Australia

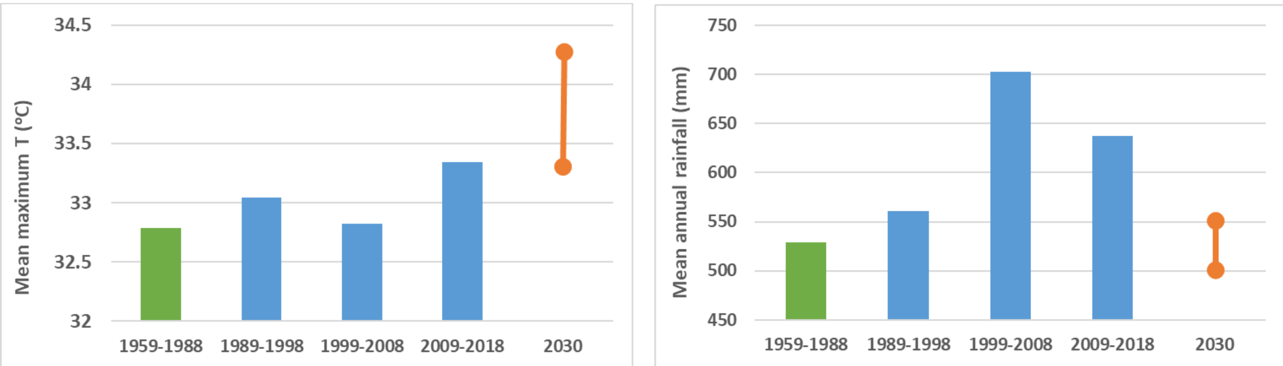


Figure 16 Changes in mean annual maximum temperature (left panels) and mean annual rainfall (right panels) for a baseline climate period of 1959 to 1988 and in each subsequent decade. Projected temperatures and rainfall for 2030 are also shown based on Moise et al. (2015)

As expected, rainfall is highly variable, even when averaged over a 10-year record, and consequently the decadal rainfall since 1988 bounces up and down. Rainfall has been consistently higher in WA (Kimberley and Pilbara) in the last three decades compared with the 1958–1988 period. This is clearly shown in Figure 16 above. There is also an increase in rainfall in recent decades across the three stations in the NT but this increase is solely in the Katherine observations with no increase at Alice Springs or Barkly. In Queensland, even though rainfall in each decade since 1988 has been highly variable, the average of the last 30 years is similar to the previous 30 years.

There is anecdotal evidence that the increase in rainfall over the last 30 years in the Katherine–Victoria River Downs and Kimberley regions has been a factor in increased investment and development in the beef industry. The increase in rainfall that has occurred, particularly in the Kimberley region, has masked underlying temperature increases. In the decade from 1999 to 2008 the steady rise in temperature was not apparent in WA and this is correlated to much higher than average rainfall in that decade (i.e. more rain days usually means a lower maximum temperature). This is highlighted in Figure 17, which shows the relationship between annual rainfall and annual average mean maximum temperature at Halls Creek.

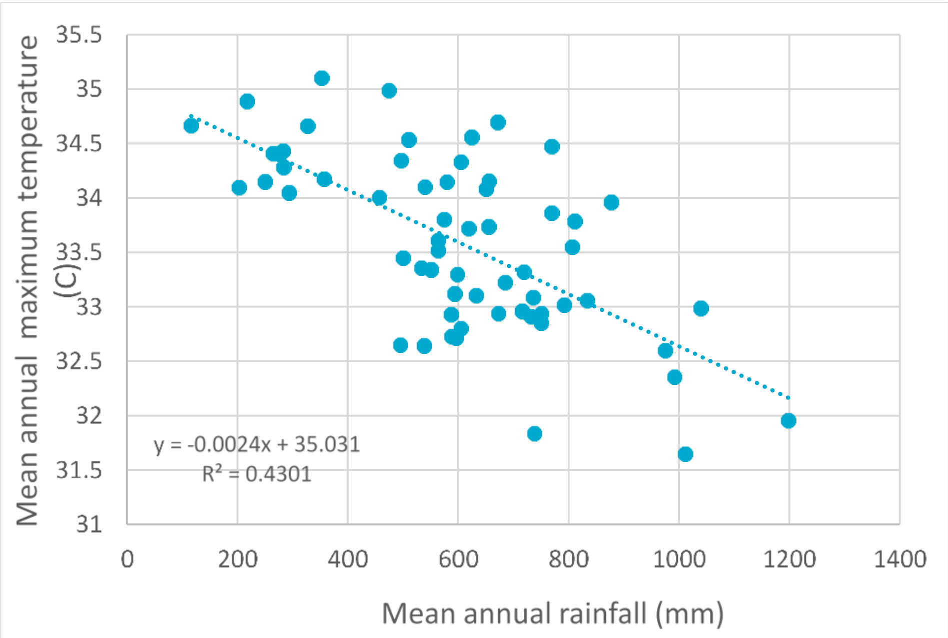
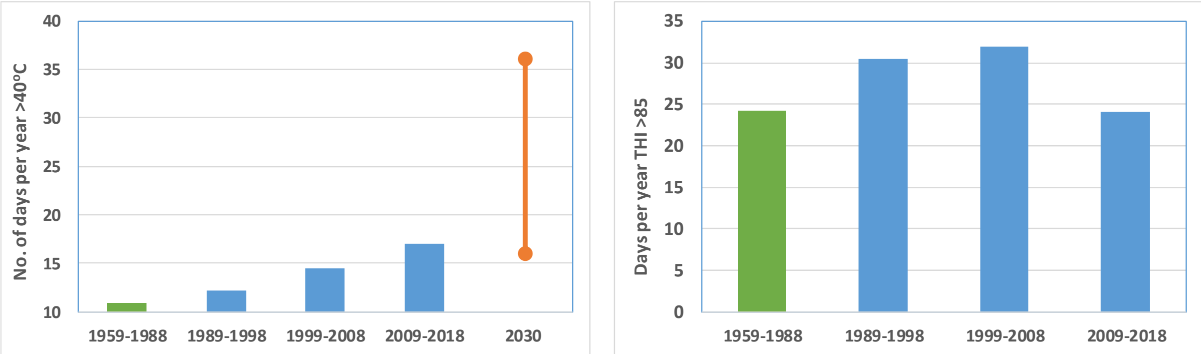


Figure 17 Relationship between mean annual rainfall and mean annual maximum temperature at Halls Creek, WA

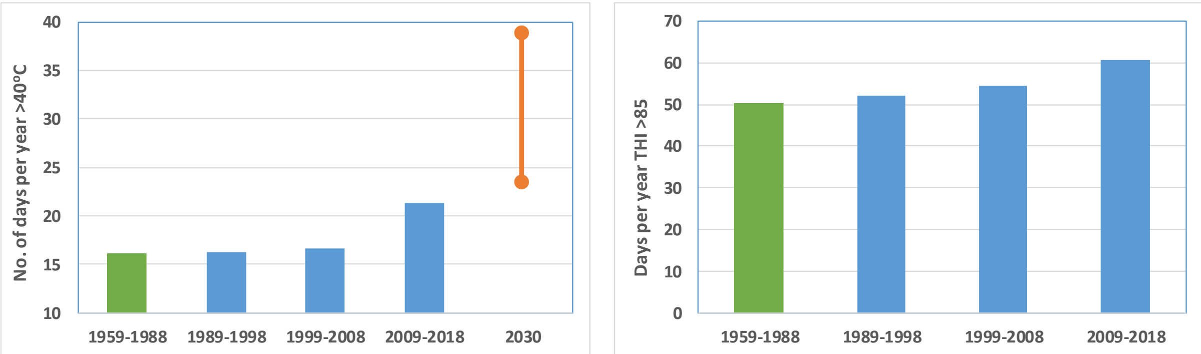
An important feature of climate change is the projected change in extremes. The number of days over 40 °C have been generally increasing in the last 30 years (Figure 18) with around 50% more extreme days recorded in Queensland and the NT in the last decade. This trend is not so obvious in WA, which is most likely related to higher rainfall over the summer period, as explained above.

High temperatures will not only affect people in northern Australia, but also cattle. For cattle, heat stress is experienced most acutely as a combination of temperature and humidity and a temperature–humidity index (THI) is commonly used as a means of expressing heat load in dairy and beef cattle (Roseler et al., 1997; Gaughan et al., 2008). Brahman (Bos indicus) cattle are more tolerant of heat loads than are British breeds (Bos taurus) such as Angus or Hereford (Beatty et al., 2006). Bos taurus cattle are likely to experience severe heat stress when THI is in the range of 79 to 88, with feed intake decreasing significantly when THI is >85 (Beatty et al., 2006). Based on the results of Beatty et al. (2006), feed intake in Bos indicus cattle may only be affected when THI is greater than 90. The number of days per year when the THI index exceeds 85 has generally increased each decade since 1988 (Figure 18).

(a) Queensland



(b) Northern Territory



(c) Western Australia

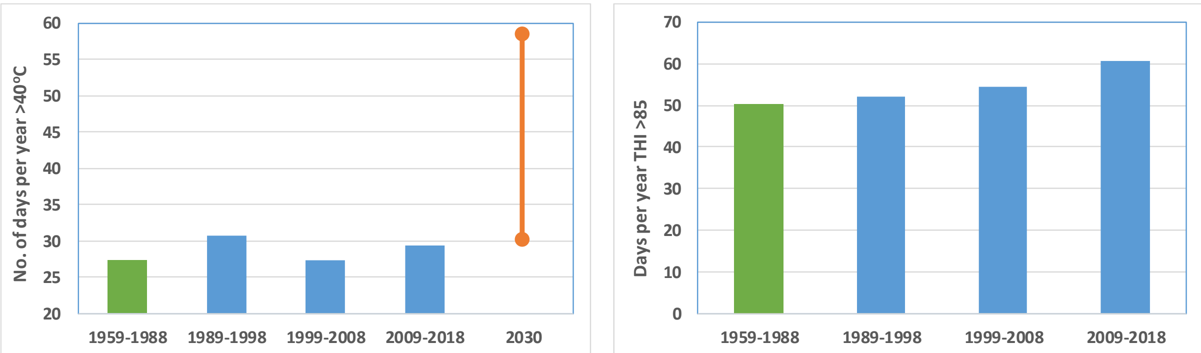


Figure 18 Changes in mean number of days per year over 40 °C (left panels) and mean number of days per year where the temperature–humidity index (THI) is greater than 85. Projected extreme temperatures for 2030 are also shown

12.2.3 Climate change impacts

Climate change will impact the rangelands of northern Australia in a number of ways. The most certain aspect of the changing environment for future livestock production is the rising level of carbon dioxide (CO_2) in the atmosphere. In rangelands, the biggest benefit of CO_2 is likely to be improvements in plant water use, which allows pastures to grow more using the same amount of water. However, the trade-off is that increases in pasture production come at the expense of reduced forage quality, since grasses grown at high CO_2 have lower protein content and lower digestibility (Wand et al., 1999; Morgan et al., 2008; Stokes et al., 2008, Stokes et al., 2010). Increasing concentrations of CO_2 may alter vegetation composition and in particular the balance between woody plants and the herbaceous layer, with woody thickening more likely in the tropical savannas of northern Australia.

Increasing temperatures will affect the length of the growing season, plant productivity and animal production through increased heat loads in summer and in tropical climates. Hotter conditions will tend to reduce forage quality and increase the risks of plant heat stress. Further, evaporative demand is likely to be greater, lowering water use efficiency, which will offset some benefits of higher CO_2.

As indicated above, cattle will be exposed to a greater risk of heat stress, particularly for cattle with higher levels of Bos taurus genetics. This potential increase in heat stress is occurring at a time when there is a movement towards inclusion of higher levels of Bos taurus genetics in northern herds to improve fertility and to produce a product more acceptable to southern markets. Increased heat loads mean that livestock will be unable to travel as far from watering points in large paddocks, concentrating grazing pressure and risks of soil degradation near watering points while areas further from water are left underutilised. Livestock diseases are also likely to be affected by climate change through changes in pathogen behaviour, host vulnerability, distribution of insect and other vectors, and epidemiology of diseases (Thornton et al., 2009). This could increase the costs of control and damage from pests (e.g. cattle ticks).

As indicated above, rainfall projections for northern Australia are highly uncertain, although there is a weak trend towards a slightly drier future. Even small declines in mean rainfall when combined with higher temperatures can have the potential to significantly reduce forage production (McKeon et al., 2009).

In most environments it is expected that rainfall will become more variable with extreme events becoming more intense. Even small changes in the frequency of extreme events may have a disproportionately large impact on rangeland ecosystems (Allen-Diaz, 1995). River flows are even more sensitive to changes in rainfall (e.g. a 10% decrease in rainfall can reduce runoff by 30 to 40%), which could affect beneficial flooding (e.g. in the Channel Country of Queensland). Prolonged droughts followed by above-average rainfall appear to be an important agent in initial invasion by high-impact weedy grass species (e.g. gamba grass and buffel grass) (van Klinken and Friedel, 2017). While increased temperatures are mostly predicted to see a southwards expansion of pests such as cattle ticks (White et al., 2003) (for which the northern cattle herds are mostly resistant), there are also projections indicating an expansion in distribution of the insect vector of bluetongue disease, *Culicoides wadia* (Sutherst, 2001), which would affect market access for live cattle into markets such as China.

The impacts of climate change on rangelands is summarised in Table 34.

Table 34 Summary of the impact of climate change on northern Australia's beef producing regions

PLANTS & NATURAL RESOURCES	LIVESTOCK AND PEOPLE
Increased CO_2	
Increased pasture growth per unit of available water and nitrogen (and light) Reduced forage quality (protein and digestibility) Prolonged moisture availability (and growth) at end of wet season from water savings Species-specific CO_2 responses cause shifts in vegetation composition	Reduction in animal performance with reduced forage quality may or may not be offset by increases in plant water use efficiency
Increased temperature	
Reduced water use efficiency and increased evaporation Decreased forage quality (digestibility) Earlier start to spring growth in cooler climates Southern expansion of weeds, and pasture species (e.g. less nutritious tropical grasses)	Increased heat stress and greater water requirements Livestock concentrate more around water points Southern expansion of tropical pests and diseases More challenging climate for labour
Rainfall and other changes in climate	
Changes in forage production magnify percentage changes in rainfall Changes in seasonal rainfall affect seasonality of forage availability (e.g. declining spring/autumn rainfall would reduce the length of growing seasons) Increased rainfall intensity and inter-annual variability creates greater challenges for managing forage supplies and limiting soil erosion Greater risks of flooding (and saltwater intrusion) Increased risk of weed invasion	Changes affect availability of water for livestock
Broader context and other issues	
Uncertainty over climate change impacts and adaptation options could create reluctance and delays in taking pre-emptive action, exacerbating impacts Changes in regional/international competition from geographic differences in effects of climate change (magnitude of impacts/benefits and adaptability of beef industry) Changing demand for livestock products as a result of climate change and consumer attitudes to greenhouse gas efficiency of food products Cost-price squeeze from greenhouse gas reduction measures that increase input and processing costs (indirect) Potential shifts in land use and competition between land uses (e.g. expansion of cropping into pasture areas, less productive cropping lands converting to pasture, loss of land for carbon sequestration and renewable energy generation) Conflicts and synergies with other public and private policies and initiatives (especially drought, water, natural resource and greenhouse gas emission policies)	

Source: Adapted from Stokes et al. (2012)

12.2.4 Supply-chain impacts

Compared with the production system, there has been relatively little analysis of climate change impacts on the supply chain. This is a gap that needs to be addressed.

Existing climate and weather extremes can significantly disrupt beef supply chains in northern Australia, through transport disruptions, continuity in meat processing and through market prices. Normal wet-season rainfall across northern Australia affects the supply of cattle to markets due to a reduced ability to muster cattle in paddocks and because roads can often be untrafficable for days to weeks (Higgins et al., 2018). This has flow-on consequences for the processing of cattle because live export of cattle is concentrated during the dry season and abattoirs (e.g. Townsville) can have extended wet-season shutdown periods (ACCC, 2017). An increase in frequency of extreme rainfall events would exacerbate these disruptions to supply chains.

The disruptive effects were evident in the southern and eastern Queensland floods in 2011. Access to abattoirs and feedlots was cut due to inundation, major transport routes were cut, and the supply of feed and supplies to feedlots was affected, causing major animal welfare concerns.

Droughts and flood events can have a significant effect on prices through fluctuations in supply. During the early stages of a drought event prices can fall rapidly as producers seek to destock and the market is oversupplied. However, as droughts persist and if they become more widespread, prices can rise if there is a shortage of cattle in the market. This was apparent during the drought that commenced in 2013–2014 and has persisted through large parts of eastern Australia. The unprecedented extreme rainfall event in north-west Queensland in February 2019 caused significant stock losses (approximately 300,000 head lost) with flow-on consequences for prices as a result of reduced supply to the live export market.

12.2.5 Adapting to climate variability and change

Beef producers in northern Australia can manage the impacts of climate variability and change through either reactive or proactive adaptation (Ash et al., 2012). Currently most adaptation to climate risk is reactive and tends to be a function of management skills and diversity of resources available to balance profitability with resource management (O’Reagain et al., 2011; Stokes et al., 2006; Walsh and Cowley, 2011). For example, drought events have been recurring across Australia’s rangelands for well over a century, yet management responses are largely reactive, even in relatively recent history when lessons from earlier episodes were broadly understood (Stafford Smith et al., 2007). Producers tend to have overly optimistic expectations of future climate and this has been coupled with economic drivers that lead to livestock being retained beyond limits of ecological sustainability.

However, despite limitations in their accuracy (Brown et al., 2017; Ash et al., 2007), better use can be made of seasonal forecasts as an adaptation strategy that can be adopted now to better manage existing and future climate risk. Seasonal and shorter-term forecasts would benefit from investment in improving forecast skill as well as some additional framing to link the forecasts with the challenges and opportunities of responding to climate change. This approach would help producers focus more on future climate impacts, when natural human behaviour is to discount the future.

There are adaptation options that can be implemented over the coming decades to help producers cope with climate change. Many of these adaptations are modest and can be implemented within current business operations. These are summarised in Table 35. For example, increasing temperatures may require provision of additional water points in extensive pastoral systems. That adaptation can be implemented as the relatively slow increase in temperatures begins to impact on livestock productivity. One example of research that can be undertaken now is with plant and animal breeding, in seeking to develop new forage species that are better adapted to a world with more CO_2 and higher temperatures. Similarly, although livestock breeding for improved heat and disease tolerance is not a new challenge, it is an extended challenge because much of the ‘low-hanging fruit’ in developing heat tolerance through traditional breeding practices has already been harvested. New approaches to plant and livestock breeding will take many years to come to fruition so while the need is not immediate effort should be made to increase research in these areas.

Beyond incremental on-farm responses, there may need to be a rethink of rangeland livestock systems as well as the institutional and policy responses needed either to support the viability of pastoralists and ranchers, or the structural adjustment mechanisms required to support people exiting the rangelands or diversifying their livelihood enterprises. New approaches to land tenure and land use, governance, mobility enhancement and flexible use of resources, and fostering new enterprises such as carbon farming should be explored (Dale, 2018). One of the key challenges for transformational change when the future is uncertain is deciding when and how to respond and understanding the consequences sufficiently to avoid unintended outcomes (Leary et al., 2007).

Table 35 Potential adaptation strategies that can be adopted by the northern Australia beef industry

ADAPTATION OPTION
Grazing and pasture management
Introduce stocking rate strategies that are responsive to seasonal climate forecasts and track longer-term climate change trends
Redefine safe stocking rates and pasture utilisation levels for climate change scenarios
Improve on-property water management, particularly for pasture irrigation
Improve nutrient management using sown legumes and phosphate fertilisation where appropriate
Develop 'climate-ready' forage species that will be better suited to future projected climate conditions
Develop software to assist proactive decision making at the on-farm scale
Accept climate-induced changes in vegetation and modify management accordingly
Expand routine record keeping of weather, pests and diseases, weed invasions, inputs and outputs
Diversify on-farm production and consider alternate land uses
Managing pests, diseases and weeds
Improve predictive tools and indicators to monitor, model and control pests
Increase the use of biological controls (with caution)
Incorporate greater use of fire and alternative chemical and mechanical methods for controlling weeds and woody thickening
Livestock management
Select animal lines that are resistant to higher temperatures but maintain production
Adjust use of supplements and planted pasture species to offset declines in diet quality
Modify timing of mating, weaning and supplementation based on seasonal conditions
Provide extra shade trees and constructed shelters
Broad-scale adaptation
'Mainstream' climate change considerations into existing government policies and initiatives (particularly those relating to drought, greenhouse gas emissions and natural resource management)
Encourage uptake of 'best practice' in livestock enterprises (and evaluate current recommendations to ensure benefits will continue under future climate scenarios)
Work with the livestock industry to evaluate potential adaptive responses to the system-wide impacts of a range of plausible climate change scenarios
Provide adequate buffering to buffer early adopters from adaptation failure
Modify transport networks to support changes in agricultural production systems
Continually monitor climate change impacts and adaptation responses, adjusting actions to support and ensure effective and appropriate adaptation

Source: Adapted from Stokes et al. (2012)

While the biophysical and institutional responses to climate change can be analysed and discussed, little will happen proactively unless producers both understand their vulnerability and have the capacity to change. There is a need to identify the thresholds to social change, the barriers that would most likely inhibit change processes, and to identify the factors and processes that could minimise vulnerability and enhance the resilience of the industry. A survey of beef producers in northern Australia found that 85% were highly vulnerable to climate change because they had poor planning skills, low interest in adapting to the future, managed risk and uncertainty poorly and were not strategic in their businesses (Marshall and Stokes, 2014; Marshall et al., 2014). Barriers to change were also able to be identified (e.g. beef producers with a lifestyle approach would erect barriers around proposed adaptation strategies that threatened their sense of lifestyle). In terms of adaptive capacity, producers with higher adaptive capacity have stronger networks, a strategic approach to their businesses, had high environmental awareness and high local environmental knowledge (Marshall and Stokes, 2014). Such kinship networks can be useful in adaptation responses (e.g. adapting to a spatially heterogeneous climate through temporary relocation of cattle via reciprocal grazing arrangements such as agistment) (McAllister et al., 2006).

Marshall and Stokes (2014) concluded that investments into the development of adaptive capacity of pastoralists across northern Australia would heighten the success of any climate adaptation planning and that the findings of this social research support existing initiatives to improve resilience in the beef industry.

There is also a need to consider wider supply-chain adaptation options. As yet, no such analysis of supply-chain adaptation options has been undertaken for the northern Australia beef industry. Work in other agricultural supply chains in Australia has shown that more complex supply chains with many nodes and links are more resilient to climate disruption (Lim-Camacho et al., 2017). However, supply chains of all complexities have diminished resilience as the frequency of climate disruptions increases.

While the consequences of drought on cattle supply have been well documented and should be predictable, this presumes that the historical understanding of the impacts of drought remain consistent in the face of climate change. The increase in export demand for Australian beef provides an opportunity for the northern Australia beef industry, but this will require improve supply-chain management to ensure supply certainty and mitigate reputational risks to the red meat industry.

13 Natural resource management

13.1 Background

Beef production in northern Australia experiences two disparate sets of issues in relation to natural resource management. First, the industry is exposed to environmental risk because it depends on water from the natural environment and the feed base is largely comprised of intact native pastures. Changes in the conditions of the natural environment, whether driven by factors external to the industry or by the actions of the industry itself, impact the profitability and sustainability of beef cattle production. Second, extensive beef cattle production occupies a large proportion of the land mass of northern Australia. The industry plays a significant role as a land manager. This role requires the industry to focus on environmental management both to allow functioning of the beef value chain and for broader whole-of-community needs. This latter point is underappreciated, but it has important implications for social licence to operate. Specifically, pastoralists are the only land managers present across much of northern Australia and the Australian community is reliant (and has been reliant) on pastoralists to effectively manage the environment for the range of ecosystem services that are required. This reality is both a challenge and an opportunity but its relevance to pastoral production is intensified by recent policy initiatives seeking to incorporate ecosystem accounting into assessments of environmental services.

This section deals with natural resource management. Although some of the issues covered here are also discussed in other sections of the report, the current section examines these issues from the perspective of the natural environment and its management rather than production and profitability. In this section, several key issues regarding natural resource management are identified and for each issue, the challenge presented is outlined, any past and current responses are summarised and opportunities to potentially resolve or progress the issue are provided.

13.2 Key issues

13.2.1 Greenhouse gas emissions and changing climate

The issue

The northern beef cattle industry is an emitter of greenhouse gases along the entire value chain. The industry is like other systems of food production in releasing greenhouse gases, including methane and carbon dioxide (CO_2), directly into the atmosphere and driving land-use change when vegetation is cleared that releases additional CO_2. Greenhouse gases are emitted primarily through cattle digestion (releasing methane) and use of fossil fuels on farm and in processing.

Greenhouse gas emission is acknowledged as a major contributor to climate change. This is particularly the case for methane, which has 56 times the global warming potential of CO_2 over 20 years (Willett et al., 2019). Climate change presents an environmental risk to the industry because it threatens profitability through impacting soils, pasture production and animal health. It is a further challenge because it is a significant reputational risk with the potential to negatively impact the industry's social licence to operate. For example, the recent EAT-*Lancet* Commission report (Willett et al., 2019) identified food production as the primary source of the globe's methane emissions.

The climate in northern Australian is projected to change in multiple ways including increases in maximum temperatures and increases in the occurrence of extreme climate events (see Section 12.2 of this report for a summary). These changes in climate will affect beef production in northern Australian in several ways including through rising levels of CO_2 in the atmosphere, changes in plant growing seasons and increased heat stress for cattle (Table 34). These changes, though not all negative, present an overall environmental risk to the industry because of the potential for decreased profitability.

Existing responses

The challenge of managing climate change risk both from a production and a reputation perspective is widely acknowledged by the northern Australia beef industry (e.g. 2017 Framework report). A range of national actions have been undertaken in response to this challenge over the past decade. An important initial project was the Reducing Emissions from Livestock Research Program (RELRP) undertaken from 2009 to 2012. RELRP aimed to develop knowledge and technologies on methane emissions to enable producers to reduce livestock emissions while maintaining or improving livestock productivity. It focused on methane emissions from the rumen of cattle and sheep and methane and nitrous oxide emissions from feedlot manure. RELRP was followed from 2012 to 2016 by the National Livestock Methane Program (NLMP), a project developed to coordinate national research to reduce methane emissions from livestock while increasing productivity. It consisted of 16 projects led by major research groups in Australia with expertise in the science of rumen biology and livestock management collaborating to develop practical on-farm options for reducing methane emissions from livestock.

Currently Meat and Livestock Australia (MLA) is exploring the option of the Australian red meat industry becoming carbon neutral by 2030. This is an ambitious target that would require changes both in production systems and in vegetation management.

Opportunities

An immediate opportunity is to develop a pathway by which the northern Australia beef industry (as part of the Australian red meat sector) can reduce greenhouse gas emissions through land management. This process could form part of a target for the Australian red meat industry to become carbon neutral by 2030. The key aspects of land management to reduce greenhouse gas emissions are vegetation management and fire management. Mayberry et al. (2018) proposed a pathway that assumes that deforestation ceases within the next 5 years, and that soil carbon stocks have stabilised by 2030 (i.e. there are no emissions associated with deforestation in 2030). This pathway involves the following: (i) implementing savanna burning management in northern Australia to reduce emissions from wildfire by controlled burning in the early dry season (which release less methane and nitrous oxide than fires that occur later in the dry season and also sequesters higher levels of carbon in living woody biomass); (ii) developing methods of balancing permanent tree and pasture cover to sequester carbon; and (iii) undertaking carbon sequestration by reducing vegetation clearing, undertaking tree planting and enabling tree regrowth through temporary fencing to exclude livestock. Further research on and refinement of the components of this pathway in northern Australia is an important opportunity for natural resource management to contribute to reduction of greenhouse gas emissions within the beef industry.

13.2.2 Land condition

The issue

The sustainability of the northern Australia beef industry is directly dependent on the condition of the natural environment. The industry requires high-quality forage, productive soils and water to operate. However, much of the land that the industry occupies is vulnerable to overgrazing and degradation. Declining land condition involves reduced ground cover, increased runoff, reduced soil quality and increased salinity. Threats to soils include acidification, erosion and loss of soil carbon.

State of the Environment reporting for 2016 concluded that livestock grazing in Australia continues to have a negative impact on land condition, although its impact is declining (Metcalfe and Bui, 2017). The decline in land condition is of concern from the perspective of biodiversity conservation (see section directly below); however, it is also a major issue for the sustainability of the industry itself.

A challenge for the industry is to adapt management practices to ensure that production is sustainable in the long term. In this regard, the risk of overgrazing from any new approaches/technologies that allow more animals to be carried and/or to consume more pasture (see Section 7) needs to be carefully managed.

Existing responses

Overall, managing the condition of grazing land has been a minor component of beef production in northern Australia over the long term. This aspect of beef production has received research attention from the 1990s onwards. A history of past efforts is provided in Section 5.3. A key area of grazing management research has been the development of sustainable carrying capacities (Hunt et al., 2014). This work is summarised in Table 7 of the report. At the property scale, sustainable land management involves controlling grazing pressure to preserve perennial, palatable and productive grasses while maintaining the soil in a healthy condition so that it can support economically viable cattle numbers (Hall et al., 2017b).

A range of responses is currently being undertaken to improve land management practices so that further declines in resource condition will be prevented. One area of focus is to minimise nutrient and sediment loss and maintain water quality through matching stock numbers to available feed. Another focus is to ensure a balance of tree and grass cover. The later response involves reducing vegetation clearing, minimising woody thickening from regrowth and managing native and improved grasslands for soil health, soil carbon, soil organic matter and for ground cover quality. Grazing land management approaches aim to improve land condition through an understanding of soil condition and pasture condition (Eyre et al., 2011).

Opportunities

A potential opportunity to address declining resource condition is to develop a system of natural capital accounting for the northern Australia beef industry. Measured natural capital should include soil, water, air and biodiversity, which are the natural resources used to produce beef. Such a system could have multiple benefits for the industry. First, it enables producers to incorporate natural assets into property business planning to identify costs and risks associated with depleting these assets. Second, it provides opportunities for producers to access beneficial rates of finance from financial institutions that incorporate natural capital as part of calculations of credit risk and offer lower interest rates for landholders who effectively manage these assets. Third, it can be used to showcase best-practice management of land and offers the opportunity of increasing profitability by providing access to premium markets that seek beef produced under this level of management.

13.2.3 Biodiversity management

The issue

Globally there is increasing awareness that biodiversity is in decline. This trend has been highlighted recently by the release in May 2019 of a global assessment report on biodiversity and ecosystem services (IPBES, 2019). Among other issues the report identified that approximately 25% of all species globally are threatened with extinction.

It is currently unclear how the beef industry in northern Australia performs in relation to biodiversity conservation. No baseline on biodiversity values of the lands that form the northern Australia beef industry has ever been undertaken. Likewise, the role of the industry in managing threatened species has not been formally assessed. Several lines of scientific evidence suggest that the extensive landscapes of the northern Australia beef industry play an important role in biodiversity conservation. There is potential to build a positive message from an assessment of management of biodiversity by the northern Australia beef industry. First, the strength of evidence for the role of cattle grazing as a threatening process for biodiversity is not clearly established and is open to debate (see the next three paragraphs). Second, recent research has shown that members of the beef industry in Australia (including northern Australia) highly value biodiversity on their properties and have a high degree of property-level ecological knowledge (Addison and Pavey, 2017). Further, these managers actively undertake management actions to protect biodiversity such as by eradicating feral cats and red foxes (Addison and Pavey, 2017). These actions are undertaken independently of any government incentives or requests. In addition, many species of plants and animals that are listed nationally as threatened in Australia under the Environment Protection and Biodiversity Conservation Act occur on pastoral properties in northern Australia. Several species, such as the plains mouse (*Pseudomys australis*), occur almost entirely on grazing properties and coexist with beef cattle production (Pavey et al., 2014; Pavey et al., 2016).

In Australia, livestock grazing, including by the northern beef industry, is commonly identified as a factor contributing to the loss of biodiversity (Cresswell and Murphy, 2017). As an example, livestock production, together with the effects of introduced herbivores, has been identified as a threatening process for eight species of mammals that are threatened nationally (Woinarski et al., 2015). This is a relatively low number compared with some other threating processes such as predation by feral cats and red foxes, which threaten 38 and 24 species of mammals, respectively (Woinarski et al., 2015).

The impacts of livestock grazing on biodiversity globally is not clear-cut and livestock grazing is increasingly considered to be only one, relatively minor, factor affecting the vegetation, soil and biodiversity of drylands (e.g. Curtin et al., 2002; Gilbert, 2013). However, the very recent advent of pastoralism in Australia and the absence of native ungulates have resulted in pastoralism being regularly identified as a source of biodiversity loss (Bastin et al., 1993). Despite this widely held belief, linking pastoral production and loss of biodiversity has proven to be difficult in Australia (Williams and Price, 2010) and reliable evidence establishing grazing as a threat to the maintenance of biodiversity is often lacking (Fensham et al., 2010; Frank et al., 2012; Silcock and Fensham, 2013).

Within production systems of the northern Australia beef industry, there are two causal pathways that may impact and eventually decrease biodiversity. First, consumption of vegetation (herbivory) by livestock directly changes and reduces vegetation structure and composition (Kutt et al., 2012). This process impacts on plants and has cascading effects on those components of the fauna that are associated with vegetation. Second, the management of landscapes for livestock results in structural changes such as the diversion or alteration of water bodies, addition of water points, introduction of pasture grasses, clearing of vegetation and changes in natural processes such as fire regimes (Kutt et al., 2012). These structural changes, although positive for some species, have the potential to have negative impacts on many species of plants and animals.

Existing responses

At a national-scale, the beef sustainability framework has as a target that 1.35% of cattle-producing land should be set aside for conservation or protection purposes. However, there is currently no formal mechanism in place to reach this target. Generally, programs that roll-out environmental stewardship activities, particularly those that promote setting aside of land for biodiversity conservation, are undertaken at a regional scale and cover the entire agricultural sector. A current example is the payment for ecosystem services approach being undertaken by the Biodiversity Conservation Trust in NSW. Several mechanisms are used in this program to encourage biodiversity conservation on private land including conservation tenders and fixed price offers. In the north-west plains of NSW, landholders are paid from $75 to $423 per hectare per year over the life of the conservation agreements (https://www.bct.nsw.gov.au/private-land-conservation-outcomes). This program is not specific to the beef cattle industry.

Likewise, in May 2019 the Australian Government announced an agriculture biodiversity stewardship pilot program and a farm biodiversity certification scheme (http://www.agriculture.gov.au/about/reporting/budget/sustaining-future-australian-farming). Both schemes are designed for the entire agriculture sector.

Opportunities

Carry out a baseline assessment of the biodiversity values of the northern Australia beef industry

An analysis should be undertaken that provides an assessment of the biodiversity values of the northern Australia beef industry. The purpose of this analysis would be to develop an understanding of the species of plants and animals that occur on properties in northern Australia with a focus on nationally listed threatened species. Such an analysis has not previously been undertaken; however, it will provide an important baseline against which the value of the northern Australia beef industry for biodiversity conservation can be measured. The availability of national databases such as the Atlas of Living Australia facilitates such an assessment being undertaken.

Develop best-practice property management for biodiversity conservation

An opportunity to develop improved biodiversity management within the northern Australia beef industry involves undertaking a whole-of-industry review of current management practices to identify those that do not represent best practice. In addition, alternative, preferable approaches should be outlined. Emphasis should be given to those management approaches that have negative effects on both biodiversity and profitability. One highly contentious example of such a management approach is wild dog/dingo control. Recent research shows this approach to negatively impact biodiversity and beef profitability because ongoing kangaroo competition with cattle is costlier to beef producers than predation of calves by dingoes (Allen, 2015). Modelling by Prowse et al. (2015) for the semi-arid rangelands, assuming a typical stocking density, estimated that kangaroo control by an unbaited dingo population would: (i) increase pasture biomass by 53 kg/ha; (ii) improve gross margins by $0.83/ha; and (iii) reduce inter-annual variability in profits.

Develop a whole-of-industry approach to payment for environmental services schemes

As noted above, there is currently no biodiversity stewardship program that is targeted at the northern Australia beef industry. Such a program, targeting maintenance and enhancement of biodiversity values on pastoral land, should be developed. An industry-specific approach will enable some of the unique aspects of beef production in northern Australia to be incorporated into the design of the program. All potential market-based policy instruments that provide a financial incentive for biodiversity conservation should be assessed to select one or more that is most suitable for the beef industry in northern Australia.

13.2.4 Increasing climate variability

Existing responses

A range of strategies, including those that involve flexible stocking rates featuring cattle mobility, are used by the industry to mitigate the effects of climate variability (McAllister, 2012; Pahl et al., 2016, reviewed in Section 12.1 of this report). Constrained flexible stocking, where the stocking rate changes but within fixed limits, has been proposed as a risk-adverse adaptation to high and unpredictable rainfall variability for the northern Australia beef industry (Pahl et al., 2016).

Opportunities

A proactive response to increased climate variability is needed across the northern Australia beef industry. Approaches undertaken should seek to maximise the resilience of ecosystems prior to the advent of increased climate variability. From a natural resource management perspective, increased resilience should involve retaining key components of the environment for long-term maintenance of ecosystem services despite ongoing short-term economic pressures. One way of doing this is to develop more conservative stocking strategies that ensure the maintenance of intact natural systems in the face of increased climate variability and to support the adoption of these through an incentive scheme such as a payment for environmental services scheme. Hacker et al. (2010) have shown the potential of such an approach in the western division of NSW.

13.3 Future Research and Development implications

The challenges and opportunities in successfully managing the natural resource base that underpins the northern beef industry are well document and understood, This section outlined some of those challenges, the production risk exposure of climate change and land degradation and the potential for those to impact on profitability and sustainability. Given the extensive land mass the industry covers in northern Australia (see Figure 2), the industry plays a land stewardship role unrivalled by other land manager, but the consequence is the expectation that land will be managed in a manner that meets broader community expectations on ecosystem services (such as biodiversity conservation and weed and pest management) in order to maintain the social license to operate, especially given the land is mstly leasehold not freehold tenure. allow functioning of the beef value chain and for broader whole-of-community needs. This contribution is underappreciated, and this should be measured and objectively assessed and documented for the sector.

14 Industry-wide issues

14.1 Global megatrends and national policies

As a beef exporting nation, Australia is blessed with a varied range of options for markets. From large commodity markets for ground beef, to boutique markets for hormone-free, grass-fed beef, to live export of feeder cattle and the growing demand for beef in developing countries, the Australian producer has options. By exploiting market options, the industry remains resilient and is less susceptible to sudden downturns or trade embargos (Bortolussi et al., 2005a).

Despite the natural advantages afforded to the Australian and northern Australia beef industry, it is not immune to global megatrends and the impacts of associated policy responses. Megatrends are defined as a significant shift in environmental, economic and social conditions that will play out over the coming decades (Hajkowicz et al., 2012).

In 2009 CSIRO started a global foresight project in order to understand where to make future investments. The research was aimed at providing industry, government and community organisations with the likely future state and context they will operate in over the next 20 years. The most recent analysis looked to 2032. The megatrends presented below are not 'likely' actual scenarios but 'worst-case' scenarios by which planning for resilience can be made looking at the trends that flow through all of the scenarios (rather than choosing and planning to manage just one scenario that could develop). The six interrelated megatrends identified in the report are:

- *More from less* – This is where the limited supplies of natural mineral, energy, water and food resources essential for human survival and maintaining lifestyles are being depleted at an alarming rate and climate change impacts are placing considerable pressure on water availability and food production systems. Food production will need to increase by 70% by 2050 to meet the expected growth in population (FAO, 2009), and this will be under increasingly constrained water and energy supplies and loss of productive agricultural land (UNCCD, 2014). On the positive side for the northern Australia beef industry, changing diets are expected to see more demand for high-value products, but a greater emphasis on premium foods and food safety (MLA, 2017b).
- *Going, going ... gone?* – Many of the world's natural habitats, plant species and animal species are in decline or at risk of extinction. The trend of biodiversity decline has continued to be driven by habitat fragmentation, deforestation and other stresses on remaining habitat such as climate change (Butchart et al., 2010). There is likely to be a need to increase the areas of protected habitat and to mitigate the impacts of land management practices on biodiversity in landscapes such as the rangelands, which may have implications for the northern Australia beef industry (given it is largely based on native pastures).
- *The silk highway* – This is reflecting the rise in incomes and economic growth in the Asian economies, but also similar trade that could occur in Africa and South America. The Asian Century has been recognised in previous government white papers. In 2012 the then Australian Government's white paper *Australia in the Asian Century* (Australian Government, 2012) highlighted the potential to boost prospects for Australia's agriculture and food sectors, leading

to 'commercial incentives for new infrastructure investment to enable new, sustainable agricultural production in northern Australia to flourish'. Given the positive economic growth forecasts for Asia and the existing trade ties, this will likely result in increased investment interest into Australia. Northern Australia is geographically well positioned to those emerging markets and that proximity, favourable business and investment conditions (The World Bank, 2018), and history of positive foreign investor sentiment (Laudicina and Peterson, 2017) have given rise to the aspirations to intensify agricultural production systems in northern Australia. One challenge is how Australia best takes advantage of the economic expansion, and the idea that Australia becomes the 'Switzerland of Asia' is proposed where new niche industries are identified and developed that feed into Asian markets, rather than continuing to compete in commodity exports (Hajkowicz et al., 2012).

- *Forever young* – The ageing population is viewed as an asset and their wealth of experience and knowledge is taken advantage of through retaining a connection to the workforce via appropriate tapered retirement models. This could provide access to a hitherto underutilised skills base for all industries including the agricultural sector.
- *Virtually here* – A world of increased connectivity where individuals, communities, governments and businesses are immersed in the virtual world to a much greater extent than ever before. There is and will continue to be a rapid expansion in online retailing, which will inevitably change business models. The rise of internet-enabled micro-transactions will see a closer connection between consumers and producers, and could open up significant opportunities for the northern Australia beef sector.
- *Great expectations* – This is a consumer, societal, demographic and cultural megatrend. It explores the rising demand for experiences over products and the rising importance of social relationships. In Asia, as people transition from poverty into middle income classes, they will be in a position to search for higher levels of service and experience, and this will provide higher-value market opportunities for the northern Australia beef sector. With that comes a rise in the importance of moral and ethical consideration by consumers, evident by the increase in environmentally and socially responsible products (Angus and Westbrook, 2019), and this will provide a challenge to the northern Australia beef sector on both environmental and animal welfare grounds, although this could also provide market opportunities.

The megatrends approach was subsequently refined to take an industry view, and a roadmap for the Australian food and agribusiness sector was developed. It concluded that Australia's food and agribusiness sector has the potential to strengthen its position as a small but significant exporter of sustainable, authentic, healthy, high-quality and consistent products. It challenges the notion of being an Australian food bowl (Dent and ward, 2014) and to a more realistic expectation of being a 'delicatessen of high-quality products for the informed and discerning customer'. Through consultation with industry and research communities, the report identified five megatrends that will have a significant impact on Australia's food and agribusiness sector (Hajkowicz and Eady, 2015). The five megatrends are:

- *A less predictable planet* – There will be increased competition for limited natural resources such as land, energy and water, and these operational constraints will be exacerbated by more severe and unpredictable climate events affecting yields and livestock health. There is already evidence of increased virulence of microorganisms and parasites, and of pathogens to novel geographies.

There is also a major concern of antimicrobial resistance (AMR), with a large growth in antimicrobial use predicted by 2030 (FAO, 2017).

- *Health on the mind* – An ageing population will see an increase in chronic disease, changed diets and increasingly sedentary lifestyles, which will result in increased social awareness around health and wellbeing and create demand for foods that provide specific and holistic health outcomes (OECD, 2015). A potential disruptor will be the use of food as medicine and more targeted holistic health services that target wellbeing, including consideration of diet, which is likely to change demand.

  Trust of food safety is also likely to increase demand for products from reputable sources, such as Australia. For example, consumer concerns in China have been traced back to the farm level, with the high use of pesticides (Calvin et al., 2006) and antibiotics in the livestock sector (Ortega et al., 2011). And while those concerns have resulted in tougher regulator regimes in China, there remains a willingness by Chinese consumers to pay for food safety standards (Ortega et al., 2011). There is a known preference for Australian beef over other imports (Ortega et al., 2016) because the food safety standards can be guaranteed.

- *Choosy customers* – The growth of emerging economies, particularly in Asia, will see rising wealth as people transition out of poverty to the middle class. The urbanisation of those economies will also result in changed expectations and a move towards convenience and reduced preparation time. Another factor will be a reduction in kitchen size and increased internet-enabled food delivery services.

  The transformation of agrifood systems in Asia has been documented by Reardon and Timmer (2014) with five transformations emerging: (i) urbanisation; (ii) diet change; (iii) agrifood system transformation; (iv) rural factor market (i.e. land, variable input and credit markets) transformation; and (v) intensification of farm technology. These transformations evolve as an economy modernises and becomes more productive and less dependent on agriculture-related economic activity.

- *One world* – As food and beverage value chains become increasingly global, new market opportunities are created while at the same time competition and supply resilience risks in a volatile world are introduced. The emphasis in recent years on improving market access through free trade agreements and removing technical trade barriers (Commonwealth of Australia, 2015b) will also lead to improved access to markets for northern Australia.

- *Smarter food chains* – Given the constraints outlined in the megatrend 'A less predictable planet' and the growing conscience of the need to reduce food losses in all parts of the food supply chain, food supply chains will need to become more efficient. The transition will be supported by the Internet of Things use of big data and more sophisticated e-commerce platforms driving the creation of leaner, faster, more agile and low waste value chains.

  A recent review commissioned by Meat and Livestock Australia (MLA) (KPMG, 2019) found that if connectivity on farm could be resolved, there are significant technologies currently available that would increase on-farm efficiency and lead to productivity gains, including farm management platforms, smart irrigation (and water management), weather and climate monitoring, pest management, and imaging drones and unmanned aerial vehicles (UAEs) that could be deployed for surveillance activities. This may lead to more informed decision making and planning; less use of precious resources and less waste; and quicker speed to market with traceability, improved biosecurity and enhanced food safety.

The roadmap also identified the comparative advantages and disadvantages the Australian food and agribusiness sector has relative to other industries. According to Deloitte Touche Tohmatsu (2014), agribusiness is one of five industries (the others being gas, tourism, health, international education and wealth management) where Australia is thought to have a competitive advantage in the next 20 years (following the mining boom). The Australian advantages are world-class resources, proximity to the world's fastest growing markets in Asia, use of English, a climate that is counter-seasonal to most of the world's population, and well understood tax and regulatory regimes. These were further refined for the food and agribusiness sector and summarised in Figure 19.

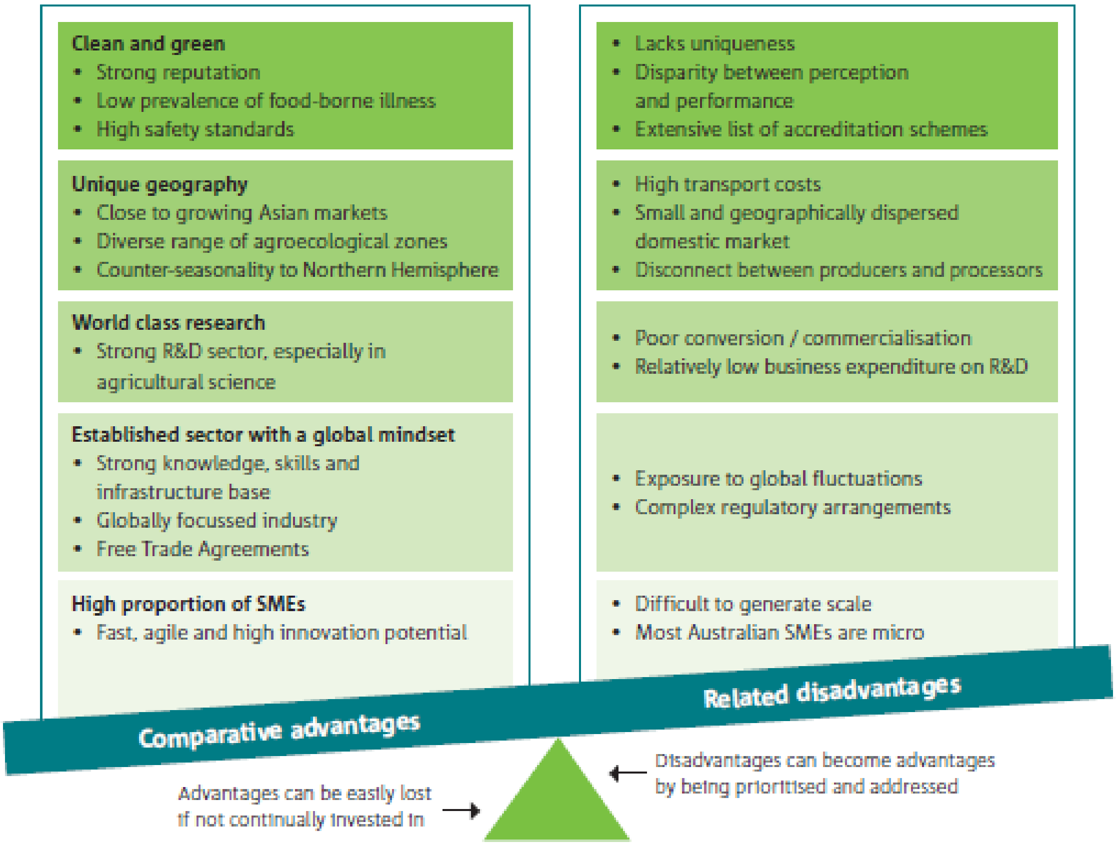


Figure 19 Australia's comparative advantages and disadvantages for growth in the food and agribusiness sector in the next 20 years
Source: CSIRO (2017)

Successive governments of different persuasions have had supportive policies and programs to encourage northern Australian development. In 2012 the then Australian Government's white paper *Australia in the Asian Century* (Australian Government, 2012) highlighted the potential to boost Australia's agriculture and food sector prospects, which would lead to 'commercial incentives for new infrastructure investment to enable new, sustainable agricultural production in northern Australia to flourish'. At that time, interest in northern Australia was also driven by prolonged drought events in southern and eastern Australia such as observed in the Millennium

Drought (2001–2009), and the risk to Australia as a major food producer and exporter (Qureshi et al., 2013). Current high-level government policies that support northern Australia development are in the Australian Government's 2015 white paper titled *Our north, our future: white paper on developing northern Australia* (Commonwealth of Australia, 2015a). The white paper contains 51 policy and program measures and a combined investment value of over $6 billion grouped into actions to address issues in land; water; business, trade and investment; infrastructure; workforce; and governance. At the most recent update, 38 of the 51 measures had been delivered and over $6.2 billion invested, with most funds initially going towards undertaking water resource assessments and feasibility assessments, building economic enabling infrastructure such as roads, and investments through the Northern Australia Infrastructure Facility (NAIF) (Office of Northern Australia, 2018).

In 2015 the Australian Government also released the *Agricultural competitiveness white paper* (Commonwealth of Australia, 2015b), which espoused the pivotal role agriculture has played in developing the Australian economy, while establishing new initiatives to drive better returns to farmers. The white paper recognised the 'trajectory of change that will have profound implications' identified in the megatrends (see above) and committed to the responses below:

- A fairer go for farm businesses, to keep families on the farm as the cornerstone of agriculture, by creating a stronger business environment with better regulation, healthier market competition, more competitive supply chains and an improved tax system.
- Building 21st century water, transport and communications infrastructure that supports efficient movement of produce, access to suppliers and markets, and production growth.
- Strengthening the approach to drought and risk management, including providing the tools to facilitate more effective risk management by farmers and a long-term approach to drought that incorporates provision of enhanced social and community support for farming families and rural communities, and business initiatives for preparedness and in-drought support.
- A smarter approach to farming based on a strong R&D system that underpins future productivity growth; and an effective natural resource policy that achieves a cleaner environment as part of a stronger Australia.
- Access to premium markets through the availability of a large number of premium export markets open to produce and a strong biosecurity system that maintains a favourable plant and animal health status.

Critically the white paper emphasised the need to move towards 'premium' products and adding value, and differentiating Australian products from others as a mechanism to provide value back to the farm gate. There were 31 actions and investments as part of the white paper, of which none were specific to the northern Australia beef industry, although they would clearly be beneficial once implemented. The actions relevant to northern Australia were a combination of policy changes and funding in: improving the competitive environment, reducing regulation, improving tax policy, enhanced infrastructure, drought and risk management and support, enhanced R&D support, additional biosecurity funding, and improving market access.

14.2 State government policies

In 2012 a collective of the Australian Government, the three northern Australian jurisdictions, the Red Meat Advisory Council (RMAC), the North Australia Beef Research Council (NABRC) and the Northern Australian Indigenous Experts Forum on Sustainable Development published a Strategic Direction and Action agenda for the northern Australia beef industry (Department of Infrastructure and Regional Development, 2012). At that time, the state and territory governments had ambitious growth targets that drove their strategies:

- The Queensland Government had a doubling of food production by 2040 target, and with beef the biggest agricultural sector, achieving that target required significant growth in the beef industry.
- The Northern Territory Government estimated that the cattle herd of 2 million head (2012) would grow to 2.5 million head in 10 years through greater efficiency of herd productivity and land utilisation.
- The Western Australian Government WA Beef Vision 2020 estimated that the northern beef herd had the capacity to expand to over 1.5 million head by 2020 at an approximate farm gate value of $500 million.

The contemporary issues were the risks to the northern Australia beef industry from weight restrictions imposed by Indonesia on live cattle imports followed by the suspension on exports by the Australian Government in 2011. The need to diversify the income base of properties through the application of mosaic irrigation to support intensification and generate greater value was also proposed, along with the recognition that to realise the economic potential of the pastoral estate (through alternative markets such as environmental stewardship, tourism and carbon farming) there was a need for land tenure reforms. The strategic priorities were:

- trade relationships and market access, which included securing and growing existing markets as well as looking at the viability for meat production in northern Australia
- investment security through land tenure and water rights, which included an assessment of whether land tenure limited the flow of investment capital into northern Australia and explored opportunities to use Indigenous land tenure as collateral
- transport, logistics and infrastructure, which included an investment in the development of the TraNSIT model (Higgins et al., 2016) and an investigation into food and fibre supply chains (Ash et al., 2014)
- research, development, extension, education and training across the supply chain, which supported the research priorities established by the NABRC and endorsed the need for a Northern Beef Cooperative Research Centre
- Indigenous involvement in the industry, which sought to empower pastoral property development via support of an Indigenous Pastoral Project
- compliance costs, by identifying and reducing unnecessary regulatory burden
- understanding of the resource base via a mosaic irrigation project (Grice et al., 2013) and the North Queensland Irrigated Agriculture Strategy, which developed the *Flinders and Gilbert agricultural resource assessment* (Petheram et al., 2013a,b).

Since then the focus of the jurisdictions has changed. For example, the NT recently released the *Department of Primary Industry and Resources' strategic plan 2018–2022* (Department of Primary Industry and Resources, 2018), *Growing the Northern Territory: opportunities for plant industries in the NT* (Department of Primary Industry and Resources, 2016) and *Investing in the horticultural growth of central Australia* (Department of Primary Industry and Resources, 2017). The focus has shifted to developing and growing new types of agriculture on land that is currently being grazed, and was not previously thought suitable for agriculture. The agricultural development plans are part of the *Northern Territory economic development framework* (Northern Territory Government, 2017a), which seeks to inform long-term decision making, policy and regulatory certainty for economic growth. The economic development framework views agribusiness (defined as livestock, horticulture and forestry, commercial fishing (including aquaculture), and bush medicine and foods) as industry sectors expected to experience strong demand growth, and has six specific actions to support this growth:

- development of an agribusiness hub in Katherine
- support investment in technology that improves productivity
- increase the profitability and performance of the pastoral, horticultural and aquaculture sectors through R&D into supply chains
- identify priority supply chains through the Territory-Wide Logistics Master Plan and co-design a 10-year planning program in the 10 Year Infrastructure Plan
- continue to lobby the Australian Government for special working and immigration visa categories to attract and retain overseas skilled, semi-skilled and unskilled workers
- explore the commercial potential for bush foods and medicine as a niche regional growth sector.

The *Northern Territory infrastructure strategy* (Northern Territory, 2017b) referred to in the actions above states that: 'Prudent infrastructure investment decisions will allow the Northern Territory to improve its competitiveness in key industries, reduce the cost of doing business, build local capacity and boost productivity and create jobs'. The view being that 'pre-emptive investments in infrastructure *is* necessary to reduce the investment risk profile for business and to make the Northern Territory competitive. Such investment positions the economy to take advantage of opportunities that might otherwise be lost because of an inability to deliver infrastructure with the certainty needed to secure private investment'.

WA's Agrifood 2025 initiative aims to double the real-term value of sales from WA's agrifood sector between 2013 and 2025 (Department of Agriculture and Food, 2017). The focus for the department (previously the Department of Agriculture and Food and now Department of Primary Industries and Regional Development) is the Northern Beef Development project (formerly known as Northern Beef Futures). The aim of the project is to support the northern Australia beef industry to become more prosperous, resilient and sustainable to meet this growing demand for products. This is in recognition of increased demand from Asian countries, providing the opportunity to expand the industry and move towards higher-value products. The initial focus of the work, which commenced in 2014, was diversification of market options that were export focused and had greater value add (as opposed to the existing industry reliance on live exports to a limited number of markets). The resulting ten projects spanned market investigations, supply-chain analysis, and production and diversification, and were summarised in a project aptly titled 'Joining the Dots' (ACIL Allen Consulting, 2018). The collective findings of the various studies were as follows:

- Demand for live cattle and boxed beef is growing but the increasing demand would not be met by business as usual.
- The region is a source of cattle rather than an accumulator of cattle, with very few entering the region.
- There is surplus of port capacity and the use of alternative ports (other than Broome) was restricted by the poor quality of pre-loading facilities, which have subsequently had some investment in improving.
- Through improved supply-chain coordination to service higher-value markets the industry can reduce price volatility and increase revenue and profit significantly. Four alternative supply-chain models were proposed.
- The current approach to selling cattle through a spot market limited the ability to gain greater value and to recognise (through price received) the unique characteristics of the region (e.g. rangeland beef from an iconic region).
- There is the need for the ability to provide fodder in the dry season so cattle can be finished in the north and the industry can buffer supply to meet demand/manage quarantine without needing to fatten in the south.
- There is considerable interest in developing irrigated fodder on pastoral leases using water from mines and other local sources.
- There is an immediate need to provide extension to assist pastoral businesses and to address their current development priorities irrespective of any other development activities.
- There is a need to translate the conceptual models of supply-chain collaboration into practice and that needs to be co-developed with government and industry.
- Policy reform on developing the sustainable economic potential of the natural resource base and the important role of Indigenous pastoral stations is a key priority and should continue.

The Queensland Government priorities are under the banner of the Advancing Queensland priorities. The *Department of Agriculture and Fisheries strategic plan 2019–2023* will work with industry 'to create the conditions to drive innovation, productivity and jobs' (Department of Agriculture and Fisheries, 2019). In 2019 the Queensland Government began development of a new agribusiness and food industry development strategy through the release of the Growing for Queensland discussion paper (State of Queensland, 2019). The Queensland Government has recently developed six documents on the investment outlook for the Queensland beef supply chain. The series documents the 'value proposition of the Queensland beef industry' and outlines its competitive advantage relative to the global beef market. Unlike the NT, WA and parts of the northern Australia beef industry, the Queensland industry has considerable market opportunities, which afford greater flexibility in their markets, and given the state of the industry, considerably greater service sector and quality assurance regimes. The six publications are:

- *Investment analysis of the Queensland beef supply chain* (EY, 2018a)
- *Future outlook for Queensland cattle and beef products* (EY, 29018b)

- *Strategic drivers of the Queensland beef supply chain* (EY, 2018c)
- *The Queensland beef supply chain* (EY, 2018d)
- *Queensland beef producer investment guide* (EY, 2018e)
- *Investor's guide to the Queensland beef supply chain* (EY, 2018f).

The Queensland Government also has policies to move towards net zero emissions by 2050 (Department of Environment and Heritage Protection, 2017), which is consistent with the beef industry's recent commitment to be carbon neutral by 2030 (See https://www.mla.com.au/news-and-events/industry-news/archived/2017/red-meat-industry-can-be-carbon-neutral-by-2030/).

14.3 Industry strategies

The northern Australia beef industry is 'blessed' with a vast array of industry strategies and policies to guide its future. These are summarised below.

14.3.1 National Farmers' Federation

The National Farmers' Federation *2030 roadmap* plans for the value of Australian agriculture to exceed $100 billion by 2030. The industry was valued at $59 billion when the roadmap was released (National Farmers' Federation, 2018). The roadmap describes 2030 megatrends that will drive and influence agricultural industries in Australia:

- Unprecedented demand through population growth, particularly in Asia, and the likelihood of improving market access through trade liberalisation and broking bilateral market access through free trade agreements.
- Heightened expectations with consumers shifting diets and having a greater concern for animal welfare, sustainability and health meaning that producers will need to demonstrate their ethical and environment credentials.
- The rise of disruptive technology, with new technology seen as essential for closing the productivity gap, and estimates of the full adoption of digital technologies yielding $20.3 billion in gross value (Perrett et al., 2017).
- Response to climate change with an acknowledgement of the exacerbated risks to production as well as the new income opportunities that come with changing climate patterns and warming. The National Farmers' Federation plan aspires for Australian agriculture to be a global leader in low emissions agriculture, but recognises that if policies are poorly implemented they would likely cause additional costs to businesses.
- Consolidation of communities recognising the shift of population from regional and rural centres to urban centres, and the impact that will have on skills and labour availability.
- Fierce new competition with intensification from developing nations who are developing their supply chains and competing in Australia's traditional markets, competition from non-traditional sources such as alternative proteins, and global forces that will disrupt the established rules of international trade.

By setting a bold growth target within the roadmap, the National Farmers' Federation is seeking to solidify effort within the industry. The targeted growth assumes that the recent growth in Asian demand and the changing nature of those customers' requirements will continue and will flow through to demand for Australian products. The roadmap sets out five pillars to build growth:

- Customers and value chains – which seeks to retain and strengthen community trust based on transparency, development of a trusted 'Brand Australia', and labelling and product integrity. To improve value chains the roadmap recognises the need to 'establish Regional Agricultural Deals to provide a multi-government framework for physical infrastructure investment and regional development policy'. The roadmap recognises that the global competitiveness of Australia's products relies on the efficient movement of goods from farm to market, and to achieve this requires the mapping of strategic transport infrastructure for Australian agriculture to identify cost reduction opportunities, using tools such as TraNSIT (Higgins et al., 2018).
- Growing sustainably – which sets transformational targets for the agriculture sector, including the development of monitoring frameworks and financial instruments to support sustainable investments, and potentially create new income streams. The pillar targets a 20% improvement in water use and investments into research to make all sectors carbon neutral by 2030. The pillar also recognises the need to intensify production and 'advocate for infrastructure projects that ensure productive water capture and use, particularly in northern Australia'.
- Unlocking innovation – which recognises the poor translation of research into innovative new products and services, and the need to enhance innovation efficiency. This pillar also recognises the need to invest in improving access to connectivity infrastructure with the ambitious target of 'every Australian farm has access to infrastructure and skills to connect to the Internet of Things', implying that reaching the $100 billion target would be difficult without improved connectivity. The National Farmers' Federation has also set a target to reduce reliance on fossil fuels with a target of 50% renewable energy sources by 2030.
- Capable people, vibrant communities – which recognises that growth will be driven by a skilled, gender-balanced workforce living in resilient regional communities. There will be significant challenges caused by steady declines in the supply of agricultural graduates, and inherent workplace safety issues, both physical and mental.
- Capital and risk management – which recognises the limits of farm businesses in succession planning, financial literacy and risk management, impacting on the profitability of those businesses. Reducing risk is key to increasing capital flow, and this would require innovative financial instruments to reduce risk and allow the flow of external capital. Greater policy and regulatory certainty will be needed to encourage new business models.

The roadmap also recognises that the representative structure of the different sectors may not be fit-for-purpose and a process of cultural change, collaboration and consolidation is required in the way the agriculture sector represents itself.

14.3.2 Red Meat Advisory Council

The RMAC was established via a Memorandum of Understanding between the peak industry councils and the service companies. It plays a coordinating role between peak industry councils and companies, and as such develops visions and strategies for the collective industry. The current Meat Industry Strategic Plan (MISP) 'frames the overarching strategic priorities for Australia's red meat and livestock industry, comprising the production, processing and live export sectors of

Australia's beef, sheep meat and goatmeat supply chains'. It provides an overarching strategy to enable the Australian industry to target investments. It set a goal to 'unlocking up to $7 billion in growth by 2030' across the red meat industries with the value of the Australian beef sector estimated to be $32.7 billion by 2030. Those additional gains that could be realised through the MISP were predicted to come from 'a combination of actively mitigating risks which could either reduce demand for products and/or impose impediments to productivity. The industry must also capitalise on opportunities associated with more efficiently supplying and building demand'.

The latest MISP (Red Meat 2030) was released in October 2019 (Red Meat Advisory Council, 2019). It contains six high-level priority areas:

- People – People see being part of the Australian red meat and livestock industry as attractive now and into the future.
- Customers, consumers and communities – People feel good about eating Australian red meat. Our customers, consumers and communities recognise the vital role our industry plays in food production and food security, and trust us to deliver high-value, high-quality products.
- Livestock – We set the standard for world-class animal health, welfare, biosecurity and production practices.
- Markets – We improve the economic resilience for our industry by increasing access to, and the performance of, existing and new markets.
- Environment – We demonstrate leadership in sustainability, delivering on community expectations in the areas of land, water, biodiversity, climate variability and biosecurity.
- Systems – We are a trusted brand because of our integrity systems, built on trust and respect that supports strong partnerships and sharing of information, reducing unnecessary industry and government regulation.

14.3.3 Cattle Council of Australia

The Cattle Council of Australia Beef Industry Strategic Plan 2020 (Cattle Council of Australia, 2015) has the same priority areas as the MISP but with an emphasis on the grass-fed beef sector and towards strengthening the competitive position of Australia's beef industries. The five pillars of the strategy are designed to support a profitable and sustainable beef value chain and to meet consumer expectations. The plan recognise that many investments will only yield results beyond the 5 years of the plan and that there was a need to invest in industry leadership to maintain community and consumer support. The five pillars of the strategy are:

- market growth and diversification
  - support export market differentiation to attract premiums
  - maintain technical market access and improve access with free trade agreements
  - create flourishing commercial brands that support industry marketing campaigns in new and emerging markets
  - create a premium domestic market that out-competes other proteins
- value chain efficiency and integrity
  - use timely and reliable signals back to producers on cattle value based on objective measures

– develop improved beef language
– support improved value chain information, with reduced regulatory impediments
– use product integrity systems throughout value chain

- productivity and profitability
  – use widespread application of existing R&D for measurable farm-level benefit
  – provide value-based marketing feedback to farm on quality
  – increase alignment of producers to brands
  – find productivity gains to improve efficiency and profitability, not just reducing cost of production
- community and consumer support
  – maintain and improve customer confidence in products
  – encourage agreed animal welfare indicators with compliance
  – provide evidence of improving environmental performance
  – create herds of high health status with robust surveillance and emergency response
  – integrate sustainable production as part of the premium quality Australian products narrative and marketing
- industry leadership and collaboration
  – increase leadership skills across value chain
  – increase sales from collaborative value chains of premium products
  – improve industry representation and service body to be more flexible and focus on high priority issues
  – form new national cattle producer body.

14.3.4 North Australia Beef Research Council

The NABRC is an independent organisation comprising the major R&D providers and producer representatives across northern Australia. Through the development of a research prospectus it provides recommendations to MLA on research investment. NABRC also plays a role in the selection of projects that are funded by MLA via the allocation of the grass-fed levy funds.

In 2012 NABRC published research development and extension priorities for the northern Australia beef industry (NABRC, 2012). These were formed as strategic imperatives that followed the priorities of the MISP (see Section 14.3.2) and the Beef Industry Strategic Plan (see Section 14.3.3). The strategic imperatives are:

- **Enterprise viability** – increasing cost efficiency and productivity and profitability
- **Enterprise sustainability** – increasing natural resource use efficiency and managed environmental impacts
- **Human capacity** – enhancing human capital – producers, researchers, extension
- **Preserving social licence to operate** – practices and perception – animal welfare and resource management
- **Enhancing product** quality and acceptability

- **Biosecurity**.

Through a consultation process six priority areas for research were identified: reproduction, grazing land management, nutrition and growth, human capacity and enabling change, animal welfare, and information technology and precision livestock management. Since 2000, the greatest number of projects have essentially followed these themes with the greatest number of projects funded by MLA being in the themes of nutrition, reproduction, herd management and pastures (See Table 16).

14.4 Indigenous involvement in the industry

Given the scale of land held under Indigenous ownership, northern Australia offers a unique opportunity for the development of Indigenous engagement in the beef industry (Figure 2). The beef industry has the potential to provide for significant and sustainable wealth creation for Indigenous communities and businesses. There has been a general observation that Indigenous properties in northern Australia have been 'underutilised' and there is scope to increase production, but this will need to occur with appropriate support programs and investments (Gleeson et al., 2012; Neithe and Quirk, 2008).

There has been increasing recognition of Indigenous rights and interests in land over the last two decades (Hill et al., 2013) and very recent work by Barber and Woodward (2018) found that Indigenous people want to be owners, partners, investors and stakeholders in future developments. This reflects their status as Australia's longest-term residents, with deep inter-generational ties to the land. There are some existing and perceived constraints on progressing development, particularly with security of tenure, and the ability for that to allow for investment on properties to improve productivity (Dale et al., 2013).

There have been programs and projects recently to support and empower Indigenous pastoralists towards viable and sustainable development pathways. The NT has the Indigenous Pastoral Program (IPP), which commenced in 2003 with the stated aim of increasing Indigenous landowner participation in the pastoral industry. The program is now in its third iteration, with an increase of 100,000 head of cattle in 11 years (2003–2014). The approach is to support and develop capability for Indigenous managers on farms (Northern Territory Government, 2018). In WA, the Kimberley Indigenous Management Support Service and the Pilbara Indigenous Management Support Service programs were jointly funded by the state government with co-investments from the Indigenous Land Corporation (now the Indigenous Land and Sea Corporation). Like the IPP, on-property support to develop skills and businesses was part of the outcome, with an initial focus on building on-property management capacity and business skills. The objective was to improve the management of properties; increase productivity through improvements in skills, infrastructure and cattle quality; and via that increase economic activity and provide training and employment. As the program developed it also supported co-investment, joint ventures and subleasing arrangements as a business-led solution to utilising Indigenous-held properties and generate income without necessarily having Indigenous managers and staff. There has been no publicly available evaluation of the business success of the program in the NT.

More recently in WA, emphasis has moved towards supporting the development of business model opportunities for Aboriginal pastoral businesses (Department of Primary Industries and

Regional Development, 2019). This recognises the challenges and realities facing Indigenous pastoral operations, such as:

- limited access to finance
- complex decision-making structures relating to boards, councils and committees
- the realisation that bad governance directly hinders property and business management
- the lack of appropriate training opportunities
- few opportunities for employment
- that the pastoral business is not the only business of the community, meaning that profits can be directed into other uses and not re-invested
- that there are multiple outcomes for Indigenous businesses and communities including social, cultural and environmental outcomes.

The report also promotes a number of business models such as subleasing, agistment and partnerships, with joint ventures and joint management as alternatives to direct management.

The *White paper on developing northern Australia* (Commonwealth of Australia, 2015a) established a number of initiatives to simplify and modernise land arrangements in the north to support Indigenous economic activity. This included the development of the *Investors' guide to land tenure in northern Australia*, which explains land tenure arrangements and native title, and provides information on how investors can partner with Indigenous communities (https://www.austrade.gov.au/land-tenure).

14.5 Infrastructure

14.5.1 Transport and Logisitcs

The northern Australian livestock industry is a complex set of supply chains between farms, feedlots, processing export depots, ports and export markets. Transport distances can be in excess of 3000 km and this adds to the cost of production, with the cost generally borne on farm. There are a variety of supply chains from northern Australia, but in general the focus is on beef exports in Queensland and live exports from the NT and northern WA. The analysis of cattle movements in northern Australia was updated using historical data from between 2014 and 2016 for this study. There were 76,851 cattle supply chain paths in Australia, and of these supply chains, 24,345 passed through, into or out of northern Australia. With a transport cost of $250 million, 7.1 million head of cattle moved across northern Australia.

Supply chains source cattle from a vast geographic distribution of properties in regions with sparse road networks coupled with long-distance transport, seasonal access issues, and limited port and shipping capacities. Animals entering the beef export supply chain are moved long distances to feedlots and then onward to processing plants that are concentrated near major population centres, mostly on the east coast of Australia, with very few processing plants located in northern Australia.

Table 36 summarises information about these trips, showing the number of supply chains, the average travel distances, transport costs and head of cattle moved. The table includes the total number of cattle moved between enterprises and how many supply chains these represent. This information helps to explain how many stakeholders are involved in the industry across the broader cattle supply chain. Table 36 shows that generally, distances are long in terms of kilometres travelled and trips take more than eight hours on average, requiring vigilance around animal health issues and driver fatigue management, particularly for movements from properties. Movements from property to port highlight the challenge for some producers in that the duration of the trip is long, with marginally longer distances compared to trips from property to processor. For some trips, reduced road quality will reduce truck speed, requiring extended rest periods to help manage driver fatigue. This has a knock-on effect for transport costs.

Table 37 provides the indicator statistics for long haul trips of more than 14 hours. These trips generally require fatigue management breaks (mandated under Basic Fatigue Management regulations). They impact about 20% of the total number of supply chains and 15% of the cattle moved in northern Australia. Often, these trips are movements between properties for finishing.

Table 38 provides the indicator statistics for shorter movements, where the fatigue management time in nil. These shorter trips are mostly property to property or export yard to port.

Table 39 provides the indicator statistics for movements having an origin in northern Australia. Over 70% of movements in northern Australia have an origin in northern Australia and 90% of these have a destination in northern Australia.

Table 40 provides the indicators statistics for movements *not* having an origin in northern Australia, but with a destination in northern Australia. These movements start in southern Australia, with 95% having a destination of a property or saleyard in north Queensland.

Figure 20 shows the annual number of cattle vehicles along each segment of the road network for trips that have an origin, destination or pass through northern Australia. The majority of trips that leave northern Australia head to processing facilities or feedlots in southern Queensland, with a small number of trips heading towards Adelaide or Perth.

Table 36 Summary of road freight movements in northern Australia for cattle

ORIGIN/DESTINATION ENTERPRISE CLASS	NUMBER OF SUPPLY CHAINS	HEAD OF CATTLE	NUMBER OF TRAILERS	AVERAGE TRIP DURATION (hours)	AVERAGE TRIP DISTANCE (km)	TOTAL COSTS FOR MOVEMENTS	AVERAGE COST PER TRAILER	AVERAGE COST PER HEAD	NUMBER OF FATIGUE MANAGEMENT HOURS
Export depot	**22**	**866,291**	**14,438**	**3.60**	**157.67**	**$11,237,314.57**	**$778.30**	**$12.97**	**1.37**
Port	22	866,291	14,438	3.60	157.67	$11,237,314.57	$778.30	$12.97	1.37
Feedlot	**280**	**146,160**	**3,654**	**9.87**	**861.76**	**$10,197,754.83**	**$2,790.85**	**$69.77**	**2.87**
Abattoir	264	129,840	3,246	11.03	964.96	$10,008,371.27	$3,083.29	$77.08	3.26
Rail point	16	16,320	408	1.67	129.95	$189,383.56	$464.18	$11.60	0.12
Property	**19,454**	**5,080,080**	**93,316**	**6.81**	**486.14**	**$151,426,763.03**	**$1,622.73**	**$29.81**	**2.07**
Abattoir	1,666	456,480	11,412	3.94	336.11	$12,397,358.41	$1,086.34	$27.16	0.43
Export depot	2,847	956,880	15,948	9.23	547.81	$29,836,848.46	$1,870.88	$31.18	3.14
Feedlot	905	233,520	3,892	8.55	684.04	$8,300,038.62	$2,132.59	$35.54	2.64
Property	11,796	2,851,920	47,532	7.17	503.61	$79,507,338.52	$1,672.71	$27.88	2.36
Rail point	115	33,360	834	7.36	495.37	$1,197,846.06	$1,436.27	$35.91	2.98
Saleyard	2,125	547,920	13,698	5.71	470.92	$20,187,332.96	$1,473.74	$36.84	1.60
Saleyard	**2,046**	**1,009,440**	**20,356**	**5.55**	**485.88**	**$32,231,580.86**	**$1,583.39**	**$31.93**	**1.35**
Abattoir	305	344,160	8,604	6.77	609.04	$19,120,678.74	$2,222.30	$55.56	1.96
Property	1,646	585,600	9,760	4.69	393.75	$11,042,493.11	$1,131.40	$18.86	0.84
Rail point	19	27,360	684	2.63	202.01	$545,962.10	$798.19	$19.95	0.67
Saleyard	76	52,320	1,308	4.37	394.60	$1,522,446.91	$1,163.95	$29.10	0.80
GRAND TOTAL	21,802	7,101,971	131,764	6.32	460.03	$205,093,413.30	$1,556.52	$28.88	1.89

Table 37 Summary of the longer road freight movements in northern Australia for cattle (where animal health and fatigue management time is significant)

ORIGIN/DESTINATION ENTORTERPRISE CLASS	NUMBER OF SUPPLY CHAINS	HEAD OF CATTLE	NUMBER OF TRAILERS	AVERAGE TRIP DURATION (hours)	AVERAGE TRIP DISTANCE (km)	TOTAL COSTS FOR MOVEMENTS	AVERAGE COST PER TRAILER	AVERAGE COST PER HEAD	NUMBER OF FATIGUE MANAGEMENT HOURS
Export depot	**1**	**105,630**	**1,761**	**31.73**	**1,072.09**	**$7,511,967.02**	**$4,266.95**	**$71.12**	**14.00**
Port	1	105,630	1,761	31.73	1,072.09	$7,511,967.02	$4,266.95	$71.12	14.00
Feedlot	**172**	**60,720**	**1,518**	**21.73**	**1,890.42**	**$7,965,873.92**	**$5,247.61**	**$131.19**	**8.02**
Abattoir	172	60,720	1,518	21.73	1,890.42	$7,965,873.92	$5,247.61	$131.19	8.02
Property	**5,932**	**1,528,320**	**26,752**	**17.25**	**1,169.45**	**$88,673,231.09**	**$3,314.64**	**$58.02**	**7.84**
Abattoir	50	14,640	366	11.20	791.83	$875,162.27	$2,391.15	$59.78	7.00
Export depot	1,110	333,120	5,552	23.27	1,235.32	$21,542,599.77	$3,880.15	$64.67	9.39
Feedlot	329	90,240	1,504	19.64	1,590.37	$6,068,769.00	$4,035.09	$67.25	7.86
Property	3,922	951,360	15,856	15.54	1,104.60	$49,108,486.88	$3,097.15	$51.62	7.43
Rail point	43	12,720	318	9.82	647.81	$594,232.67	$1,868.66	$46.72	7.00
Saleyard	478	126,240	3,156	15.53	1,276.74	$10,483,980.50	$3,321.92	$83.05	7.37
Saleyard	**401**	**165,120**	**3,736**	**19.78**	**1,757.33**	**$17,333,086.26**	**$4,639.48**	**$104.97**	**8.05**
Abattoir	225	110,400	2,760	22.50	2,024.01	$14,917,034.24	$5,404.72	$135.12	8.36
Property	164	47,040	784	11.39	907.15	$1,885,632.94	$2,405.14	$40.09	7.11
Rail point	2	2,880	72	12.44	1,106.97	$194,817.64	$2,705.80	$67.65	7.00
Saleyard	10	4,800	120	12.22	1,134.99	$335,601.44	$2,796.68	$69.92	7.00
GRAND TOTAL	6,506	1,859,790	33,767	18.50	1,267.07	$121,484,158.29	$3,597.77	$65.32	8.19

Table 38 Summary of the shorter road freight movements in northern Australia for cattle (no fatigue management hours required)

ORIGIN/DESTINATION ENTERPRISE CLASS	NUMBER OF SUPPLY CHAINS	HEAD OF CATTLE	NUMBER OF TRAILERS	AVERAGE TRIP DURATION (hours)	AVERAGE TRIP DISTANCE (km)	TOTAL COSTS FOR MOVEMENTS	AVERAGE COST PER TRAILER	AVERAGE COST PER HEAD
Export depot	**8**	**347,835**	**5,797**	**0.25**	**19.44**	**$780,631.77**	**$134.66**	**$2.24**
Port	8	347,835	5,797	0.25	19.44	$780,631.77	$134.66	$2.24
Feedlot	**19**	**17,760**	**444**	**1.27**	**103.03**	**$175,982.77**	**$396.36**	**$9.91**
Abattoir	10	9,360	234	1.58	129.84	$108,283.43	$462.75	$11.57
Rail point	9	8,400	210	0.95	75.40	$67,699.34	$322.38	$8.06
Property	**2,541**	**666,000**	**13,042**	**1.30**	**85.97**	**$4,934,459.88**	**$378.35**	**$7.41**
Abattoir	503	135,840	3,396	1.20	92.16	$1,275,552.87	$375.60	$9.39
Export depot	287	99,600	1,660	0.73	50.40	$432,760.31	$260.70	$4.34
Feedlot	132	32,640	544	1.77	132.90	$269,013.71	$494.51	$8.24
Property	1,249	300,720	5,012	1.48	82.36	$2,008,273.30	$400.69	$6.68
Saleyard	370	97,200	2,430	1.35	104.41	$948,859.69	$390.48	$9.76
Saleyard	**133**	**182,640**	**4,248**	**0.54**	**38.50**	**$827,404.12**	**$194.77**	**$4.53**
Abattoir	12	124,320	3,108	0.36	26.31	$454,628.68	$146.28	$3.66
Property	101	38,160	636	0.84	51.77	$177,185.70	$278.59	$4.64
Rail point	5	12,000	300	0.76	48.69	$78,020.59	$260.07	$6.50
Saleyard	15	8,160	204	1.97	160.43	$117,569.15	$576.32	$14.41
GRAND TOTAL	2,701	1,214,235	23,531	0.92	62.01	$6,718,478.54	$285.51	$5.53

Table 39 Summary of road freight movements having an origin in northern Australia for cattle

ORIGIN/DESTINATION ENTERPRISE CLASS	NUMBER OF SUPPLY CHAINS	HEAD OF CATTLE	NUMBER OF TRAILERS	AVERAGE TRIP DURATION (hours)	AVERAGE TRIP DISTANCE (km)	TOTAL COSTS FOR MOVEMENTS	AVERAGE COST PER TRAILER	AVERAGE COST PER HEAD	NUMBER OF FATIGUE MANAGEMENT HOURS
Export depot	**22**	**866,291**	**14,438**	**3.60**	**157.67**	**$11,237,314.57**	**$778.30**	**$12.97**	**1.37**
Port	22	866,291	14,438	3.60	157.67	$11,237,314.57	$778.30	$12.97	1.37
Feedlot	**218**	**100,080**	**2,502**	**11.45**	**984.30**	**$7,937,608.71**	**$3,172.51**	**$79.31**	**3.71**
Abattoir	202	83,760	2,094	13.72	1,182.48	$7,748,225.15	$3,700.20	$92.51	4.54
Rail point	16	16,320	408	1.67	129.95	$189,383.56	$464.18	$11.60	0.12
Property	**17,859**	**4,653,600**	**84,110**	**6.82**	**479.45**	**$136,054,900.78**	**$1,617.58**	**$29.24**	**2.14**
Abattoir	1,085	282,720	7,068	3.29	274.37	$6,660,140.68	$942.29	$23.56	0.32
Export depot	2,716	924,960	15,416	8.72	508.15	$27,148,377.89	$1,761.05	$29.35	2.96
Feedlot	895	231,120	3,852	8.60	688.40	$8,262,618.75	$2,145.02	$35.75	2.66
Property	11,212	2,711,520	45,192	7.16	499.96	$75,148,040.80	$1,662.86	$27.71	2.38
Rail point	25	8,160	204	5.49	374.82	$219,857.81	$1,077.73	$26.94	0.69
Saleyard	1,926	495,120	12,378	5.81	478.13	$18,615,864.85	$1,503.95	$37.60	1.68
Saleyard	**1,288**	**650,640**	**13,702**	**5.13**	**440.58**	**$20,980,852.91**	**$1,531.23**	**$32.25**	**1.55**
Abattoir	261	265,680	6,642	6.07	540.83	$13,834,795.91	$2,082.93	$52.07	1.92
Property	936	307,680	5,128	4.08	315.46	$5,130,194.03	$1,000.43	$16.67	1.25
Rail point	19	27,360	684	2.63	202.01	$545,962.10	$798.19	$19.95	0.67
Saleyard	72	49,920	1,248	4.43	399.47	$1,469,900.87	$1,177.81	$29.45	0.83
GRAND TOTAL	19,387	6,270,611	114,752	6.28	443.42	$176,210,676.97	$1,535.58	$28.10	1.99

Table 40 Summary of the road freight movements not originating in northern Australia for cattle

ORIGIN/DESTINATION ENTERPRISE CLASS	NUMBER OF SUPPLY CHAINS	HEAD OF CATTLE	NUMBER OF TRAILERS	AVERAGE TRIP DURATION (hours)	AVERAGE TRIP DISTANCE (km)	TOTAL COSTS FOR MOVEMENTS	AVERAGE COST PER TRAILER	AVERAGE COST PER HEAD	NUMBER OF FATIGUE MANAGEMENT HOURS
Feedlot	**62**	**46,080**	**1,152**	**6.86**	**627.63**	**$2,260,146.12**	**$1,961.93**	**$49.05**	**1.26**
Abattoir	62	46,080	1,152	6.86	627.63	$2,260,146.12	$1,961.93	$49.05	1.26
Property	**1,595**	**426,480**	**9,206**	**6.73**	**543.26**	**$15,371,862.25**	**$1,669.77**	**$36.04**	**1.52**
Abattoir	581	173,760	4,344	5.24	460.39	$5,737,217.73	$1,320.72	$33.02	0.66
Export depot	131	31,920	532	26.07	1,858.16	$2,688,470.57	$5,053.52	$84.23	8.93
Feedlot	10	2,400	40	3.93	273.55	$37,419.87	$935.50	$15.59	0.48
Property	584	140,400	2,340	7.25	566.73	$4,359,297.72	$1,862.95	$31.05	1.92
Rail point	90	25,200	630	8.05	539.41	$977,988.25	$1,552.36	$38.81	3.82
Saleyard	199	52,800	1,320	4.80	404.59	$1,571,468.11	$1,190.51	$29.76	0.82
Saleyard	**758**	**358,800**	**6,654**	**6.39**	**574.68**	**$11,250,727.96**	**$1,690.82**	**$31.36**	**0.95**
Abattoir	44	78,480	1,962	9.45	868.62	$5,285,882.84	$2,694.13	$67.35	2.10
Property	710	277,920	4,632	5.20	460.31	$5,912,299.08	$1,276.40	$21.27	0.50
Rail point	4	2,400	60	3.35	308.08	$52,546.04	$875.77	$21.89	0.19
Saleyard	758	358,800	6,654	6.39	574.68	$11,250,727.96	$1,690.82	$31.36	0.95
GRAND TOTAL	2,415	831,360	17,012	6.60	562.27	$28,882,736.33	$1,697.79	$34.74	1.27

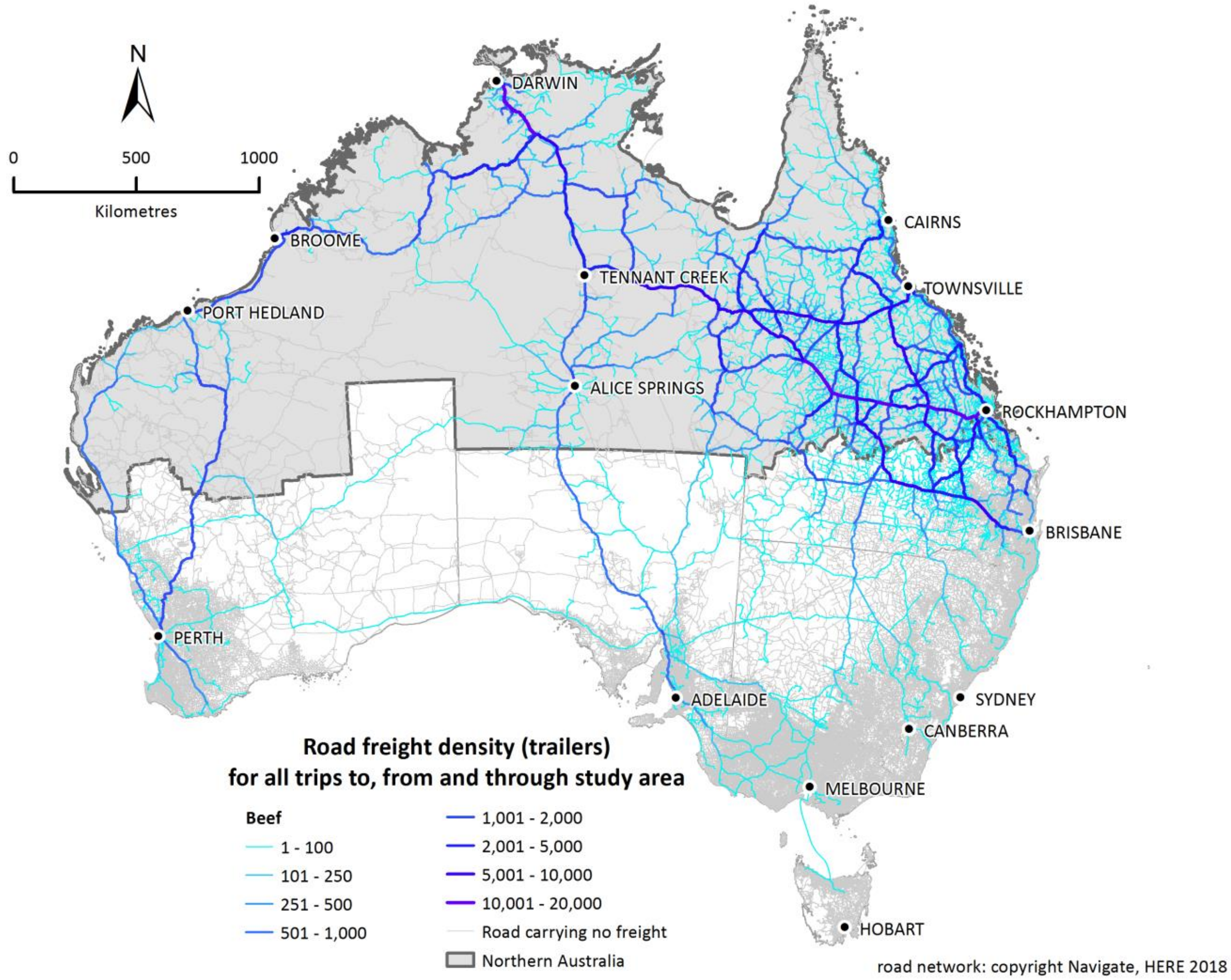


Figure 20 Current trailer count (full semitrailer equivalents) across the road network

Previous reviews and strategies recognise the need to improve enabling infrastructure across the northern Australia beef industry. The *Our north, our future: white paper on developing northern Australia* had a specific investment of $100 million for the Beef Roads Program (Office of Northern Australia, 2015). This provided funding to target upgrades to key roads to improve the reliability, productivity and resilience of cattle supply chains in northern Australia, with the desired outcome of reducing freight costs and strengthening links to markets (Department of Infrastructure, Regional Development and Cities, 2018a).

The Australian Government originally commissioned the development of TraNSIT in 2013 to address the cattle transport challenges in northern Australia (Higgins et al., 2013), before further investment by MLA to cover all livestock movements in Australia, and then an extension to broader Australian agricultural commodities (Higgins et al., 2017). TraNSIT is a computer-based tool that assesses expected savings to industry and calculates the cost of transport and logistics to individual components of the supply chain (Figure 21).It has subsequently been applied to Northern Beef Roads Program investment (described below), Roads of Strategic Importance (described below), and most recently to live export supply chains (described below).

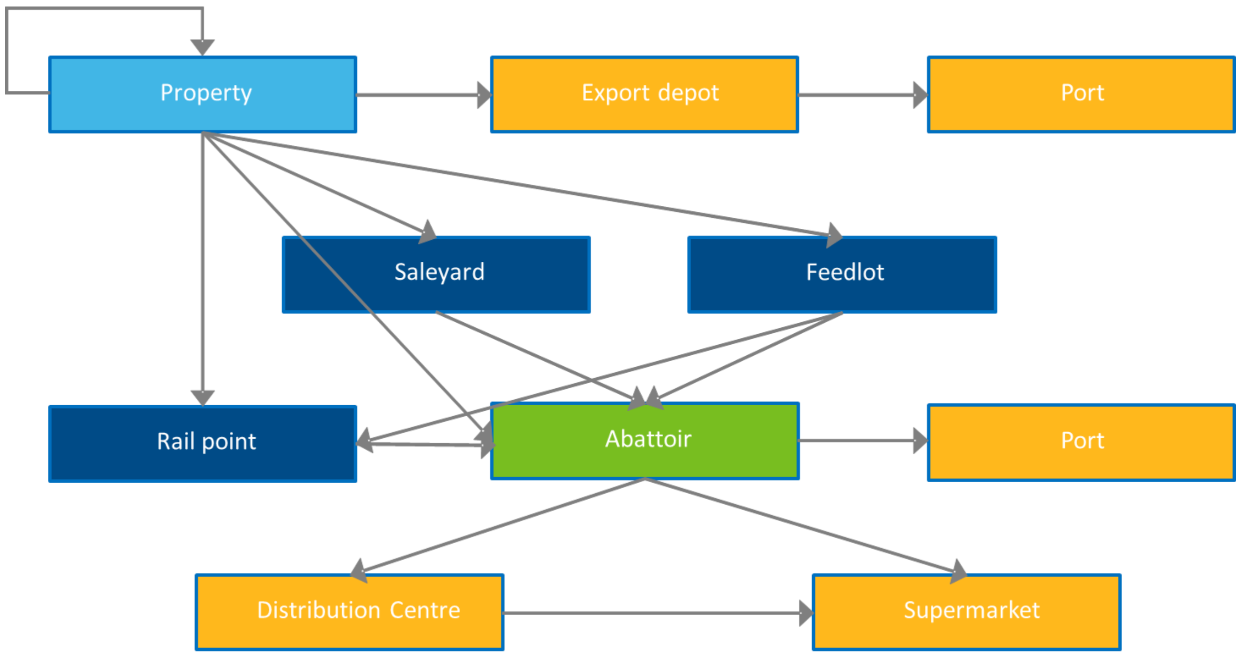


Figure 21 Northern Australia beef supply chain

Northern Australia Beef Roads Program

To prioritise where to invest in roads to support the northern Australia beef industry, a series of stakeholder roundtables identified priorities, which were then tested in CSIRO's TraNSIT tool to estimate cost savings for cattle transport for the different road infrastructure scenarios across the Northern Australia Beef Roads Program in the *White paper on developing northern Australia* (Office of Northern Australia, 2015). This is the first program for which the Australian Government has requested use of a logistics optimisation tool like TraNSIT to directly prioritise road investment options and at such a large scale. TraNSIT was used to evaluate the transport cost savings of over 60 road upgrade submissions with a combined total construction cost of over $3 billion. Previously, typical practice was for the Australian Government to put out a call to state and territory governments, local governments and industry to submit proposals for upgrading road segments they deemed as priority (Higgins et al., 2018).

As a result of the Northern Australia Beef Roads Program's roundtable discussions, 62 submissions were received for road upgrades, with the total cost of those submissions over $3 billion. The nature of the upgrades give a sense of the characteristics of the road network, with 35 involving sealing of gravel or dirt roads, 12 widening sealed roads from 3 m wide to 9 m wide, 9 involving upgrades to allow access to higher productivity vehicles (and reducing the need to 'breakdown' truck trailers in order to complete the journey), 4 were bridge upgrades to reduce the time roads are cut by flooding, and the remainder were to overcome last mile restrictions to road train access to processor feedlots or ports (Figure 22 and Figure 23) (Higgins et al., 2016). Overall, the use of TraNSIT achieved a 72% increase in transport cost savings compared with allocating funding without knowledge of the transport cost savings. The analysis indicates the last mile road upgrade scenarios produced the largest benefits to the beef industry per dollar spent on investment (Higgins et al., 2018).

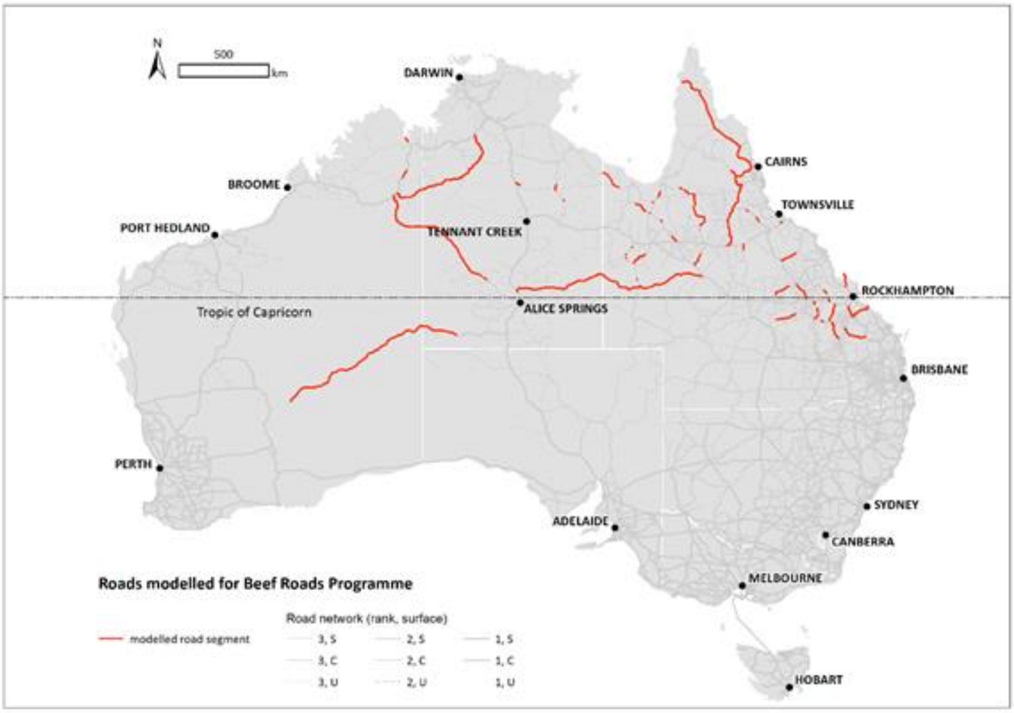


Figure 22 Location of all the road segments considered for upgrade across the Northern Australia Beef Roads Program submissions

Source: Higgins et al. (2016)

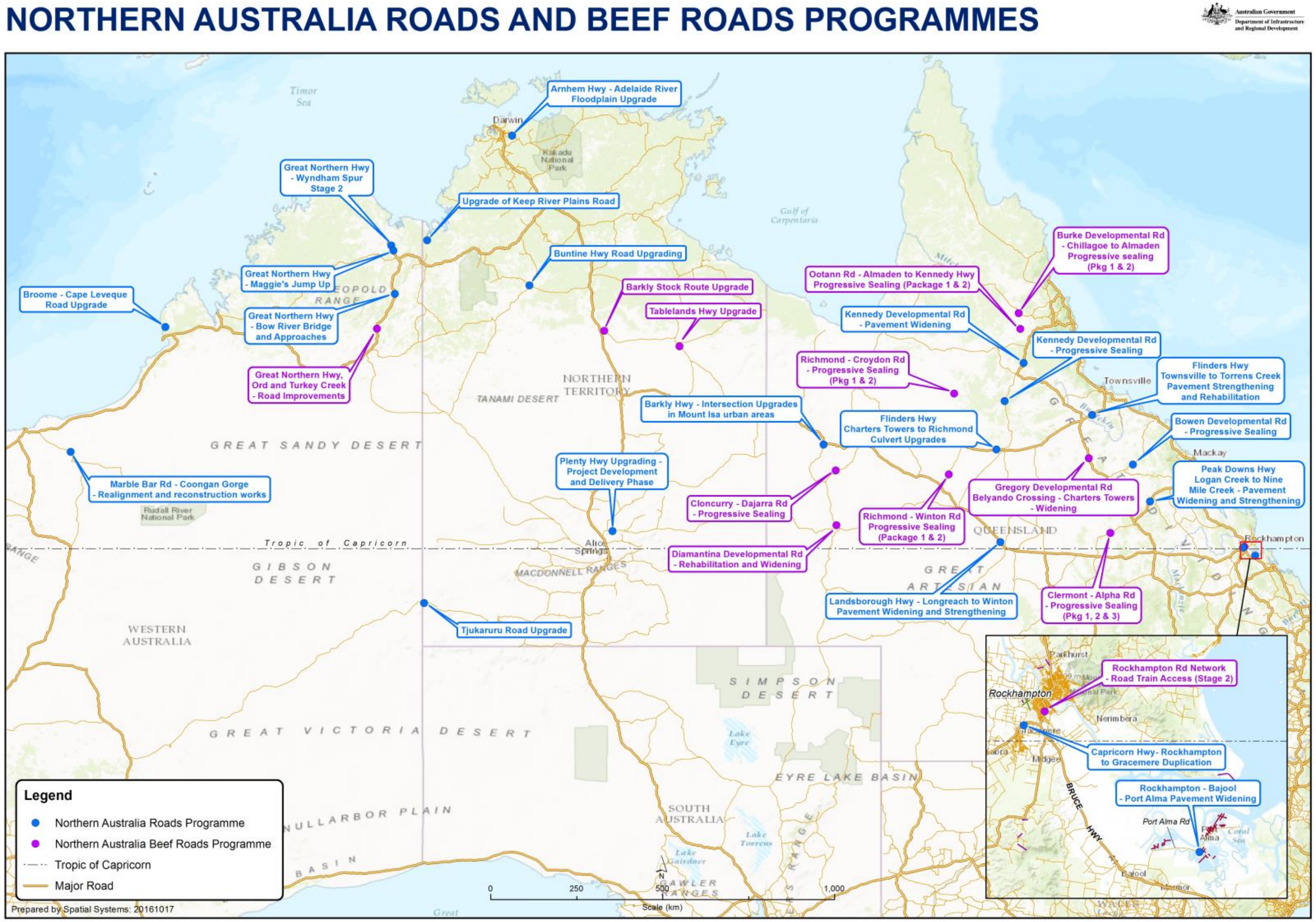


Figure 23 Funded road upgrades across northern Australia
Source: Office of Northern Australia (2018)

Roads of Strategic Importance

In 2018 the Australian Government announced investment of $3.5 billion through the Roads of Strategic Importance (ROSI) initiative, to improve productivity and efficiency on Australia's key freight roads. There was a ROSI reserve of $1.5 billion for projects in northern Australia (Northern Australia ROSI), acknowledging the importance of this region, building on the benefits being delivered through the Australian Government's Northern Australia Roads Program and Northern Australia Beef Roads Program (Department of Infrastructure, Regional Development and Cities, 2018b). The emphasis was on funding to connect regional businesses to local and international markets, and better connect regional communities. Specifically, key freight roads that connect agricultural and mining regions to ports, airports and other transport hubs were targeted for works such as road sealing, flood immunity, strengthening and widening, pavement rehabilitation, bridge and culvert upgrades, and road realignments. Ten ROSI corridors were identified for funding in northern Australia.

Capacity constraints in live export supply chains

MLA commissioned CSIRO (Chilcott et al., 2019) to undertake an assessment of the Australian live export supply chains to characterise the nature of the supply chains and the current constraints, bottlenecks and inefficiencies. Via consultation with key industry participants and relevant government agencies, constraints and operational inefficiencies were identified and grouped (Table 41). The long transport distances and geographic spread make the live export supply chain prone to extreme and unpredictable climate events that can cause significant and major disruptions. Multiple transactions and changes of ownership along the supply chain add actors and also leads to inefficiencies, with many industry actors expressing frustration with the previous or next step in their supply chain. Another challenge raised was the ability of the industry to lobby for infrastructure upgrades given the size of the industry relative to other agricultural industries; any request would be considered against priorities in other agricultural sectors and more broadly against all freight. A common observation was that inefficiencies and bottlenecks are often 'caused somewhere else by someone else', in other words, rectifying inefficiencies and bottlenecks remain out of the control and/or influence of individual businesses. While new market opportunities were discussed there was no concern expressed that new market development would cause issues (i.e. the current infrastructure is not restricting access to current or new markets). The exception was that protocols for China would require additional capacity in registered premises to allow for isolation of consignments of animals, although stakeholders considered that if that became a problem it would quickly resolve through a commercial solution.

Key findings in the report relevant to the northern Australia beef industry are as follows:

- The industry spent $43.9 million (2014–2016) on cattle movements from properties to export depots, with over half spent on the movements to depots servicing Darwin Port, and $7.8 million in movements from export depot to port. Darwin and Townsville had the most cattle moving through the ports.

Table 41 Grouping of capacity constraints and operational inefficiencies identified through the live export supply chain

CATEGORIES	EXAMPLES PROVIDED
Physical infrastructure constraints	Road access during wet season in northern Australia Requests for new ports and development of new registered premises in some locations First and last miles issues across the road network
Operational constraints on adequate infrastructure	Capacity of registered premises Road maintenance and upgrades through the remote network First and last mile issues at key infrastructure points of supply chain Lack of supporting facilities, breakdown pads and wash facilities Curfews on local roads
Regulatory inefficiencies and duplication (and new regulations)	Biosecurity regulations Changes to bovine Johne's disease management Implementation of individual identifiers on sheep in Victoria Australian Maritime Safety Authority inspections
Port infrastructure and operational constraints	Port scheduling issues, especially in northern ports Operational delays causing additional demurrage charges Lack of preference to live export vessels in port scheduling and access Ship loading constraints in remote ports
Input cost and operational inefficiencies	Potential competition for cattle with new abattoir developments Cost of and access to fodder in remote ports

Source: Chilcott et al. (2019)

- Supply chains are long and fragmented and the sourcing of animals is geographically spread. Changes to ownership and a lack of vertical integration also lead to inefficiencies within supply chains, captured in this study by the observation that inefficiencies and bottlenecks are often 'caused somewhere else by someone else'.
- A consequence of the fragmented supply chains is that any benefits that might come from improving infrastructure along a supply chain may not benefit those who invest, so it is unlikely that an individual actor within the supply chains will invest in improvements in transport and logistics if it does not give them a market advantage or reduce costs, and as such funding will only flow through collective industry actions or by governments.
- There are challenges to the industry attracting funding from government over another industry. The small (economic) scale of the live export industry (1.5% of the value of Australian agricultural transport costs) makes it unlikely that it can 'lobby' for industry-specific investments to overcome capacity constraints and bottlenecks. Despite the small scale, the industry is high profile and faces challenges in maintaining its social licence to operate, which will also create a challenge in lobbying for regulatory reforms that would reduce inefficiencies.
- The northern wet season lowers the number of cattle movements to northern ports, but does not stop those movement entirely. Further investigations of market demand are suggested, but the simple initial analysis suggests an additional 40,000 head of cattle per month in the wet

season could be exported if there was investment in infrastructure that could stage and hold cattle in the wet season (that would otherwise not be able to be transported off properties). This would be dependent on market demand, but a possible indicator of market demand was the movement of about 2000 head to southern ports, which were sourced from properties that only exported cattle into southern ports. Whether accessing southern ports is restricted (by wet-season access) could not be established but further investigations into market demand are warranted.

- The changing dates of Ramadan offers an opportunity for northern cattle exporters. There is about 40,000 head per month spare capacity for the wet season (December–January–February) and the development of infrastructure that 'stores' cattle to ensure supply for the Indonesian market should be considered.
- The constraint across the northern wet season is the ability to source cattle on properties. The likely development of the onshore (unconventional) gas industry in the Beetaloo Basin in the NT could result in the building of roads that provide year-round access. If that is the case, the live export industry could work with companies that are developing gas fields to have roads constructed for mutual benefit.
- The competitive advantage of the industry against global competitors is in short shipping times and high levels of quality assurance (through regulation), but this could be lost without continual enhancements and improvements to landside transport infrastructure across the cattle and sheep supply chains. Stakeholders emphasised the need to upgrade all-weather roads, improve port operability (especially in tidal ports) and increase private sector investment in support infrastructure, such as registered premises. The need to continually 'lobby' for road improvements was identified by the Australian Farm Institute (Keogh et al., 2016) who stated:

  > There is an opportunity for livestock exporters to play a very prominent role in planning and advocacy associated with transport and logistics development in northern Australia, and such involvement would also confer stronger recognition of the economic significance of the sector amongst governments and livestock producers.

14.5.2 Abattoirs

The Australian Competition and Consumer Commission (ACCC) (2017) review found that there is a significant concentration of ownership of processing capacity, estimating that the top five processing firms account for around 57% of Australian slaughter. And there are significant barriers to entry into processing, which are exacerbated by seasonal and cyclical fluctuations in the supply of cattle. The ACCC (2017) believes that those conditions reduce the incentive for new entry and dampen competition among incumbents.

There have been many recent investigations and pre-feasibility assessments of the opportunities to build new abattoirs in northern Australia. The motivation has been to bring the abattoirs closer to the source of cattle, or to increase the options that cattle producers have to market their cattle. Most recently, the Queensland Department of Agriculture and Fisheries commissioned an independent investigation into the Queensland beef supply chain to provide current information on key issues with the potential to impact future growth of the industry (Meateng, 2018). The study found that, apart from cyclical destocking periods (in response to dry seasonal conditions), there was currently both sufficient capacity to process cattle turn off (and that the existing operations have sufficient latent capacity to respond to peak periods), and that incremental upgrades of existing abattoir locations could achieve increases in capacity at a much lower cost per unit of throughput than a new greenfield abattoir.

The study conducted a detailed analysis of the viability of 27 different locations for greenfield abattoir developments, assessing the availability of cattle, labour, water, power, fuel and supporting infrastructure. After an initial screening they found 11 sites (Charleville, Charters Towers, Cloncurry, Emerald, Goondiwindi, Hughenden, Innisfail, Longreach, Moranbah, Mount Isa, and Roma) that had the minimum requirements for a successful or viable abattoir location. A financial analysis found that in most cases there was a negative return on investment, with one of the sites showing a positive return under average or expected supply and market conditions. The factors that contribute to negative returns are the lack of economies of scale, high depreciation allowances on new capital and the low input of cattle (where there is already sufficient supply of processing capacity). A sensitivity analysis demonstrated the impact of throughput and cattle costs on profitability, reflecting how challenging it is to make a greenfield abattoir viable.

The Northern Queensland Outback Meatworks study was established to evaluate the commercial viability of a meat processing facility (or facilities) in northern outback Queensland (Department of Agriculture, Fisheries and Forestry, 2012). The study investigated whether it was viable to develop a regional abattoir, providing an alternative marketing option for the region's cattle producers. It found that there were sufficient slaughter-ready cattle within the region to support a 100,000 head/year abattoir, and that an abattoir would support the development of local finishing operations. Proposed irrigation areas on the Flinders River enhance this opportunity (Petheram et al., 2013a). A regional abattoir would reduce transport costs and cattle shrinkage, providing savings to the producer and processor. The study found that the best location was Cloncurry, where there was available labour, energy and fuel and there would be transport savings to the abattoir operator and producer. However, the benefit to the producer is not evenly distributed throughout the region, with those producers close to the abattoir having the greatest benefit and those some 400 to 500 km away having a marginal benefit. This is consistent with the Productivity Commission's recent findings that 'competition for the acquisition of prime cattle typically takes place within a 400 km radius of a point of sale' and as such competition is regionally based (limited by transport costs) (ACCC, 2017). However, this analysis also found that there was no shortage in slaughter capacity within Queensland, so the only benefits of developing a regional abattoir would be to producers in northern Queensland, with savings from transport and reduction in animal welfare risks.

There have been some recent small-scale abattoir developments in northern Australia, which have had mixed success. The Colourstone Abattoir has a capacity of 70,000 cattle per year that it will source from the regions. The Livingstone Abattoir near Darwin has also processed cattle from the regions although has now been closed due to operating efficiencies and costs. The ACCC (2017) and the Department of Agriculture, Fisheries and Forestry (2012) reviews provide insights as to why small-scale and remote abattoirs have struggled to survive or thrive:

- There is a minimum efficient scale for processing of 400 head per day to justify new investment.
- Volatility of supply will significantly impact on viability, and that is a characteristic of northern Australian seasonal conditions.

- The level of regulation on the food processing sector has risen in recent years, and this has resulted in high costs, along with other high costs associated with small-scale and remote abattoirs (labour, energy).
- Vertical integration is not a significant feature of the industry, and smaller operators struggle for economies of scale.
- Tropically adapted cattle that perform better in high temperatures are more resilient to long-distance transport, are tick resistant are of a lower eating quality (MLA, 2011), and as such of lower value.

14.5.3 Digital technology

The adoption of digital technology is seen as one driver of productivity increases in the agricultural sector (National Farmers' Federation, 2018; KPMG, 2018). Perrett et al. (2017) estimated that if digital agriculture was fully adopted it would deliver an estimated boost to the value of all Australian agriculture of 25%, with an increased value of $20.3 billion. Those gains come from improving the 'decision-making or management that exploits the genetic potential within the environmental limitations' (i.e. producers have little influence over the genetic quality of animals, and little control over environmental constraints, but are completely in control of management decisions). The estimated gains in the livestock sector were lower than those expected in plant-based industries, with the gain in gross value of production predicted to be 16% (whereas the increase for grain was 51%). Those gains at a property level would come through:

- improved breeding decisions via objective carcass measurements providing reliable feedback to producers from processors
- improved feed base management via soils (land condition), pasture quality and quantity, weather and climate predictions being linked to allow better stocking decisions and grazing rotations (to allow for resting of pastures)
- animal health and disease surveillance, which would improve the detection of sub-clinical disease before it impacts on performance and to improve overall animal condition and welfare
- labour saving through automation and robotics allowing for remote monitoring and the real-time capture and analysis of that data.

The report highlights the likely opportunities and benefits, but also identifies the challenges of a lack of connectivity in remote locations. This is particularly relevant in the northern Australia beef industry, with issues around data sharing and ownership of data collected through the value chain, such as objective carcass measurement. In 2016 MLA developed a Digital Value Chain Strategy, with the report from the consultation process highlighting lack of connectivity as being a major barrier to developing digital technology in the beef sector. The report included a call for government 'to prioritise mobile and internet coverage to regional areas and enable connectivity for all the red meat industry, from producers to processors' (MLA, 2016c).

MLA (2019) commissioned an assessment of options to improve telecommunications across northern Australia for connectivity in the beef industry. It found that the 'infrastructure costs in providing communications to emerging agtech devices are seen to be prohibitive' and that the business case to invest is not justified across the scale of the properties. The report found that the general awareness of the opportunities was high, but the sparseness of coverage is currently an insurmountable barrier to innovation. Key business drivers for improving connectivity are summarised in Figure 24 below.

People	**Environment**
HSE Duty of Care Safety through location services Talent acquisition with progressive facilities Staff retention through social amenity	Condition monitoring of land Improved decisions through analytics Sustainable and ethical production practices Water usage monitoring and control
Production	**Profit**
Whole of Life data capture for cattle Pregnancy management (e)NVD and supply chain improvement Virtual fencing and cattle segregation	Maximising cattle sale prices Minimising people and equipment costs Improving reporting requirements Smarter production through data analysis

Figure 24 Identified technology and connectivity business drivers
(e)NVD = electronic National Vendor Declaration.
Source: MLA (2019)

The report made the following suggestions for improvement in connectivity for the northern Australia beef industry:

- Increase coverage from the Regional Black Spot program, with the emphasis on major transport links as identified through the TraNSIT modelling (See Section 14.5.1).
- Encourage state and territory governments to invest in regional digital connectivity, where they highlight the opportunities to form investment through the NAIF and the CRCNA.
- Develop targeted technology extension and adoption programs using a model such as the MLA Edge workshops, suggesting a connectEDGE workshop.
- Develop co-funding of technology pilot programs in conjunction with vendors with 'go-to-market' ready solutions, and combine this with cooperative purchasing through industry or producer groups (such as Agforce, the National Training Centre of Australia and the Kimberley Pilbara Cattlemen's Association).
- Adopt (via MLA) common procedures and technologies that allow for integration from paddock to plate to track and record animal performance (and other consumer-related data).

While the opportunities for information communication technology (ICT) are improving in regional areas of northern Australia, connectivity and bandwidth still lag behind those in urban centres. Connectivity across extensive areas is an impediment to the roll-out of many data-hungry applications (Curtin, 2001), and download speeds can be as low as 0.7 Mbps (BIRRR, 2015). A national survey conducted in 2014 (BIRRR, 2015) demonstrated the almost complete lack of access to the internet in the Australian rangelands. Nevertheless, the opportunities ICT present for the beef industry are huge and will be realised over the next decade as the above limitations are overcome.

For the northern Australia beef industry to remain competitive, productivity gains have to exceed current levels (Red Meat Advisory Council, 2019). While a transformative technology such as new breeds of cattle or novel pasture species are unlikely to occur in the foreseeable future, ICT offers the ability to add value to existing systems and to reduce labour and operating costs. This could have a transformative impact on the industry similar to the introduction of Bos indicus genetics in the 1950s and 1960s. Over the past decade a range of novel ICT advances have been developed and are now on the cusp of widespread adoption by the northern Australia beef industry. Some of the more advanced technologies beginning to be adopted by pastoralists include drones, walk over weighing systems and remote satellite monitoring. However, communications connectivity across Australia has limited the widespread adoption of ICT (Curtin, 2001). Yet these limitations are gradually being overcome through new satellites, especially low Earth orbit technologies, providing broadband access. A plethora of novel devices and management tools will shortly become available. The challenge for the grazier will be to determine which ICT will actually transform the industry. The challenge for the ICT industry will be to design robust, reliable, cost-effective tools that can be seamlessly integrated into monitoring and management systems for specific uses.

Monitoring pastures and livestock

Remote landscape sensing is a relatively mature technology and spatial and temporal resolution continues to improve. Satellite imagery can now differentiate certain plant species, can estimate biomass and can identify patterns in the landscape down to a metre resolution. Multispectral imaging, LiDAR (light detection and ranging) and radar imaging offer the potential to monitor and forecast land condition, pasture biomass and ground cover, and in the future identify pasture species and nutritive value. At present, producers can subscribe to commercial services such as FarmMAP4d and Pastures from Space that provide high-resolution spatial data.

Figure 25 is an example of the sort of imagery new remote sensing technologies can provide. Bright red areas indicate bare ground and light green trees. Browns and darker green areas represent naturalised pastures and purple areas are buffel grass.

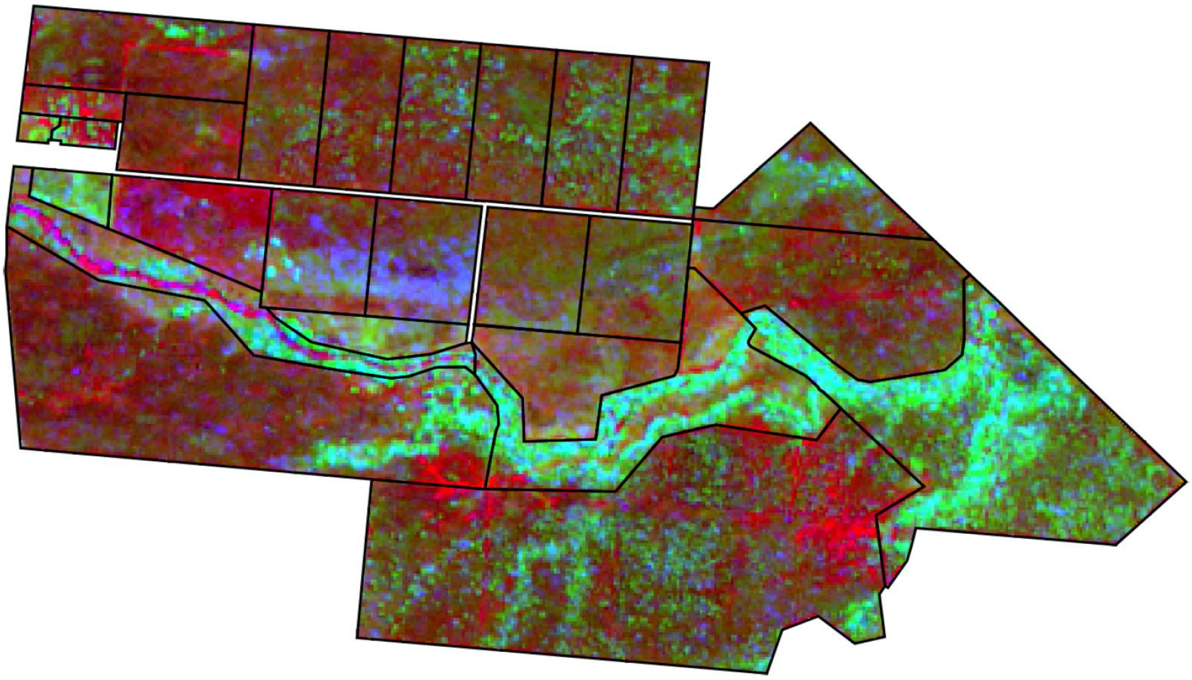


Figure 25 False colour map of Lansdown Research Station using Sentinel 1 and 2 and radar imagery

In extensive grazing systems cattle have a high degree of autonomy in how they interact with the environment. Large paddocks with a variety of soil types, vegetation and riparian areas result in complex grazing patterns, which in turn influence the balance of pasture species as well as the amounts of various species in the paddock. Managers have had limited options to optimise paddock utilisation for the performance of the animal and the persistence of the forage base, until now. Positioning of fence lines and waterpoints were often made based on least cost options, ignoring the possibility of strategic placement of controls (fences) and attractants (water, supplements) to optimise paddock utilisation. The introduction of the National Livestock Identification System (NLIS) uses passive radio frequency identification (RFID), a passive system for animal identification and traceback. In the paddock, NLIS technology offers limited information on animal whereabouts if readers are placed at strategic points within the paddock (Rutter, 2014). It can also be used in combination with walk over weighing and autodrafting capability to facilitate in-paddock control and recording, facets that were hitherto impossible without mustering. Global positioning satellite (GPS) systems are now widely available and recently have begun to have an impact in the cattle industry (Swain et al., 2011). As such technologies become smaller and more robust, and as the issue of a sustained power supply is overcome, the possibility of using GPS to monitor (Greenwood et al., 2014) and even control (Anderson, 2007; Bishop-Hurley et al., 2007) cattle in the paddock is becoming a reality.

Early adopters in the cattle industry are now deploying commercial walk over weighing and autodrafting systems such as Tru-Test (https://livestock.tru-test.com/en-au/product/remote-wow-systems) and DataMuster (https://www.datamuster.net.au/) and realising savings in labour and improved returns through more timely management. High-frequency weight recording throughout the season permits producers to identify changes in performance that allows for management intervention in a timely manner, thus avoiding costly periods of weight loss or poor performance. On animal units are also under development that can identify cattle location in the paddock and beyond. Using GPS or ground-based triangulation, animal position can be identified to identify behaviours in the paddock, such as movement, location, grazing or ruminating (Gonzalez et al., 2014). Ear tag mounted systems are currently under development that will provide lifetime identification and monitoring of cattle position and activity, thus allowing for improved management in the paddock and traceability across the supply chain (https://www.cerestag.com/).

With any new electronic technology there are technological and adoption challenges. Rapid developments in technology are overcoming many of the limitations that prevented use in extensive grazing systems. Size and weight limitations are being overcome such that more and more applications can be fitted into tag-sized mounting systems. Solar energy systems are becoming more efficient and smaller, such that small devices will power on-board electronics indefinitely. In the future health, grazing and reproductive indices will be monitored and relayed via reliable communications systems in near real time.

Monitoring cattle in the paddock is a first step, but systems that allow for control of cattle are also reaching commercialisation. Virtual fencing, where GPS is used to establish electronic boundaries and identify animal position, was developed over 10 years ago and is now commercially available as eShepherd (https://www.agersens.com/). The system relies on knowing the relative position of the boundary and the animal. As the animal approaches the virtual fence a signal is relayed to the animal. The animal is trained to respond to the signal and it from moves away the virtual fence.

Post farm gate technologies

Dexa technology is currently being adapted from human application to the meat processing industry to assess carcass composition in real time (https://www.mla.com.au/globalassets/mla-corporate/news-and-events/documents/dexa-factsheet-lr.pdf).

14.1 Summary

The Australian beef industry is not short of strategic directions and these plans and strategy documents articulate the challenges and opportunities facing the northern beef industry (and documented in Table 1,Table 2, Table 3 and Table 4). However, the inherent low productivity, high capital costs and over reliance on a small number of markets make it vulnerable to market shocks. We found that the industry faces challenges in maintaining profitability and its social license to operate. Further, it is not immune to Global megatrends, where megatrends are defined as a significant shift in environmental, economic and social conditions that will play out over the coming decades, and the impacts of associated policy responses, some of which are already influencing industry strategies and investments.

15 Industry-level cost–benefit analysis

15.1 Background

In order to guide R&D investment in the beef industry it is useful to be able to quantitatively estimate and compare the industry-level benefit for different investments or portfolios of investments. This is needed not only for future planning (ex-ante financial analyses, based on projected potential costs, risks and benefits), as is the focus of this report, but also for retrospective evaluation of investment performance against planned outcomes (ex-post analyses, based on what was achieved).

There are three main routes to improving the financial performance of the beef industry: (i) increasing the amount of beef produced, (ii) reducing the cost of production, and (iii) improving product quality to generate extra revenue through price premiums. Section 8 used North Australian Beef Systems Analyser (NABSA) simulations to estimate the benefits at the enterprise level for a range of R&D options. As noted in that section, the focus was on technologies that could increase production, since this is where most remaining opportunities lie. The rationale for this was that, after decades of efficiency gains and reducing inputs, there is limited scope to further reduce input costs in northern Australia beef enterprises.

For investment decisions, however, it is more useful to be able to compare different technologies on the basis of their benefits to the whole of the northern Australia beef industry, rather than just the improvements at the level of individual animals in a herd at the enterprise/property scale *after* the technology is successfully developed and adopted. The way in which potential R&D benefits scale from the enterprise to industry level depends on the adoption pathways and risk profiles of the technologies. The key factors governing this scaling are:

- the base level of net benefit per animal
- the adoption of the new technology attributable to the investment
- technical risks of the technology failing or achieving a lower benefit on commercial properties
- a set of time-based factors (adoption and obsolescence curves, and future discounting).

Investment decisions need to consider how relative differences in these factors between different R&D options would affect the likely long-term, whole-industry benefits achieved. Each of these factors is discussed further in the section below.

15.2 Analytical approach

The Australian beef industry already has an analytical approach for quantifying the financial return on R&D investments. The approach was developed by Meat and Livestock Australia (MLA) together with the Centre for International Economics (CIE), and is currently used by MLA for both ex-ante and ex-post assessments, applied programmatically across portfolios of investment in different R&D categories. Recent and ongoing applications of this approach include its use in the Meat Industry Strategic Plans. The approach uses discounted cash flow analysis that incorporates the scaling factors discussed above to estimate the industry-wide return on investment for R&D spending (and can be used as inputs to other economic models in further analyses to evaluate second-order impacts that propagate through supply chains, such as the CIE's global meat industries (GMI) and integrated framework (IF) models). The approach used in this report therefore built on this existing precedent. It should be noted that this approach combines costs and benefits from different private and public parties (including producers, research funders and research providers) into integrated measures of financial performance, as is typical of cost–benefit analyses. Neither non-market costs and benefits nor equity considerations of the distribution of the financial costs and benefits were within the scope of this analysis.

The broad concept of this analysis is outlined in Figure 26. The starting point for the analysis is (1) the net dollar benefit that the new technology is estimated to deliver once successfully implemented within a business (e.g. the extra revenue per head of cattle sold from a cattle property) (numbering of text in this paragraph follows Figure 26). This is then multiplied by the estimated eventual maximum number of attributable units of adoption (2) and discounted for the technical risks of the technology failing or underperforming under real-world conditions (3) to calculate the peak risk-adjusted level of annual benefit (once adoption reaches it maximum level). Three time-based factors are then considered to account for how the stream of benefits vary over time (4): the discount rate, which accounts for the fact that future costs and benefits are worth less than those incurred/received in the present; an adoption time series, quantifying how benefits of the new technology increase over time as it is gradually implemented; and an obsolescence time series, accounting for any decline in the efficacy of the technology over time. These time factors are used to calculate the final risk-adjusted stream of projected benefits to estimate the present value (PV) of the new technology. The time series of estimated research expenses (5) is then used to calculate the PV of the costs associated with developing the new technology. Finally, the streams of discounted costs and benefits are used to calculate a range of metrics of financial performance of the proposed innovation, such as the internal rate of return (IRR), NPV, benefit–cost ratio (BCR), and discounted payback period (6).

After consultation with the CRCNA, some adjustments to MLA's use of this approach had to be made to adapt it to meet their requirements for this situation analysis. The application of this approach taken by MLA and the CIE has been to use it as a tool to interactively evaluate alternate investment scenarios during the final decision-making process about how resources are allocated across a full portfolio of research. Here it was adapted to uncouple the tool from the investment decisions and use it as a static analysis providing one line of evidence that was incorporated with review material in the previous chapters to derive the final set of recommendations (in Part I of this report).

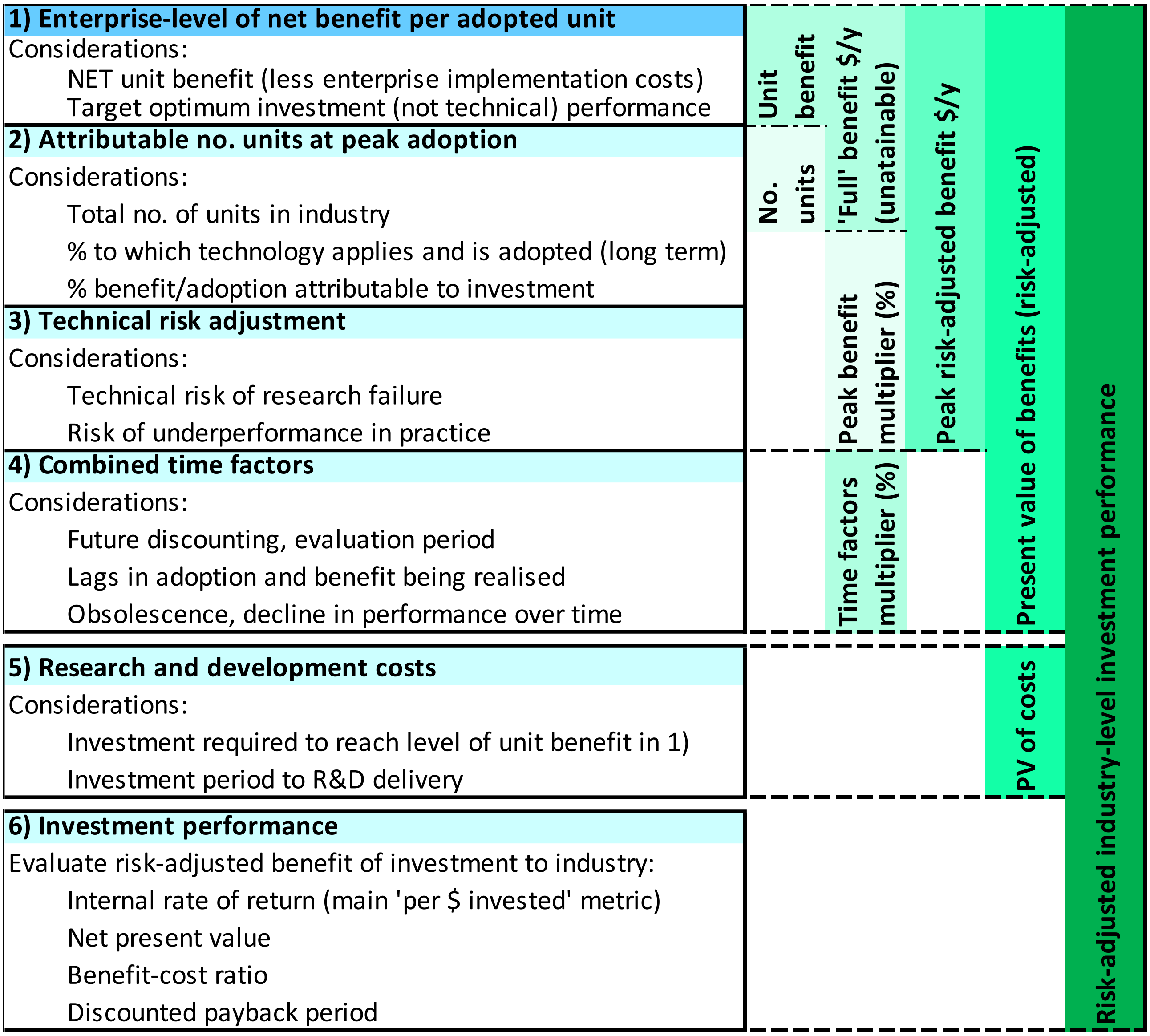


Figure 26 Summary of the factors affecting the projected first order financial impacts of investment in northern Australia beef industry innovation

Part of the adapted approach developed here included reducing the inputs to as few parameters as possible, particularly the smaller subset of these parameters that differ between the technologies being evaluated. This was both to make it easier to obtain input from the experts who had reviewed these technologies (in the previous chapters of this report) and to make the process as consistent, transparent and repeatable as possible. To further assist with this, a ‘relative’ approach was taken to parameterising the analyses (adjusting parameters for each technology *relative* to those of a relatable ‘reference’ option, with an emphasis on evaluating the *relative performance and ranking* of technologies, not the absolute IRR value: discussed further in the ‘Assumptions’ section below).

For each of the sections of the conceptual approach in Figure 26, details are provided below on how those factors were represented parametrically in the analyses (Table 42).

Table 42 Breakdown of the parameters used to quantify and represent each of the factors that contribute to projected industry-level financial performance of R&D investments in the northern Australia beef industry
The breakdown of groups of parameters follows the conceptual approach outlined in Figure 26. This is for an assessment of first order financial performance. Outputs from this analysis have been structured so that they can feed into subsequent models that evaluate knock-on economic effects that propagate through beef supply chains.

CATEGORY	PARAMETER	UNITS
1) Base unit net benefit		
Enterprise-level benefits per adopted unit (relative to current practice, less enterprise implementation costs)		
	Financial net benefit per unit†	$/unit/y
	Units for benefit	unit
2) Attributable adoption		
Total size of region; proportion targeted by innovation; proportion of adoption directly attributable to innovation		
	Total number of units in region	units
	% units applicable and eventually adopted†	%
	% attributable to investment†	%
3) Risk adjustment		
Technical risk of innovation failure; realistic proportion of potential benefit realised in real-world practice		
	% benefit realistically achievable (at peak)†	%
4) Time-related factors		
Parameters account for future discounting, adoption curves, and lifespan of innovation benefit		
- Discounting, period	Discount rate	%
	Start evaluation year	y AD
	Evaluation period	y
- Benefit time lag	Years to delivery (start of benefit/adoption)†	y
	Delivery year benefit/adoption (% of long-term peak)†	%
	Years from delivery to peak benefit/adoption†	y
- Obsolescence	Years after start before decline	y
	Decline per year	%
5) R&D costs		
Size of the upfront R&D investment		
	Research costs per year†	$/y
	Start year of investment	y AD
	Number of years of investment†	y
6) Performance		
Risk-adjusted projected measure of benefit to industry, based on assumptions in above parameters		
	Internal rate of return (IRR = discount rate at which NPV = 0)	%
	Net present value (NPV = PV benefits – PV costs)	$
	Benefit–cost ratio (BCR = PV benefits / PV costs)	$
	Discounted payback period (time for PV benefits to exceed PV costs)	y

†Parameters marked by † were adjusted for each technology; other parameters were kept constant.

15.2.1 Enterprise-Level Unit benefit

The only innovation options reviewed in this report that were suitable for quantitative industry-level financial analysis were those for which financial benefits at the enterprise scale could be estimated to begin with. These were the set of options that were assessed with the NABSA enterprise modelling in Section 8. The basis for calculating these benefits was as the net improvement in enterprise revenue once the new technology was successfully adopted, relative to a baseline of current practice, after accounting for any extra on-property costs of implementing the new technology. The net benefit was expressed as the dollars per adult equivalent (AE) averaged across the herd on a property. There were two components to this enterprise-level benefit in the NABSA evaluations: changes in herd size and changes in the gross margin (GM) per AE (Table 43). These were combined into a single measure that could be scaled across all northern cattle following the steps shown in the last three columns of Table 43. First, the enterprise GM for each technology was calculated by multiplying the herd size by the GM per AE. Then enterprise net benefit of the technology was calculated by subtracting from this the enterprise GM for the baseline scenario. Finally, the net benefit per baseline AE was calculated by dividing the whole-enterprise net benefit by the average herd size in the baseline scenario. This gave the required metric of net benefit that could be scaled based on the *current* number of beef cattle in northern Australia.

The three 'integrated' options that were evaluated in NABSA were not used in the industry-scale analysis given the complexities of evaluating these and the minimal additional insights that they would provide. The complexities in scaling the integrated options arise from the fact the individual technologies are unlikely to be adopted uniformly as a complete package, so there would be multiple combinations of the subsets of the technologies being adopted at different places at different times, each with their own adoption pathways, risks and combined benefits. However, a comparison of the NABSA benefits of the integrated options to the additive effect of their individual components shows that for the first two integrated options there are potential synergies where additional benefits might be gained when several innovations that target different aspects of production are implemented in a planned combination. For the third integrated option, which combined two technologies that performed a similar function (cheap protein and rumen modification), the benefits of implementing the changes as a planned combination were lower than the additive benefits of the individual component technologies. These results indicate that the final realised benefits of technologies, once they are adopted in practice where multiple parallel changes can be taking place on a property, can differ slightly from when each is evaluated in isolation. The impact of these interactions is relatively small compared with the other factors and uncertainties in this analysis, but some consideration should be given to how new technologies will interact with other changes occurring in the industry (as is common practice in considering the animal genetics (G), environment (E) and/or management (M) GxExM interactions) when planning property-level improvements to beef production systems).

Table 43 Summary of enterprise-level net benefit estimates, calculated from the previous NABSA evaluations

The enterprise-level net benefit ($/AE) is expressed on the basis of the baseline (current) number of AE cattle, using the changes in herd size and GM ($/AE) from the previous NABSA analyses (averaged across five regions in northern Australia). Improved reproduction[a] was used as the reference technology from which relative adjustments in parameters were made for the other technologies in the industry-scale financial analyses (see 'Assumptions' section). The capital letters in parentheses next to each technology indicate whether it is primarily related to animal genetics (G), environment (E) and/or management (M). Superscripted lowercase letters (a–h) are used are as shorthand identifiers for the individual 'translational' and 'future' technologies: these are then referenced to indicate which combinations of individual technologies were used in the 'integrated options' in the last three rows of the table (as the lowercase letters in parentheses after each 'integrated option'). The last column for the three 'integrated options' provides the total additive benefit of the individual technologies (a–h) for comparison against the estimated benefit when implemented in a planned integrated package.

TECHNOLOGY/DEVELOPMENT	HERD SIZE (AE)	GM ($/AE)	GM ($/enterprise)	NET BENEFIT ($/enterprise)	NET BENEFIT ($/AE)	
Current practice (GxExM): BASELINE	11,870	165	1,958,550			
Translational technologies – animal						
Improved reproduction[a] (G): REFERENCE	11,967	176	2,106,192	147,642	12.4	
Reduced mortality[b] (M)	12,209	180	2,197,620	239,070	20.1	
Increased growth efficiency[c] (G)	12,154	183	2,224,182	265,632	22.4	
Translational technologies – feed base						
Oversown legume (stylo)[d] (ExM)	13,796	203	2,800,588	842,038	70.9	
Leucaena[e] (ExM)	12,132	217	2,632,644	674,094	56.8	
Irrigated forage sorghum[f] (ExM)	12,406	198	2,456,388	497,838	41.9	
Future technologies						
Cheap protein[g] (M)	11,970	205	2,453,850	495,300	41.7	
Rumen modification[h] (M)	12,001	186	2,232,186	273,636	23.1	
Integrated options (GxExM)					Integrated (modelled)	Addition of individual components
Integrated genetics (a,c)	12,512	194	2,427,328	468,778	39.5	34.8
Genetics + oversown legume (a,c,d)	14,095	235	3,312,325	1,353,775	114.1	105.8
Genetics + cheap prot. + rumen mod. (a,c,g,h)	12,575	228	2,867,100	908,550	76.5	99.6

The enterprise-level benefits from the NABSA modelling were averaged over the length of the model runs (and across the five locations considered in northern Australia). At the enterprise level it would also be important to consider cash flow when planning changes to how the business operates. The implementation stage in adopting a new technology can create substantial short-term financial challenges for a grazing business as current management systems and herd structures are disrupted, implementation costs are incurred, and some revenues are delayed, while anticipated future benefits are not entirely assured. The industry-level analyses in this chapter did not deal with these enterprise-level issues. At the implementation planning stage, however, it would be important to consider strategies for how businesses could deal with these cash flow and financial challenges and risks, and not just the technical and logistical aspects of adoption.

15.2.2 Attributable adoption

The peak levels of adoption attributable to the new technology were represented by three parameters (Table 42):

- The total number of cattle AE in the northern Australia region considered in this study. This was taken to be 11,000 AE (~12,000 head × 0.9 AE/head) consistently across all technologies considered (so did not affect final relative performance). The choice and definition of this base unit were determined by needing to match the units used in NABSA estimates of enterprise benefit.
- The proportion of cattle to which the technology applied and which would ultimately adopt the technology in the long term. The approach here was to assume that, in the long term, most new technologies would ultimately be adopted widely where they were applicable, practicable and profitable. The main source of discounting for adoption was in the benefit curves in the 'Time factors' section below, where low initial rates of adoption and slow uptake rates were typically assumed. Since the net benefit data from NABSA were evaluated for the entire enterprise integrated across the full herd on an enterprise (even when the technology might only have been applied to part of the property or herd), the proportions used in setting this parameter were based on the estimated proportion of *properties* in northern Australia where the technology would be applicable and adopted.
- The proportion of that adoption and benefit that could be attributed to the current investment, after accounting for how much of the overall benefit could be ascribed to other previous and ongoing initiatives related to this technology.

15.2.3 Technical risks

A discount was applied for the technical risk of the research failing to deliver or underperforming (Table 42). This considered the risk-adjusted level of benefit that might realistically translate from research to real-world practice on commercial properties, as a percentage multiplier.

15.2.4 Time factors

The discounted cash flow analyses used an evaluation period of 40 years, a discount rate of 5%, and were based on real 2020 dollars (for both inputs and outputs). The 5% discount rate was used to be consistent with what MLA and the CIE have used for similar analyses in the past. The evaluation period of 40 years is longer than has been used before but was chosen so that realistic slow rates of adoption could be evaluated, given that other parts of this review highlighted this as a major issue. Sensitivity analysis of using a 20-year evaluation period showed that this captured less than half the cumulative discounted net benefit of technologies relative to using a 40-year evaluation period.

The adoption time series used a set a parameters that represented points on a curve joined by linear interpolations (Table 42):

- The number of years (from 2020) until the research is delivered, the technology starts to be adopted and the initial financial benefits start to be realised. This parameter also accounts for any lag if the financial benefits do not occur immediately after the technology is adopted.

- The proportion of the ultimate peak level of adoption and benefit that occurs in the year above.
- The numbers of years it takes to reach the peak level of adoption and benefit after the first year above.

An allowance was made to capture obsolescence in the analyses through two parameters: the number of years after adoption starts before the benefit of the technology starts to decline, and the number of percentage points per year (additive) by which the peak benefit is discounted after that. Although this capability was included in the analytical approach, it was not ultimately used in the main analyses because it did not apply to any of the technologies evaluated here. However, the 'pessimistic' scenario in the sensitivity analyses (described later) did include obsolescence. Obsolescence would not apply if the technology were replaced by something better in the future because the benefit would persist as the baseline used for evaluating that newer technology. Obsolescence only applies in this analytical approach where there is an actual decline in performance of a technology that continues to be used, irrespective of what improved alternatives may become available later. An example of such obsolescence would be disease resistance that becomes less effective over time. Some care has to be taken throughout the analyses to avoid double accounting for costs and benefits, and to apply each discounting factor once and only once.

15.2.5 Research Costs

Research costs were represented by the starting year of investment (2020 in all cases here), the level of annual investment and the number of years over which investment occurred (Table 42).

Extension costs would be additional to this, and are not included here, following the practice used by MLA in similar analyses. Extension programs in the beef industry are evaluated separately. Extension activities draw broadly across the range of available technologies that are suitable within a region and are not directly linked to individual research projects or technologies. As such extension costs, benefits and effectiveness cannot be readily attributed to individual technologies.

15.2.6 Performance Metrics

A range of financial performance metrics were calculated from discounted cash flow analysis of the streams of costs and benefits associated with the above parameters (Table 42). The primary metric used was IRR, since these gives a 'per-dollar' measure of performance for investments of different sizes. However, the NPV and benefit–cost ratio are also provided, as is the discounted payback period (the number of years taken for the cumulative discounted benefits to exceed the cumulative discounted costs).

15.3 Assumptions

In setting the above parameters for each of the technologies evaluated here, the emphasis was on providing a consistent approach for comparing the investment performance among the options that accounted for *relative* differences in risks and adoption pathways in an equivalent manner. The aim was to calculate financial performance metrics that would allow different investment options to be ranked and compared on an equivalent basis, not to calculate stand-alone absolute measures of performance for each individual option. To set parameters on this relative basis, a reference option was first chosen as a technology for which the R&D and adoption pathways were widely understood. Genetic improvements in cattle for improved reproduction was chosen for this purpose. Parameters were estimated for this option based on the expert opinions from the authors of the related review sections of this report. Other technologies were then dealt with by making relative adjustments to each 'reference option' parameter based on how that aspect of the adoption pathway might be expected to differ. Most parameters were held constant across all technologies and only nine key parameters required adjusting to reflect the relative differences in risk and adoption profiles (marked by '†'s in Table 42). The full list of assumptions used for the industry-level benefit scaling parameters for each technology is presented in Table 44.

Table 44 Assumptions for all parameters used to account for risks and adoption pathways in scaling enterprise-level benefits of R&D investments to performance at the level of the whole northern Australia beef industry

PARAMETER	TRANSLATIONAL TECHNOLOGIES – ANIMAL			TRANSLATIONAL TECHNOLOGIES – FEED BASE			FUTURE TECHNOLOGIES	
Technology option	Improved reproduction	Reduced mortality	Increased growth efficiency	Oversown legume	Leucaena	Irrigated forage sorghum	Cheap protein	Rumen modifica-tion
1) Base unit net benefit								
Net benefit per unit ($/AE)	12.44	20.14	22.38	70.94	56.79	41.94	41.73	23.05
2) Attributable adoption								
Total units (AE millions)	11	11	11	11	11	11	11	11
% Units applicable and adopted	80%	90%	70%	30%	30%	10%	30%	40%
% Attributable	30%	50%	30%	10%	10%	10%	100%	100%
3) Technical risk adjustment								
% Benefit achievable	80%	60%	80%	60%	60%	80%	10%	15%
4) Time factors								
Discount rate (%)	5%	5%	5%	5%	5%	5%	5%	5%
Start evaluation year (y AD)	2020	2020	2020	2020	2020	2020	2020	2020
Evaluation period (y)	40	40	40	40	40	40	40	40
Years to delivery (y)	3	3	3	3	2	5	15	10
Delivery year benefit (% of peak)	5%	5%	5%	1%	1%	1%	1%	1%
Years from delivery to peak benefit	15	10	15	20	20	15	10	10
5) R&D investment								
Costs per year ($ millions)	5	3	5	2	2	1	2	2
Start year (y AD)	2020	2020	2020	2020	2020	2020	2020	2020
Number of years (y)	5	5	5	5	5	5	10	10

Following the rationale used to select these technologies in enterprise-level evaluations in NABSA, options were considered in two broad categories. 'Translational' R&D options covered those for which there was already a strong existing evidence base from previous research but remaining work was still needed to translate those research principles into commercial practice. 'Future' technologies covered longer-term options where there are promising prospects but where foundational evidence is required before further development can occur.

‘Translational’ options would have a relatively low technical risk, since the evidence base is already established and the next steps in developing the technologies are clear. However, that previous investment means that a high proportion of the benefit of that technology needs to be attributed to the those preceding (and ongoing) initiatives, not just to the final stages of R&D now required for translating that knowledge into practice.

Translational options related to direct improvements in animal performance were considered to apply to most of the northern Australia beef herd. Such technologies would be expected to eventually be adopted across most properties with relatively rapid adoption. Options that only required changes to management were considered to be less expensive to develop and quicker to implement than those requiring improved herd genetics.

Translational options related to improving the feed base were generally considered to be less widely applicable than the animal options, because the soils and climate would need to be suitable to grow the forages and there are restrictions on introducing forages into native pastures in some locations. For irrigated sorghum the need for a source of water would further restrict where this option could be applied. The remaining investment required for these options is low, relative to the work that has already been done, so attribution of benefits to the final stage of R&D would be low. Adoption rates were considered to be slower than for animal options given the upfront expenditure and cost of establishing the forage, and the associated implementation risks during the establishment phase.

Future technologies do not yet have an established evidence base. There are likely to be multiple pathways for developing these options through to commercial implementation requiring staging and re-evaluation where some pathways end in failure. Relative to the translational options, therefore, technical risks, time frames and R&D costs would be expected to be higher, but any ultimate benefit would be almost entirely attributable to this investment.

15.4 Results and discussion

The results of the analyses are summarised in below. The main metric of financial performance chosen for the analysis in was IRR, but the NPV, BCR and discounted payback period are also provided. Other information in the table summarises how the risks and adoption factors affect different intermediate parts of the pathway between the research investment and the estimated risk-adjusted industry benefit. The ‘% peak risk-adjusted benefit’ indicates the combined effects of adoption and risk discounts (1 and 2 in Figure 26) expressed as the risk-adjusted level of annual benefit when peak adoption is reached, relative to the ‘full’ annual benefit (Figure 26) that would be achieved if the full base benefit for the technology were applied to the entire northern Australia cattle herd.

Table 45 Comparison of industry-level financial performance of different R&D investment options after accounting for differences in adoption and risk profiles

The full annual benefit was taken to be the enterprise-level unit net benefit multiplied by the number of units (AEs) in northern Australia, and this was multiplied by 40 years to give the overall full benefit over the evaluation period (as per Figure 26). Although this full benefit would never be achievable, it was used as the common starting point for all technologies to which discount adjustments were made. 'Improved reproduction' was used as the reference technology when setting the parameters for the analyses.

METRIC	TRANSLATIONAL TECHNOLOGIES – ANIMAL			TRANSLATIONAL TECHNOLOGIES – FEED BASE			FUTURE TECHNOLOGIES	
Technology option	Improved reproduction (REFERENCE)	Reduced mortality	Increased growth efficiency	Oversown legume	Leucaena	Irrigated forage sorghum	Cheap protein	Rumen modifica-tion
Benefits and risk adjustments								
Net enterprise-level benefit per unit ($/AE)	12.44	20.14	22.38	70.94	56.79	41.94	41.73	23.05
Peak risk-adjusted benefit/y ($ million/y)	26.3	59.8	41.4	14.0	11.2	3.7	13.8	15.2
% Peak risk-adjusted benefit (% full/y) Multiplier for peak adoption & technical risk	19.2%	27.0%	16.8%	1.8%	1.8%	0.8%	3.0%	6.0%
PV industry benefits ($ million)	259	672	407	118	101	31	67	107
% PV of peak benefit in all years Multiplier for time-related factors	24.6%	28.1%	24.6%	21.0%	22.4%	21.1%	12.1%	17.5%
Combined multiplier (% full)	**4.73%**	**7.58%**	**4.14%**	**0.38%**	**0.40%**	**0.17%**	**0.36%**	**1.05%**
Combined multiplier vs REFERENCE	1.00	1.60	0.88	0.08	0.09	0.04	0.08	0.22
Costs								
PV research costs ($ million)	22.7	13.6	22.7	9.1	9.1	4.5	16.2	16.2
Performance								
IRR (per $ invested metric) (%)	**27%**	**63%**	**35%**	**26%**	**26%**	**18%**	**12%**	**16%**
NPV ($ million)	236	658	385	109	92	27	50	90
Benefit–cost ratio (unitless)	11.38	49.26	17.92	12.96	11.08	6.86	4.11	6.57
Discounted payback period (years)	8	5	7	9	8	13	23	16
Investment performance ranking (best to worst)								
1: IRR > 60%		1						
2: 30% < IRR < 40%			2					
3: 20% < IRR < 30%	3			3	3			
4: IRR < 20%						4	4	4

The discounting resulting from the time-related factors (3 in Figure 26) is expressed as the PV after future discounting and accounting for the gradual adoption until the peak benefit is achieved relative to the PV with no future discounting and full adoption from the start of the evaluation period. The product of these two intermediate multipliers gives a measure of the combined overall discounts applied in projecting the risk-adjusted PV for the benefits of the technology over the 40-year evaluation period. This combined multiplier is then expressed relative to the multiplier for the reference 'improved reproduction' technology (4.73%) to summarise the overall *relative* differences in adoption and risk profiles applied in the analyses. Based on the assumptions above only 0.17% to 7.58% of the 'full' benefit (base benefit × no. cattle × no. years) was estimated to scale to the industry level after accounting for risks, adoption pathways and future discounting. There was over an order of magnitude difference in the combined scaling multipliers, indicating that the different scaling and adoption pathways can have a substantial effect on the risk-adjusted industry-level projected benefits of different technologies.

Financial performance of the technologies fell into four non-overlapping bands that allowed ranking the different options into groups from best to worst as 1 (IRR > 60%), 2 (30% < IRR < 40%), 3 (20% < IRR < 30%), and 4 (IRR < 20%), and these were associated with increasing payback periods, lower NPVs and lower BCRs.

A sensitivity analysis indicated that the relative differences in performance between options, and the final rankings, were reasonably robust to assumptions about the main controlling factors (Table 46). Three sensitives were considered. The first was a 20% increase in peak annual benefit, representing a 20% increase in either the enterprise-level unit net benefit, the proportion of properties to which the technology applied, the peak level of adoption, or the technical risk multiplier (or any combination where the product of proportional changes to these factors was 120%). The other two sensitivity adjustments tested the effects of a 20% reduction in the period of time taken from technology delivery until peak adoption/benefit was achieved, and a 20% reduction in R&D costs. A 20% change in any of these factors had a very similar effect on the final estimated IRR, changing IRRs by 0 to 6 percentage points (Table 46). The highest sensitives were for those options that already yielded very high returns (IRR > discount rate of 5%) and were therefore strong prospects for viable investment anyway.

Table 46 Sensitivity of financial performance (IRR) to assumptions on adoption and risk profiles

SENSITIVITY SCENARIO	TRANSLATIONAL TECHNOLOGIES – ANIMAL			TRANSLATIONAL TECHNOLOGIES – FEED BASE			FUTURE TECHNOLOGIES	
Technology option	Improved reproduction	Reduced mortality	Increased growth efficiency	Oversown legume	Leucaena	Irrigated forage sorghum	Cheap protein	Rumen modifica-tion
Sensitivity analysis (IRR)								
Base, no adjustments (%)	27%	63%	35%	26%	26%	18%	12%	16%
120% peak (%) **(unit benefit, applicable, adopted, and/or attributable)**	30%	69%	38%	29%	29%	19%	13%	18%
80% Adoption period (%)	30%	68%	38%	29%	29%	19%	12%	17%
80% R&D cost (%)	30%	68%	38%	29%	29%	19%	12%	17%
Pessimistic to optimistic range (IRR)								
Pessimistic (%)	10%	36%	16%	10%	8%	5%	4%	6%
Optimistic (%)	41%	98%	53%	39%	40%	26%	17%	24%

In addition, given the subjectivity and uncertainty in assigning some of the parameters in this analysis, a broader range of possible outcomes was indicated by using a 'pessimistic' to 'optimistic' scenario span. The pessimistic scenario consisted of a 20% decrease in net benefit per unit, a 20% increase in the time taken to delivery, a 20% decrease in the starting level of adoption, a 20% increase in the time taken to reach peak adoption after delivery, and a 20% increase in research costs. The optimistic scenario reversed all the above increases and decreases to instead have a positive effect on financial performance. The pessimistic scenario also added obsolescence, where the unit benefit was reduced by 5% per year (additive) after the technology was delivered. Even under the pessimistic scenario, most technology options provided returns above the discount rate (i.e. IRRs > 5%), except for the bottom-ranked group of three technologies where the IRRs approximately matched the discount rate (indicating that NPVs and BCRs would therefore also be low at a 5% discount rate).

The translational R&D options represented the low-hanging fruit, where sunk costs of past work have already proven the technologies' efficacies, and it makes clear financial sense to take the final steps to ensure that the unrealised benefits of those past investments are captured in commercial practice. Among these translational options, the standout performer was reducing animal mortality. The high ranking of this option was related to it being a low-risk animal/herd management option (lower research costs and simpler pathway to implementation) with broad applicability and adoptability across northern Australia.

The remaining two translational animal technologies, both related to animal genetics, fell in the second- and third-ranked group for overall investment performance, with 'increased growth efficiency' performing better than 'improved reproduction'. Although these were broadly applicable and adoptable, like the first animal option, they were building on a more substantial base of past genetics work, so attribution for the final step of R&D was considered to be lower. The costs of genetic research would also be higher than for improving animal management, and there would be slightly more technical risk in the magnitude the of genetic gains that might be realised in commercial practice.

The translational feed base technologies ranked in the third and fourth performance groups, with the 'oversown legume' and 'leucaena' performing better than 'irrigated forage sorghum'. These options had high unit benefits on those properties where they could be adopted, but location-specific conditions limit where each forage can be grown, making them less broadly applicable than the animal-related technologies. There are also challenges in the implementation phase in the upfront expenses and effort for an enterprise and the delays until the forage is established and starts generating extra revenue for the enterprise. An important component of the translation phase of these technologies would therefore be addressing the initial short-term negative cash flow and risks while the forage is being established. The three forage technologies had similar IRRs and serve a similar role in improving animal nutrition, but each would be suited to different locations. Several options for improving the feed base would likely need to be pursued in parallel to ensure that the diversity of local limitations and requirements could be met across the northern grazing industry.

As would be expected, the future technologies rated as the worst R&D investments in this analysis. This was mainly a consequence of the higher discounting from the high technical risk and long time frames associated with more novel and unproven avenues for innovation. However, it is not entirely valid, nor desirable, to compare R&D options with very different time frames, at least not without more rigorous attribution of benefits to the high-risk early stages of R&D relative to the translational efforts that occur on those technologies that have proven themselves and survived elimination through the early phase of development. Clearly, too, it is unsustainable to only focus on translating proven R&D into practice, otherwise there would be limited opportunities for translation in future: a balanced portfolio of R&D investment needs to ensure there is consistent development in all stages of the innovation pipeline if there is to be regular delivery at the end. Furthermore, leaders and early adopters in the beef industry can be ahead of the types of translational options considered here. Serving this high-performing part of the industry requires an R&D balance that can assist them with developing newer technologies and options (which provides an avenue for testing, refining and proving these technologies in commercial practice ahead of extension and adoption more broadly across the industry).

The value of the approach used here is in systematically identifying the issues affecting investment returns and considering how differences in these factors affect relative overall financial performance of alternative R&D options. It is the structured process of working through these issues on an equivalent basis that can be of more use than the final analyses and financial performance metrics themselves in informing investment decisions.

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Appendix A Results for productivity and key financial indicators for each of the five study locations across northern Australia

Kimberley

The case study enterprise (Table 52) is 2800 km^2, of which 2200 km^2 are presently available for grazing – the balance being either undeveloped country without adequate water distribution or low-value country. Grazing is based on native pasture on moderate productivity (duplex) soils. The enterprise runs a maximum of 11,000 breeding cows and seeks to turn off steers at about 24 months (<350 kg) for the live export market via the Wyndham or Broome ports. The baseline herd averages 12,500 AE (adult equivalent) (average stocking rate of 4 AE/km^2). Other turn off includes heifers that are surplus to self-replacement requirements and a proportion of the breeders that are culled earlier for fertility or as a drought destocking requirement.

The starting land condition is B condition (good) as rated against a four-category 'ABCD' land condition rating system that is commonly employed by state land management agencies in northern Australia (e.g. Chilcott et al., 2003). The herd baseline mortality rate is 7%, although this can increase when animals are in poor condition. For the baseline management scenario, it is assumed that there is full equity. Any debt that is incurred attracts a 7% interest rate.

Table 47 Results for productivity and key financial indicators for the Kimberley

TECHNOLOGY	HERD SIZE (AE)	GM ($/AE)	PROFIT ($)	WEANING RATE (%)	ANNUAL LWG (kg/head/y)	BEEF SOLD (kg/AE)
Baseline	12,449	91	167,113	49	111	73
Reduced mortality	12,790	105	311,050	51	111	76
Improved reproduction	12,474	107	367,299	55	111	79
Increased growth efficiency	13,012	116	544,684	55	129	82
Oversown legume	13,073	134	762,709	57	138	73
Leucaena	13,294	166	1,225,005	52	211	107
Irrigated forage sorghum	13,280	142	729,330	52	200	98
Cheap protein	13,345	164	1,125,367	61	159	100
Rumen modification	12,655	136	749,479	60	137	92
Integrated genetics	13,607	147	759,751	61	128	86
Genetics + legume	13,240	194	1,256,528	61	156	95
Genetics + rumen modifier + protein – FUTURE TECHNOLOGY	13,864	257	2,008,902	72	187	132

Katherine

The case study enterprise (Table 48) is a 5520 km^2 property, of which 4416 km^2 are presently accessible for grazing – the balance being undeveloped country without adequate water distribution. Grazing is based entirely on native pasture on open downs country with clay soils. The enterprise has a baseline herd that averages 18,000 AE (average stocking rate of 4.2 AE/km^2) and seeks to produce young animals (steers and heifers) at about 24 months (<350 kg) for the live export market via Darwin. Other turn off includes heifers that are surplus to self-replacement requirements, aged cows, and a proportion of the breeders that are culled earlier for fertility or as a drought destocking requirement.

The starting land condition is B/C condition as rated against a four-category 'ABCD' land condition rating system that is commonly employed by state land management agencies in northern Australia (e.g. Chilcott et al., 2003). The herd baseline mortality rate is 5%, although this can increase when animals are in poor condition. All animals receive urea lick during the dry season.

Table 48 Results for productivity and key financial indicators for Katherine

TECHNOLOGY	HERD SIZE (AE)	GM ($/AE)	PROFIT ($)	WEANING RATE (%)	ANNUAL LWG (kg/head/y)	BEEF SOLD (kg/AE)
Baseline	18,198	150	1,404,380	56	125	98
Reduced mortality	18,622	165	1,730,440	58	125	106
Improved reproduction	17,855	163	1,580,639	61	125	104
Increased growth efficiency	18,183	176	1,890,194	60	142	110
Oversown legume	22,825	184	2,761,916	63	142	113
Leucaena	17,915	170	1,727,472	56	185	112
Irrigated forage sorghum	18,239	159	1,397,370	56	175	106
Cheap protein	17,142	184	1,784,479	61	154	115
Rumen modification	18,018	183	1,982,223	64	141	116
Integrated genetics	18,474	187	2,167,054	65	142	116
Genetics + legume	22,937	211	3,459,283	66	158	120
Genetics + rumen modifier + protein – FUTURE TECHNOLOGY	18,040	215	2,217,612	72	178	127

Barkly

The case study enterprise (Table 49) is a 5000 km^2 property, of which 4000 km^2 is accessible for grazing. In this region, water and related infrastructure development such as fencing are allowing greater areas of stations to be utilised than in the past. Grazing is based entirely on native pasture on open downs country with clay soils. The enterprise runs a maximum of 22,000 breeding cows and seeks to turn off steers at about 24 months (<350 kg) for the live export market via Darwin. In this region many animals are also flow down through Queensland to be fattened but for this study the live export market was chosen as the baseline. The baseline herd averages 16,500 AE (average stocking rate of 4.1 AE/km^2). Other turn off includes heifers that are surplus to self-replacement requirements, aged cows, and a proportion of the breeders that are culled earlier for fertility or as a drought destocking requirement.

The starting land condition is B/C condition as rated against a four-category 'ABCD' land condition rating system that is commonly employed by state land management agencies in northern Australia (e.g. Chilcott et al., 2003). The herd baseline mortality rate is 3%, although this can increase when animals are in poor condition.

Table 49 Results for productivity and key financial indicators for Barkly

TECHNOLOGY	HERD SIZE (AE)	GM ($/AE)	PROFIT ($)	WEANING RATE (%)	ANNUAL LWG (kg/head/y)	BEEF SOLD (kg/AE)
Baseline	16,527	155	1,311,191	61	122	108
Reduced mortality	17,036	170	1,640,325	62	122	119
Improved reproduction	16,907	165	1,530,932	66	122	113
Increased growth efficiency	16,760	162	1,415,414	64	136	111
Oversown legume	17,186	179	1,696,034	68	157	118
Leucaena	16,846	197	1,973,050	61	175	130
Irrigated forage sorghum	17,436	189	1,892,807	61	172	128
Cheap protein	16,783	198	1,914,022	66	151	128
Rumen modification	17,104	160	1,455,150	65	143	114
Integrated genetics	17,528	185	1,986,340	69	137	123
Genetics + legume	17,320	243	2,837,185	72	171	140
Genetics + rumen modifier + protein – FUTURE TECHNOLOGY	17,273	220	2,346,155	76	178	144

North-West Queensland

The case study enterprise (Table 50) is a 166,000 ha property, of which 25% is inaccessible to grazing, either being topographically challenging or too far from water. Grazing is based on native pastures (consisting of Mitchell grass, silky browntop and wiregrass) on either productive clay soils or shallower, infertile duplex soils. The baseline herd size is 8500 AE consisting of breeding cows and growing steers for finishing in southern Queensland or in feedlots. The target is to reach 420 kg liveweight by 30 to 33 months of age. Other turn off includes heifers that are surplus to self-replacement requirements and a proportion of the breeders that are culled early for fertility, culled for age (10 years) or sold as a drought destocking requirement. There is an average stocking rate of an AE to about 16 ha, which gives a utilisation rate of 15 to 20%.

Calves are weaned at eight months and females receive urea blocks during the dry season.

The starting land condition is B condition as rated against a four-category 'ABCD' land condition rating system that is commonly employed by state land management agencies in northern Australia (e.g. Chilcott et al., 2003). The herd baseline mortality rate is 3%, although this can increase when animals are in poor condition.

Table 50 Results for productivity and key financial indicators for north-west Queensland

TECHNOLOGY	HERD SIZE (AE)	GM ($/AE)	PROFIT ($)	WEANING RATE (%)	ANNUAL LWG (kg/head/y)	BEEF SOLD (kg/AE)
Baseline	8,515	184	613,225	53	115	109
Reduced mortality	8,846	201	818,246	54	115	118
Improved reproduction	8,815	194	759,089	58	115	114
Increased growth efficiency	9,007	200	845,713	57	129	116
Oversown legume	11,770	236	1,824,200	61	140	124
Leucaena	8,823	240	1,145,979	53	220	138
Irrigated forage sorghum	9,018	223	974,725	53	212	133
Cheap protein	8,816	207	884,024	63	148	126
Rumen modification	8,572	201	762,587	59	132	120
Integrated genetics	8,977	208	923,655	62	130	120
Genetics + legume	12,690	258	2,291,790	68	155	133
Genetics + rumen modifier + protein – FUTURE TECHNOLOGY	9,652	218	1,165,673	72	173	135

Tropical Queensland

The case study enterprise (Table 51) is a 30,000 ha property, of which 25,000 ha are available for grazing – the balance being undeveloped country without adequate water distribution or inaccessible country. Grazing is based on native pastures (Queensland and Indian bluegrasses, golden beard grass, speargrass, and wire grass) on mostly moderately productive soils. The baseline herd size is 3660 AE consisting of breeding cows and growing and fattening heavier steers for the meatworks in Townsville. The target is to reach Japanese ox markets (580 kg liveweight or approximately 300 kg carcass weight by 42 months of age). Other turn off includes heifers that are surplus to self-replacement requirements and a proportion of the breeders that are culled early for fertility, culled for age (10 years) or sold as a drought destocking requirement. There is an average stocking rate of an AE to about 8 ha, which gives a utilisation rate of 20 to 25%.

Calves are weaned at eight months and females receive urea blocks during the dry season.

The starting land condition is B condition as rated against a four-category 'ABCD' land condition rating system that is commonly employed by state land management agencies in northern Australia (e.g. Chilcott et al., 2003). The herd baseline mortality rate is 3%, although this can increase when animals are in poor condition.

Table 51 Results for productivity and key financial indicators for Tropical Queensland

TECHNOLOGY	HERD SIZE (AE)	GM ($/AE)	PROFIT ($)	WEANING RATE (%)	ANNUAL LWG (kg/head/y)	BEEF SOLD (kg/AE)
Baseline	3,660	244	548,826	63	130	119
Reduced mortality	3,750	258	620,904	65	130	123
Improved reproduction	3,782	252	606,642	68	131	123
Increased growth efficiency	3,809	262	647,603	67	142	127
Oversown legume	4,127	282	821,499	73	157	134
Leucaena	3,781	311	845,047	63	256	152
Irrigated forage sorghum	4,055	276	751,805	63	197	142
Cheap protein	3,766	269	644,393	73	158	132
Rumen modification	3,657	250	574,982	69	146	128
Integrated genetics	3,973	265	705,292	71	140	129
Genetics + legume	4,288	294	926,707	77	167	142
Genetics + rumen modifier + protein – FUTURE TECHNOLOGY	4,047	297	775,319	78	178	146

Appendix B Listing of individual on-farm MLA projects undertaken since the early 2000s

Table 52 lists the individual on-farm MLA projects undertaken since the early 2000s. Project areas are classified according to relevance based on whether they were: (i) undertaken in tropical Australia and/or focused directly on issues in the tropics, (ii) projects that are more generic in nature but with relevance to tropical Australia, and (iii) also generic projects relevant to tropical Australia but with a digital technology focus. The database of projects was provided by Meat and Livestock Australia (MLA). All short-term projects (reviews, specific consultancies, coordinator roles, priority setting activities, scholarships, workshops, travel grants, etc.) were excluded from the analysis.

Table 52 On-farm projects funded by MLA since the early 2000s

CLASSIFICATION	LOCATION	PROJECT TITLE
Animal health	Tropical	Vaccination of calves and weaners for Clostridial diseases
Animal health	Generic	Buffalo fly in vitro culture and infections with Wolbachia
Animal health	Generic	The Probio-TICK initiative
Animal health	Tropical	Supplement feeding/buffalo fly trap combination
Beef genomics	Generic	BCRC 3 – gene discovery for post-partum reconception and age of puberty in the Australian beef population
Beef genomics	Generic	Comparative tick gene expression in Brahman and Holstein Friesian cattle
Beef genomics	Tropical	Developing selection and breeding objectives to optimise production and market suitability of Brahmans in the tropic and sub-tropic regions of the Northern Territory
Beef genomics	Tropical	Reproduction traits of tropical composite bulls through genome-wide association
Beef genomics	Generic	Barriers to adoption of genetic technologies in northern Australia
Beef genomics	Generic	Improved methods for genotypic data analysis
Beef genomics	Tropical	Ideal markers for tropically adapted cattle – proof of concept: causative mutations for bull fertility
Beef genomics	Generic	Evaluation of gene editing technologies for the red meat industry

CLASSIFICATION	LOCATION	PROJECT TITLE
Capacity building	Tropical	Mentoring of stock people in north-west Queensland – a pilot
Capacity building	Tropical	Best practice reference for the Katherine region
Capacity building	Generic	Attracting and retaining staff in Australia’s beef, sheep and pastoral wool industries
Capacity building	Tropical	Enhancing adoption of best practice grazing management in northern Australia: phase 1
Capacity building	Generic	Industry fact sheet – attracting and retaining staff
Capacity building	Generic	Attracting and retaining staff in the red meat industry
Capacity building	Digital	Australian satellite connectivity producer engagement strategy development
Capacity building	Generic	Supporting The Leucaena Network; national research and the regional adoption outcomes for a highly productive beef industry
Capacity building	Tropical	Scoping the viability, feasibility and capacity for a northern beef centre of excellence
Capacity building	Generic	Building capacity in the rangelands
Climate change and variability	Generic	Managing Climate Variability Program 2007–2008
Climate change and variability	Generic	CCH – climate change adaptation
Climate change and variability	Generic	Managing Climate Variability Program 2008–2010
Climate change and variability	Generic	Australia’s farming future: climate change research
Climate change and variability	Generic	The identification of regions where severe fire regimes affect red meat producers
Climate change and variability	Generic	Evaluating transformative adaptation options for Australian extensive farming
Climate change and variability	Generic	Innovative livestock systems to adapt to climate change and reduce emissions
Climate change and variability	Generic	MCV phase 4 2014–2016
Economics	Generic	Increasing cull cow values
Economics	Tropical	Economics of improving reproduction of beef cattle in northern Australia
Economics	Tropical	Pastoral company production and financial benchmarking
Economics	Tropical	Pastoral company production and financial benchmarking – 2
Environment	Generic	Biodiversity impacts of meat systems

CLASSIFICATION	LOCATION	PROJECT TITLE
Environment	Generic	EMS module for the red meat industry's Livestock Production Assurance (LPA) Program
Environment	Generic	Water foot printing of livestock products: impact assessment of beef production systems
Feral management	Generic	New feral pig toxin (HOG-GONE®) development & delivery
Feral management	Tropical	STRATEGY: northern feral animal management
Feral management	Generic	Wild dog ecology, impacts and management in northern Australian cattle enterprises: a review
Grazing management	Tropical	Part 1 – Wambiana Grazing Trial Phase 3: stocking strategies for improving carrying capacity, land condition and biodiversity outcomes
Grazing management	Tropical	Part 2 – Wambiana Grazing Trial Phase 3: stocking strategies for improving carrying capacity, land condition and biodiversity outcomes
Grazing management	Tropical	Wambiana – grazing strategies and tools to improve profitability and land condition
Grazing management	Generic	Grazing with self herding to improve performance of pastoral cattle
Grazing management	Tropical	'The sweet spot': improving breeder herd performance through optimal pasture utilisation
Grazing management	Generic	The use of grazing behaviour to improve grazing management and animal performance in the beef industry
Grazing management	Tropical	Spatial grazing patterns in northern Australia: management tools and guidelines
Herd management	Digital	Evaluating the business case for investment in development of precision livestock management (PLM) technologies and applications
Herd management	Digital	Remote calf alert – technology development
Herd management	Tropical	Breedcow and Dynama software redevelopment
Herd management	Digital	On-property benefits of precision livestock management (PLM) technologies and applications
Herd management	Digital	Walk over weighing technology: commercial refinement
Herd management	Tropical	Beefing up the north (Kimberley and Pilbara) – phase II
Herd management	Generic	A tool for standardising adult equivalent calculations
Herd management	Tropical	Reducing breeder and steer mortality on northern beef properties
Herd management	Tropical	Turn-off options for NT cattle

CLASSIFICATION	LOCATION	PROJECT TITLE
Herd management	Digital	Demonstrating the value of animal location and behaviour data in the red meat value chain
Herd management	Digital	A digital hub for automated cattle monitoring and management
Herd management	Tropical	Reducing calf loss due to exposure
Herd management	Digital	Automated sensors to quantify and help manage calf loss
Herd management	Generic	Optimising heifer development and management to increase whole herd profit
Herd management	Generic	Investigating causes and prevention of calf mortality for beef heifers
Herd management	Tropical	Management interventions to reduce calf wastage in northern beef herds
Herd management	Digital	Remote calving alert for beef cattle – technology development and testing
Herd management	Tropical	Development of candidate management interventions to reduce foetal and calf loss in beef herds in northern Australia
Herd management	Tropical	‘Meating’ the grid with culled cows in northern Australia
Herd management	Digital	Remote calving alert for beef cattle – technology development (phase 3)
Herd management	Generic	Adding value to weighing scales by measuring animal temperament
Herd management	Tropical	Testing remote cattle management systems for the northern pastoral industry
Herd management	Digital	Virtual fencing
Mitigation	Generic	Evaluating data capture and predictive analytics for managing the C footprint of red meat value chains
Mitigation	Generic	Life cycle analysis of the grass-fed red meat industry
Mitigation	Generic	Adapting to a carbon constrained future
Mitigation	Generic	CCH – reducing greenhouse gas emissions
Mitigation	Generic	Support for development of a greenhouse gas mitigation program and selected strategic science activities
Mitigation	Generic	Sampling methodology for estimating the impacts of pasture type and management on soil carbon stocks in grazing lands
Mitigation	Generic	On-farm case study of greenhouse gas emissions for beef enterprises
Mitigation	Tropical	Life cycle assessment of two northern beef supply chains

CLASSIFICATION	LOCATION	PROJECT TITLE
Mitigation	Generic	McSweeney – intraruminal
Mitigation	Tropical	Managing carbon in livestock systems: modelling greenhouse gas emissions from northern pasture systems
Mitigation	Generic	Quantifying trends in greenhouse gas efficiency of red meat production
Mitigation	Generic	Calculating the global warming impact of enteric methane emissions from ruminant livestock in Australia
Mitigation	Generic	Adapting the FarmGAS calculator to be relevant and easily used for specific beef and sheepmeat production systems
Mitigation	Generic	Developing a life cycle inventory for Australian agriculture (PRJ – 007363)
Mitigation	Generic	An evaluation of the options for selection, adoption and commercialisation of low heritability traits to develop lower emission red meat farming systems
Mitigation	Generic	Modelling of selected CFI offset options
Mitigation	Generic	An approach for assessing the environmental sustainability of Australian primary foods (RIRDC PRJ-008423)
Mitigation	Generic	A life cycle assessment of beef and lamb supply chains from Australia to the USA market
Mitigation	Generic	Improving production efficiency and reducing methane emissions in meat and wool sheep
Mitigation	Tropical	Development of two carbon farming initiative methodologies relevant to northern Australia
Mitigation	Generic	Use of peptide-phage display libraries to discover targets for bioactives and vaccination against rumen methanogens
Mitigation	Generic	Maximising energy-yielding rumen pathways in response to methane inhibition
Mitigation	Generic	Life cycle assessment, geographic information systems, biodiversity
Mitigation	Generic	Validating antimethanogenic properties of red macro algae for provisional patent
Mitigation	Generic	A marginal abatement cost analysis of practice options related to the NLMP program
Mitigation	Generic	Minimising the risks of nitrite toxicity when dietary nitrate is used to mitigate methane output in sheep and cattle
Mitigation	Generic	An opportunity assessment study for pastoral operations to engage in the Emissions Reduction Fund
Nutrition	Generic	Delivery of NIRS to improve cattle nutrition
Nutrition	Tropical	Optimising growth paths of beef cattle in northern Australia for increased profitability
Nutrition	Generic	Hormonal growth promotant (HGP) use in the Australian beef industry
Nutrition	Tropical	Casual factors affecting liveweight gain in north Australian beef herds

CLASSIFICATION	LOCATION	PROJECT TITLE
Nutrition	Tropical	The effect of utilisation rate on intake of pasture from various plant communities in northern Australia
Nutrition	Generic	Review of alternate sources of phosphorus for ruminant supplementation
Nutrition	Tropical	Producer phosphorus manual for the northern cattle industry
Nutrition	Tropical	Factors associated with divergent post-weaning live weight gain in northern Australian beef cattle
Nutrition	Generic	Phosphorus and non-protein nitrogen DSS: feasibility assessment and technical specifications
Nutrition	Generic	Re-alimentation of phosphorus deficient cattle
Nutrition	Tropical	Senepol feedlot performance and meat tenderness
Nutrition	Tropical	Entire male productivity and meat quality: phase 2
Nutrition	Generic	Target dry-season weight gains for weaner
Nutrition	Tropical	Vitamin A treatment for improving calf survival during drought
Nutrition	Tropical	Barkly water quality impacts on cattle production
Nutrition	Generic	LPP Revise Australian feeding standards to better achieve product specifications and improve ruminant efficiency
Nutrition	Generic	LPP Improving profit from pasture through increased feed efficiency
Nutrition	Generic	Practical antioxidant supplementation to boost breeder productivity
Nutrition	Tropical	Growth and meat quality of grain finished entire male Bos indicus cattle
Nutrition	Tropical	Phosphorus diagnostic tool – validation and demonstration of a diagnostic tool for phosphorus status of beef cattle
Nutrition	Tropical	Improving prediction of phosphorus intake of cattle grazing tropical pastures
Nutrition	Generic	Enhancing compensatory growth through increasing skeletal growth in the dry season
Nutrition	Generic	Algal ponds as a source of protein supplementation
Nutrition	Generic	Improved management of cattle phosphorus status through applied physiology
Nutrition	Generic	Gestational nutrition impacts on net fee
Nutrition	Tropical	Assessing productivity gains for cattle grazing ‘Redlands’ (R12) leucaena in northern Queensland
Nutrition	Tropical	Target dry-season weight gains for weaner heifers

CLASSIFICATION	LOCATION	PROJECT TITLE
Nutrition	Tropical	LPP Optimising supplement use in Australia's northern beef industry
Nutrition	Tropical	Nitrogen recycling as determinant for feed efficiency of Bos indicus cattle
Nutrition	Tropical	Transforming growth pathways with leucaena for greater profitability in the northern beef industry
Nutrition	Tropical	Impact of Phosphorus deficiency on lifetime cow productivity in northern Australia
Nutrition	Generic	Development of a decision support tool for mineral supplementation of livestock
Nutrition	Tropical	Diet quality and performance of grazing cattle in the Pilbara
Nutrition	Generic	Monitoring the performance of FNIRS calibration equations
Nutrition	Generic	Benchmarking alternative combinations of custom finishing and marketing cattle
Nutrition	Generic	Using chewing behaviour as a surrogate for forage intake to improve nutritional and grazing management and animal performance in the beef industry
Nutrition	Generic	Faecal NIRs (QAAFI)
Nutrition	Generic	Electrolytes and other compounds: qualitative evaluation of effects on animal welfare, shrinkage/liveweight, carcass attributes and meat quality
OHSE	Generic	Development of a driver fatigue management scheme for remote area livestock transport
OHSE	Generic	Thermal strain associated with wearing protective helmets during horseback mustering
Pastures/fodder	Tropical	Managing old plant evaluation sites: Containment and progressive eradication
Pastures/fodder	Digital	Phone app for pasture management – development of app and web-based version
Pastures/fodder	Digital	Phone app for pasture mgt – overview of development
Pastures/fodder	Generic	Assessment of promising pasture legumes and grasses
Pastures/fodder	Tropical	Progressing superior tropical grasses and legumes in seasonally dry Queensland
Pastures/fodder	Generic	High-output forage systems for meeting beef markets: phase 2
Pastures/fodder	Tropical	Effectiveness of *S. jonesii* inoculum for cattle grazing leucaena
Pastures/fodder	Tropical	Presence, impact and retention of *Synergistes jonesii* in 'problem' herds grazing leucaena
Pastures/fodder	Generic	High-output forage systems for meeting beef markets

CLASSIFICATION	LOCATION	PROJECT TITLE
Pastures/fodder	Tropical	Improved empirical models of cattle growth, reproduction and mortality from native pastures in northern Australia
Pastures/fodder	Generic	Strategy – northern plant genetics
Pastures/fodder	Generic	Shrubby stylos – improving feed quality
Pastures/fodder	Tropical	Grasses for dry-season irrigation in the … (incomplete title)
Pastures/fodder	Generic	Legumes for buffel grass pasture in the … (incomplete title)
Pastures/fodder	Tropical	Psyllid-resistant leucaena to market
Pastures/fodder	Generic	Accelerating uptake of leucaena-based pastures
Pastures/fodder	Generic	Optimising leucaena-based forage productivity
Pastures/fodder	Generic	Development of a sterile leucaena to enhance red meat production in new regions of Australia
Pastures/fodder	Tropical	Feeding leucaena to manage the rumen for maximum beef profit
Pastures/fodder	Generic	Rhizobia survival and new methods to improve nodulation in tropical legumes
Pastures/fodder	Generic	Fertilising for yield and quality in grass pastures and forage crops – scoping study
Pastures/fodder	Generic	Generating buffel grass cultivars with greatly enhanced nutritive value
Pastures/fodder	Generic	Stocktake and analysis of tropical legume evaluation
Plant breeding	Generic	Leuceana DNA profiling
Plant breeding	Tropical	Breeding a psyllid-resistant leucaena hybrid for northern Australia – phase 2
Plant breeding	Tropical	The case for developing a sterile variety of leucaena
Plant breeding	Generic	Conserving *Leucaena* spp. germplasm collection
Plant breeding	Tropical	Psyllid-resistant leucaena hybrid for northern Australia
Plant toxins	Tropical	Improving beef production through management of plant toxins
Property management	Generic	Stage 2 – NRM Spatial Hub – underpinning better management decisions in the Rangelands
Property management	Digital	Developing the use of ground robotics for data gathering and analysis to assist farming decisions
Property management	Digital	Autonomous range management vehicle (ARM-V) program: observation phase

CLASSIFICATION	LOCATION	PROJECT TITLE
Property management	Digital	UAV image data standards specification
Property management	Digital	Options for improving telecommunications across northern Australia for a connected beef industry
Property management	Digital	Evaluating process intelligence methodologies for the red meat value chain
Property management	Digital	Terrestrial based digital connectivity at Calliope
Property management	Digital	KoolNotePLUS – A paddock-to-enterprise decision-making tool for beef; matching feed supply and demand with value chain objectives
Reproduction	Tropical	Enabling genetic improvement of reproduction in tropical beef cattle
Reproduction	Tropical	Genetics and herd profitability in northern Australia
Reproduction	Tropical	Industry initiatives to improve young breeder performance in the Pilbara and Kimberley of WA
Reproduction	Generic	The manipulation of nutrition in pregnancy to increase weaning weights
Reproduction	Tropical	Industry initiatives to improve young breeder performance in the Northern Territory
Reproduction	Generic	BCRC 3 – early predictors of lifetime female reproductive performance
Reproduction	Tropical	CashCow – Northern Australian Beef Fertility Project
Reproduction	Generic	Markers and genes influencing puberty in tropically adopted beef cattle
Reproduction	Tropical	Breeder mortality: determining property-level rates in northern Australia
Reproduction	Tropical	Strategies to enable genetic selection for improved reproductive efficiency in tropical beef genotypes in northern Australia
Reproduction	Tropical	Northern reproduction strategy
Reproduction	Generic	SCSA and bull breeding soundness examination
Reproduction	Tropical	Development and validation of novel tool to assess reproductive traits and improve beef cattle reproductive efficiency
Reproduction	Tropical	Investigating the causes of calf losses in extensive pastoral systems – calf watch
Reproduction	Generic	A novel semen extender to accelerate genetic improvement programs
Reproduction	Digital	Improving crush-side semen analysis using a mobile phone and laboratory diagnostics

CLASSIFICATION	LOCATION	PROJECT TITLE
Reproduction	Generic	‘Paddock power’: increasing reproductive productivity through evidence-based paddock design
Reproduction	Tropical	Improving AI rates in Bos indicus heifers
Reproduction	Tropical	Improving fertility to AI in Bos indicus cattle
Reproduction	Generic	New genetic predictors for improving cow reproduction
Reproduction	Generic	Heritability and role of new sperm assays
Reproduction	Tropical	Understanding and improving heifer fertility in the Northern Territory
Rumen function	Generic	Enhancing digestibility of native pastures by cattle using kangaroo fibrolytic bacteria
Rumen function	Generic	Increased efficiency of microbial protein production in the rumen through manipulation of nutrients and rumen microbial populations
Rumen function	Tropical	Determining the effectiveness of poly ethylene glycol (PEG) in the utilisation of topfeed by cattle in central Australia
Rumen function	Generic	Optimised rumen function
Rumen function	Generic	Leucaena rumen inoculum – composition and activity along the supply chain
Rumen function	Generic	Feeding to increase productivity and reduce greenhouse gas emissions
Weed management	Tropical	New biocontrol opportunities for prickly acacia: exploration in India
Weed management	Tropical	Assessment of new biocontrol agents of Parkinsonia
Weed management	Tropical	Rubber bush – distribution, invasiveness, biology and control
Weed management	Tropical	Bellyache bush rust, *Phakopsora jatrophicola* – host testing
Weed management	Tropical	Prickly acacia biocontrol phase II: host specificity testing of agents from India
Weed management	Digital	New detection and classification algorithms for mapping woody weeds from UAV data
Weed management	Tropical	Parkinsonia bioherbicide – field scale evaluation
Weed management	Tropical	Biological control of bellyache bush: native range surveys in South America
Weed management	Tropical	Bellyache bush and Parkinsonia biocontrol agents
Weed management	Generic	UAV surveillance systems for the management of woody weed infestations

Appendix C Detailed record of feedback from stakeholder consultation

Table 53 Detailed record of stakeholder consultation feedback

MEETING	KEY POINTS
Queensland feedback	
	Vegetation management laws • This received a lot of mentions, usually referred to as 'veg management' • Overregulation prevents development – need to ask whether return on assets would be improved if this obstacle was removed • Green tape • All the Mulga country that nobody can use, which is especially critical in drought
	Feed base/pastures and land condition • Overgrazing is an issue and the rundown of natural assets (and high real estate values) • Land values have risen steeply and this leads people to push their country too hard – tired country, tired people • Can't double cattle production (state goal) without further pushing the country too hard • Weeds and pasture dieback and *Pimelea* is a problem • Need better pastures for high rainfall and coastal areas – why can't we use pasture species that work well in the Philippines be used, for example? • Drought tolerant (rather than just improved) pasture species; no work on new pastures for two decades • The grass is not there like it used to be – need innovative ways of retaining water on property so it can be used for pasture production. This may need mechanical interventions (e.g. ripping)
	Markets • Market access, competition from South America • Need to make more of ethical production in Australia to provide marketing advantage over competitors such as Brazil • Regulatory burden to gain market access can take years with the example of chilled beef access into China taking years, we are being out-competed by South American countries • It does not make sense when the McDonald's consumer wants environmental and ethical production, why doesn't the industry make better connections to those consumers? • Government charges 100% administration for vets in abattoirs • For the northern industry, access to China and grass-fed brands. What are the messages we can market northern beef to consumers with? Can the CRCNA undertake this type of research? • Chilled access into China takes a long time to put in place, can be revoked in an instant • Provenance is big in China. Is this a lost opportunity for the northern beef industry? • Top three values for McDonald's: environmental, ethical, economical – why don't we make more of that? • Domestic consumers/marketing, are retailers (Coles, Woolworths) too powerful ($1 milk is an example)? They get the benefit from levy-funded marketing but do not pass it on • Vertical integration has the potential to distort this picture further

MEETING	KEY POINTS
	Productivity • Raising calving percentage as it is too low in the north (<50% in some areas). Calf losses are a huge issue for the north – increasing with hotter climate. Climate change is making the north hotter and this will lead to more calve losses • Fertility of pastures and low nutrition. Do licks help the cows? • Wild dogs? • Management of ticks and acaricide resistance, particularly on the 'clean' side of the tick line • Worms • Need greater use of agtech (e.g. water monitoring, calving, stocking rates) • Need better monitoring of costs of production • Phosphorus is a finite resource and this needs to be looked at in terms of affordable P supplements • Question of what the optimal level of intensification is on extensive properties • Also need research into improving productivity in the high-rainfall areas, especially with subtropical and tropical pastures
	Regulation • Regulation costing 10% of revenue is 'ridiculous' – and is this additive along the supply chain? Returns would be higher with less regulation • Red tape/green tape and difficulties with securing water – also applies to uptake; beef businesses are subject to a very complex set of factors that all influence net profit; this already makes it difficult to decide where to innovate or adopt R&D; add to that the high cost of compliance with complex regulatory requirements – there is no time to spare for thinking • Tired country and tired people, there is a huge burden of cost and time in regulation and compliance, and it passes through the supply chain, which means less money is made as the costs are passed back to producers
	Low adoption of existing research and development • R&D can be irrelevant when fences are what is required. Smaller producers are not willing to or able to adopt R&D and there is a question as to what is the best form to get information to them. For example, the "Managing southern speargrass: a graziers guide" (available at https://futurebeef.com.au/wp-content/uploads/managing_northern_speargrass_a_graziers_guide-LR.pdf), which gave good management tips, was completed 25 years ago and there are low levels of adoption • Better returns from more fences and water to increase productivity rather than R&D • Even in central Queensland, many small producers do not adopt (e.g. pasture improvement), there is already lots of R&D, not enough adoption • Same point as made in the regulation discussion: beef businesses are subject to a very complex set of factors that all influence net profit; this already makes it difficult to decide where to innovate or adopt R&D; add to that the high cost of compliance with complex regulatory requirements – there is no time to spare for thinking • Extension services focus on management not on the business
	Infrastructure • Roads need to be sealed and widened: it takes six hours for a road train to reach Mount Isa from property located 220 km away – this causes big losses • Ability to get road trains into Dinmore will make a big difference • Lack of digital connectivity • Roads/truck access needs improving • Where the infrastructure is the question rather than how much is provided and upgraded each year. Building infrastructure that enables new development as well as enhancing the existing infrastructure, overcoming truck breakdown costs (last mile issues such as access to abattoirs It isn't correct to assume there is sufficient infrastructure, sometimes it needs to be built before it is really needed.

MEETING	KEY POINTS
	• Connectivity and the ability to utilise available technology, the adoption path will need to account for improved communications • Agtech on water monitoring and carbon sequestration measurements, using satellite and near Earth sensors • There is a need to better deploy new technology on farm, but there is limited good advisory and technical services and the lack of connectivity is a real constraint
	Issues with initiating R&D • IP ownership issues with R&D are a big impediment (R&D provider will usually want to own the data) • Would like to do more R&D on sustainability but does not agree with the quoted metrics on cattle methane output • Meat and Livestock Australia (MLA) Fast-Track projects have been easy to put in place and effective • Hard to initiate R&D projects – MLA's gatekeeping role • Hard to understand why MLA's technical committees do not support R&D the industry sees as important. There seems to be gatekeeping in MLA. There is a disconnect to the demand rather being driven by the researcher's skills • How to prioritise R&D to get the most bang for the buck in a complex business and biological system • Too much R&D has been researcher-driven • Need better benchmarking and monitoring by producers to connect to R&D • Can we use research opportunities to move some of the 'better' 75% up? R&D only as good as the adoption, and the extension services are lacking • First step is to measure property performance, as one little management change will have flow-on effects
	Extension services • No succession planning in government extension staff as they retire and are not replaced • Issues with commercially driven extension is that it is specialised and not holistic • The chemical/lick/supplement the supplier sells not what might best suit
	Research and development effectiveness • Does not accommodate variability and can be too prescriptive. It is all very well weaning early but if the pasture is not there and the market is flooded then where is the profit? • Would be interested in a more risk-based approach rather than absolutes • Nutrition research is not practical in focus (extension) • Business planning benchmarking needs to be the norm. Can't tell what R&D is effective without a measure of where you are and where you need to be • Millions invested in CashCow but very little practical application from the project
	Natural capital • Weeds, we need to understand what they are telling us about pasture soil health. Herbage is a natural process, what does it achieve? • Exclusion fencing impact on kangaroos may become a big issue • Producers can chase profits through over-grazing their land but the recovery time eats all additional profits until the country regains equilibrium
	Profit drivers • Herd management, pregnancy testing, disease management and fertility • Questions whether vaccinating northern herds stacks up financially over time. There are benefits to herd resistance generated through infection over the longer term • Calving rate and kg/AE (adult equivalent) are key profit drivers in the north
	Policy issues

MEETING	KEY POINTS
	• Native title and land tenure • Potential that producers may no longer be exempt from land tax • Market valuation between lease and freehold is about the same and it is difficult to see the benefit in converting • However, when the land valuations increase there will be a significant bill
	Flood recovery • The severity of the floods washed away roads and infrastructure that has been in place for 40+ years. There probably isn't a better spot to rebuild, but it is worth considering before you do
Western Australian feedback	
	Research providers • Market failure in the north of WA with the supply of consultants, and ag consultants try to deliver into areas where they have no skills. The Department of Primary Industries and Regional Development (DPIRD) has tried to build the skills base through the Northern Beef Futures Business Improvement Grants Program with limited success. There is an overreliance on ex-government staff • Research system in the current approach is a disconnect between the research providers and funders in publishing research, and there isn't an assessment of the impact of the research and where the 'gold' is, which is the most valuable research. Can they take a systematic approach and see where they will have the best benefits and outcomes? • Much can be achieved addressing these issues rather than investing in new R&D – any new R&D should be targeted. As there are less R&D funds we need to better target research, improve the priority setting processes and look for where the 'best' and immediate impact of research comes from assessment of a range of interventions that are best at improving productivity and profitability
	Industry challenges • Land tenure constraints on development in the industry, limiting diversification regimes, do not get the benefits that are available within the native title regimes, the introduced species list, other biosecurity constraints on cross-border trade • Given the regulatory constraints and risk of limited likelihood of substantial beneficial change occurring to benefit the industry, it is probably better focusing in on on-farm productivity • Currently in the midst of a pastoral land tenure reform, which is going through a Cabinet process prior to an amendment Bill being drafted for comment and public consultation. The current government process is saying that they will have a less ambitious approach • There is a 5-year rent review process, and that is happening soon (notices to be issued on 1 July) with significant increases expected • The minister has just announced a review of the *Animal Welfare Act 2002* (WA) overseen by an independent panel. DPIRD is working on getting a more workable outcome with the non-indigenous pastures policy (Under the *Land Administration Act 1997* (WA)) so it is less restrictive. There is a potential risk that there is worse tenure than they currently have (i.e. more conditions imposed on lessees as an outcome of tenure reform) and worse, outcomes might be perverse (e.g. still no addressing perversities in the system that reward managing land poorly) • The exposure to a small number of markets for live exports is a real risk, and in WA there are not the market options that you see in northern Queensland • Social licence – especially the idea that the Kimberley should become a national park. Much more environmental lobby group attention. The focus is in the West Kimberley as well as Eighty Mile Beach, and no recognition of the role of pastoralists play in maintenance of the landscape/stewards of the land • Land management – there is enough information available but it is not delivered holistically and current tenure/rent/compliance policies provide incentives to flog the land rather than look after it. An outcomes focus to regulation and management would be far more sensible

MEETING	KEY POINTS
	• Welfare – legislative amendments at the end of 2018 will result in WA adopting various national standards (livestock transport, saleyards, cattle and sheep) and moving away from the model codes of practice. This is subject to the development of regulations and may become confused with the independent panel review of the Animal Welfare Act, which has just been announced
	Industry and regional opportunities • There are many challenges, but the short-term opportunities to improve on-farm productivity may be the place to focus effort (as the others are more difficult to deal with) • Evidence base on non-indigenous plants and linking them to policy improvements. What is the path of less resistance for WA producers to become more profitable? • Need for different and bespoke approaches to extension and outreach of research findings and translating research to practice. Is there a model where there is some subsidy where the government or industry pay and the beneficiary pays some amount? Producer innovation fast track. Need to look at the way information is delivered • Profitable properties workshops tend to follow a particular theme rather than holistic approaches • Always better off having outcome-based regulation than an approach that sets disincentives. Need for industry codes of practice (leucaena, animal welfare, national land transport and cattle standards, ASEL) • Technology if the CRCNA is going to do anything in this area, then they need to work closely with MLA. See it as an extremely important area for maintaining industry competitiveness. Digital technologies – sufficient investment in individual technologies but there is an issue with connectivity and data capture and platforms that can integrate different bits of information • Supply chain – not much communication along the supply chain. There is a lack of competition in the region (one exporter dominates) and this means there is not enough transparency. Maybe a need to form cooperatives to provide additional leverage but there are risks to this approach. MLA is in the process of engaging a consultant to scope a live export supply-chain project looking to develop approaches that provide better information back to producers about their animals post farm gate. It will be interesting as to whether the exporters' response to this (as well as producers') demonstrates that people are prepared to make decisions beyond best price alone
Northern Territory feedback	
	Processing costs • Processing sector costs are high relative to competitors as meat inspection charges all charged to the processors in Australia and these costs are passed onto industry. Energy costs – northern Australian gas costs are substantially higher, and electricity costs are double. Oil and fuel costs more in the north. Energy costs for northern Australia need to be included in this report
	Regulation and policy • Need to reduce regulatory burden across the industry • Land tenure and tenure security a major issue for expansion in industry • Diversification • Lack of policy intent • Brand new environmental regulation about to be released in NT. Potential issues emerging with the formation of the Environmental Protection Agency. New development applications will need to look at the environmental impact, social impact and commercial viability • Is it a regulatory framework in government that is stopping this? There is a reluctance to assessing this in a different way
	Productivity

MEETING	KEY POINTS
	• The data seem to show that herd productivity has not increased since 2000. Combination of finding with review of regulation and potentially other matters and the cost that those regulations have on profitability • In 2000 we were doing less and getting the same amount out of the business. So higher margins come from less cost and costs have increased. Increase efficiency or become bigger to get economies of scale. No increase in genetic opportunities evident • Top 25% with 3.3% return on interest (ROI) – is there any data correlation from 15 to 20 years ago? Have they changed much in 15 years or had they already had it right or did they lead adoption? • Better understanding of business performance, low return on capital as a reasonable outcome, that can lead to running down of natural capital to increase returns. Concluded, much can be achieved to address these conditions without need for new R&D
	Research and extension • Extension consultants, (lack of people generally specialist) integration of research is left to property manager. Lack of uptake of R&D. It is not published in a way that has a financial benefit or implementation • Genetic improvement and adoption of these is one part of productivity. You can have the best genetics but if feed is not suitable production will still be low. Solutions to these (productivity issues) have been researched. No lack of research for gains from what we currently know. It is to make what we already know work well • Average turnover rate (for farm manager) is 8 to 9 years. Increasing scale of properties is also considered. Lack of trained farm managers trained in animal husbandry. Skills and training are constantly coming up as an issue • Any new R&D targeted at gains for those at top 25% and how do they continue to do well? How will any R&D help that? • MLA research investment in north (be North Australia Beef Research Council (NABRC) priority) most investment in animal nutrition, climate change mitigation, herd management, pastures, reproduction. On-property productivity • Business education missing? Business performance, lots of managers are good at this. Analysis is focused on input costs and this can be a trap, as they need to look at costs and benefits • Need to look at the education sector and the way it is serving the agricultural sector. There also are not the opportunities for training, you can get training to be a ringer, then move up to head of a stock camp, but after that there isn't the support to develop a career as a manager. How do they get the skills to run the business? • Plenty of research but not much adoption. Need targeted research and to do that need the researchers to understand the business. Failure to adopt is the number one issue for the industry. MLA key performance indicator (KPI) is to demonstrate the adoption but they are not following up on it
	Markets • Risk of having an overreliance of one industry (market). Continue to improve animal welfare conditions, but is there is a future for this? • What are the options to really improve turn-off weights on properties and what are the right types of animals? Do we need centre pivots, improved pasture, improved nutrition to get the livestock gains? Also, how to get a feedlot industry as our current markets are changing? • Vietnam, for example, there is emerging market for quick-fry steak restaurants US/Australian beef (frozen not fresh), local beef thin cut. Not a huge part of the Vietnamese diet, but mostly in soup. Swine fever is a big concern (pork is huge part of the current diet). No waste at all. Market dynamics are dictated by demand in China • How can the processing sector be more competitive? What were views from other states? • Queensland has a strong connection with northern beef into the south. We need more abattoirs in the north as the market is unfair. Buyers have competitive advantage. Keen to see new abattoirs built, but the investments will come from outside of the cattle-producing part of the industry

MEETING	KEY POINTS
	• New operation in north-west WA seen as a win. Takes off animals that are out of spec. Positive about industry. How do you improve turn off, wean them earlier for better return from females when live export is the main business? • Live export, risk to trade. 'Need to look at what we can do to "bulletproof" the industry against all the forces that want to bring it down'. There is surprise that after the investments the industry has made in Australia and overseas that there is still an issue with the social licence to operate. There are now cameras on boats, and cameras could replace the independent observers, similar to what we see in the supply chains in overseas countries with CSaw. R&D money to be spent, or public relations programs, regulations, put something together to bulletproof industry • One thing project does not look at is proximity to South-East Asia. Northern Australia isolation. Look at what is happening in these markets for demand, to make this project viable. Need to take the opportunity of the closeness to South-East Asia, there is ongoing and increasing demand
	Infrastructure • Digital connectivity – there is none! Connectivity is very ordinary, especially once you get away from the homestead. Difficult for take up of apps. It is possible and does exist, but it is hard. Expensive proposition. Much harder in the north than in the south • Telstra CDMA network still exists/operational but unutilised and could be used for app development at CDMA network level. This could be a low-cost option in the north for technology uptake. But no developers work in this space • Opportunities with traceability and off-farm supply-chain security for live export. Smart ear tags, tracking trucks, etc. Need for camera on boats to replace people
Industry representative and agency consultation	
	Drivers and challenges Queensland • Vegetation management, carbon tree grass balance in Queensland, continue to be areas of policy focus for industry • Queensland Department of State Development, Manufacturing, Infrastructure and Planning leading the development assessment in the north-west mineral provinces, including diversification projects such as cropping opportunities • Policy of the government is to increase jobs, and while there are no set targets on value of the industry, there is an emphasis on increasing the value of beef, and improving the profitability of the industry • An ongoing recognition of the role of China in changing the market • Most of the cattle in northern Queensland are part of the whole of state slaughter supply chain. Processing profitability relies on high-value markets such as Korea, Japan and the US (and now China) • Flow of animals from north to south remains strong with a large increase in recent years in feedlot capacity in southern Queensland, and even through the drought there have been ongoing, investments in feedlots • Increasing commercial arrangements between supply of cattle from property to feedlot to abattoir. It can be high value, supply animals for feedlotting over 100 day, but many other feed systems to move into other markets (30-day gap feeding) and into specific markets. There is a trend to integrate supply chains to improve reliability to meet specs and guarantee supply into specific markets • Increasing live export numbers out of Townsville, but with animals sourced from across the state, not just northern Queensland • Three recent beef supply-chain studies • Defence land acquisition • Abattoir capacity, which was found to be adequate but notwithstanding development opportunities for products into new markets such as China (Meateng study) • Ernst and Young (*The Queensland beef supply chain* made up of six reports: *The Queensland beef supply chain*; *Strategic drivers of the Queensland beef supply chain*; *Investment analysis of the Queensland beef supply chain*; *Future outlook for Queensland beef and cattle products*; *Queensland beef producer investment guide*; *Investor's guide to the Queensland beef supply chain*)

MEETING	KEY POINTS
	• In northern Queensland, diversification opportunities focusing in the Flinders and Gilbert catchments • Big issues for industry are biosecurity, transport and market access • Queensland emissions reduction goal with 50% carbon neutral by 2030 for the whole economy so there is more emphasis on soils and vegetation • *Reef 2050 Long-Term Sustainability Plan* and its implications for the beef industry • Climate adaptation and business resilience linked to the Drought and Climate Adaptation Program, see: https://www.longpaddock.qld.gov.au/dcap/ • R&D and extension working together so that synergies are exploited and extension is at the cutting edge • In the Flinders and Gilbert catchments there is a focus on diversification and intensification • Project evaluation and monitoring to assess the value of a service and its impact • Effective RD&E collaboration across aligned organisations while helping build a viable private sector of beef extension advisors • Have a very strong R&D effort in the feed base and examining the commercialisation options of new cultivars
	Drivers and challenges Northern Territory • Lack of certainty in the regulation and the absence of policy, not adaptive enough to allow significant investment in land and what is required to allow the innovation • Tenure, water management and onshore gas developments • Two recent pastoral surveys of NT producers are helpful documents to obtain – 2004 and 2010 • NT stocking rates generally much lower than Queensland, which provides opportunities for intensification (in this case through an increase in cattle numbers) • high turnover in management in northern half of NT. Average owner been in place for 8 years and average manager been in place for 3 years • Central Australia is far more stable with longer-term family operations • Focus has been on productivity and the hope that leads onto profitability • Aiming for growth in value and turn off. Industry focus on value • Measure of 'success' through increased turn off • NT has scale and labour efficiency but productivity is low. Reviews of performance have talked about scale, labour efficiency and productivity. The NT has scale and labour efficiency, therefore there is a need to work on productivity • Cattle population is increasing by 3% per year and they project that the cattle population will reach 3 million by 2025 and 4 million by 2035 • Increasing fences and water can allow the increase to 3 million without any other intensification strategies required • Increasing the herd from 3 million to 4 million needs a different approach (e.g. expanded cropping industry to support higher quality feeds and by-products) • 3 million will be achieved by increasing water points and fencing, but after reaching 3 million the gains will need to come from better utilisation of Indigenous-managed lands and interaction with an expanding farming sector. The cotton industry and improved pastures is also part of the next stage • Cross-breeds can reduce the risks of live export cattle because cross-breeds can be sold more easily into southern markets • Calf mortality is still in double figures. Major research focus at the moment • Industry talks about the opportunity to expand by building feedlots • For central Australia there are niche marketing opportunities for organics (into the domestic market) • Gaps/opportunities – integration with crop development – strategies for managing market risk – making full use of big cattle datasets

MEETING	KEY POINTS
	– extension – integration of private operators – labour – attracting and retaining right skills to address current high turnover in the industry – Indigenous pastoral development/agribusiness – Labour and skill gaps for farming rather than for pastoralism – Improved pasture/fodder systems
	Drivers and challenges WA • The diagram of development, the pathway to develop is defined and while it is long it is possible • Recent consultancy, 'Joining the Dots' undertaken by ACIL Allen that integrates the various projects and consultancies undertaken in the first phase of NBF • Herd efficiency is seen as a driver of profitability • The program is focused on driving productivity gains and is underpinned by capturing data for benchmarking and measuring improvements • Mosaic agriculture is important. Apart from existing systems being developed with known grasses (e.g. Rhodes) efforts are focused on a sterile seed, hybrid Leucaena • Agtech and data analytics seen as big gap in extension and adoption • Gaps/opportunities – Benchmarking – Improving herd efficiency – Cattle growth pathways – Regionally relevant data – Breedcow/Dynama being used to assist – Producer demonstration sites – Re-engaging in extension – both soft infrastructure and improving adoption through transforming collaboration into action – Rangelands reform (tenure)
	Research and extension • How you deliver the extension message and a deeper understanding of the social and cultural aspects that limit change? • There are examples such as 'Project Cane Changer' where behavioural psychologist are undertaking the extension • The extension approach needs to consider the typologies of the beef producers (leaders, middle part and the laggards) • Expectation management can they clearly articulate what they want, and we are necessarily focused on the property level • Areas of current science interest – DEXA (dual-energy X-ray absorptiometry) feedback and how it can be used in terms of on-farm productivity changes – High-performing tropically adapted cattle through genetic improvement – Animal production/welfare/husbandry – Technology adoption and on-farm implementation – Evaluating and breeding promising legumes and grasses – Grazing land management – Tree grass balance with implications for a whole lot of new science in Decision support systems (DSS), remote sensing and carrying capacity – DSS and next horizon: integration with modelling and remote sensing technology – Climate adaptation – Business planning facilitation – Extension services employing a whole of business approach covering the broad themes of land and pasture management, animal production, animal welfare, business practices and people

MEETING	KEY POINTS
	Profitability • What changes to practice (the low-hanging fruit) would immediately impact on profitability? Could you go to each region and see what the two next best things are to make businesses more profitable? • Financial literacy and preparedness are low in the industry. Need to build resilience and build financial knowledge and skills
	National view of northern Australia beef industry challenges • Northern Australian cattle industry is marginally profitable, generally breeding operations limited by the inherent low levels of fertility • There is a need to implement the existing learning and development into the cattle operations before worrying about new technologies • Transport and roads are always an issue in the north • Move away from Jap Ox to live export animals resulted in the loss of processing sector, and to return there are challenges of attracting cattle and labour • Feedlots into the north – can they expand from where they are currently? • Diversifying and value-adding beyond the cow–calf operations that are currently dominant in northern Australia • Regulatory barriers: EPBC Act and the water trigger are current regulatory barriers to development; Great Artesian Basin regulations are a possible issue as well; animal welfare and land transport; constraints on land management, especially tree clearing regulations • Overall there is limited access to capital and investment across the north, with twin challenges of businesses not being investment ready and the perceptions on foreign ownership • Indigenous land ownership, the opportunities that this provides aren't fully utilised
Recommendations review workshops in Brisbane and Darwin February 2020	
Brisbane	**Review of situation analysis** Review of findings • Most producers are time poor, non-readers and busy running their businesses, so it isn't surprising that the step between awareness and implementation is where extension breaks down • For producers they often question: What is the value for them in collecting data, in being part of R&D when there aren't obvious returns on that time nor money investments? • Transformational research: need to look back at the development of the northern Australia beef industry as to where the transformational research resulted in a major step changes in the industry: For example, the introduction of Bos indicus, improved pastures, early weaning, feedlots and increased investments in fencing and water points. These might be the same transformations required in the north, where they are still exporting live cattle. Brucellosis and Tuberculosis Eradication Campaign (BTEC) capture transfer/legacy impact on northern industry • But the past selection of Bos indicus resulted in lower fertility and currently there is not the effort in selecting quality bulls/weeding out non-performers. There has been some effort in breeding over last 10 to 20 years – higher quality Bos indicus for meat quality instead of Angus in the north • For the corporates, they look at the impact of an investment through the full supply chain, not just at one part, need to assess the impact of investments across the whole business to assess whether it is worth doing. No live export. Their focus on integrated supply chain investment decisions and approaches that improve the value per animal and move towards vertical integration (e.g. feedlots) • Currently in parts of northern Australia, especially WA, it is policy and regulations and the way that they are imposed that restricts the ability of businesses to diversify and innovate

MEETING	KEY POINTS
	• Novel things need to be tested and there isn't the skills base, nor the time, on most properties to test • MLA (and others) now looking for fewer, bigger and bolder research projects, more collaboration, but also looking back to make sure we are investing in new research (not missing things that have been done before). The challenge of adoption is front of mind, and wanting to see projects that have adoption as a key outcome • There is a challenge in moving from awareness of research outcomes (with the main vehicle being BeefUp Forums) to uptake (through MLA EDGEnetwork workshops and Profitable Grazing Systems). PDS are also a useful tool to raise awareness but also the hope is that they then move into practice change • Agreement with the report's strong recommendation to strengthen extension and adoption of existing technology and R&D • Why is there a need to improve the adoption of R&D on farm? – It is needed to make businesses more profitable and to build economic resilience – A need to accelerate industry moving to best practice – Market access into the future is a big issue, and only large corporates are addressing it – Everybody needs to get to the point where they know their cost of production • What is wrong with the current situation? – There are significant barriers to adoption in the north – There is a view that the current system of extension is broken: 'no point throwing more money at it' – Very fragmented industry with diverse needs – different business models, supply chains, environmental conditions – Adversarial behaviours in the industry (e.g. processors versus producers) – Unmet technology needs for the smaller operators (e.g. remote sensing), in the cropping sector, there is better access to tech – Messages from R&D (for example on managing land condition, or CashCow outcomes) are too complex and confusing to be able to be adopted by individual managers/producers – Market signals (quality, sustainability, welfare) are not received strongly by individual producer – Producers aren't motivated to respond to market signals unless there is a crisis – Extension relies on a strong R&D pipeline, we are at risk of neglecting that – Extension should not try to get involved with running businesses – When banks get involved in providing business advice, there is a conflict of interest • What could be done to improve it? – Generational change is under way and will increase the momentum to improve on-farm practices – One-on-one is an effective method in extension, but very costly to deliver in the north – Better connectivity (broadband) could help in delivering one-on-one advice and coaching – Bring the training courses to the regions, instead of holding leadership training in cities – Find the individuals that are seeking information to change and narrow the focus of the extension effort – Researchers need to be prepared to simplify and use plain language in their messages – 'Benchmarking' projects in the beef industry are a good example of effective extension – Money is an important motivator – need to clarify the role for financial advisors in extension and uptake of practices – Better communication of supply-chain signals – role for agents as part of extension?

MEETING	KEY POINTS
	– Important to conduct R&D that help businesses cope with larger shifts and challenges, such as those identified in the megatrends analysis of the review – Free access to tools (for example good quality climate outlooks) for farmers • What is the willingness to adopt practice change? What are the incentives if the lifestyle is ok? Is there a need to look at regulatory levers to drive change? Could LPA be used in a more effective way in terms of driving productivity? • MLA is looking at lack of capacity of service providers' and what incentives could be created to increase the number of providers available to overcome the lack of skills and people, through the future livestock consultants' program • Update the extension model with alternatives such as training online, but this would require better station connectivity • Mapping workshop – have seen a higher adoption in the last 2 years, significant improvement from the last 10 years. Not sure why but could be driven by the compliance requirements. It could be a shift in demographics, but still a reluctance to pay a monthly subscription for the mapping tools • Did producers use the 2018 flooding event to re-examine their land management fencing, water points? Is there opportunity to track through subsidies? Has there been a big realign of water points post flooding? • The cattle processors are starting to run workshops on compliance, and associating this with access to markets (i.e. they will only buy from compliant producers) • Crossover between compliance adoption and regulation pushing change in business practice • Biggest drivers of change have generally been the processors and they are responding to the consumer • Currently the private sector companies aren't playing a role in extension. For example, you can buy a set of scales and the seller will show you how to use the scales but not how to integrate the equipment into your business. The banks and other agencies in the private sector could play a bigger role in extension and adoption • Bigger business can afford an agronomist and other specialist, but most smaller producers are not inclined to pay for specialists, and thus rely on government extension services • In the past there was a great deal of funding put into Queensland projects and everyone became used to receiving information for free. The transition to user pays has not been handled well • Confidentiality is an issue with collaboration when undertaking R&D projects on property. The funding agency restricts collaboration due to protecting intellectual property • The push for the identification of adoption pathway is frustrated by lack of extension staff. There is a policy question around who funds improved adoption/extension, should this the beneficiaries? Is there an opportunity for MLA to ask producers how much they want to spend on adoption? Potential for MLA to look at the levy breakdown and make adjustments (i.e. increase the amount of funds going into R,D & E) • Improved infrastructure to diversify the market pull adoption process so if you focus only on live export then the need for adoption is narrowed. Processors are calling for more stock to move to them where the connection with the consumer is stronger than in live export markets • How could better infrastructure improvements impact cold chain and MSA grading move to higher-value market
Darwin	**Review of situation analysis** • It was a good idea to only base recommendations on information that was backed up by reports or documented evidence. Was good that it was a review of reviews in a format that we can do something about it and not just another report • CRCNA doesn't think there is enough emphasis on market access. When it was put forward at another meeting was met with – 'markets aren't an issue'. However, no evidence was provided to demonstrate what the 'market access' issue actually is. Needs broader emphasis on social licence including how industry is making improvements to tackle climate change

MEETING	KEY POINTS
	• By way of an example, the UK are looking to pay farmers for ecosystem services. CRCNA interested in understanding what policy is needed to lock up country without devaluing the property? (noting you can't just lock up country – it still needs to be managed) Current policy is 50 to 100 years, which certainly devalues the value of the property. (R*eport requested but not provided, noting that with Brexit the UK will exit the CAP*) • CRCNA feels there isn't much mention of human capital. There is a push now to diversify on property, however there is a bit of a skills shortage and sometimes a lack of understanding that new skills need to be brought – rather than pastoralist trying to be an expert on irrigation, etc. How do we free up pastoralists' time so they can focus on their role of feeding the planet? There is a lack of appreciation of the role the broader industry plays in managing the landscape • Lack of understanding about the role of a pastoralist as being 'custodians of the land'. What does this actually mean? If someone from the city drove past a cattle station, they would say it looks really bad. Do we need better communications? Pastoralists have been primarily focused on feeding people, perhaps they haven't put time into thinking about their public perception. Cattle producers are the custodian of the land – need to communication this better and make it part of school education • CRCNA posed the question: Infrastructure – any thoughts? • Northern Territory Government priorities: – Beef and social licence – School engagement – agriculture – Communication – Drought recovery • CRCNA wondered in the northern beef industry work with the Primary Industries Education Foundation? Primary school education is a big issue for the northern Australia beef industry, increasing skills as well as social licence training. Currently schools are busy promoting 'veganism' • Lots of single points of failure for industry and big risks, and the fall-back is governments should bail them out. What's missing is economic drivers to utilise historical R&D. It's not just about having more extension officers. There is relatively poor adoption apart from movers and shakers (innovators). Extension officers also tend to spend more time with people open to change. Perhaps needs to be broader reach • In the NT, the National Training Centre of Australia has been the conduit for R&D, which is fed up from Regional Beef Research Committees regions, however this is missing a large chunk of ideas if they don't become a priority for the National Australia Beef Research Council • Extension is only part of the bigger picture. It's actually a whole of team effort, including researchers and industry and others. Current extension approaches don't support practice change. Change management is all about people – social change. How do you motivate pastoralists to change when there is no incentive to change? How can we demonstrate needs? • A lot of programs are shaped to the top 10% of producers (i.e. low-hanging fruit). There is an enormous gap from these producers to the lower end producers. R&D is still important however we need good communicators. R&D also needs to be over the horizon – this is what takes us into the future. This is where is the expertise in the northern beef industry come from. However, if all the researchers are all in Queensland, are they out of touch with the rest of Australia's needs? Needs to be a balance in R&D. Proof of concept comes at a significant cost and they need to share the risk for industry • Infrastructure always need better and more, especially if the northern live export industry wants to continue exporting all year rather than seasonally in response to the continual changes in peak demand in Indonesia • More intensive feeding of cattle in the north. Need for a national discussion on processing costs and penalties in market for cross-breed cattle. All relative to market risk and market closure • Locally, large abattoirs have recently closed. Not necessarily fit to the market. Small abattoirs have started and have started with multi-species but will inevitably need to have guaranteed throughput of cattle

MEETING	KEY POINTS
	• Some of the potential barriers to diversification are regulatory and policy barriers in land tenure, water access, and development approval processes. Non-indigenous plants policy in WA is an example of the very conservative approach of the environmental regulator • More intensive feeding of cattle in the north. Need for a national discussion on processing costs and penalties in market for cross-breed cattle. All relative to market risk and market closure. Increasing sophistication of the data requirements for the consumers and to meeting the market expectations

Brisbane	**Review of recommendations**
	• Calf loss is an example where the completely obvious things aren't getting fixed, so the theme around failure to adopt is very relevant still. Projects such as those being developed by the North Australia Beef Research Council (NABRC) will have a greater focus on the Adoption and a little Research and Development to support that
	• Is there the potential to do things differently, producer driven and producer owned, and with the involvement of some social science and adoption?
	• It isn't that there is no need for research, we just need to give adoption a big push. There are some barriers to entry of translating research to science, the bigger companies and corporates can bear the risk. How can the small businesses overcome those barriers to adoption, can they be assisted by others in the industry?
	• There is a resurgence of hard copy/old school approach to extension, tips and tricks and booklets that provide the extension support
	• Theme 1 need to have R&D that is understandable and applicable to industry. Put into a simple action orientated paper/digital format/video/, and accept that at least half the R&D isn't going to be successfully implemented
	• For Theme 1 and Theme 2, there is a loss of adoption if anything. 'Bulls: Power Up!' program from some years ago – lots of learnings but knowledge no longer applied/well known. Power of this project was massive initially. Systemic failure to adopt new R&D but also loss of adoption of old, proven R&D. NABRC Northern Breeding Business Project will review last 50 years of R&D (loss of knowledge/lack of capture of Ord leucaena experience from the last 30 to 40 years in the new work being done by MLA and DPIRD is also another example)
	• Need to demonstrate there are on-ground benefits and consider the unintended consequences of some policies. Regulation and funding of land use is warping the outcomes. Emission reduction fund, Land Restoration Fund policy setting potential income from carbon, confusion over the best pathway for producers. Understand of what the practical applications and the R&D gaps
	• Banking, financiers and those entering into supply agreements are starting to require disaster recovery plans, business plans and they will need to have one-on-one consultation and support to build those. The 'Taking Stock' program in the dairy industry is a good approach and could provide an example
	• Theme 1 and Theme 2 are 'a little nondescript' and overlapping. Support for more private sector capacity in adoption. Not sure about the term 'top businesses'
	• Incremental change is more likely/realistic and has cumulative impact over time (e.g. Bos indicus herd comments in the general section below. Examples also include early weaning, botulism and P supplementation). MLA like to talk 'transformational'
	• Proposal for a Theme 4 in the recommendations: 'Future-proofing northern beef'. Needed in order to:
	  o De-risk investment in the industry (for example international investors, superannuation funds)
	  o Protect the beef industry's social licence
	  o Attract the next generation of people (with professional qualifications) to the industry
	• Path to implementation for Theme 4:
	  o Move paragraph 4 and 5 from Theme 3
	  o Recognition that practice changes are often driven by smaller farms
	  o Development of sustainability metrics (linked to productivity)
	  o Investment in compliance methodology

MEETING	KEY POINTS
	o Find out what questions international investors are asking o MLA Integrity Systems Company focused on biosecurity and provenance, but doesn't promote the use of its supply-chain data for compliance with sustainability criteria o Live export – technology to improve and document animal welfare metrics o Land management – promote involvement of Indigenous people o Improve digital connectivity to underpin innovation and professionalism o Invest in leadership and professional development in the regions • 'What, Who, How – Implementation Statement – Expected Impact' o Need to keep talking about adoption – this has been known for 30-odd years o Pathway to practice concept o Calf loss – wastage (CashCow key finding) – not being addressed effectively – has led to collaborative project NABRC and MLA are looking at to try and stem/turn around the failure to adopt o Importance of producer driven and owned adoption. Need to really engage. Sociology of adoption/producers o CRCNA focusing on extension and adoption with limited resources o Co-investment/in-kind contributions need to be considered o Need for departmental people who 'translate' R&D – diminished capability/resources in this regard o MLA bushfire response – one-on-one consultation – worked with dairy (Taking Stock program). Translation of MLA PGS model from south to north questionable. Trying to be more efficient/save money by grouping 'neighbours' to be 'coached'. Challenges with getting neighbours to work together/collaborate • Simplify titles. Theme 1 is long-winded, why not 'Implement existing R&D' • Split Theme 3? We discussed splitting into 'Infrastructure', 'Markets and supply chains', and 'Biosecurity' (plus I added one on 'De-risking' which came up in the context of Theme 3 a couple of times). Maybe de-risking is core to all of them? • How do you drive sociological change? Maybe need a behavioural economics team? But we recognised that the sociology of decision making was very important and not well handled in previous grazing R&D work (nor has there been funding for it) • On the subject of Theme 3 and Theme 4, we thought that the key components to implement Theme 1 were (i) cultural shift, (ii) ongoing knowledge management, and (iii) stimulating the private sector • Theme 3 could be broken into: o Inter-modality, cross-industry sector infrastructure. I think of it as 'beyond beef roads'. Allan's phrase was 'cattle, cotton, corn' although I think that is already a song title by the Go-Betweens o Market and supply chain. Much more recognition of relationships and collaboration and the need to scale up o Biosecurity policies streamlined, risk management, cross-sectional (e.g. swine fever, human health – 'beyond beef' again) o De-risking across all four jurisdictions. Perhaps having government-sponsored brokers to steer it through • First two themes are OK … but maybe third could be broken into 'Infrastructure', 'Supply chains' and 'Biosecurity' • Themes are high level, so maybe need more strongly defined Initiatives as the foundation for 'Pathway to implementation' • Under 'Improve the translation of R&D' key pathways themes included: (i) a strong and continuously improving knowledge management and brokerage system across the north; (ii) a major cultural and leadership shift in the second tier leaders (the second 25%); (iii) rebuilding and stabilising a core extension capacity/ network across the north; and (iv) improved de-risking to lift investment and lifting investment readiness on farm (i.e. business improvement grants in the WA) • Under 'Ongoing R&D' … needed to focus on agreed industry strategies with the most significant impact on profitability. Should perhaps focus on two or three key priorities

MEETING	KEY POINTS
	(e.g. consistent with MLA – reducing calving mortality, increasing pasture system profitability). 'Ongoing R&D' was seen to be of secondary importance to 'Improve translation' • Under 'Infrastructure' there were at least two clear priorities. One was developing the next generation of supply-chain modelling inclusive of supply-chain values, big data analysis, cross sector and inter-modal opportunities (but building on the transit model foundations). Another was communications access and digital capacity • Under 'Supply chain' … need to focus on supply-chain collaboration, analysis and strategy building. There was discussion about getting greater value out of NLIS and blockchain for real-time supply-chain feedback • That current dot point about native title might better be integrated as an investment de-risking action (and maybe that fits under the 'supply-chain' theme) • Biosecurity rule harmonisation as a key pathway to implementing the 'biosecurity' theme • Overall there were strong statements about maintaining a strong inter-relationship between higher level strategies (e.g. the Red Meat Strategy) and this northern expression of strategic need • The group was broadly supportive of the work and directions and were well engaged on the day
Darwin	**Review of recommendations** • With regard to implementation, one size doesn't fit all. R&D needs to be fit-for-purpose and localised. Government regional development commissions make mistakes rolling out programs 'for the pastoral industry' that aren't effective. The industry is too diverse (multiple externalities: states, conditions, corporate – family – Indigenous, dealing with different starting points, different markets from the tropics to the desert) • Biosecurity plans are a good start; however, they need to be front and centre and discussed, not in the bottom drawer • Don't think the recommendations are prioritised correctly. Also, the themes are very broad, it's a missed opportunity to make them actionable and measurable • Too many pathways per recommendation – should be two or three maximum • Think we need sociology as a recommendation • Recommendations need to be SMART and actionable – can't be too broad – won't go anywhere with them • Do any themes address risk? That is, highlight issue and show resolution. Action/reaction. (e.g. market failure, biosecurity) • Need for investment into cross-industry methodologies • Attraction and retention of staff is a big issue as is connectivity. We need data to support R&D, however not everyone can/ is collecting data • Why aren't producers seeking R&D? Why aren't they being proactive in obtaining information? If it was any other industry, people would be trying to be innovative to get ahead THEME 1: • Yes, is important. Needs to shift more towards the social aspect. That is, practice change = a change of focus towards extension and adoption. Almost needs to change the wording as research, development, extension and adoption (RDEA) has a historical expectation around it and means different things to different people • Translation of R&D is an issue. Perhaps a website to translate highly technical data into producer level needs. Future Beef does this to a degree – perhaps strengthen these type of interfaces • Extension needs to address shared values – and focus on intent. Also needs to be a research partnership – not just up to the extension officers THEME 2: • Yes, is important. Needs to be holistic R&D with a pathway to adoption. Step back and look at bigger picture issues and then R&D feeds into answering broader questions for producers. Current R&D is too localised and narrow – hard to translate into actionable solutions

MEETING	KEY POINTS
	• Must meet industry needs – not researchers' needs • RDEA needs to be targeted and long term, flexible. Can't set criteria for length of time. Findings may show changes needed or industry needs may shift, therefore needs to be able to shift to continue to meet needs. We have 30 years of R&D – we need to know the WHY. Pathway needs to be at the producer level • R&D brings expertise into the industry/region. Raises the knowledge of the service industries • Needs to incorporate better human capital skills THEME 3: • Theme is too broad and wide sweeping. Hard to turn into actions Suggest split as follows: • MARKET ACCESS/TRADE, information flow such as blockchain technologies. Ties in infrastructure conversation, include other issues – water access, native title, biosecurity • Northern Australian policy development. Need better alignment across borders (i.e. state government differences), need a northern Australia policy, harmonising the industry across northern Australia and have biosecurity across states THEME 4: • Group felt there needed to be a theme around the opportunities to develop Indigenous owned properties and assets • They have different legislation governing management (i.e. can't take out a mortgage) • What is the best model – Joint ventures, devolving responsibly and land grants through Indigenous Land and Sea Corporation, or subleasing arrangements, etc.? • Requirements around training and skills development • Needs to be progressed as an opportunity (as opposed to an issue) • There are some papers around collective leadership versus hierarchical leadership that need to be considered. That is, one size doesn't fit all – rules and ideas for producers doesn't always translate to properties managed by Indigenous people • Fit-for-purpose recommendations • Biosecurity, front and centre • Theme 1: Remove reference to R&D but rather call it adoption. Targeted and long-term, flexible and funded. More like an aid project, in the model of ACIAR (Australian Centre for International Agricultural Research), with an understanding of impact pathways. Shared value research partnerships. Longer term • Theme 2 needs to meet industry needs, holistic, and adaptable. Importance of maintaining the R&D, human capital and skills • Theme 3 quite broad, split into Theme 3a and 3b. Trade, market access theme (infrastructure, market access, etc.) education at school levels • Policy (in Theme 3b) different policies across the states. Harmonising biosecurity regulation across the states, looking at the opportunities if that is possible • Theme XX Indigenous opportunities – what is the best model (for whom?) • Bureau of Meteorology (BOM) as an implementation partner in Theme 1, with the example of the northern Australia climate project • Concentration on animal production rather than scale. Better is not necessarily about being bigger • The sustainable kg of beef per ha, rather than the measure on costs • Training cowboys to be farmers, what is the pathway of education and adoption? • Talent pipeline in private consultants, reliance on an ageing demographic and retirees from government • Can state Farming Organisations become part of the extension service? • Issue of adoption has been floating around for a long time, what is the fundamental reason that people don't seek the information, especially when it is so readily available? The red meat strategic plan recognises the need for more extension, but why aren't producers seeking the information more readily? • Is it that the producers don't know how poorly they are going?

MEETING	KEY POINTS
	• Market signals need to be stronger, and an understanding of who is the customer, and what are the market needs throughout the supply chain. Key profit drivers on farm are probably different than the next step in the supply chain

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