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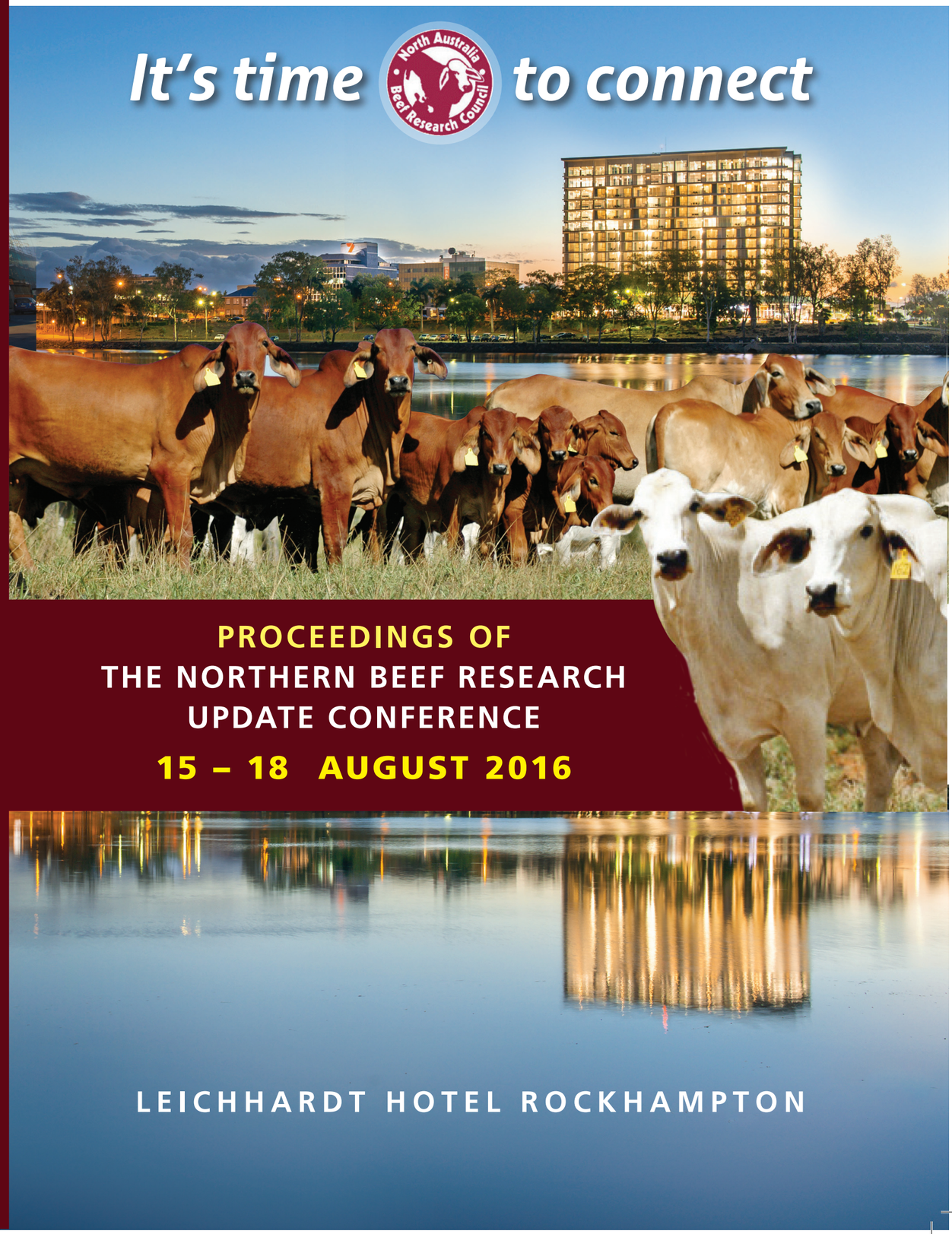

PROCEEDINGS OF THE NORTHERN BEEF RESEARCH UPDATE CONFERENCE

15 – 18 AUGUST 2016

LEICHHARDT HOTEL ROCKHAMPTON

FOREWORD

It is my pleasure to introduce these proceedings for the 2016 Norther Beef Research Update Conference (NBRUC).

The North Australia Beef Research Council (NABRC) continues to take a leading role in consulting with beef cattle producers in northern Australia to identify R, D and A priorities that are relevant to achieving sustainable increases in profitability for the industry, and seek out and facilitate collaborations that endeavour to take innovative ideas and make them a reality. We are proud to host this forum for highlighting the contributions made by individuals and organisations to the improvement of the northern Australian beef industry through research, development and adoption. Those contributions are all the more precious in what continues to be a challenging and rapidly changing environment for R, D and A. Of equal importance to the science and the outcomes presented at NBRUC are the opportunities for meaningful conversations and comradery between the research and extension community and beef cattle producers.

On behalf of the industry I thank the organising committee, chaired by Libby Homer, and everyone who will contribute to the conference, especially those whose sponsorship makes it all possible and Jackie Kyte's team who make it happen.

Dr Lee Fitzpatrick
Chairman
North Australia Beef Research Council

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These papers have not been refereed by the Conference Organising Committee. The content of each paper is the responsibility of the authors. The papers have been formatted to a common abstract style.

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How industry can influence research investment and outcomes

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Introduction

A great honour has been bestowed on me as a beef producer to address the NABRC at their conference in that it provides a unique opportunity to speak directly to those of you working in R & D about my sector of the industry. My presentation will cover some of the areas of research that have influenced our business growth over the last few years. I then intend to speak to how producers can influence where investment is directed and what outcomes I would like to see for individual farm business owners as well as for the industry as a whole.

I would also like to extend my topic to cover some issues that relate to sustainability in the beef industry and the impact that these will have on R & D investment and priorities in the next few years.

Background

My husband has been a seedstock producer all of his life and I joined him in the business about 27 years ago. We operate a number of properties at Emerald, Miles, Warwick and down into NSW at Glen Innes. The Palgrove herd includes Charolais, Charbray, Angus and our newly developed Angus/Brangus cross described as Ultrablacks. Our numbers now exceed over 2500 registered breeding females as well as a commercial herd. Our clients are located from far north Qld and W.A. to the southern tip of the country. If nothing else, we are well travelled and have an understanding of many of the issues facing beef producers across a number of regions both in Australia and overseas.

The diverse geographic spread of our land holdings and diversity of the breeds of cattle we produce has provided many challenges for us in terms of managing environment and climate, people, business and breeding strategies.

Very early on in the development of our business, we made a strategic decision to breed the type of cattle that would meet premium quality market specifications; the type of cattle that would breed as genetically consistently as possible and the type of cattle that would allow our clients to achieve the optimum returns in the markets that they bred their cattle for. In other words, without thinking it through specifically, we wanted our cattle to appeal to leaders in the commercial industry who valued genetics as one of the key profit drivers in their beef business.

In the last 27 years, this has not been an easy strategy to follow and it has taken a great deal of collaboration, learning, education and our own research, many errors of judgement and just a bit of luck to continue to achieve the standards of excellence that we set for ourselves and guarantee to our customers.

Adoption of technology, embracing innovation and learning new skills

The first point to make (and I make it with the greatest respect to all beef producers), is that because producers are required to manage both land *and* cattle operations, it is necessary for us to have knowledge across a very broad range of areas such as water, climate, soils, plants, infrastructure development, genetics, meat science, biosecurity, business management, people, taxation, environment, workplace health and safety and animal welfare and the list goes on. The skill set required to be a successful manager of all of these is vast and places a lot of stress on the average farming family operation.

We must operate as best we can to adopt to new technologies; embrace innovation and regularly grow our skill set. With both time and 'opportunity' the enemy, no wonder we fall behind. I hope

that this may go some way to explain our shortcomings in not always having a thirst for embracing the new methods and technologies advanced by the R & D sector.

However, from my point of view, there are some key technologies that have been developed in the last twenty years that have the capacity to add significant value to our cattle herds and the quality of the beef products that are produced. Unfortunately, time prohibits me expanding on many of the areas of innovation that have boosted our bottom line in the last 25 years.

1. Breedplan (EBVs)

Back in the late 1980's and an industry 'outsider', one of the first systems that I became aware of on-farm was a method of objective performance recording that was in place at Palgrove. From the stud's early years, the family had based their genetic selections on lowering birth weights and increasing the weaning weight ratios of the progeny to objectively identify the outstanding 'contributors' to both live calf and weight gain traits. This early information later became a foundation for the development of datasets for the Charolais Breedplan models.

Adaption was the only way that these European breeds could be integrated into Australian environment and markets. Breedplan was used to underpin the phenotypic selections that were needed to adapt the genetics. The result has been that we have reduced the massive birth weights and absence of fat cover that were inherent in the early European imports of our Charolais breed, whilst maintaining the weight gain and carcass traits that are the breed's hallmark. The photos in Fig. 1. show the phenotypical change that mirrors the genetic gain made through the utilisation of Breedplan.

Fig. 1. UK bred 'Euro' steer in the early 1970's (left) and Australian bred 'Euro" steer 2016 (right)

If our business were to make a list of the most influential research outcomes that has delivered practical and commercially advantageous returns, then the development of first generation Breedplan and its subsequent adjuncts would rate as number one. It has been responsible for changing the way our genetic selections are made. It has assisted the seedstock industry to understand and select for the most economically relevant traits and enabled studs to pass these traits on to their commercial clients. This has in turn provided added value right across the supply chain.

Starting with weight, then came fertility traits, carcass traits and the development of combinations of trait selections in estimated breeding values that were bundled together to provide a specific Index for a host of variable production systems and environments. Producers have the tools to make informed decisions on their genetic choices. They have objective estimates to guide them to select bulls and females that will add value to their weaning percentages; weights at various intervals; the carcass that they produce and all focused on enabling them to better analyse which off-take market pathways best suit their cattle.

The research has been done, the data is available and it is simple to interpret and a great deal of time and money has been spent on extension and dissemination. The direction of new research is unquestionably led by southern seedstock breeders.

Has northern Australia dropped the ball on Breedplan? A 2014 report suggests that approximately 1,500 bull breeders are estimated to be using BREEDPLAN in Australia, which represent an 80-90% share of the bull market in southern Australia and about 50% in northern Australia). Furthermore, average rates of gain and BREEDPLAN adoption are far lower in northern herds than southern herds (Woolaston 2014).

I would submit that any discussion on Breedplan utilisation in Northern Australia must include an understanding and analysing adoptive behaviours within our industry. Perhaps more needs to be done in analysing the current barriers to adoption. Is it the dissemination process, delivery methods, current market signals, perceived lack of incentives, group think or lack of leadership?

Previous research undertaken in the area of adoption of innovation in the beef industry (Moreland and Hyland 2013) suggests that the method of communicating is one of the most defining factors in adoption of technologies. Moreland and Hyland noted that, "the complexity of a scientific innovation is not a barrier to adoption if the communication pathway is appropriate and the message is tailored to the end user and can be understood and translated by intermediaries so that it fits with the practices of end users".

They concluded that for technologies such as Breedplan, higher uptake rates may be possible if a more collaborative communication approach were undertaken as well as tailoring the communication to specific end users to demonstrate either an economic benefit or it to enable differentiation to be established.

The Beef CRC's Beef Profit Partnerships (BPPs) was a ground breaking initiative aimed at accelerating the rate of adoption of new technologies in the beef industry. The programme's success was attributed to the fact that it offered an innovative and stimulating way to achieve rapid, measurable and sustainable improvement in the profitability of beef businesses through working in groups. In terms of Breedplan, the most relevant delivery mechanism should be through the breed societies that have a high concentration of northern industry members. Perhaps what has been lacking is the disconnect then with commercial producers.

Project manager, Cynthia Mulholland said, "an individual is more likely to look at new things and make changes to their operations if they are surrounded by peers that share a similar background and goal".

A summary of why the group believed that they were so successful can be found in the CRC Beef Profit Partnership Project Magazine 2011 http://www.beefcrc.com/documents/publications/beef-profit-partnerships/BPP-Magazine2011-web.pdf

2. Polledness

I don't think that I'm alone in promoting the view that the breeding of polled cattle both in northern and southern Australia will be an imperative from an animal welfare perspective and this alone should be a reason to accelerate the inclusion of polled cattle in commercial herds.

In practical terms, loss of productivity following dehorning and additional labour add to the economic cost of calf mortality, where one study concluded that in northern Australia, almost all calf deaths post-branding (assessed from n = 8348 calves) occurred in calves that were dehorned, totalling 2.1% of dehorned calves and 15.9% of all calf deaths recorded (Bunter *et al*. 2013).

Unlike southern production systems where dehorning can be undertaken within a week or two of birth and de-budding is practiced. Northern Australian management means that calves are at least 4-5 months old and mid-summer when dehorning occurs. Producers suffer not only productivity and mortality losses, but face additional costs of time and labour, there is also potential injury to animals and staff that must be taken into account.

Where there is a genetic solution to one of the most invasive animal management practices in cattle production, it defies common sense that we aren't working towards an outcome that takes it out of our systems.

As we've seen with other species, from an animal welfare perspective, more pressure is likely to be placed on the industry by external stakeholders when there is a viable genetic alternative. Future research in the area of polled genetics in northern herds must surely rate as a high priority and

seedstock producers should be involved in changing industry perceptions about the inferiority of polled Bos Indicus cattle in terms of productivity.

3. Artificial Reproduction

The development and refinement of embryo transplant, artificial insemination and invitro-fertilisation techniques in the last 30 years or so has changed seedstock production systems and resulted in rapid genetic gains to be made in a shorter period of time. Additionally, the uptake of artificial breeding methods such as fixed time AI in northern Australia also has the potential to produce 'game changing' genetic gains in our extensive herds as long as the skills gap continues to close.

Artificial reproduction technologies and methods are easy enough to measure in terms of positive pregnancies or live calves born on an annual basis. What is more difficult is the rate of genetic improvement that results and this data is even more difficult to collect for commercial beef producers where seasons play a big part in the outcomes.

Seedstock production is an extremely competitive business and we are always striving for differentiation and 'an edge' over our competitors. Perhaps this has had a flow on effect of challenging researchers in the reproductive science disciplines to develop new technologies that reduce time and cost and at the same time improve outcomes.

Lead producers directly and indirectly influence others in the seedstock industry as well as their commercial customers by making available in the market the improved genetics that have been produced. This begs the question – does everyone in the industry have to adopt new technologies to have a positive impact on genetic gain, or is it enough to have industry 'leaders' diffusing their improved 'products' (bulls and females) across the rest of the industry?

We are close to the technologies, and our service providers are close to those who can influence new developments through their research channels. If I was to nominate a pathway whereby producers could influence the investment or outcomes of research and development across reproductive technologies, I would suggest that it is through the relationships and discussions that we have with our reproductive vets and technicians and then they in turn seek out pathways to assist in finding a solution, reducing a cost or an invasive practice or achieving better results.

This would be done through their organisations, conferences or direct applications for funding of producer groups or organisations. Research and development in these areas of production I would argue are very reliant on direct conversations that are started in order to solve individual producers' existing problems.

At no point do I suggest that this is a pathway for the bold research project that looks at 'blue sky' techniques and challenges the status quo of how we do things. These conversations solve specific issues or effectively look at ways to directly save time and money within an operation.

Encouraging researchers to continue to think long term, to consider projects that address the 'what ifs' and challenge industry thinking has been made more difficult by funding constraints. Think tanks, engaging with 'lead players' from across the beef supply chain and outside industry would be a good place to start, but projects seem to now require definitive returns on investment to attract funding.

Sustainability

This leads me into my final comments which are about sustainability in the beef industry and the imperative for adopting a value base that leads to continuous improvement right across each sector of our industry and embraces the northern production systems as much as the southern.

I have been appointed Chair of the Steering Committee to develop a Sustainability Framework for the Australian Beef Industry that encompasses the whole beef supply chain. It is relevant in this presentation to address some of the major issues that have been identified as areas of concern for our stakeholders. We are currently developing the indicators and measures that will address the priority issues and demonstrate both our credentials and highlight the weaknesses in our industry.

It is these indicators that we believe will form the basis for future R & D and extension services in the next few years and will provide the industry with the long term projects that be will required, thus necessitating a change in funding thinking away from the direct short term gain approach. These are however, crucial for our industry to address. At a high level, the themes include livestock wellbeing (health and welfare), economic contribution and resilience, environmental stewardship and community.

By identifying and defining the themes and issues that arise under those, it will hopefully provide both grassfed and processing service providers and the research industry a more defined set of parameters to set priorities for projects and funding.

The last 2 years has resulted in an elevated level of urgency that for the Australian beef industry to demonstrate it is serious about adopting a continuous improvement approach to broader industry sustainability issues. Across the supply chain, these include reduction in CO_2 emissions, W H & S as well as more specific production sector issues such as reduction in invasive practices or use of pain relief. The R & D sector will be at the forefront of developing new outcomes that will achieve better genetic, technical and management solutions to these concerns and assist the industry to produce more with less for future generations.

The risk for our industry in terms of sustainability is (once more) the level of adoption of these outcomes. If we were to address the risk associated with non-adoption with more vigour, perhaps we will see an industry where R & D is seen as the fundamental partner to business success and the beef industry, including all sectors benefit more directly from new and current knowledge and technologies.

I would like to end with a quote from a young researcher that I have been communicating with as part of my role with the sustainability framework and it made a very poignant point. The email said, “I would definitely like information from my work to go further than a journal publication.” My answer to that was, “so would I”.

Surely that’s incentive enough to try to close the communication and adoption gap.

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Connecting the industry with research: opportunities and outcomes in a consultative framework

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Abstract. Meat & Livestock Australia (MLA) has implemented its first full cycle of annual producer consultation and its annual project call. This process has involved the establishment of a Southern Australian Meat Research Council (SAMRC) and the Western Australian Livestock Research Council (WALRC) to complement the already existing North Australia Beef Research Council (NABRC). Each of these regional councils oversees the compilation of producer identified Research, Development and Adoption (RD&A) priorities within these regions. The regional priorities feed into a single set of industry endorsed RD&A priorities around which MLA runs an annual call for projects. This paper will describe the industry consultation process, the annual call for projects and how these align to the industry Strategic Plans and MLA's 2016-2020 Strategic Plan.

Industry Strategic Planning and oversight

The MISP 2020 (Meat Industry Strategic Plan) sets the higher level objectives and targets that the red meat industry must meet to optimise its future productivity, profitability and sustainability. In response to MISP 2020, the red meat industry Peak Councils (the Sheepmeat Council of Australia (SCA) and the Cattle Council of Australia (CCA)) have released the Sheep and Beef industry specific strategic plans (SISP 2020 and BISP 2020) that guide how investment in RD&A for these industries will deliver the national objectives for the grassfed beef and sheep meat industries.

MLA is the RD&A and marketing service provider for the red meat industries overseen by the SCA and CCA (and other Peak Councils). It is imperative therefore that planned RD&A and marketing investments by MLA on behalf of the red meat industries are aligned to the priority areas of SISP and BISP for delivery through MLA's 2016-2020 Strategic Plan. All RD&A investments by MLA will therefore, be aligned to the key industry outcomes identified in MISP 2020 and those defined within the SISP and BISP that are priorities for the Australian sheep meat and beef industries.

MLA's Strategic Plan 2016-2020 (www.mla.com.au/strategicplan) sets out MLA's strategic direction and investment priorities over the next four years which contribute to the profitability, sustainability and global competitiveness of livestock levy payers. MLA's Strategic Plan closely aligns with the red meat industry's MISP 2020 and the Australian Government's research priorities. Six strategic pillars form the foundation of the MLA Strategic Plan which directly relate to the MISP 2020 (Table 1). The industry outcomes sought and the investment priorities defined for each outcome describe the focus of MLA's investment in RD&A and marketing to deliver its component of the MISP 2020. With respect to on-farm RD&A alignment to the MLA Strategic Plan 2016-2020, these investments primarily fall within Pillar 1 and 4.

Table 1: MLA's strategic pillars, outcomes and priorities 2016-2020

Pillar	Outcome	Priority
1. Consumer and community support	The community continues to support the industry, with industry practices in step with community expectations.	• Continuous improvement of the welfare of animals in our care • Stewardship of environmental resources • Role of red meat in a healthy diet
2. Market growth and diversification	Improved access to markets, with marketing programs driving increased consumer preference and premiums for Australian beef, lamb and goatmeat.	• Efficiency and value in trade and market access • Marketing and promoting Australian red meat and livestock
3. Supply chain efficiency and integrity	Increased returns through the value chain, with end user customers confident in product quality and integrity systems.	• Optimising product quality and cost efficiency • Guaranteeing product quality and systems integrity
4. Productivity and profitability	Productivity gains through the value chain from the adoption of tools and technologies.	• Production efficiencies in farms and feedlots • Processing productivity • Live export productivity
5. Leadership and collaborative culture	Industry participants are confident in industry leadership capability.	• Building leadership capability • Protecting and promoting our industry
6. Stakeholder engagement	Industry participants are confident that the levy investment is delivering value.	• Engagement with producers and stakeholders

The MLA Regional Consultation Process

An independent review of MLA's levy investment systems for on-farm R&D in 2013 (LPI Systems review www.mla.com.au/About-MLA/Planning-reporting/On-farm-RD-systems-review) recommended that MLA adopt a formal process for stakeholder engagement in setting priorities, implementation of strategy and two-way industry communication. The report recommended the establishment of advisory panels of credible, experienced industry leaders and other stakeholders that would recognise regional (e.g. north, south) and industry (e.g. beef, sheep meat) diversity across the red meat industries. These panels would:

- Identify and monitor issues of national and regional importance;
- Identify, develop and recommend on RD&A investment priorities and project selection via the relevant MLA business units (e.g. On Farm Innovation and Adoption) to the MLA Board;
- Interact with producer groups and other research advisory committees to exchange information;
- Keep industry peak bodies, producers and advisors informed about MLA's strategic direction, investment portfolio and research projects;
- Assist MLA managers in monitoring the effectiveness of the investment portfolio.

MLA has implemented a new regional consultation framework for directing RD&A investments for sheepmeat and grassfed cattle levies to address these core recommendations. The principles underpinning the MLA regional consultation framework include:

- It enables broad, transparent and effective levy payer engagement (and subsequent co-investor engagement) in identifying industry RD&A priorities;
- The framework enables MLA to provide a leadership role for addressing the RD&A priorities under the MISP 2020 and CCA and SCA industry plans;
- There is alignment to the project call process and the management of the MLA RD&A portfolio balance;
- There is clear delineation of roles and responsibilities of committees involved. Each committee has a consistent charter of operations that stipulates deliverables and processes that underpin operations and conduct;

- It enables transparency in the process of priority setting, project assessment, external peer review processes, and the achievement of outputs and outcomes from RD&A investment;
- The process enables a two-way flow of information utilising a bottom-up, top-down system of information flow involving testing of RD&A concepts as well as identifying regional RD&A priorities;
- The industry focus areas are sheepmeat and grassfed beef levies given the processing, feedlot sector, live export and goat levies operate under existing structures. However, there is flexibility to allow for different red meat sectors to engage as appropriate and refer proposals to the relevant expert panel on an ad hoc basis;
- Representation within committees across all levels engages levy payers on a regional basis, which utilises a skills-based selection process, and includes co-investors and supply chain members as appropriate;
- It provides a clear separation between project decision making and project management;
- The system is subject to a process of annual review and continuous improvement to ensure it remains relevant, representative and cost effective.

Figure 1 (below) describes the integration of priorities identified within producer groups or through producer forums up through regional research committees, the NABRC, SAMRC and WALRC councils to a single high-level Red Meat Panel which agrees on consolidated priorities that underpin MLA's annual call for projects.

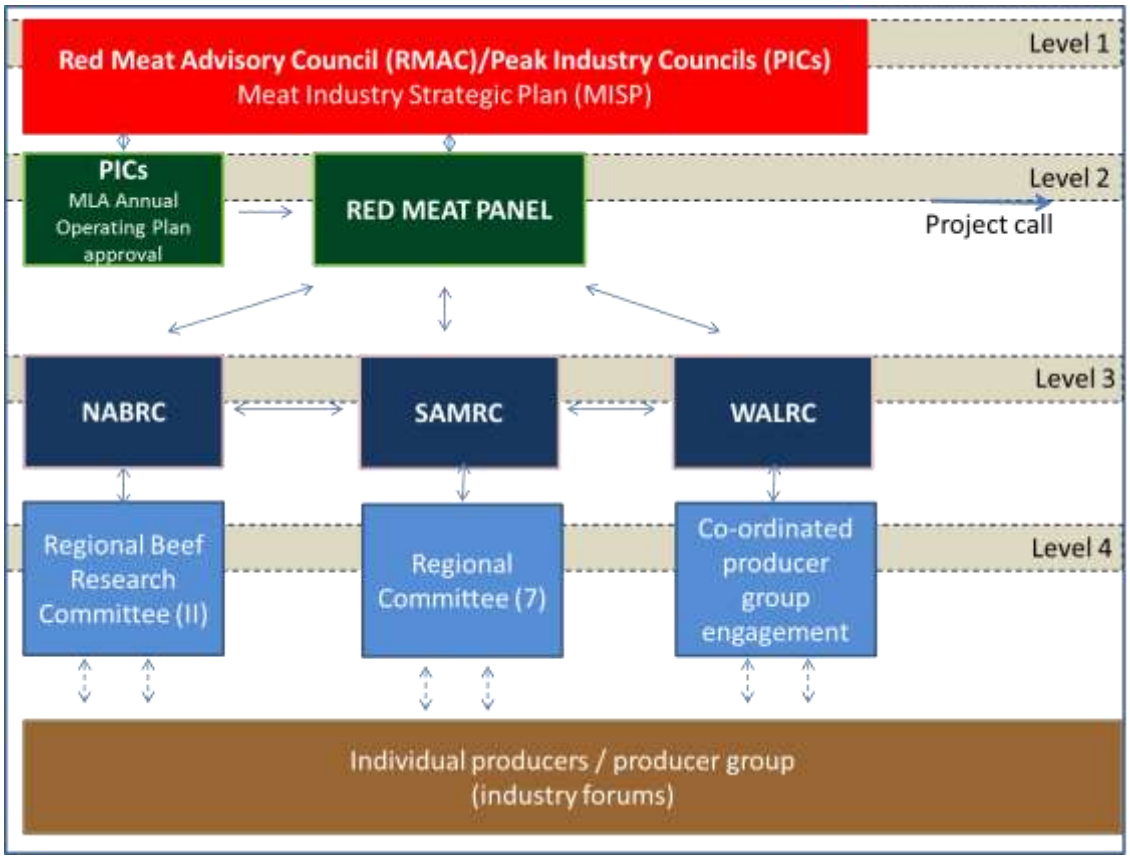

Fig. 1. MLA Producer Consultation Framework and consolidation of priorities for the annual project call.

Within the network of regional committees underpinning producer RD&A priority consultation, there are 11 northern producer committees, seven southern committees and a co-ordinator to work with existing producer groups in Western Australia. These committees represent different agro-

climatic zones and production systems. Each committee consists of at least six producers from a range of geography and enterprise types. The committees help set the RD&A agenda through identifying relevant priorities and also provide a platform for testing new concepts. The committees feed up recommendations to NABRC/ SAMRC/ WALRC and MLA on regional trends/priorities and are also a central point to co-ordinate regular MLA communication activities, such as RD&A updates, thus providing a two-way feedback mechanism.

The three regional councils - NABRC, SAMRC and WALRC - represent the interests of northern, southern and western sheepmeat and grassfed cattle levy payers. These councils bring levy payers and co-investors together to review regional priorities against the national priorities, allowing exchange of ideas on the specific need of RD&A in an area (e.g. genetics for fertility in northern cattle). These councils also enable ground truthing of regional priorities, testing of RD&A concepts and enable collaboration and co-investment arrangements to be developed.

The Red Meat Panel consists of representatives of the CCA, SCA, NABRC, SAMRC and WALRC and MLA. It considers the balance of regional versus national investment priorities and is the single point of advice on RD&A investment for implementation through the Annual Project Call cycle by MLA for on-farm grassfed beef and sheep meat levy funded RD&A. The Red Meat Panel provides direction in prioritisation of the RD&A portfolio, taking into account national priorities and feedback from the Producer and Expert panels. It is informed on national RD&A issues by consolidated regional information from the regional councils (NABRC/SAMRC/WALRC).

The MLA Annual Call Process

In 2016, MLA initiated an annual call for sheepmeat and grassfed cattle RD&A, in conjunction with the regional consultation framework. Figure 2 illustrates the annual call process and timelines proposed for the 2017/2018 financial year. The process is a staged annual program management and approval process which involves evaluation of the RD&A portfolio balance by the Red Meat Panel, an annual call for new short, medium and long term investments, as well as review of existing projects. Key components of the 2017/18 MLA annual call process are:

- An open call for preliminary proposals that address the producer and industry RD&A priorities described in Terms of Reference (approved by the Red Meat Panel);
- Producer review of preliminary proposals by producer panels comprising the chairs of the SAMRC and NABRC regional committees, and producer members of WALRC;
- Invitation to submit full proposals for preliminary proposals evaluated as having high potential producer and industry impact
- Review of the technical merit of full RD&A proposals by an independent Expert Panel;
- Short-listing of high industry impact proposals by MLA managers prior to final review of full proposals by producer panels;
- Advice from the Red Meat Panel on MLA's proposed strategy to invest in high impact RD&A proposals within each Terms of Reference;
- Review of the proposed investment strategy through the internal MLA project governance procedures prior to contracting and implementation.

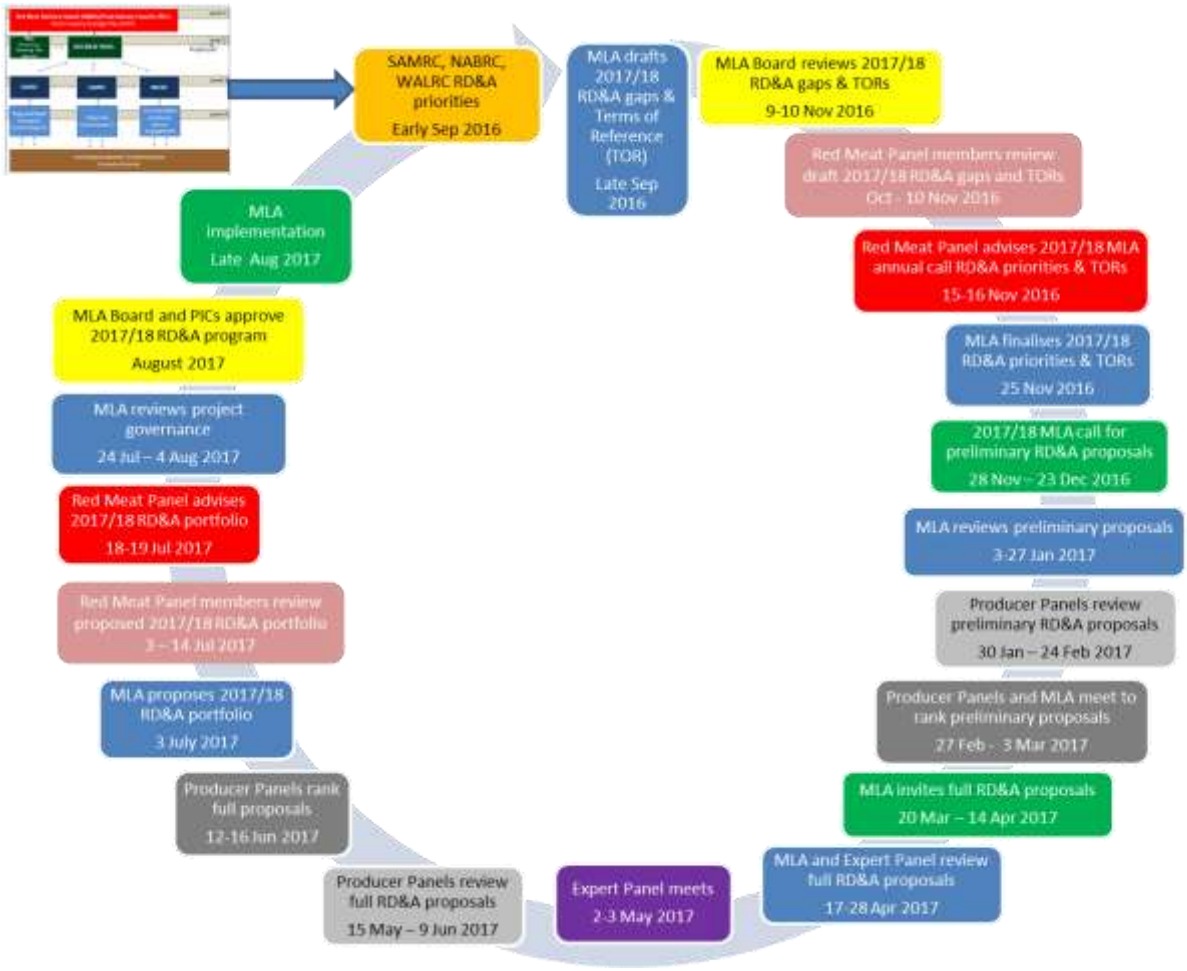

Fig. 2. Detailed draft timelines for the 2017/18 MLA Annual Call process

Summary

MLA has implemented its first full cycle of producer consultation aligned to an annual call for sheepmeat and grassfed beef RD&A. Producers now set the RD&A priorities for the MLA annual call process through broad-based regional consultation. Terms of Reference for each project call area align the RD&A priorities to the industry strategic plans and the MLA Strategic Plan. MLA has separated industry priority setting by producers from technical review of RD&A projects, by putting in place an Expert Panel to provide independent technical review of projects. MLA now operates its industry consultation process and call for projects on an annual basis with full accountability and transparency. MLA will review and continue to improve this annual process in consultation with industry and our RD&A partners.

The need for R&D in the northern beef industry?

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Introduction

The question of whether R&D is needed in the northern beef industry is, perhaps for many people and especially those that attend technical conferences like NBRUC, a rhetorical question – of course it is needed, isn't it?

Investment in R&D is often discussed and/or assessed in terms of the triple bottom line, i.e. financial, environmental and social impacts. In this paper, the need for investment in R&D will be considered solely from the productivity and financial perspective and the potential for R&D to increase enterprise and industry profitability. Most researchers would argue that R&D leads to increased productivity and profitability. However, there are a few producers in the industry that believe that R&D is simply increasing the amount of beef produced and, all things being equal, putting downward pressure on the price received per kilogram of beef produced. This paper will look at the evidence base for whether or not R&D is needed and also whether R&D is producing benefits for the industry.

Why do we need R&D?

Numerous analyses have reported on the extremely poor performance of the northern beef industry over the last 10-15 years (e.g. McCosker *et al*. 2010, Mclean *et al.* 2014) but these were preformed when beef prices were in a downward trend – price received was $1.90/kg LW in 2001-03 and had decined to $1.64 by 2010-12. The most recent ABARES report on farm financial performance (Martin 2015) reported the following key measures for the northern beef industry:

- Average property cash income increased from $74,700 in 2013–14 to $148,000 in 2014–15 (approximately 50% above the average for the previous 10 years in real terms).
- Average property profit increased from a loss of $76,900 in 2013–14 to a loss of $19,000 in 2014–15 (below the average for the 10 years ending 2013–14 of $22,600).
- Return on total capital used (excluding capital appreciation) averaged:
    - –2.1% for properties with a herd size between 100 and 400 head.
    - –0.6% for properties with a herd size between 400 and 1,600 head.
    - 1.9% for properties with a herd size between 1,600 and 5,400 head.
    - 3.2% for properties with a herd size greater than 5,400 head.
- Average farm debt increased by 2% in 2013–14 to $647,000 a farm.

Beef producers who have not been affected by drought and who have been able to maintain their herd numbers will benefit greatly from the current record prices being paid for cattle in Australia – the $64,000 question is how long these prices will persist?

The Australian beef industry operates in an extremely competitive world protein market competing against beef and buffalo from other major exporting countries such as India, Brazil and the United States, as well as other proteins in the form of poultry, pork, lamb/mutton and fish. Globally beef trails fish, pork and poultry in terms of overall consumption (Fig. 1), with fish and poultry rates of consumption increasing much faster. The domestic Australian market is the most important one with 26% of total Australian beef and veal production consumed locally in 2014-15 and the remainder exported to 86 countries (MLA 2015), with the top 10 export countries shown in Figure 2. Live exports accounted for 13.4% of the national production countries in 2014-15 with Indonesia and Vietnam being the major importers (745,000 and 312,000 live cattle exported respectively; ABARES 2015).

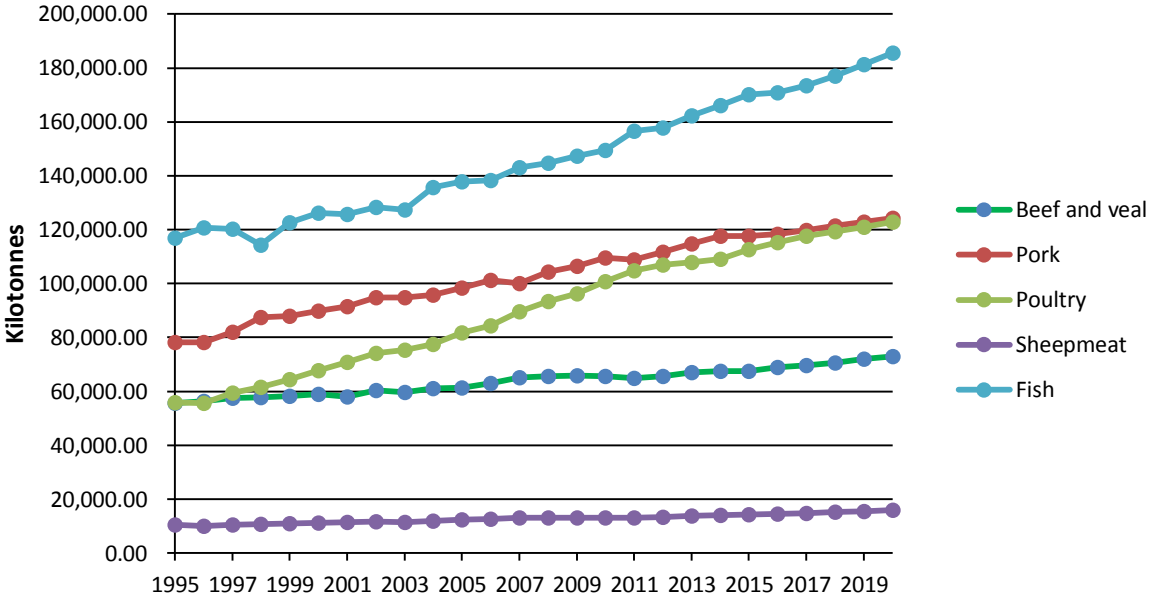

Fig. 1. World protein consumption 1995-2020 (2015 data are estimated, 2016 data are provisional, 2017-2020 data are forecast; Beef and veal - cwe, pork – cwe, sheepmeat – cwe, poultry – rtc; Source: OECD.Stat: OECD-FAO Agricultural Outlook 2016-25).

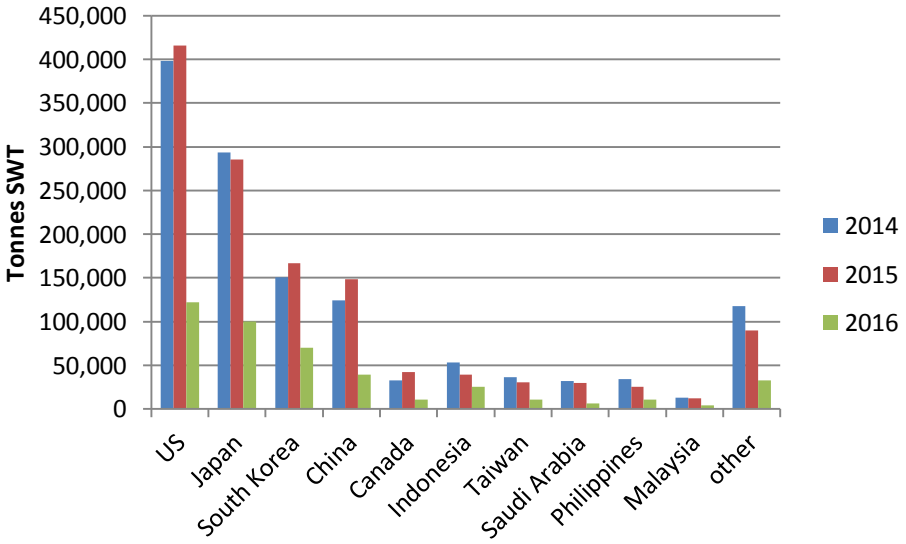

Fig. 2. Australia's Top 10 beef markets - based on 2015 volumes (2016 data are for January – May; Source: DAFF via MLA Market Information Statistics Database, http://statistics.mla.com.au/Report/List).

Of interest in each of the main markets for Australian beef and cattle is the relative role that beef plays as a protein source (Fig. 3). Other than Australia and the United States, beef consumption is a relatively minor component of total protein consumption. In Australia, beef and veal consumption is almost half that of poultry consumption. The rise of poultry consumption and fall of beef consumption is shown in Figure 4. Since 1980 nominal retail beef prices have increased steadily whilst at the same time chicken retail prices increased through to 1990 but since that time have largely plateaued. At the same time as beef prices climbed, per capita beef consumption steadily declined. In contrast, poultry consumption has steadily climbed. The data would indicate Australian

consumers have changed their protein buying and consumption behaviour in response to relative changes in retail prices for beef and poultry. Unfortunately, consumption data for 2015 are not yet available – it will be very interesting to see what impact the recent spike in farm-gate and retail beef prices has on consumption.

The market data presented in Figures 1 – 4 highlight that the Australian beef industry cannot afford to not focus on increasing productivity, reducing its cost of production and maintaining, if not improving, its key competitive pricing position against both other beef producing countries and other protein sources.

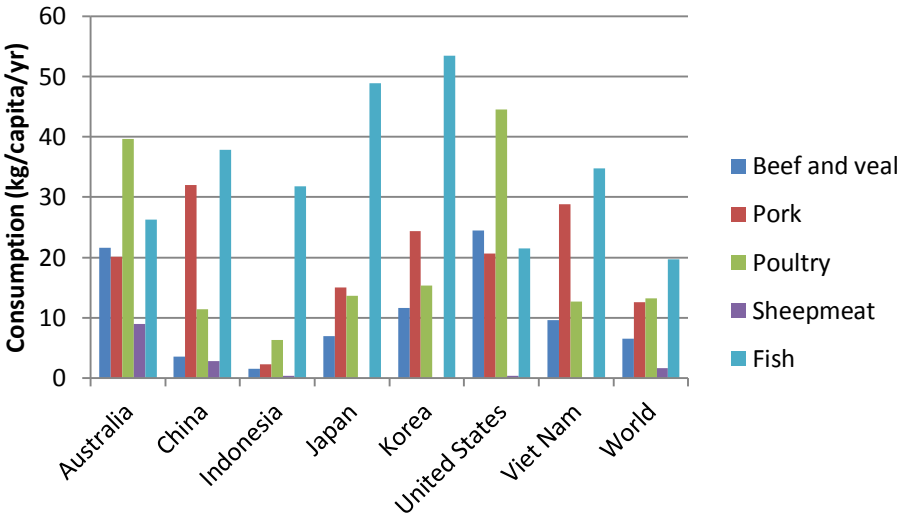

Fig. 3. Annual consumption (kg per capita) of protein sources in the main markets for Australian beef and cattle (Data for fish are for 2013 and for other proteins 2014; Sources: OECD (2016), Meat consumption (indicator). doi: 10.1787/fa290fd0-en (Accessed on 29 June 2016) and ftp://ftp.fao.org/FI/STAT/summary/FBS_bycontinent.pdf).

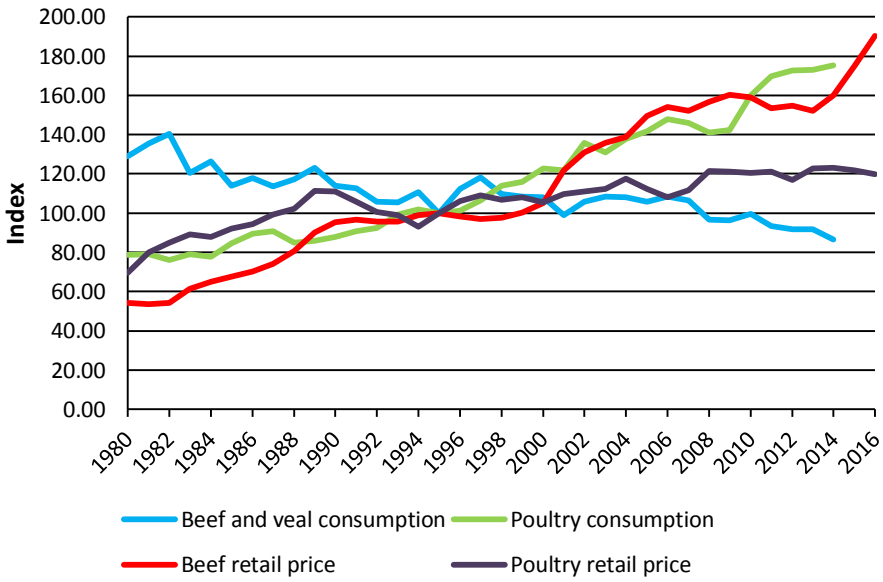

Fig. 4. Calendar year Australian beef and veal and poultry consumption and nominal retail price indices (1995=100; 2016 data are for January – March; Sources: ABARES and ABS from MLA Market Information Statistics Database, http://statistics.mla.com.au/Report/List).

Consumer demand for a specific product is not driven by price alone – other factors such as food safety, animal welfare, environmental performance, product consistency and convenience can also be drivers. The Australian beef has addressed some of these issues through the development of industry systems including Livestock Production Assurance, National Livestock Identification System and Meat Standards Australia. Another example of R&D addressing a driver of consumer demand is in the area of convenience. Australian supermarkets and takeaway stores sell 100 million and 24 million barbecue chickens per annum respectively, worth $932M in 2014 (MLA 2016). In response the Australian beef industry, through R&D, has recently developed “grab and go" hot roast and corned beef products now available via Woolworths, competing head-to-head with barbecue chickens.

Is R&D having an impact?

There is much data to support the position that investment in R&D is having an impact on the northern and/or Australian beef industry including:

- Wiedemann *et al*. (2015) demonstrated that over the three decades since 1981 there has been a decrease in GHG emissions intensity of 14%, (excluding land use change emissions), from 15.3 to 13.1 kg CO2-e/kg LW. The improvement was due to efficiency gains through heavier slaughter weights, increases in growth rates in grass-fed cattle, improved survival rates and greater numbers of cattle being finished on grain.
- ABARES (Martin 2015) reported that productivity of the northern beef industry increased by an average of 1.4% pa between 1977–78 and 2012–13 (0.5% productivity growth pa for the southern beef industry).
- The recent performance evaluation of MLA expenditure from 2010-11 to 2014-15 on R&D found:
    - $458M benefit and BCR of 3.5 for increasing on-farm productivity (beef and sheep);
    - $89M benefit and BCR of 2.1 for animal health and biosecurity (beef and sheep)
- The earlier performance review by CIE (2009) of MLA and partner expenditure between 2000-01 and 2007-08 in northern beef R&D found a benefit of $411M and BCR of 1.9.

In contrast to the above findings, Fennessy *et al.* (2014) in their analysis of the investment by MLA and its partners in beef genetics and genomics over the period from 2001/02 to 2011/12 reported a benefit of $49M from an investment of $48M, and a BCR of 1.0 (southern beef had a benefit of $486M and BCR of 4.4). The analysis found that while there was significant genetic gain in growth rate in northern Australia this impact was offset by the lack of change in genetics of reproduction and the low rate of adoption of genetic technologies. This lack of genetic focus on reproduction is supported by branding rates for Queensland in the ABARES Australian agricultural and grazing industries survey (AAGIS, Fig. 5). The data would indicate that there has been no improvement trend in branding rate in Queensland from the late 1980s to the latest available 2014-15 data.

In contrast to the increasing liveweight gain genetic merit of tropical breeds that can be identified from analysis of Breedplan data (Fennessy *et al.* 2014), data on actual industry liveweight gain trend performance in northern Australia are difficult to find. One example is the analysis of Lean *et al*. (2011), which analysed 457 liveweight gain comparisons of cattle in northern Australia from 1959–2000 covering all breeds (and cross-bred steers), classes of stock, improved and native pastures, and dry and wet season performance. Their analysis found little or no evidence of improvement in the liveweight gain performance of cattle over the 41-year period.

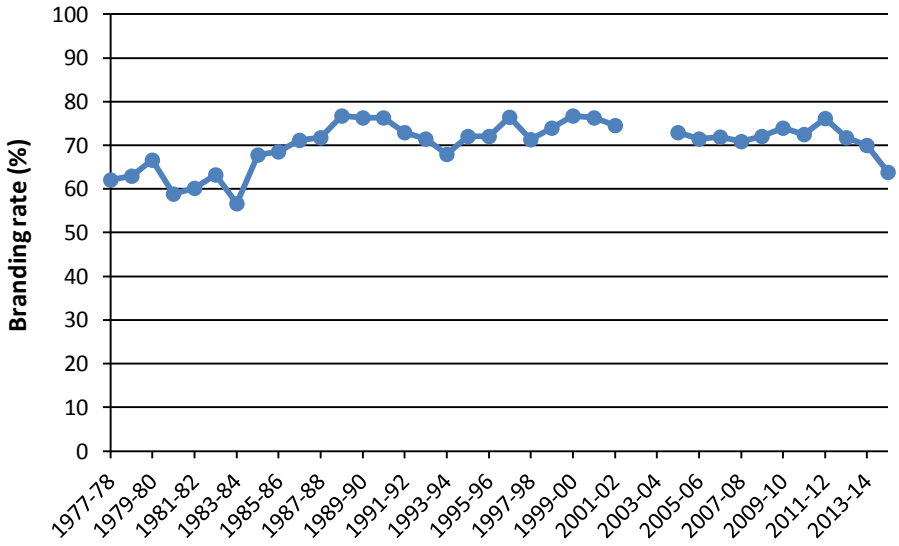

Fig. 5. Branding rates for Queensland specialist beef properties – data for 2002-03 and 2003-04 not available (Source: ABARES AAGIS database, http://apps.daff.gov.au/MLA/).

Discussion

Numerous financial analyses have shown that the northern beef industry as a whole has struggled in terms of long-term financial performance and viability (e.g. Martin 2015, McCosker *et al.* 2010, Mclean *et al.* 2014) and operates in extremely competitive markets, both domestically and in our export markets. On this basis, it is essential that investment in production R&D is maintained if not increased.

The data available on the R&D impact on productivity and profitability presented in this paper are somewhat contradictory. On one hand MLA performance reports show positive returns to industry from the R&D investment, and ABARE total factor productivity analysis show increasing productivity, albeit at low rates. On the other hand, the recent focussed genetic review and the limited actual industry performance data paints a different picture.

Possible explanations for these differences include:

- Economic impact analyses are generally driven by future, unrealised benefits which are in turn driven by assumptions on adoptions of technologies; and the rigour of the counter-factual analysis; and
- Surveys may have limited sample size, be biased towards those willing to participate, and that the information provided by producers is not correct because they either do not have actual data or their responses are biased by what they believe the answer should be.

Looking to the future it is essential that:

- In an environment of declining public R&D funding, available funds are invested in those projects and areas with the highest potential to benefit the industry – identification of the key drivers of profitability is critical;
- Adoption is a key component of all R&D discussions and investment programs and outcomes must be accompanied by robust cost benefit analyses; and
- Business management skills must be a priority to ensure producers have good data on their physical and financial performance, and can assess the potential impact that new technologies will have on their business performance.

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Better genetics for better steaks – a producer perspective

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Introduction

Research and Development (R&D) in the modern era has become R,D&A – Research, Development and Adoption (or extension – R,D&E). Including adoption created a significant step forward, highlighting the importance of recognizing that the true value of research comes from the implementation of it. Marketing of R&D is a vital component to ensure we really do have 'Research In Action' (Weatherley 2016) for the Australian Beef Industry. Once implemented successfully, good research outcomes have the potential to positively influence beef production capability for a long period of time. Dr Jane Weatherley summed up the long lasting effects of influential research outcomes in the Research In Action special edition of the MLA March/April 2016 Feedback publication – "The immediate benefits of R,D&A investment are often not apparent. It can be the cumulative outcomes of numerous projects which lead to transformational change."

Motivation

As a producer the importance of adoption and how it is achieved cannot be overlooked. Of course adoption will not happen unless outcomes from the research are relevant and show the possibility of having a positive influence on the production system. Ultimately the key to adoption of any research outcome is motivation of the producer. We need to be motivated to seek change, regardless of whether it is a large or small change. We need to perceive a relative advantage in adopting the change. Our motivation increases if we are aware of strengths and weaknesses in our business, can set goals, measure, analyse and where possible benchmark to understand what is achievable.

Ultimately, we need to be aware of the research, have conviction in the outcomes, believe it is compatible with our goals and preferably have a budgeted and appealing cost/benefit ratio to successfully seek to adopt research and development outcomes. We cannot be motivated to do something if we are unaware of it. We cannot be motivated to do something if we don't have a strong enough belief in the benefits of implementing it, to ensure we overcome the various obstacles that will inevitably arise. We shouldn't implement something if the cost of doing it is far greater than the expected benefit, whether this is measured fiscally, environmentally, in terms of sustainability, in terms of time or in whatever unit of measure is perceived as valuable to the producer.

It cannot be overemphasised that adoption is typically a journey. Each of the small steps along the way become fundamental to the progress as a whole. As humans we are often better at implementing small changes and then continuing to build on these changes over time. Similarly, we become more enthusiastic to change once we are confident in the success we have achieved through other changes we have made previously.

What are better steaks?

Through our business we have a 'steak' in the Australian Beef Industry. For us, producing a 'better steak' becomes vitally important to maintain a market for our product and to remain financially sustainable into the future. Within our business a better steak has both a quality and quantity aspect. We need to produce a product for the consumer that is more pleasing or acceptable to their preferences, providing a memorable eating experience that we hope they will want to repeat often, thus helping to maintain or increase the demand for beef. Quality typically comes down to the production of beef, within market specifications and with traits to maximize eating quality. Quantity refers to maximizing the amount of quality beef we can produce from a finite resource (our land) in a sustainable manner to ensure future production and environmental standards are not compromised.

To help measure quality, Australia has produced a unique system with significant scientific backing to identify aspects of meat that effect eating quality through Meat Standards Australia (MSA). Processing of cattle through this system enables us to receive valuable feedback on the eating quality of the beef produced. Assessment of this feedback is now much easier through the development of online tools in MyMSA, enabling us to identify areas of possible improvement in terms of the eating quality aspects of the beef we have produced. This online benchmarking and interpretation of MSA results is a useful tool for producers to use in their own research into the options available to improve in specific areas that influence meat quality and ultimately increase carcase compliance. Increased ease of reporting through an online carcase feedback system such as Livestock Data Link (LDL), may further improve the ability of producers to act on information to improve compliance (Quigley 2016).

You don't know your performance if you don't measure it. In saying this, measuring reveals little if you don't take the time to interpret and understand the results. By marketing a portion of our cattle through MSA we have gained insight into how we can and have improved quality of the product we supply in relation to eating quality. Management alterations we have focused on to increase compliance to MSA include: sales concentrated during optimal seasonal conditions, cattle handling, husbandry procedures, nutrition and genetic selection for important carcase characteristics.

Why are we motivated to produce better steaks?

Our business aim 'is to develop a supportive working environment to efficiently produce quality adapted beef cattle using sustainable environmental management; combined with objective selection for growth, reproduction and carcase traits.' Key to achieving this is to develop ways to effectively measure and implement objective selection. Within our business it is important that we measure performance, take the time to interpret these measurements and where possible use benchmarks to compare the performance to what may be achievable. Inevitably through measurement of performance, aspects within the business that represent opportunities for improvement are revealed. Through efficient improvement in the quality of the product we produce, we are better positioned to be able to market our product or maximize returns through achievable premium market compliance.

How do we produce better steaks?

As a fifth generation cattle producer with a rich history of family involvement in research and development I can only possibly highlight the 'tip of the iceberg' where research outcomes have been adopted into our business model and the direction of research we hope can be adopted in the future. Numerous people and organisations have left a significant legacy for our business from previous research, development and adoption opportunities.

Some of the current practices we accept every day in our business were not part of 'normal' operating procedures in the past. Improved efficiencies and production gained through the business over time highlights the importance of not continuing tradition for traditions sake. 'Our business concentrates on performance, not tradition. Our focus is on efficiency; however, we do not compromise quality.' Data driven justification of our decisions and practices is extremely important to ensure the relevance of them achieving our goals. The more information we have to understand the cost and predicted benefit of different practices, the more likely we are to adopt them into our business.

A general understanding of our production background will help to put some of the following comments and observations in context. Barranga Grazing breeds and finishes cattle within the tick zone of Central Queensland. Seasonally mated cattle are expected to wean a calf each year to continue as part of the reproductive herd. Cattle are marketed according to their weight, age, finish and ability to achieve market specifications as export carcases, MSA carcases, feeder cattle and cull cow or bull carcases. It has been important for us to set the parameters within which the herd needs to perform in this typically variable climatic environment. Having clear performance parameters

helps to maintain the quality we aim to achieve – 'the standard you walk past is the standard you accept'.

Information typically comes through data collection and ultimately interpretation of this data into a meaningful form to understand what is happening. The epidemiological approach of the CashCow project (2008 to 2011) highlighted that significant data collection in a large variety of settings is possible. This data has provided a valuable resource for benchmarking and in herd testing of various identified practices, forming a useful guide for production decisions - with the proviso that the CashCow data is relevant to the individual country type (McGowan et al. 2015).

Research and development of this type has and will continue to provide a comparative means by which producers can converse in the same language. CashCow ultimately refined definitions and measures of reproductive efficiency for the Northern beef herd and at the very least stimulated the investigation of what constitutes reproductive efficiency and how we measure it.

Within our own herd performance recording, incorporation of standardized production and performance measures as influenced from the CashCow project have better explained reproduction performance of the business. Retrospective calculation of these measures (where the data is adequate to make it possible) has similarly given us an opportunity to see the relevant trends over time and in years representing our highly variable climate. Whilst we had production and performance measures recorded before, advantages came from making the performance measures used reflect all stages of losses or gains throughout the year, as well as including liveweight production in the performance measures, hence encapsulating body weight changes of cows and losses through mortality.

In many ways, the CashCow project highlighted the different levels of decisions that can be made through collection of data. Available immediately are crush side decisions on an individual performance level, a tool that we rely heavily on for timely decision making on an individual level. Whole herd performance results are typically used to demonstrate performance over time, assist with goal setting and influence decisions on whole business directional change.

Bull power and phase II and III of the Beef CRC gave us some very practical measures to apply, whilst still appreciating the superiority of selection that will come through improved accuracy of Estimated Breeding Values, particularly for hard to measure traits. Within our commercial herd, the use of rotational cross breeding and lack of pedigree data becomes limiting in the implementation or recording of specific breeding values within the herd. Of benefit to us though is to utilize what practical measures we can to improve selection within our herd for relevant reproductive traits.

Measures of scrotal circumference and percent normal sperm (PNS) are a simple pre-requisite for all bulls mated each year, with further refinements in reducing the age of measurement for scrotal circumference to help improve 'selection criteria for genetic improvement of bull fertility' (Burns et al. 2015). A relatively high genetic correlation between PNS in Brahmans at 24 months and Lactational Anoestrus Interval in females (-0.65) (Burns et al. 2015), has given encouragement to possibly utilize this with some caution as a 'potential indirect selection criteria' (Burns et al. 2015) for earlier selection for positive influence on an important female trait. These are not definitive measures, however in recording these we are able to place some selection pressure on individuals, the outcome of which is aimed at accelerating genetic improvement in our herd.

The Beef Information Nucleus (BIN) project with the Brahman breed has already provided increased accuracies in some Estimated Breeding Values for individual performance. Providing an important database to underpin genomic evaluation, with time this project should help reduce our long generational interval through access to accurate state-of-the-art genetic evaluation technologies applicable to early in life selection. Whilst growth data formed part of the project, data collection on meat quality and fertility traits that are typically hard to measure have the potential to provide some of the greatest gains for the breed. Good planning of the project to include linkage to earlier CRC sires and to sires utilized in other projects has improved the applicability of the data collected. Ultimately, the database should continue to add value for the Brahman breed well into the future, helping to drive genetic improvement as genomic technologies evolve and are refined.

Utilisation of EBVs for genetic selection within our business has certainly been a progressive journey and will continue to be. As one of many tools in our toolbox for selection, the ability to utilize EBVs provides us with increased confidence that our selections for current genetics (typically as semen or bull purchases) will continue to help us achieve our production goals in the future. Like all tools, EBVs need to be used in conjunction with other tools available, but they do help to make our selections more efficient. Unfortunately, in wanting to utilize them we have been frustrated with low accuracies on hard to measure traits, difficulty in accessing cattle with EBVs for hard to measure traits and restricted availability of genetically evaluated cattle across different breeds for a variety of carcase and fertility traits. This is where we hope for significant breakthroughs in genomic evaluation to supply accurate data earlier in life, to assist to accelerate genetic improvement of our herd.

What influences us to produce better steaks?

There have been many projects, reports and research findings that have influenced our business decisions and modelling. Practical extension opportunities have and will continue to be fundamental to giving us confidence in implementing different technologies or utilizing new tools. MLAs new Profitable Grazing Systems program may become another on ground support tool to improve best practice uptake of data driven decision making through a small group learning model (Nott 2016). Key to this and other successful adoption strategies is the availability of support and practical expertise.

Adoption success can also be heavily influenced by how difficult it is to actually implement the practice or research into the business. It is very easy at workshops to theorize on the ideal practices to follow, but indefinitely the application in reality is not as simple. Planning can help to decrease and preempt some of the difficulties that may be encountered, but inevitably the practical experience of application reveals aspects not considered. Ultimately we need enough conviction and support to persist through the obstacles that will become apparent. Sometimes committing to an involvement with a research and development project has been crucial to ensuring we see it out. Similarly a commitment through formally recorded goal setting can sometimes be the reminder necessary to ensure we continue to implement a change. Follow up support, whether on the ground or simply through verbal communication has proven invaluable to maintaining our enthusiasm to implement new technologies or tools.

With the need to be financially viable into the future, cost of implementation has a major influence on motivation to adopt a new technology or tool in our business. The running of financial evaluation of cost/benefit ratios as part of every research and development project cannot be over emphasized. Whilst overall cost may in some instances prevent an adoption of a practice, typically we can implement something with confidence when the payout is expected to be greater than the investment. If we are able to demonstrate good returns on investment, the technology has a much higher chance of being utilized by us and adopted into the business at a much faster rate.

In promoting uptake of different research outcomes the focus on producer experiences through case studies and demonstration sites are a vital tool we have relied heavily upon to stimulate our interest. All producers have differing personal motivations and desire to want to find out research outcomes, but so many of us cannot help but look over the fence to see if the pasture really is ‘greener’ on that side. The 2016 Northern Beef Research Update Conference theme ‘It’s time to connect’ and current MLA focus on ‘Research in action’ are timely reminders of how we can all improve what we learn through sharing of experiences.

Where are we planning our next great steak?

As we go forward we need to make sure we are not reinventing the wheel of research and development. Certainly opportunities for collaboration ensure greater efficiency in research & development planning. The three phases of the Co-operative Research Centre (CRC) were excellent examples of the enhanced value possible from collaboration and sharing of research assets to achieve research outcomes. Similarly the design of linkage between genetic research projects

expands the database available to utilize in the research, thus helping to improve accuracies of outcomes. Currently the possibilities of accelerated improvement in genetics through genomic development is very exciting.

Core to all desirable research outcomes is the successful adoption by producers to enhance their own productivity and the overall performance of the Australian Beef Industry. Practicality of research and development, promotion of the outcomes and support in implementing the outcomes are all key aspects to ensure every dollar spent on research, development and adoption has the potential to convert to improved performance and productivity of the Australian Beef Industry. To remain competitive on a global scale it is important to continue to build on the gains of the past with positive future influences. This is not a journey with a finite end, but it is a journey the entire industry is on together. In this 'time to connect' we have tremendous opportunity to share and celebrate our progress to ensure we have enough enthusiasm to continue on the next steps of our journey together.

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A producer's perspective of R&D – "The farmers and the cowboys should be friends"

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Introduction

As a beef producer I have been asked to give my perspective on how research and development has impacted on how we run our property in Western Australia. Indeed the role and ongoing impact of R&D has been significant for the beef industry in general over the years. However, one can become sceptical in how any of this can make a tangible impact on one farming business in an area well known for grazing since 1851 when leases were taken up by the Cattle Company, and the first house of wattle and daub with thatched roof was built. In 1859 the first tillage lease was taken up in the district by John Smith, who built the first flour mill near the Irwin River Estuary in 1865 so our district has been associated with grain and grazing operations for a long time.

Our change in operations since the 1990's has been driven by a number of external factors far removed from the concept that R&D opportunities were there for the choosing and immediate adoption was to bring about significant farm practice. In reality what has driven our change of management on Avoca has been based on having to face the ongoing issues of water logging across the property, herbicide resistance in traditional crops and overall wind erosion. The pathway to change has however, been facilitated by R&D. We've been lucky to maintain relationships with the Mingenew Irwin Group to ensure new practices on farm are not only applicable to the sand plains of WA, but also drive the change required to ensure environmental sustainability and profitability. Without doubt "the fear of growing broke is the mother of innovation' and if R&D gets innovation on farm that keeps farms and families in agriculture then that has to be a good thing. For us the change required was obvious; it's been rewarding and we're still on Avoca, but it's been a long journey with a few twists.

Background

When we first took up Avoca the property relied on an income derived from sheep and some cattle. We also cropped some wheat and lupins, which wasn't unusual for the area, but years of farming was taking its toll on a reasonable fragile land base. For those familiar with WA, there's a lot of sand and the Irwin District is no exception. High coastal dunes are backed by lower dunes on limestone. Deep sands are the dominant soil and most of the land is gently sloping. Calcareous deep sands are found on the coastal dunes. Inland on the low dunes over limestone are Yellow deep sands with Yellow/brown shallow sands and Calcareous shallow sand. There are also patches of Red shallow and deep sands. Only the colour of the sand seems to vary. The white sand plains are extensive in our part of the country and keeping them covered is a priority especially when that's most of the 3600 ha that makes up Avoca. Across the Geraldton-Dongara area about 43 % remains uncleared including most of the coastal dunes. We've retained 600 ha under remanent vegetation, mainly Banksia, Melaleucas, Mallee and various Acacias and this is not a small area to have out of production, but to be honest it's just not worth clearing. For the present we're content to concede that it does provide a natural habitat, maintains diversity on farm and a refuge for native fauna and flora. It also provides a refuge for some ferals, which we're all familiar with, but at least it's not deemed a national park and we can exercise some control over how it's managed.

Despite having an annual rainfall of 400 mm per year, we were still experiencing water logging across some parts of the farm and combined with herbicide resistance this was making cropping less and less feasible (Figure 1). We knew we had to change the way we operated. Across the district the discovery of natural gas, the development of the rock lobster industry and the mining of lime sands added new economic dimensions to the long established agricultural industry, but we needed an

alternative. Current irrigated agriculture includes nuts, olives and melons, but we needed something innovative that would keep us viable.

Figure 1. The transformation of Avoca. In 1999 we faced water logging, herbicide resistance and significant wind erosion (left) and now 2016 (right).

Avoca now

In 2003 we made the decision to run Avoca as a cattle backgrounding operation and a "Beef Alliance" was formed. The whole idea was really based on maximising complementary grazing systems and there was no R&D that suggested we couldn't. Our current operation is now based on growing out or backgrounding pastoral cattle which have come down from a Tropical region characterised by December – April rainfall (500-1200 mm). We specifically source cattle from properties in the Kimberleys, Pilbara, Upper Gascoyne and Central highlands near Walloona. Our Mediterranean climate, characterised by 350 – 600 mm annual rainfall in May to October, provides stock an opportunity to achieve quite acceptable live weight gains on our perennial pastures, annual shrubs and shrubs. The feed complementarity to background and value-add pastoral cattle has sound justification from existing R&D, but the actual application across the two regions is far less detailed. Nevertheless, I believe we are now maximising the potential of both our northern station partners and Avoca – and I have some new "friends". Our top carrying capacity is 2800 head in spring and our annual turnoff is often 3000 head (Table 1). The feed complementarity to background and value-add pastoral cattle is based on our mix of annual and perennial pastures; Gatton Panic, Rhodes grass, blue lupins, Rye grass, clovers and serradellas. More importantly, we have and continue to invest in perennial shrubs; Umbrella bush (*Acacia ligulata*), Saltbushes (*Atriplex amnicola*, *A. rhagodioides*, *Enchylaena tomentose*, *Rhagodia presseii*), Nitre goosefoot (*Chenopodium nitrariaceum*) and small leaf blue bush (*Maireana brevifolia*), but now more selective in the varieties we plant out. Most of these shrubs have already been identified in the ENRICH program which was part of the Future Farm Industries CRC which was responsible for developing profitable shrub-based systems for the low-medium rainfall (250-500 mm) mixed-farming region of southern Australia. The investment in the perennial shrubs has not been taken lightly as it's a significant commitment of time and land that could be used for other purposes. For us it suits the country and offers diet diversity, shade and shelter and I also believe some extent of self-medication against parasites such as lice and intestinal worms. Again, there's some justification in current R&D, but it would be highly valuable to capture this aspect across the two regions with some new projects and how we're producing better beef in the long run.

Table 1. Average grazing potential for pastures typical of the Irwin District

Pasture	LSU grazing days/ha/year
Annual grasses – no rotational grazing	75
Annual grasses- with rotational grazing	120
Perennial grasses with rotational grazing	300
Tagasaste with rotational grazing	250
Perennial shrubs	250

What is R&D?

For us R&D has provided tools and some validation that our change of operation was indeed the right thing to do. Improving pasture utilisation has always been a goal and there's sufficient science out there that clearly shows that this translates to better animal productivity. Matching the feed demand to the feed supply is also critical to this – our version of "sustainable grazing" is now based on a combination of annual and perennial pastures, but just as important has been our investment in native perennial shrubs. I believe the environmental benefits/biodiversity we get from these plantations far outweigh the effort in getting each shrub individually planted as tube stock. Some of these aspects are yet to be quantified and we'd dearly love to see more work in this area to demonstrate that a viable alternative to monocultures exists for the beef industry in this part of Western Australia.

In 2013 we got involved in a project with our local land care group, Minginew Irwin Group called Shrubs for Emission Reduction and Carbon Storage (SERCS). We were at the pointy end of R&D and planted 7256 shrubs as tube stock over a 16 ha block (453 plants/ha) in July after a very dry winter in 2013. Only 71% of those shrubs survived – it was a terrible season, but we persevered with the shrubs. Undeterred we planted more shrubs two years later. In 2015 we planted about 10,000 salt bush seedlings of a new variety "Anameka" (Figure 2). This was a new variety of old man salt bush developed by CSIRO and supplied as tube stock by Chatfields Nursery. We changed our configuration from two rows which was commonly being used to 4-5 rows with larger inter-rows for additional shade and shelter. The 10,000 Anameka were planted out over 20 ha and we managed 92% survival on 50 mL of rain that year. We grazed this block in December 2015 and again in April/May 2016 with a 100% recovery rate. Our contribution to on farm R&D was looking good. This year, 2016 we planted out about 10,000 additional perennial shrubs so are truly committed to the perennial shrub system that supports our own "beef alliance".

What have we learned from our involvement in the SERCs program? The problems associated with traditional monoculture in crops and pastures can all too often lead to the adoption of too many alternative species. The SERCS project had seven different species, mainly saltbush of one type or another, but the plantings couldn't support a replicated grazing trial although there was no shortage of diet diversity across that 16 ha. Replication is king in R&D if you have any aspirations to get meaningful data from on farm projects. Unfortunately it doesn't always get the commensurate level of funding it deserves and work becomes indicative, or another proof of concept, in the hope that larger funding opportunities are on the horizon. At worse we can end up with another producer demonstration site for a couple of years that all too soon gets forgotten when the funding dries up. However, to be fair the SERCS project involved seven participating properties in WA, NSW and

Victoria, each dedicated about 20 ha to establishing shrubs to incorporate into their existing grazing system. The sites differed in climates, soil types, enterprises and farming systems. These sites were not intended to be replicates, but were designed to demonstrate to landholders that shrub-based systems can be incorporated into their farming operations. On farm we now know that improved management and ultimately cattle productivity can be achieved by using a couple of performance species and annual/perennial grasses only. Diet diversity is highly regarded in extensive grazing systems, but having shrub species with similar attractiveness/palatability and growth habit proves to be particularly useful if achieving uniform cattle productivity across each hectare is the end game.

Figure 2. Anameka is an improved line of Old man saltbush developed by CSIRO and now commercially available at Chatfields Nursery (WA).

The SERCS project hasn't been our only involvement in on farm R&D. In 2014/15 MIG also managed to secure funding for CSIRO to measure methane emissions from cattle grazing these shrubs (Figure 3). The use of lasers to measure methane in the paddock is attractive because it not only gives us direct measures at the herd scale, but also becomes very regionally relevant. For us, it was equally important to know if any improvement in animal productivity on shrubs could be related to lower emissions intensity (methane/ kg ADG) compared with grass only pastures. Unfortunately, the exercise was only a short term trial of about 60 days, although measurements were carried out daily except when adverse weather created unstable conditions which for one event included hail!

The two groups of animals had similar weight gains over the grazing trial and methane emissions were estimated to be between 115 to 125 g/head/d for both groups. We had expected some difference in emissions, but the short term nature of the trial didn't help. Shrub-based grazing systems have been shown to reduce GHG emissions intensity of sheep production compared to grazing conventional, senesced annual pasture in autumn. The study suggested that over a five week period there was no abatement benefit for cattle grazing pastures with perennial shrubs over grass only pastures. We need more production and emission data especially when the shrubs constitute a larger proportion of the diet. Our project had well established shrubs, but they were still small plants, and constituted only about 5% of the feed on offer and possibly as little as 1% of the total intake of

the cattle. Nevertheless, the complementarity between the pasture and shrubs is evident. The SERCS project has shown us that shrubs provide a higher level of crude protein and a lower level of plant fibre compared to typical grass pastures across southern Australia. Some of the shrub species possessed nearly twice the concentration of crude protein and half the concentration of fibre as the grasses assessed in the SERCS project. As the shrubs grow and become a greater proportion of the diet of our cattle I would still expect that the benefits arising from the shrub forage will be realised. Industry needs more data especially when we include more perennial shrubs in the diet. Lowering our GHG emissions is likely to occur, and it's a benefit for both us and our northern partners or "friends", but we need another opportunity to get those lasers back to WA so we can actually measure it.

Soil organic carbon data was also collected at Avoca as part of the SERCS project. This will now enable us to make more measurements in the future to assess if a net improvement in carbon balance can accrue through increased carbon storage in the shrubs. Any measurable change in soil carbon due to the perennial shrubs would not be expected for some years, but we can now be more confident that our "beef alliance" will keep us in business for a few more years yet and we can capture these long term benefits.

Figure 3. Open path lasers have been used by CSIRO on Avoca to measure methane emissions form cattle grazing perennial shrubs.

The future

Our involvement in R&D with the shrubs has not only been personally interesting, but of significant benefit to our industry in WA. The alliance with properties in the north has provided a productive outcome and maximises complementary grazing systems. However, with distance and the logistics involved in this operation we still need to improve our transfer of information and that is not unique to our own beef alliance. The issue of information transfer across the industry is critical to beef producers being more informed and competitive in a global market. Specifically we need to be able to readily identify animal weight gains in grazing systems and use this basic information to our advantage. If some of us are to use more perennial shrubs on our properties then we need to know what benefits we accrue over time. The better combination of perennials and annuals really is a form of symbiosis and the adoption of improved paddock design for wind protection, erosion and optimal grazing management can only be a positive for the beef producer. These paybacks may not necessarily result in financial gains which we can add up on a spreadsheet. We're seeing an increasing focus on sustainability and environmental benefits because there's also growing interest from the consumer in what we do on farm…and why. The R&D really gives us the "why" which is so important.

Conclusion

Our interest, and involvement in on farm R&D has now become long term. In the late 1990's we knew we knew we had to change the way we operated. Almost 17 years later we're now in a far different and better positon than we would have been if we had kept doing the same old thing. We've embarked on a R&D journey which may have no end, but the payback to date has kept us in operation and for the most part my involvement on committees and panels is invigorating. I expect delivery of R&D is similar and there's always room for change, but we need to fund projects for 5 – 10 years rather than three to really appreciate the value to the producer and capture any seasonal biased that can easily influence results and interpretation. We shouldn't be frightened of new ideas, nor the challenge that comes with them.

Acknowledgments

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Measuring the impact of on-farm R&D: Benefit-cost approaches and trends

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Abstract. There is general agreement that research and development (R&D) has positive returns, but measuring the impact is possible only over broad ranges. This paper briefly looks at two methods, the bottom up and top down approach, of measuring the impact of R&D as it pertains to agriculture and specifically research to improve on-farm productivity. The findings suggest that for the beef industry limitations exist in attribution of impact to specific research projects, access to data, and the response curve of technologies at the farm level. However, these limitations are becoming fewer overtime. The synthesis of literature suggests the current Benefit-Cost Ratio (BCR) on R&D in beef cattle in Australia is between 2:1 and 4:1 when measured at the "on-farm" level. Much higher benefit cost ratios are reported when analysis include wider impacts such as producer and consumer surpluses. Interestingly, there appears to be diminishing returns on research and investment dollars spent, however, since this was not tested explicitly in the paper, it is an area of further investigation. Lastly, on limited information, it appears that both methods produce similar results when used to measure beef industry returns on R&D.

Introduction

There is broad agreement that there are impacts of, and returns on, research and development (R&D) (Parham 2007) but outside of broad estimates being able to describe the results with confidence is difficult (Productivity Commission 2007). However, measuring the impact of R&D is vital for research funders to determine if their investment is making the intended beneficiaries better off. Around $400 million dollars per annum was spent by MLA into grass-fed beef research across a number of marketing, on ground, processing and other areas over a 5-year period (Centre for International Economics, Agstrat Associates Pty Ltd, ISJ Investments 2016). Therefore, it is critical to know whether this funding is making a return to the industry and that each individual project is having a beneficial impact.

Broadly, there are two methods which are used to measure the impact of R&D with the BCR approach. The first is the bottom up approach (generally at the project level) which attempts to explain impact to direct participants and industries for which the research was undertaken. These impact metrics can then be used to extrapolate benefits to larger populations, including societal and environmental impacts. The second is at an aggregated level (top down approach). The top down approach takes high level data and attempts to narrow down the probable cause of movements in data. The two methods work by analysing a "with" research and "without" research scenario and attributes the difference as impact of research.

This paper looks primarily at the first method as a means for measuring impact and provides a brief overview of the second. Lastly, it investigates what both methods suggest have been the impact of research and development on the beef and other agricultural industries.

The bottom up approach

The bottom up approach method usually seeks to determine what the impact of a project has been on either the direct participants of a program or a specified target group. For example, a project to improve the productivity of Brahman cattle might consider the entire Brahman grazier population as its intended audience, since its results or outputs would likely be limited to Brahman cattle. Many bottom up approaches to project evaluations have been done in the past, all using much the same framework (Griffith and Burrow 2014); (Moravek and Nelson 2015). In the simplest form, the approach is to determine the level of profitability or productivity increase at the farm level

for producers who adopt the research outcome and multiply that by the number of farms that adopt the technology (Equation 1).

Equation 1: Project level equation for on-farm R&D impact.

$$Project\ Net\ Benefit = \Delta Farm\ Profit \times adoption\ rate \times number\ of\ farms$$

Generally, assessing on farm profitability for agricultural activities such as broad acre cropping is simple enough (Productivity Commission 2007). However, for beef production many response functions are unknown and many estimates of impact are based on expert opinion or gathered through workshops (Centre for International Economics, Agstrat Associates Pty Ltd, ISJ Investments 2016). Measuring on farm profitability has been primarily achieved through case study approaches; however, an assessment of the micro approach (Griliches, 1979) found that while case studies provided great detail, they were never representative. Secondly, the data was rarely available for these kinds of impact analysis. On the other hand, case studies have been classified as quantitative hard analysis and possibly the best way to evaluate emerging activities (Dart *et al.* 1998). While access to data has likely improved, it is very much still an issue at the farm level (Henderson *et al.* 2013) and representative farms still do not exist.

A larger issue for determining the impact of R&D is attributing adoption to specific causes. This has been found to be a very difficult thing to achieve (Alston and Pardey 2001) and is thought to be a major factor of over-estimation of benefit-cost ratios. Alston (2001) found that earlier analysis, in particular, suffered from errors in estimation of adoption and benefits caused some projects to return 100s of times the money invested. Highlighting the attribution issue, one project evaluation calculated a benefit cost ratio which would return more than half the gross domestic product of the United States.

Many improvements have been made to the bottom up approach to reduce the limitations including improved methodologies to predict adoption peaks, curves and lag time. Tools like ADOPT (Kuehne, *et al.* 2013) can go further still by determining adoption with and without research, assisting to reduce the errors seen in earlier benefit cost analysis. The bottom up approach can also be adapted from Eqn. 1 to include environmental and social benefits and cost. Depending on the scope of analysis, it can be further modified to determine the impact on consumers and suppliers worldwide.

It should be noted that BCRs calculated using producer and consumer surpluses often have larger BCR's. One example is the BCR's calculated for the Beef CRC project. One evaluation includes producer and consumer surpluses (Giffith *et al.* 2006), while the other does not (Griffith and Burrow 2014). The former produced a BCR of the Beef CRC of 35:1, whereas the later produced a BCR of 2.94:1. While the phase of the CRC was in a different period when the analysis were undertaken, it is likely that the inclusion of social benefits significantly increases the BCR in this example. This demonstrates that the scope of analysis is important when interpreting and comparing BCR's for investment decisions and measure of success.

The continual improvement of the bottom up methodology and the underpinning data has likely helped improve accuracy and reduce variance of reported benefit cost ratios over time (Fig 1). While it is true that allocating adoption can only be done with some accuracy well after the research outcomes have been commercialised (Productivity Commission 2007), the bottom up method is still considered robust and is widely used.

The Top Down approach

The top down approach uses macro-economic, or "big data", such as total factor productivity (TFP) to estimate the impacts of research. The TFP approach generally looks at a resulting level of output based on a pre-determined set of inputs or costs after correcting for prices, inflation among others. If total output increased at the selected input level, then the industry is considered to have

become more productive. TFP for the Northern Beef industry is shown in Table 1. Interestingly, the industry showed no productivity growth for the first 20 years of analysis.

Table 1. TFP for the northern beef industry

Scale	TFP (1977 – 1995)	TFP (1995 – 2007)	TFP (1977 – 2007)
Overall	0.00	1.14	1.05

Source: (Nossal *et al.* 2008)

While such top down approaches have been found to be the most appropriate form of analysis for determining impact at large scales, the method is unable to infer causality of impacts and in general, data did not exist (Griliches 1979). Furthermore, since TFP cannot eliminate all factors other than R&D, R&D is therefore not solely responsible for all of TFP. Other factors, such as seasonality, scale, industry structural changes and public infrastructure all contribute to TFP. It therefore suffers attribution issues similar to the bottom up approach.

The most recent example of a top down approach specifically pertaining to beef research was undertaken by the CIE (Centre for International Economics 2009). To attribute the contribution from R&D the authors had to assume impact of research and development. They noted the necessity of this as both the techniques and data to do this was non-existent. However, previous research had also shown that for northern beef, TFP would have been 60% of the observed TFP without research (Nossal *et al*. 2008). Therefore, the CIE assume 40% of TFP as being attributed to Research (Centre for International Economics 2009). The results of this analysis can be seen in the following section.

Historical and current estimates of the return on research and development

In this paper, 54 individual agricultural projects' BCAs were plotted over time. The majority of these projects (n=53) used a bottom up approach. This information came from a variety of literature, synthesis reports and individual project reports (see references). This review of literature shows that the variance of reported benefit cost ratios has likely reduced overtime (Fig. 1.). However, the reason for this is not clear. It could be that methodologies are more robust, but could also mean that there is diminishing returns on R&D. There also appears to be a downward trend, but this was not statistically tested.

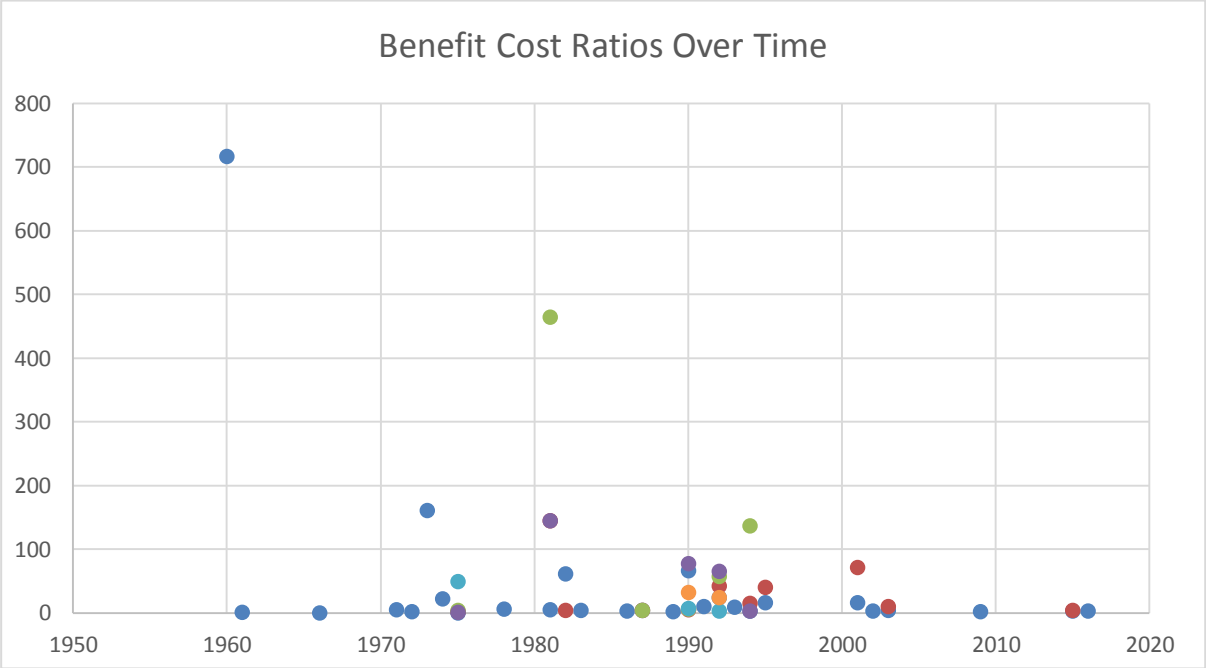

Fig. 1. A sample of benefit cost ratios over time for agricultural research projects.

Focusing on recent examples which seek to measure the impact of R&D shows that, at least on larger R&D projects, the expected industry benefits were between 2:1 and 4:1. This means that for every $1 spent on R&D, between $2 dollars and $4 dollars were generated in industry benefits. Interestingly, the approach, whether top down or bottom up, made little difference to measured impact (Table 2). It should be noted there are only four examples here and such inferences need more data.

Table 2. Recent evaluations of impact of research and development in the beef industry

Project evaluated	BCR	Approach Taken	Source
Beef CRC	2.94	Bottom Up	(Griffith and Burrow, 2014)
MLA 'On-farm productivity'	2.7	Top Down	(Centre for International Economics, Agstrat Associates Pty Ltd, ISJ Investments, 2016)
Beef genetic research -Cross Breeding and Selection	3.6	Bottom Up	(Farquharson *et al*. 2003)
MLA + DPI On-farm R&D	1.9	Bottom Up	(Centre for International Economics, 2009)

Discussion

While it is only possible to broadly measure the impact of R&D, the bottom up and top down approaches to benefit cost analysis provide a framework to both estimate the impact of research and development. However, this paper describes a number of limitations, improvements and points of context that monitoring and evaluation practitioners should account for when choosing and applying a methodology. These are:

1. Determining who the intended beneficiaries of the research are will assist in measuring the benefits. (i.e. is the intended beneficiary industry, or society as a whole)
2. Obtaining a sufficient number of case studies to provide reasonable representation of the population (particularly for a bottom up approach). Ideally, case studies should be randomly selected.
3. Measuring adoption will be difficult and is a major limitation for ascertaining impact. Sensitivity analysis and expert opinion, as well as using tools like ADOPT, can help.
4. Take care in interpreting BCRs between proposed or finished projects, particularly if the intended beneficiaries and scale of analysis is different.

Other interesting insights gained from this mini-review include:

- Bottom up methods of measuring impact of research and development over the period between 1975 and 1995 suggested BCRs of between 0.2 and 464.5 during a period where total factor productivity growth was 0.
- BCR ratios are possibly declining over time; however, this is not a conclusion that can be drawn from this data.
- Recent evaluations into the impact of R&D show BCR ratios of between 2:1 and 4:1
- Only three (3) out of the 54 projects failed to provide a BCR of 1:1.
- Widening the audience of the impact evaluation to include social benefits is likely to increase BCRs.

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Cows have no requirement for crude protein

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Introduction

Cattle have no requirement for Crude Protein. Cattle require amino acids to function, grow and reproduce. The bacteria that populate the rumen and do the bulk of digestion for the cow have a requirement for some Rumen Degradable Protein (RDP) and Rumen Ammonia (NH_3) but the animal itself simply has a requirement for amino acids.

Beef cattle are the last group of production animals worldwide where amino acid nutrition has yet to be accounted for in the ration. Poultry, swine and aquaculture nutritionists have been formulating rations based on amino acid content for decades and dairy rations are now balanced for at least 3 key amino acids in modern diets.

So what is Crude Protein?

Crude Protein (CP) is just that, a crude calculation showing the Nitrogen content of a feed. The CP formula assumes that the Nitrogen in any feed is all in the form of protein and that it has an average amino acid profile. Here is the major assumption. The average Nitrogen content of amino acids is the factor of 6.25%.

Therefore Nitrogen (N) multiplied by 6.25 gives feed a Crude Protein value. This is rarely the case of course, and means that the figure quoted on the bag, box, tub or block of feed is at best a crude approximation. Probably the best and most widely used example is Urea. Urea has a Nitrogen content of 45%. This gives Urea a CP value of 281% which is of course impossible and we know urea contains no actual protein. At this rate it is easy to see how manipulation of feed formulations can give false confidence in its value. For example, take barley straw from the table below. If we were to package barley straw with urea at a rate of 10%, you could label the product 30% Crude Protein. This would make it a better looking protein source than lucerne hay.

Table 1. Crude protein content of some common feeds

Feed	Crude protein (% DM)
Wheat grain	13
Oat grain	10
Cottonseed meal	42
Lucerne hay (early flowering)	22
Barley straw	3
Native Tropical Grasses wet*	7.8
Native Tropical Grasses dry*	2.8
Temperate Ryegrass	36.3
Urea	281
Microbial Protein	62.5

**local data Bowen et al.*

So what are amino acids?

Amino acids are small molecules that are essential for life and the building blocks for every protein in the body. Fig. 1 below shows some of the essential functions amino acids are responsible

for. Consisting of an amino (NH_2) group, a carboxylic group COOH and an active side chain that differentiates the function of the molecule, there are 20 common amino acids required for general function in all animal life. What is important to note at this point is the 'N' in NH_2. Although we now know it as Crude Protein it is this Nitrogen that is critical to the ability of the rumen bacteria to reproduce and function effectively in digesting cellulose. A minimum amount of rumen ammonia is essential to the performance of bacteria in the rumen, however if excess crude protein is fed to the animal anything surplus to requirements is simply excreted via urine.

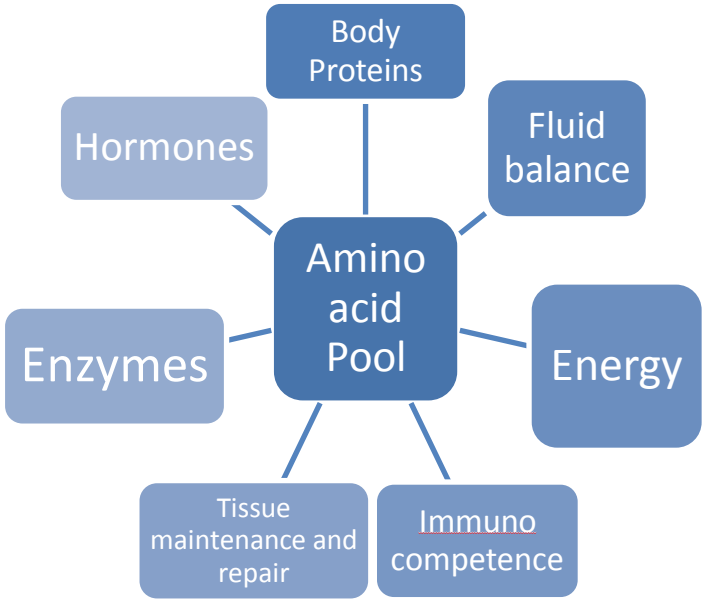

Fig. 1. Essential functions of amino acids

The rumen is the amino acid factory of the cow. Every millilitre of rumen fluid contains 10,000,000,000,000 bacteria. When you consider the mature rumen holds around 80 to 100 litres, it is easy to imagine the vast bacterial fermentation capacity. The cow has designed itself around this perfect fermentation vat. Kept at 40 degrees, warmer than the animals own core body temperature and kept at optimum pH with urea, bicarbonate and fluid levels automatically adjusted by the minute.

Why is the health of the bacterial population so important? Because they in turn become the protein for the cow. An ideal source of protein with the optimum profile of amino acids. Looking at figure 2 below, you can see the ideal profile of the three most limiting amino acids in ruminant production, Lysine, Methionine and Histidine with the perfect combination of these three labelled 'ideal'. Above this are the profiles of the same amino acids for milk and for microbial protein. It is evident that the best thing you can do for the efficient production of your herd is to generate as much milk for calf growth and encourage turnover of grass facilitating as much rumen activity as possible. There is no other form of feed (outside of high quality fishmeal) that will generate the profile required.

All bacteria are not created equal. There are over 3,000 species of rumen bacteria and archaea, with 20 species making up over 80% of the population. the 'good' bacteria can take up to 4 weeks to become a healthy dominant force in the population whereas the bad bacteria (as in the case of acidosis) can dominate the population in just 4 hours. It is important to encourage strong steady growth of rumen cellulolytic bacterial species: *Fibrobacter succinogenes, Ruminococcus albus* and *Ruminococcus flavefaciens* for example as they are your greatest carbohydrate (plant cell wall) digesters. When these bacteria thrive, they reproduce and this turnover creates a byproduct. This byproduct of bacterial fermentation and growth is actually an essential form of energy for the animal providing up to 90% of energy required. These energy sources are the Volatile Fatty Acids (VFA's) Acetate, Butyrate and Propionate. As discussed, the bacteria themselves have a finite lifespan, so

when they leave the rumen and are digested by the true stomach they become the ideal protein source, providing up to 85% of the protein requirements of the animal.

Table 2. Amino acid content of some common feedstuffs, Met (methionine) Lys (lysine) and His (histidine)*.

	Lys	Met	His		Lys	Met	His
Milk	7.7	2.7	2.7	Canola Meal	5.6	1.9	2.8
Rumen Bacteria	7.9	2.6	2	Corn DDGS	2.2	1.8	2.5
				Corn gluten feed	2.7	1.6	2.9
Ideal	7.2	2.5	2.5	Corn Gluten meal	1.7	2.4	2.1
				Cotton Seed	4.3	1.7	2.8
Lucerne silage	4.4	1.4	1.7	Linseed meal	3.7	1.8	2.0
Corn Silage	2.5	1.5	1.8	Soybean meal	6.3	1.4	2.8
Grass silage	3.3	1.2	1.7				
				Bloodmeal	9.0	1.2	6.4
Barley	3.6	1.7	2.3	Feathermeal	2.6	0.8	1.2
Corn	2.8	2.1	3.1	Fishmeal	7.7	2.8	2.8
Wheat	2.8	1.6	2.4	Meatmeal	5.4	1.4	2.1

*Adapted from Schwab 2015

What is the most efficient form of true protein/ amino acid delivery?

In a nutshell, the most cost effective and energy effective form of protein you can feed to an animal is as microbial protein that passes from the rumen and is consequently digested. What we need to do is ensure the animal has the correct building blocks in the correct form to maximise rumen fermentation and microbial load.

Forage protein is extensively fermented in the rumen, however Bowen *et al* found that Ammonia Nitrogen in the rumen when steers were fed typical C4 pasture native to the Northern Pastoral zone the rumen ammonia generated by the feed an average of 8 milligrams per litre. When we compare this to the same animals eating temperate ryegrass, 382 milligrams of ammonia per litre were generated. With 47 times more ammonia, it is obvious that the bacterial pool does not have nearly enough of our 'building blocks' to ensure cellulose fermentation and cellular turnover resulting in a limited true protein pool being delivered to the animal.

Further evidence that cattle do not have a requirement for Crude Protein was demonstrated recently when Antari *et al*. (2016) discovered that they could not increase the skeletal growth of young Brahman cross steers by feeding a high protein diet alone, and that they performed only as well as control fed animals until there was enough energy available for the rumen microbiota to turn the protein into useful components.

There is a great deal of work being done by academic and commercial groups focusing on increasing the ability of the rumen to work at peak capacity. Novel feed additives and dynamics under investigation include;

- Probiotics, such as introducing direct colony forming units (CFU) of fibre digesting bacteria into the rumen, and prebiotics such as yeast or yeast cell wall that actually feed and in effect select for the ideal classes of bacteria.
- Factors affecting microbial adhesion and penetration to the grass itself such as surfactants.
- Direct application of enzymes that break the carbohydrate bonds, or manipulation of bacteria with a strong enzymatic profile, potentially introducing some fungal enzymes into bacteria.
- Increasing residence time of the grass in the rumen by manipulating digestive hormones.
- Understanding the role of fungi in the rumen and potential to increase the number and activity increasing the intensity of cellulose breach.
- Antioxidants that readily scavenge oxygen free radicals to maintain the ideal anaerobic environment for rumen bacteria.
- The full genome of the rumen microbiota has been mapped, so understanding the synergies and competition within certain groups on certain feed base is underway.
- Genetic modification of rumen bacteria.

Some Novus heritage. Historically studies have been conducted into the value of direct feeding of amino acids and particularly the Hydroxy Analogue of Methionine (MHA). Early work concentrated on animal performance and this encouraged later studies to look specifically at the amino acid delivery to the animal post ruminally and some examples follow.

As early as 1974, Varner (1974) showed that animal performance could be improved with the addition of MHA in rangeland pasture diets. He went to some lengths to milk Hereford cows at around 56 days post calving and found an increase in butterfat from 3.8% in control to 4.6% in treated animals along with a 20% increase in milk volume. This increase in butterfat was reflected in calf weaning weights.

Hersom *et al. (*2009) were able to show that not only could feed efficiency be improved with the addition of just one essential amino acid as MHA but that overall sexual maturity and reproductive tract scores could be advanced in growing heifers.

Vázquez-Añon (2007) showed that by feeding just one single amino acid (Methionine Hydroxy Analogue) when it is first limiting can be as effective as feeding up to ½ kg of full corn gluten meal as a protein supplement. Steers gained equivalent body weight in these studies in Florida.

Gil *et al. (*1974), showed how MHA could both advance cellulose digestion with subsequent bacterial protein increase while also sparing rumen ammonia Nitrogen. Liang *et al*. (2015) went further and discovered that just 15 grams of MHA could deliver over 160 grams of true Microbial Protein.

Lactating cows have very strict amino acid requirements and these are reflected in milk solids. This is as important to the calf as it is to the milk company in the case of dairy animals. Milk lactose, fat and protein are the building blocks for a quality calf nearing genetic potential especially in the first couple of months post calving. Amino acids are the precursors for milk protein, glucose drives milk sugar (lactose), and the Volatile Fatty Acid (VFA) Acetate drives milk fat. Studies by Yi *et al*. (2005) showed that by providing MHA (Methionine Hydroxy Analogue) the rate of 15 grams, fibre digesting bacteria, particularly ruminococcus increased with a subsequent increase in the VFA Acetate. This effect lifted both overall milk production and milk fat.

At the University of Queensland, Karen Harper undertook some work on digestibility of native grasses when alternative pasture supplements were introduced (table 3). These treatments were made in an adequate rumen ammonia environment and therefore do not necessarily reflect the difficult environment faced by cattle as feed supplies become short and difficult to digest. However, the results are very interesting. They address the notion that urea placed into an otherwise healthy rumen has little effect, in fact when applied at 8% of molasses solution, there was a significant negative effect on digestion. With the addition of MHA and 5% urea, the digestibility was increased, this was also the case for a commercial supplement containing components of MHA, urea and an antioxidant. These results would support some of the very early work conducted by Gil 1974 through

to Liang *et al* in 2015 showing an increase in microbial protein production allowing the nitrogen to be utilised by developing bacteria, increasing overall Microbial Protein.

Table 3. Results of in-vitro digestion work completed by Karen Harper (unpublished) at UQ on mature Mitchell grass hay.

Treatment of late stage Mitchell Grass hay *in vitro*	Digestibility %
control	17.59
control + 5% urea and molasses	17.07
control + 8% urea and molasses	14.63
control + 5% urea + MHA[A] and molasses	18.14
control plus multilink[B] supplement	18.16

[A]Methionine Hydroxy Analogue

[B]Multilik is a commercial molasses based pasture supplement (Rural Supplements, Bouldercombe).

The topic of the presentation will expand on the theme of alternative/ novel feed additives that can assist in the digestion of pasture in Northern Australia. It is clear that the cost of supplementation must return investment in cost, time and manpower, however for the last couple of decades there has been little new technology adopted. The majority of current molasses based supplements and 'dry licks' look identical to the same products produced decades ago. This is mainly due to pressure on price that retards novel application by supplement providers. With the value of every calf hitting the ground now well into record territory it may be time to consider trialing some novel products that appeal to your production model.

Come on, your grandpa fed out M8U. It's time to adopt some science.

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Managing and reversing the decline in productivity for northern rangelands: what don't we know?

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Abstract. Across northern Australia, declines in productivity of pastures have been widely identified and documented. Extensive research has also been carried out to address pasture decline. Despite the research and extension conducted, the actual application of key management principles is not necessarily straightforward. The purpose of this review was to provide recommendations for future research to support the sustainable grazing of the northern rangelands under a variable climate. This was done by considering the major principles for sustainable management and highlighting the challenges as well as identifying gaps in our knowledge of pasture management.

Introduction

Grass-fed beef production is the predominant land use in Australia's northern rangelands. The viability of these systems is reliant upon the condition of the feedbase resources, including both native and improved pastures. Across northern Australia, declines in productivity of pastures have been widely identified and documented (Howden 1988; Tothill and Gillies 1992; McKeon *et al*. 2004; Bastin 2008). Examples include reductions in the density of perennial grasses, increases in unpalatable grasses (e.g. *Aristida* spp.), and woodland thickening.

Extensive research has been carried out to address pasture decline in northern Australia (e.g. Ash *et al*. 2001) and the major principles for sustainable management are well documented (e.g. Hunt *et al*. 2014; O'Reagain *et al*. 2014). Briefly, these are stocking around long-term carrying capacity (LTCC); adjusting stocking rates (SRs) according to seasonal forage availability; wet season spelling (WSS); prescribed burning to control woody vegetation; and developing the property with fencing and additional waters to better manage grazing distribution.

Despite the research and extension conducted, the actual application of these key management principles is not necessarily straightforward. There are also higher level factors influencing the application of recommended grazing land management practices, such as the likelihood of more extreme and variable climate, increased woodland thickening, and the pressure on producers to become ever more efficient and more productive to stay profitable and meet global demand for Australian beef. This will place further pressure on natural resources. Meeting these challenges and satisfying societal expectations to improve land management (e.g. for reef water quality), will make management even more challenging in the future.

This paper aims to identify and highlight some of the gaps in our knowledge of pasture management and provide recommendations for future research to support the sustainable grazing of the northern rangelands under a highly variable climate. We address the challenges of flexible stocking versus stocking around LTCC, managing for desirable pasture species, wet season spelling, prescribed burning, and improving evenness of grazing. Focus is placed on the management of relatively intact native pastures. This paper does not address the problem of reclaiming seriously degraded landscapes where substantial mechanical intervention is probably required.

The challenge of estimating long term carrying capacity

Long term carrying capacity (LTCC) is defined as the average number of animals (expressed as adult equivalents) a property can sustainably support over the long term (>10 years). The GRASP model has been used extensively in northern Australia to calculate LTCC for different areas (McKeon *et al*. 1990) and further refined using the local knowledge of land managers. Set-stocking around

LTCC is not only a practical option for producers, but also has both economic and ecological benefits compared to stocking above LTCC (O'Reagain and Scanlan 2012). However, with probable changes in future rainfall due to climate change, many current LTCC estimates could be compromised given that they are based upon historical rainfall (McKeon *et al*. 2009). LTCC estimates may thus require reassessment in the future if rainfall patterns change to the extent that they no longer conform within historical bounds.

Knowledge of the 'safe' pasture utilisation rate is also fundamental to calculating LTCC (Walsh and Cowley 2011). Typically, average pasture utilisation rates up to but not exceeding 30% are recommended to ensure maintenance or improvement of long-term land condition in most native pastures (Scanlan *et al*. 1994; Orr and Phelps 2013), with this figure varying with location (Hunt *et al*. 2014), land type and pasture condition. However, average pasture utilisation rates are a relatively crude tool for managing grazing impacts on plants (Hunt 2008) and do not necessarily ensure their survival. Pasture utilisation rates may need to be adjusted in relation to changes in pasture condition and the need to promote land condition recovery.

Another challenge associated with the calculation of carrying capacity is distance to water, particularly in large poorly watered paddocks. The appropriate grazing radius to use in the calculation of carrying capacity is still not settled, with a radius of either 3 or 5km around waters being used for large, extensively managed properties. Significant differences in calculated carrying capacity will occur for a given paddock depending on the assumption used. Recent analysis of grazing in relatively large paddocks across the Northern Territory suggests that 70% of grazing occurs within 3 km of water (Cowley *et al*. 2015). Setting livestock numbers based on carrying capacities calculated on a distance to water of 5km increases the risk of overgrazed pasture closer to waters with under-utilisation further out.

Adjusting stocking rates with rainfall: easier said than done

In dry years, the combination of extreme water stress and overgrazing may still lead to long term pasture decline despite stocking around LTCC. The short-term adjustment of SRs in line with available feed e.g. using forage budgeting, is thus widely recommended (O'Reagain and Scanlan 2012; Pahl *et al*. 2016). Variable stocking can also be used to take advantage of increased pasture yields in good years, providing SRs can be reduced rapidly enough before conditions deteriorate again. Upper limits to SRs even in good years are thus also recommended (Pahl *et al*. 2016). Regardless, variable stocking demands flexibility and timely action. A forage budgeting tool has been developed (FutureBeef Stocktake Plus; www.stocktakeplus.com.au) to assist producers with their calculation of SR based on the available yield.

Despite this, major practical challenges still exist for the producer applying variable stocking in practice. First, the ability of producers to vary stock numbers without adversely impacting herd structure and long-term productivity and profitability of the business is often limited. Second, accurately estimating the paddock pasture yields in large heterogeneous paddocks is difficult.

Estimates of pasture yield are typically determined visually with the aid of photo standards. However, research indicates that significant operator bias occurs with visual yield estimates: tests with agency staff show over-estimation of yields occurred at low actual yields up to 600 kg DM/ha, while under-estimation of yields occurred at actual yields >600 and up to 5,300 kg DM/ha (Spiegel *et al*. 2015a). This bias existed regardless of the level of operator experience. The problem of overestimating low yields and by inference, stocking rates, is of particular concern given the likely negative impact of overstocking on land condition and animal production.

A subsequent study showed that training can help some (78%, $p<0.05$) but not all operators improve their estimates of yield, with a general shift in yield estimates after training to be centred more around the actual yield (Spiegel *et al*. 2015b). Calibration training for estimators is therefore recommended to gauge yields and to 'get an eye in', and should obviously be carried out prior to making paddock assessments. Calibration cuts taken during paddock assessments, either intermittently or at the end of assessments are also recommended to validate visual estimates. Yield

estimates carried out on green forage or at the end of the wet season may also be problematic if moisture levels cannot be accurately gauged.

Other problems relate to the location and number of yield estimates required to get a reliable estimate of paddock yield in large heterogeneous paddocks typical of northern Australia. Thus, there is scope to further develop techniques in assessing yield and then applying this at the paddock level. Given that some assumptions are also made with forage budgeting (e.g. the level of pasture wastage), provides an opportunity for validation research. Short duration grazing trials (i.e. graze-out trials) could be used to reliably quantify the correction factors used to calculate the amount of available forage and hence the stocking rate.

Managing for desirable pasture species: ongoing gaps in our knowledge

Desirable pasture species, also referred to as 3P grasses (perennial, palatable and productive), are the longer lived, generally deeper rooted tussock grasses such as kangaroo grass (*Themeda triandra*), black speargrass (*Heteropogon contortus*), desert bluegrass (*Bothriochloa ewartiana*), and Mitchell grass (*Astrebla* spp.). Such species are the backbone of the feedbase due to their persistence and productivity. These species are also extremely important for landscape function due to their positive impacts on soil biology, nutrient cycling and rainfall infiltration. Management of these species can be challenging particularly during drought, but these species can also decline in good years through repeated selective grazing of patches or individual tussocks.

Understanding the basic ecology and life history of these species is therefore critical if we are to manage them appropriately to ensure they are maintained in the feedbase. Significant work has previously been conducted on black speargrass (e.g. Tothill 1969) and to a lesser extent, Mitchell grass (e.g. Orr and Phelps 2013). However, very little work has been conducted on *Bothriochloa ewartiana*, *B. bladhii*, or *Eulalia aurea*, which are key forage grasses through large parts of northern Australia. This lack of knowledge thus limits the formulation of management guidelines to manage these important species.

There are also gaps in our understanding of the basic ecology of introduced pasture species in grazing lands. This is concerning, particularly if these species can rapidly colonise and become the dominant pasture species under even relatively good grazing management. For instance, the exotic, stoloniferous Indian couch (Indian bluegrass; *Bothriochloa pertusa*) has invaded large areas of northeast and central Queensland. Although originally largely confined to granodiorite landscapes, more recent reports show invasion into both fertile basaltic (Stacey 2014) and lower fertility sedimentary (O'Reagain unpublished data) landscapes of north Queensland as well as in native and sown pastures in central Queensland (S. Buck *pers. comm.*).

B. pertusa tolerates grazing and is reasonably palatable, but it is also reported to have reduced drought tolerance and is lower yielding compared to 3P grasses like *B. ewartiana* and the introduced pasture species Buffel grass (*Cenchrus ciliaris*) (Spiegel *et al*. 2016). *B. pertusa* provides valuable ground cover on denuded landscapes, but its reduced rooting depth results in more runoff compared to the deeper rooted, 3P tussock grasses (Bartley *et al*. 2014). The spread and dominance of *B. pertusa* is generally attributed to heavy grazing, usually combined with drought (Walker and Weston 1990; McKeon *et al*. 2004). However, as originally predicted by Howden (1988), rapid colonisation by *B. pertusa* can occur under a range of SRs and grazing treatments, as observed at the Wambiana Grazing Trial, Charters Towers.

Despite detailed work by Howden (1988) on the comparative ecology of *B. pertusa*, there is still very little data available on the drivers of invasion, production potential and options for either managing *B. pertusa* monocultures or reversing invasions. Furthermore, recognising *B. pertusa* encroachment as being both a problem as well as a symptom of a problem(s) emphasises the need to actively manage the desirable pasture species in the feedbase, and to minimise the risk of invasion by undesirable species and the associated loss of productivity.

Pasture spelling

Spelling or resting (i.e. the complete removal of livestock from paddocks) is typically applied early in the wet season when grasses are most susceptible to grazing (Mott *et al*. 1992). Spelling is generally applied to encourage pasture recovery and ensure the survival of desired 3P grasses. This may be necessary after heavy grazing, during and after drought, after burning, and, to maintain or improve land condition. However, the benefits of wet season spelling (WSS) can be slow to emerge, at least in terms of pasture composition (Orr and O'Reagain 2011; Hunt *et al*. 2014; Jones *et al*. 2015).

There is little if any research on the methods or climatic conditions required for accelerating the pasture response to WSS. Other unknowns include the benefits of early versus full WSS, the optimal frequency of spelling, and the efficacy of spelling to ameliorate heavier stocking rates. In practice, a key challenge for producers is avoiding the overgrazing of the paddocks not being spelled through increased stocking by animals from the spelled paddocks. In this case, overgrazing of unspelled paddocks during the wet season may easily negate the benefits of spelling other paddocks and result in an overall net loss of pasture condition. While agistment of cattle from spelled paddocks is an obvious option, this is costly and not an option for all producers. Thus, if cattle are to be retained on property, they should be distributed amongst paddocks that have the most capacity, or spelling should be limited to better seasons to ensure safe pasture utilisation rates are not exceeded in other paddocks.

Grasses are also known to accumulate reserves towards the end of the wet season in preparation for the long dry season and drive growth following rainfall at the start of the following wet season (Tainton 1981). Accordingly, periodic full (as opposed to only early) WSS may be essential to maintain long-term pasture condition. Current research into this aspect in northern Australia is short-term and relatively inconclusive (Jones *et al*. 2015). In the Northern Territory, the best response in terms of greater yields, flowering rates and reduced mortality was found with full WSS (White 2011).

Finally, the potential benefits of spelling during the dry season are also worth considering. Apart from ensuring fuel loads for prescribed burning, meeting ground cover targets and conserving forage, spelling during the dry season when perennial grasses are dormant may have some benefits for improving land condition. In particular, preventing the removal of aerial buds by heavy grazing should increase the number of growing points for growth at the start of the next wet season (Scanlan *et al*. 2014).

Even grazing utilisation

Grazing within a paddock is seldom uniform and can result in significant areas of pasture decline at the landscape and patch level. Possible strategies for managing preferentially used areas include, for example, in very large paddocks positioning water points more than 5km from grazing-sensitive land types and setting stocking rates based on the carrying capacity of the most preferred land type in the paddock. Fencing land types of similar attractiveness together may also assist with the management of grazing pressure, but this may not always be a practical option. Suggested strategies for managing overgrazed patches include using fire and WSS to "re-set" the pasture (Andrew 1986; Ash and McIvor 1998), or the strategic location and regular re-location of supplements or other attractants to draw animals away from preferred areas (e.g. self-shepherding; Revell *et al*. 2015). Whilst these interventions have been shown to work under experimental conditions, their effectiveness under commercial conditions and extensive management in northern Australia is largely unknown and requires further investigation.

Prescribed burning

Prescribed burning is applied for a number of reasons, such as to encourage more even grazing pressure, to modify pasture composition, and to control woodland thickening. There is growing evidence that rising atmospheric CO_2 is increasing the growth rates of woody species and increasing the woodiness of savannas globally (Buitenwerf *et al*. 2012). These increased growth rates will

obviously reduce the window of opportunity to control woody species with fire, i.e. when they are <2 m tall. Thus, CO_2 driven changes in savanna structure may require increasing management intervention to maintain the woodland:pasture balance. Alternative burning regimes may need to be investigated, such as timing burns relative to the plants phenophase. Notwithstanding these unknowns, the likelihood of more extreme and more variable rainfall will only increase difficulties associated with decision making on when and how frequently to burn

Producers also forgo some short-term livestock production with burning, as the grass is used as fuel rather than for feed. However, the longer term costs of not burning in terms of reduced grass production needs to be adequately quantified. Spelling is often required pre-fire to ensure adequate fuel loads, and post-fire, to ensure pasture recovery. The challenges associated with spelling have already been discussed. It is also worthwhile investigating the efficacy and cost benefits of regular burning relative to less frequent, mechanical intervention e.g. strip clearing (assuming this is permissible).

Conclusions

The sustainable management of pastures in northern Australian rangelands is a key issue that has major long-term economic and ecological impacts. Given that major improvements in land condition are required in many areas of northern Australia, improved understanding and management strategies to facilitate pasture recovery is more important than ever. A major challenge for producers is balancing productivity with ecological outcomes. While there are guidelines and recommendations to assist with pasture management, this paper has highlighted a number of shortcomings and gaps in current knowledge. These gaps need to be addressed to generate improved, evidence based management guidelines to assist producers to meet the ongoing challenges to the northern grazing industry.

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Ongoing enthusiastic conversations are an alternative to a linear research-adoption paradigm

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Introduction

Adoption is often viewed as an end point of research, something that is required when all of the required information is gathered and data analysed. When research is not formally recognised as being adopted, it can be viewed as a failure; after all, if the research didn't lead to an identified practice change, then the research has questionable value (if no-one adopts the research, did it really happen?). The term 'extension' has been used as synonym for adoption in agriculture and other fields, further implying that the activity is an add-on to an existing body of research work. The term 'end user' hints even more strongly that the process is linear and that the individual or group who can apply the innovation are passive in waiting for a solution from technical experts.

An alternative approach is to trigger and maintain active, enthusiastic and ongoing conversations amongst interested people. All participants (e.g. producers, scientists, agency staff, the broader supply chain, policy makers etc.) can all contribute to the conversation, albeit in different ways. The key to success is to use enthusiastic conversations in an environment of mutual acceptance. The boundaries between 'teaching' and 'learning' become blurred and experiences are positively reinforced. In this way, a culture of change is more likely to emerge than from the more conventional linear approach.

Learning and behaviour change is not a phenomenon restricted to humans. All animals, from single-celled bacteria to complex social groups of higher-order animals learn and change in response to stimuli and feedback signals. In the following sections, I use insights from research and from field observations to outline the main characteristics of a system that allows grazing livestock to learn, broaden their experiences, and modify their behaviours; in other words, how they learn to embrace change. I suggest these principles hold for people too.

From a linear model of research-adoption

A linear and sequential process of research leading to adoption stems from a way of thinking that an identified problem has a single solution, or at least a defined set of solutions, that need to be discovered before they can be applied. There are situations where this model can be very effective, although the simplicity of a 'solution' is normally only evident in hindsight. The process is often much more convoluted, with a swirl of hypotheses, insights, data collection, testing, accidents, adaptions, experiences, mistakes and refinements.

There have been considerable efforts to identify what makes something adoptable. In fact, 'adoption' has become a research topic in its own right. It's almost ironic that the adoption of adoption research has not always been as successful as one might have hoped. Whilst it is broadly accepted that adoption is a dynamic process, it is still often described as a sequence such as (i) awareness of the problem, or opportunity, (ii) non-trial evaluation, (iii) trial evaluation, (iv) adoption, (v) review and modification and, sometimes, (vi) on-adoption or dis-adoption (summarised by Pannell *et al.* 2006).

Pannell *et al.* (2006) suggested two broad factors that drive adoption or non-adoption: relative advantage and trialability. Relative advantage is defined as the degree to which an innovation is perceived as being better than the idea it supersedes. Whilst I totally accept that the concept of 'relative advantage' is crucial, I suggest that the concept still carries the baggage of linearity; that is, one thing has to be better than the other for 'it' to be adopted. It also implies, although not explicitly,

that a new practice must supersede an earlier practice. Simple solutions to simple problems can and do exist, but in agriculture and natural resource management, complexity, variability, adaptations and emergent properties mean that single solutions are rare (Provenza *et al.* 2013).

Trialability relates to how well someone can learn about a practice and assess its effectiveness. Trialling a practice or testing an idea provides information to help evaluate the relative advantage of a practice (Pannell *et al.* 2006), but it also provides an opportunity to see and experience something in action. Trialability is a phenomenon than extends beyond scientific research; it is just as relevant to experiential learning, although a discrete trial with controls and treatments may never be formally established.

A fundamental problem with relying on a linear research-adoption model is that most people don't 'want to be told'. Feeling that you must do something because someone else says so, especially if you see the other person (or group) as being from outside your day-to-day world, rarely leads to enthusiastic or ongoing behavioural change. On the contrary, being encouraged and allowed to change is a more positive experience. In other words, changing as a consequence of learning, rather than changing through obligation. Modifying practices through learning also increases the likelihood of multiple approaches or discoveries, because the circumstances, experiences and knowledge of different people at different times will shape the outcomes.

Learning is a dynamic and ongoing process, made most effective when there is support and positive feedback. Positive feedback can be in two forms: social or internal. Social feedback can be in the form of positive reinforcement from members of a social group or other peers, whilst internal feedback can arise when an individual is rewarded for their actions. The literature on animal learning is rich, and below I take just a few examples to draw parallels to how people can best learn and change; i.e. the circumstances that best support adoption.

Lessons from how animals learn to embrace change

Dukas (2013) reviewed the effects of learning on evolution and how learning leads to robustness and innovation. He defined learning as "an internal representation of new information obtained from the current external and internal environments". By viewing the learning experience as an "internal representation", we can immediately see that what one individual perceives from new information is not necessarily the same as what another perceives. It depends not only on the package of information itself, but the external environment in which it is received (i.e., the context) and the internal state of the individual. The internal state, which could be the physiological state of an animal or an individual's state of motivation (its affective state), influences the degree to which an animal 'wants' something (the concepts of 'liking' and 'wanting' are described in detail in terms of feeding behaviour in Ginane *et al.* 2015).

Differences in the external or internal environments can help explain the typically large variation between individuals in their responses to the same signals, or to the packages of information. This phenomenon is described as between-individual differences in behavioural plasticity (Dingemanse and Wolf 2013). The great opportunity for managing change goes beyond the common sense that individuals are all different when we see that past phenotypes do not constrain current phenotypes. We can shape future animal behaviours by influencing their current experiences and providing positive feedback (e.g. through nutritional rewards), and pairing the rewards with consistent signals visual, olfactory, taste and tactile) that serve as cues. The value of the paired signals is that they help animals to know what to expect from a situation. How an animal behaves is strongly influenced by its expectations and experience (Ginane *et al.* 2015).

A case study from Rangelands Self Herding and its relevance to adoption practices

Over the past two years, the concept of Rangelands Self Herding has been refined and applied with pastoralists in Western Australia (Revell *et al.* 2015; Revell *et al.* 2016). Rangelands Self Herding is a behaviour-based approach containing tools that allow managers to positively influence grazing patterns and distribution, and change the relationship between livestock and people, using the capacity of grazing herbivores to learn and modify behaviours as their expectations and experiences

are altered. Grazing patterns, although complex, are not random; neither are they fixed. Foraging patterns are formed by associations between cues and consequences, individual and social learning, animal responses to familiarity and novelty, and spatial memory (Launchbaugh and Howery 2005). Each pastoralist is able to draw on common principles (Revell et al 2015) and make decisions and take actions that are relevant to their local environment and management objectives.

The elements to successful application of Rangelands Self Herding – which is presented here as an example of a behaviour-based approach that works *with* (not *on*) individual and groups – may have direct relevance to how people learn and change. We found the following elements were critical for positive change to occur:

1. The participants (which were livestock in the case of Rangelands Self Herding, but are people in the case of adoption) must have a choice; they must not feel 'forced' to make the change.
2. We must allow, and expect, changed behaviours to evolve and strengthen over time. Although initial responses can occur quickly, behaviour is dynamic as it responds to changing experiences and changes in the current environment.
3. Signals – i.e., the elements that create expectations – must be consistent (unambiguous) to create positive expectations and to build trust.
4. Ongoing reinforcement - i.e., support - continues to build confidence and encourage ongoing exploratory behaviour and group dynamics. The level of support, such as the provision of positive feedback or reward, does not need to be provided continuously once a positive environment is created, but nevertheless it is still required at key times to encourage continual improvement.

Participatory research and the importance of conversations

In contrast to the linear concept of research leading to adoption, there are alternative approaches that integrate the discovery of new information, its incorporation into existing practices or concepts, its testing and application under different scenarios, and ongoing refinement and adaption. These approaches include participatory research, experiential learning, or action learning. The work of Ray Ison and David Russell is amongst the most instructive approaches in social learning over the past 20-30 years (e.g. Russell and Ison 2005; Ison 2008). A point raised by them is the importance of conversation as a system for learning. They have identified that radical change in thinking from learning as an acquisition of skills and knowledge to the notion that "learning was embodied change that took place over time… created by conversation [that] shifted the emphasis from the targeted outcome to the process" (Russell and Ison 2005).

In a context where the processes of communication and conversation are not a simply a means to and end, but are in fact the very purpose of engagement, the type of communication used is critically important. Russell and Ison (2005) refer to Krippendorf's (1993) six metaphors of communication, and I think they are worth summarising here to highlight how efforts to 'cause' adoption, however well intentioned, have not adequately used the conversational model of communication, but instead have relied on packaging information and telling people about it.

1. The Container metaphor: The emphasis is placed on the content, and messages are usually discrete packages of information. An assumption is that what one person (usually the 'expert') puts into 'the container' is the same as what the receiver takes out of it. But as discussed earlier, the internal and external environment of the receiver shapes the behavioural response to information.
2. The Conduit metaphor: the emphasis is placed on the channel of communication. Perceived failure is considered to be due to the use of an inappropriate mode of communication. For example, the feeling of "hitting your head on a brick wall", where you are sure the message is right but you just can't get it through to the recipient.
3. The Control metaphor: it assumed that communication causes specific and predictable outcomes. Implied in this style of communication is that the senders are active and informed, and the recipients are passive and uninformed.

4. The Transmission metaphor: Messages are coded for transmission, and that the receiver must interpret the message (i.e. decoding is required). In this situation, the content of the communication is often shaped to suit the method of transmission. Communication via scientific journal papers, videos, or during field days, for example, each have their own characteristics, but not everyone is skilled across the different modes of transmission, and not everyone is able to decipher the coded messages.
5. The War metaphor: In this situation, arguments are either to be won or lost. Success is perceived when you are able to convince the other that your argument or approach was the correct one. Implied is the view that there is only one right answer, and people will either accept or not. The intention to win an argument rarely leads to a true dialogue.
6. The Dance Ritual metaphor. In this situation, the doing of the action is what matters most, and it involves all participants in an ongoing and co-operative fashion. It does not imply that everyone necessarily agrees – we may step on the toes of others! – but it does require a mutual acceptance amongst the participants. If we do not engage in an ongoing conversation, we risk the potentially damaging scenario of 'drive by science', where there is a short-term flurry of activity in an attempt to solve an issue, but it does not automatically lead to an ongoing conversation, continual improvement or local adaptation. Without ongoing support, short-term changes in behaviour are less likely to perpetuate.

The Dance Ritual metaphor has parallels to our insights of how animals learn and adapt in Rangelands Self Herding. Positive outcomes, however they are to be defined, are more likely to emerge over time when participants have positive expectations, have an opportunity to experience positive consequences of their experiences, receive support (or guidance) over time, and – perhaps most importantly of all – are able to make a choice.

Conclusion

Blurring the lines between senders and receivers, experts and amateurs, scientific research and practical experience need not diminish the standing of any individual. As Meuret and Provenza (2015) stated, "researchers and managers can become allied and linked with the challenges and opportunities …as social, ecological, and political landscapes transform". We need to move beyond what modern jargon describes as 'stakeholders', as this feeds into the War metaphor where each group has placed a stake in the ground and is reluctant to yield. Instead, the adoption of new practices will more likely occur as part of an ongoing and evolving process if interest*ed* participants share an enthusiastic conversation. I use the term 'enthusiastic' deliberately as it implies that people have a positive emotional involvement. Without emotion, a conversation is unlikely to continue. The aim should not be to find a single solution but, through mutual acceptance of everyone's experiences, to continuously generate new ideas and behaviours.

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Producer-funded animal health and biosecurity R&D

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Abstract. Investment of MLA producer levies in animal health and biosecurity research for more than the past decade has covered most of the veterinary spectrum. R&D of exotic animal diseases has mostly been financed through investment of co-funding contributions to the MLA Donor Company and matched by the Australian Government. This investment has been aimed at exotic diseases considered to be of greatest danger to the mammalian livestock industry. For endemic disease R&D, the aetiologies have included internal and external parasites, vector-borne and contagious infectious diseases, plant toxins, and congenital abnormalities, and most animal organ systems were involved. The research aimed to address questions about diagnosis and early detection, management of disease through prevention and treatment, and epidemiology.

Although some research projects have been initiated by MLA in response to known producer needs, the majority relied on the initiative of researchers. Such funding applications were assessed on a number of criteria, such as the economic importance of the condition in question, the soundness of the proposed scientific approach, both in terms of defining the researchable question and the technology to be used, the perceived knowledge deficit, the adoptability of the project's deliverables for levy payer benefit, partly expressed through the performance of a cost-benefit analysis, and possible uniquely local considerations.

The northern and southern Australian beef industries differ in the types of disease problems they face, and their estimated cost. Among the 10 costliest health conditions for the northern beef industry, no R&D investments have been made in dystocia, Botulism, or Vibriosis, because of the difficulty in formulating the researchable question. In contrast, conditions of lesser or unknown economic importance, such as Johne's Disease, Theileriosis, Anthrax, Besnoitiosis and plant toxicities, were investigated due to the recognised knowledge gaps, local importance and possible market access concerns.

There is still much to learn about most of the economically important endemic diseases, but much of what is already known is not yet put to profitable use. Greater emphasis on extension and adoption of available knowledge and technology can help reduce the cost of disease.

Investigated conditions

Over the past decade or more, Meat & Livestock Australia has invested grass-fed beef producer levies in research into external and internal parasites, infectious (contagious and vector-borne) disease, plant toxicity, congenital abnormalities and plant toxicity. Utilising the MLA Donor Company mechanism, additional investments from co-funding partners could also be leveraged with matching Commonwealth dollars, without expending further producer levies. The research deliverables included improved (faster and more accurate) diagnostic techniques, methods for better prevention and treatment, and better understanding of epidemiological factors.

Figure 1 is a graphic representation of the estimated cost of 17 endemic health conditions in northern and southern beef herds, the percentage knowledge deficit for each, and the amount of MLA's R&D investment in the 5 years from 2011 to 2015. This illustration shows distinct differences in the occurrence and relative importance of different diseases between the southern and northern beef industries. Climatic differences influence not only the degree of intensity of production, but also the occurrence of arthropod-borne diseases, such as Tick Fever and 3-Day Sickness (Bovine Ephemeral Fever, BEF).

In addition to the endemic diseases, research was also funded into conditions exotic to Australia, such as Foot and Mouth Disease, Old World Screwworm Fly, and via the National Arbovirus Monitoring Program. In this case, early diagnosis was a major consideration, as well as effective prevention and control measures, and faster return to disease freedom.

Cattle tick research has been aimed at control, either by exploiting the host's innate and adaptive immunity, or applying an acaricide. Due to wide-spread resistance to most acaricidal chemicals in the Cattle Tick (*Rhipicephalus australis*; previously *Boophilus microplus* and *Rhipicephalus microplus*), northern producers mitigate its impact through reliance on the indicine genotype. But there is mounting pressure to revert to a greater *Bos taurus* component in the herd, due to consumer demand for better beef eating quality. Whilst pharmaceutical companies have been investigating the possibility of delivering the Bm86 hidden antigen used in TickGARD (PLUS)® in a novel, slow release formulation, other research has been investigating the suitability of secreted tick antigens discovered during the Beef CRC's program. The entomopathogenic fungus *Metarhizium anisopliae* has been successfully commercialised in Australia for plague locust and other insect pest control and has shown promise for nuisance fly control in cattle feedlots. Its efficacy against cattle tick infestations has unfortunately been disappointing.

Buffalo Fly is estimated to cost northern beef producers $94.5M annually, mostly attributed to lost productivity. Hide damage, either by direct fly activity, or host rubbing and scratching, or by subsequent *Stephanofilaria* infestation, is a further complication. Control of this pest is totally reliant on chemicals, whose application and short duration of activity in extensive enterprises pose ongoing problems. Rubbing posts impregnated with motor oil, and dust bags dispensing carbamate insecticide suffer from undesirable consequences, such as questionable efficacy, environmental contamination, and unacceptable chemical tissue residues. Insecticidal ear tags are a convenient and attractive option, but need to be applied fresh every season and have largely lost their efficacy due to widespread resistance to all the chemicals used in them, mainly pyrethroids and organophosphates. Non-chemical control, e.g. through use of walk-through fly traps of various designs, has not been widely adopted, probably for practical reasons. Biological control, e.g. through dung beetle activity destroying the integrity of cow pats where the *Haematobia* flies breed, has not made an appreciable contribution to the pest's adverse impact. Renewed research efforts are currently aimed at exploiting entomopathogenic strains of the commensal insect bacterium *Wolbachia*.

The third costliest northern beef disease, **Bovine Ephemeral Fever**, can be kept at bay reasonably successfully through vaccination. Although the same virus isolate has been used in the vaccine for more than 30 years, it has been demonstrated that this is justifiable, based on the negligible immunogenic drift over that period. A probable explanation for poor uptake of the commercial vaccine, could be its perceived poor efficacy, coupled with the cost of the second muster required for the initial booster injection. Attempts at formulating a slow or pulse release vaccine requiring only one injection per year have thus far been unsuccessful.

Bovine Viral Diarrhoea (BVD) is an enigmatic disease on many fronts. It is highly contagious and infection results in life-long immunity, but infection of naïve pregnant females can lead to the birth of persistently infected (PI) cattle, which can perpetuate the disease in a herd, unless they're identified and managed properly. Controversy about the estimated cost of the disease partly stems from its cyclical nature – the catastrophic reproductive impact of an incursion into a naïve herd cannot be easily extrapolated on a national scale, because, if left unattended, the disease is likely to die down over the course of a few years and the herd revert to susceptibility. Producers have access to effective commercial vaccines and accurate diagnostic tests for both antigen and antibodies.

It is possible that the cost of **internal parasites** in northern beef has been under-estimated, but the extensive nature of the industry makes this difficult to assess. Widespread resistance to most of the commercially available cattle drenches in Australia is now a reality, necessitating the need for drench resistance tests and alternative approaches, such as selecting cattle for worm resistance. Although this has been shown in sheep to come at a production cost, the benefit still outweighs the cost.

Tick Fever is another enigma, having two biologically different causal components. Whereas *Anaplasma*, a Rickettsial bacterium, lends itself to immunisation with a subunit recombinant antigen, *Babesia* is an apicomplexan protozoon which, like *Plasmodium*, the cause of malaria, has thus far defied attempts at inactivated or subunit antigen vaccination. Whereas Anaplasmosis and Babesiosis are treated as separate diseases in other countries, in Australia, Tick Fever vaccine is frozen blood containing live organisms of both types. Production is expensive, relying as it does on the use of splenectomised calves. Limited shelf life and the need for maintenance of the cold chain make this a difficult vaccine to produce and manage. It remains commercially unattractive for any of the multinational animal health companies.

Theileria orientalis is known to have occurred in Queensland cattle for more than a century, without causing appreciable clinical disease. It is transmitted by the Bush Tick (*Haemaphysalis longicornis*), and the parasite is easily seen microscopically in thin blood smears. The emergence of clinical cases of anaemia in cattle in coastal Northern NSW about 10 years ago, with no apparent cause other than this parasite, led to a flurry of investigation. Molecular biological methods uncovered a number of subtypes of the parasite, with the pathogenic Ikeda subtype an evidently more recent introduction to the country, than the previously established Buffeli subtype. Although buparvaquone has been shown to be effective in the treatment of Bovine Anaemia due to *T orientalis*, the chemical is not approved for use on Australian cattle, due to tissue residue concerns. In addition to the *Theileria* parasite, research continues into its modes of transmission, the most important of which seems to be a 3-host tick which has not previously featured in the consciousness of beef producers and which requires a different management approach from what applies for the cattle tick.

Johne's Disease (JD) was first discovered in cattle in Australia in 1925 and in sheep in 1980. Although the existence of cattle, sheep and bison strains of *Mycobacterium avium* subsp. *paratuberculosis* (Mptb) is acknowledged, the distinction between Bovine and Ovine JD has become blurred in the recent past. Much of the diagnostic technology, epidemiological knowledge and understanding of the disease's pathophysiology are applicable to both cattle and sheep. MLA-funded research investments over the past 21 years have delivered improved diagnostic methods, proof of efficacy of a sustained vaccination program, and improved understanding of the disease's progression and epidemiology. Even though Queensland cattle are considered to be largely free from JD, there are still many unknowns about the infection's epidemiology in the northern beef herd. The behaviour of the sheep strain in cattle also still raises a number of question marks.

Calf scours has been known for a long time to be a multifactorial condition. In addition to primary infection by a number of enteric viruses, complicated by subsequent bacterial and/or protozoal infections, a variety of management and nutritional factors are also known to be involved. The most recently completed calf scours project has delivered a molecular diagnostic method which will rapidly identify and quantify viral, bacterial and protozoal causes of calf scours.

Discovering the extent of the economic impact of **Fluoroacetate toxicity** ($45 million) came as surprise and lends support to the ongoing investigation of possible ways of detoxification via rumen microflora manipulation. Other plants, such as Annual and Perennial Ryegrass, were also investigated.

A relatively small project investigated the epidemiology of **Anthrax** in the anthrax belt, confirmed the longevity of bacterial spores in soil, and promoted the use of the rapid lateral flow immuno-chromatographic diagnostic kit. Another small project investigated cases of epistaxis in kangaroos and related seroconversion in sympatric cattle in South Australia, but confirmed that the parasite in question was not ***Besnoitia*** *besnoiti*, the cause of Elephant Skin Disease and an emerging problem in Europe in recent years.

Investment prioritisation

The estimated cost of an endemic disease is frequently used as justification for investment in its R&D. The information is fairly readily available and is updated quite regularly. This is more difficult in the case of an exotic disease, where knowledge of the cost of outbreaks overseas has to be adjusted

by an analysis of the probability of an incursion into Australia. Such assumptions and extrapolations are always open to debate.

If cost were the only criterion for investing R&D $$, the top 10 conditions, estimated to cost northern beef producers $544 million per year, would be the obvious candidates. They are Cattle Tick, Buffalo Fly, BEF, Neonatal mortality, BVD, fluoroacetate toxicity, Dystocia, Botulism, Vibriosis, and Internal parasites. A refinement of the Cost of Endemic Diseases report of 2006 was the Priority List of Endemic Diseases published in 2015, which attempted to enhance the cost estimate for each disease with a subjective assessment of the current knowledge regarding its aetiology, prevalence and geographic distribution, as well as producers' access to means of prophylaxis and therapy.

From Figure 1 it is clear that there must be other considerations than cost in justifying R&D investments. Non-investment in Dystocia, Botulism, Vibriosis and the disease aspects of Neonatal calf mortality does not reflect indifference to their economic importance, but difficulty in formulating a researchable question for each of them. Neonatal mortality and dystocia are multifactorial in their origins, many of which can possibly be addressed through changed management practices. A few research projects have attempted to quantify the extent of these, but possible predisposing factors and how to address them are still largely unknown. The impact of Botulism and Vibriosis can probably be ameliorated through greater use of vaccines and other management interventions, e.g. P-supplementation, and little evidently seems to be gained from investing in further R&D.

Furthermore, considerations such as local concerns, market access questions and emerging conditions about which little is known will also have a bearing on investment decisions. This could explain apparently inordinate investments in R&D into e.g. Johne's Disease, Theileriosis, Besnoitiosis, anthrax, plant intoxications and Bull balanitis.

Budget constraints

Since MLA's founding in 1998, the grass-fed beef levy has remained pinned at $5 per transaction. The time cost of money, plus the tendency towards animals changing owners less frequently between birth and slaughter, means that the real value of funding available for research continues to dwindle. Following distribution of the major part of the $5 levy to MLA's marketing activities, Animal Health Australia, and the National Residue Survey, 92c remains for investing in R&D, matched by the Australian Government. This investment covers the entire beef production pipeline which means, in rough terms, 46c is available to on-farm R&D. Pro-rata allocation to feedbase and cattle production research leaves ca. 12c (2.4%) for animal health, welfare and biosecurity. The total Commonwealth-matched annual budget for this portfolio, representing levies from beef (grass-fed and grain-fed), sheep meat and goat producers, is $5-6 million. The Statutory Funding Agreement necessitates strict adherence to levy stream relevant expenditure, e.g. sheep meat levies cannot be spent on beef research.

Remaining researchable questions

There will always be unanswered questions with regard to better management of animal health and welfare. In addition to their impact on production and profitability, some conditions pose a threat to market access. These can stem from aesthetically objectionable carcase lesions (e.g. Sheep Measles, grass seed contamination, Eosinophilic Myositis), to compromised food safety through contamination by potentially zoonotic micro-organisms, or chemical residues, such as plant toxins.

But, leaving aside the knowledge deficit necessitating further research, greater effort may need to be expended in promoting the adoption of already available information and technology. This promotion will have to remain sensitive to the fine balance between profit and loss, not losing sight of the fact that in some cases, the remedy might be costlier than the disease.

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For further information see MLA final project reports

downloadable from:
http://www.mla.com.au/Research-and-development/Search-RD-reports , search on project number
Anthrax: Project B.AHE.0032.
Besnoitiosis: Project B.AHE.0083.
Bovine Ephemeral Fever: Projects B.AHW.0091; P.PSH.0575
Bovine Viral Diarrhoea: Project B.AHE.2014.
Bull balanitis: Project B.AHE.0227.
Calf Scours: Project B.AHE.0025.
Cost of endemic diseases: Project B.AHW.0087.
Ectoparasites: Projects B.AHE.0020, 0193; B.NBP.0488.
Internal parasites: Projects P.PSH.0444, 0489; B.AHE.0066.
Johne's Disease: Projects P.PSH.0576; B.AHE.0089, 0237, 0258.
Theileriosis: Projects B.AHE.0038, 0048, 0076, 0078, 0194, 0213, 0240.
Tick Fever: Projects B.AHE.0050, 0060.
Plant toxicities: Projects B.AHE.0015, 0019, 0039, 0040, 0081, 0246, 0248.
Priority list of endemic diseases: B.AHE.0010.

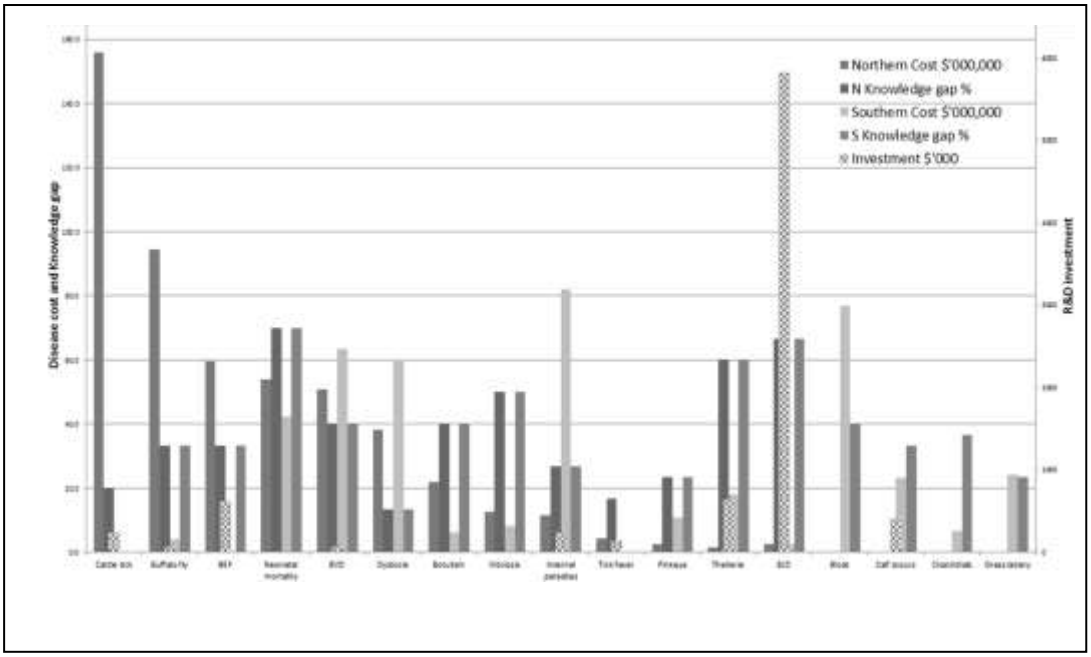

Fig. 1. Costs, knowledge deficits and R&D investments in endemic grass-fed beef cattle diseases.

Managing welfare outcomes for northern beef producers

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Australia is one of the most efficient beef producers and one of the largest beef exporters on the planet. Much of our total land mass is managed for agricultural production and much of this involves grazing livestock on native pastures in arid and semi-arid zones. There is no shortage of statistics supporting the contribution of the Australian beef cattle industry to the Australian economy and to society.

Global trends in population growth, urbanisation of society, rising affluence, transport and market supply chains and capacity, all contribute to rising demand for food and specifically protein production. Australia is very well placed to be a major contributor for future food demand because of our geographic location, availability of arable land, efficiency in livestock production and our enviable disease and chemical-free status.

At the same time there is a general trend of rising societal interest in issues such as sustainability and animal welfare that reflect changes in societal opinions and values over time.

Sustainability may be defined as having three pillars: environmental resource, economics and social. These have been explored and describe in more detail in von Keyserlink *et al.* (2013). Producers and scientists have generally focused more on environmental and economic issues and have directed less attention to social issues (von Keyserlink and Hotzel 2015).

There has particular interest and debate around the issue of whether animal welfare and productivity go hand in hand.

"Good welfare practices go hand in hand with good productivity and better quality product so a lot of these things really create a win-win for animal welfare and for production (http://www.agforceqld.org.au/file.php?id=2719&open=yes).

There is no disputing that management practices may benefit both welfare and productivity for example ensuring good housing, management, nutrition and disease control practices will be highly likely to benefit both welfare and productivity. Improvements in welfare outcomes may also provide producers with competitive advantages leading to market access and higher prices (Productivity Commission 2016). However, the welfare-productivity frontier has been described as being non-linear and if productivity gains are driven, risks to welfare rise and there is a higher likelihood of welfare compromise (McInerney 2004). The welfare-productivity frontier is a theoretical concept that is complex and likely to be different for intensive livestock enterprises vs extensive, grazing systems but the principles and drivers are likely to remain true across the spectrum. The frontier is consistent with the view that some producers may prioritise welfare outcomes above productivity and accept lower productivity in return for higher welfare outcomes.

Consumers and advocacy groups appreciate the power of their decisions through purchasing choices (choosing to buy or not buy particular products because of various concerns) and by influencing political regulatory decisions. Societal concerns about animal welfare are playing an increasingly important role in consumer and advocacy group actions and in turn are influencing agricultural practices and regulations. Interest has mainly been directed at intensive animal production systems (pig, poultry and to a lesser extent dairy) and particular issues (bobby calf industry, jumps racing, docking of dairy cow tails, induced calving in dairy cows). In extensive livestock sectors in Australia there has been considerable interest in specific practices such as mulesing in sheep, pain relief for animals undergoing routine husbandry procedures and land transport practices.

In recent years in Australia we have seen intense debate around social licence associated with the mining, fishing and live animal export industries. The recent announcement by the NSW Government

of a proposed closure of the greyhound racing industry in that state reflects the judgement of former High Court Judge Michael McHugh that the industry's social licence to operate uses animal welfare at its foundation and not measures of any human benefit through jobs, taxes or social amenity (http://www.queenslandcountrylife.com.au/story/4027097/greyhound-bans-livestock-farming-and-social-licence/?cs=4726#!). This decision appears to be explicitly placing welfare cost above any human economic or social benefit.

Rodan and Mummery (2014) describe the growth and impact of social media campaigns that target community perceptions and opinions and the impact these campaigns can have in influencing public responses. Their article uses information on campaigns mounted by Animals Australia that have used video and associated social media messaging to mobilise consumer behaviour and influence the livestock industries (Rodan and Mummery 2014).

Katherine Teh-White (Managing Director, Futureye) has cautioned in a recent article in the QLD Country Life (http://www.queenslandcountrylife.com.au/story/4027097/greyhound-bans-livestock-farming-and-social-licence/?cs=4726#!) that McHugh's greyhound report may have broader implications for Australian farmers if the same thought process were applied more generally to livestock practices. Ms Teh-White indicates that livestock industries should consider developing a social licence strategy built around transparent monitoring of key performance measures associated with social licence and engaging with stakeholders and the community about these issues.

Animal welfare in the beef industry has recently been described as a "wicked" problem based on the following characteristics (Lyles and Calvo-Lorenzo 2014):

- No single, clear definition exists for the problem;
- There is no clear solution, only shades of better or worse;
- Different stakeholders may have radically different views and values about the problem;
- Underlying cause and effect relationships are complex and poorly described

Wicked problems must be managed because they cannot be solved (Peterson 2013). This generally involves engaging relevant stakeholders to seek support for outcomes and targets and documenting a performance trajectory that is improving over time on key measures.

There is intense interest in the role of regulatory control in animal welfare.

Goodfellow (2016) describes Australia's farm animal welfare regulatory framework as serving public interest through dual actions: protecting farm animals from cruelty; and, promoting incremental and sustained improvements in animal welfare over time. Public interest in animal welfare is growing over time towards increasing expectations concerning compassion and care as opposed to more utilitarian views on production and efficiency.

Regulation refers to the broad range of legally enforceable instruments which impose mandatory requirements upon business and the community, as well as those government voluntary codes and advisory instruments for which there is a reasonable expectation of widespread compliance (Commonwealth of Australia 2013). The Productivity Commission has recently released a draft version of a report on regulation of Australian agriculture (Productivity Commission 2016). It is clear that the community attaches value to animal welfare that is distinct from the contribution that welfare may make to productivity and profitability of a livestock enterprise, and that animal welfare is of interest to the broader community regardless of whether they are involved in any way in production, processing or consuming products from relevant industries. These issues are used to justify a role for regulation in agriculture with a particular focus on welfare. The challenge identified in the draft report is to identify the level of farm animal welfare that provides the highest net benefits to the community as a whole.

Primary responsibility for animal welfare rests with state/territory governments with some particular responsibilities at both the Commonwealth level (international trade) and at local council levels. Australian state/territory governments are working through progressively replacing Model Codes of practice with Australian Animal Welfare Standards and Guidelines. The Australian Animal Welfare Standards and Guidelines for Cattle were endorsed in January 2016 and are being variously adopted within state/territory jurisdictions between 2016-2018.

There is ongoing debate about the process for developing and reviewing welfare standards and whether there are inherent biases and opportunities for undue influence in the way the process is managed (Productivity Commission 2016). There is general agreement that animal welfare regulation should be based on national standards, be as clear and as transparent as possible, evidence-based (animal welfare science and research on community views) and have more independence in the standards development process so outcomes are not unduly influenced by one group.

The draft Productivity Commission report on Regulation of Australian Agriculture is recommending that an independent body be established to take a leading role in developing standards and guidelines for farm animal welfare (Productivity Commission 2016). The report also mentions possible benefits from moving from a current prescriptive approach to standards to an approach with more focus on animal-outcomes that might represent more direct measures of animal welfare state. Outcomes based regulation may allow producers more flexibility in how they manage welfare outcomes (more capacity for customisation, innovation and efficiency) while focusing on performance outcomes that may more directly reflect the animals' welfare. There is considerable interest world wide in identifying outcomes measures that may be incorporated into welfare standards.

The report also discusses issues and options for regulatory compliance and assurance such as the APL QA program for pig producers and the Australian Livestock Processing Industry Animal Welfare Certification System. Co-regulation offers advantages and disadvantages. The report considers that more transparent and effective monitoring and enforcement would help to increase community confidence in industry commitment to animal welfare. The report recommends that state and territory governments should review (increase?) monitoring and enforcement activities including co-regulatory models with industry QA schemes.

There is also growing concern over management of enforcement in many states and territories where apparent non-compliance with welfare standards may be managed in ways that are out of step with community expectations. Goodfellow argues that this is a representation of regulatory capture – where the regulatory agency (state/territory departments) may act in a manner that is more consistent with the norms and values of the industry they are regulating than with community expectations and the public interest that the regulation may be intended to serve. Examples of this include management of live export incidents and also the response to a 2009 incident involving the deaths of several hundred cattle on a university operated cattle station in northern Australia (Goodfellow 2016). Goodfellow goes on to describe broad options for regulatory reform that have been adopted in other problematic regulatory areas (atomic energy, workplace health and safety, environmental protection) and that may offer some insight for the farm animal sector.

In recent years the concept of social licence to operate has become a topical issue amongst agricultural industries. A social licence to operate refers to community approval for the activity and is based in turn on the beliefs, perceptions and opinions held by stakeholders in a particular activity (Arnot 2009, 2011). Arnot (2011) defines social licence as the privilege of operating with minimal formalised restrictions (legislation, regulation, or market requirements) based on maintaining public trust by doing what is right. Arnot (2011) also defines public trust as the belief that activities are consistent with social expectations and the values of the community and other stakeholders.

If social licence is lost through events that erode or eliminate public trust, there is a risk of having it be replaced with social control, represented by regulation, legislation, litigation and increasing public activism opposing operation of the industry (Arnot 2009). This process may be viewed as a tipping point with a lower cost, trust-based tacit approval of industry operations (social licence) being replaced with often a higher cost, more rigid, regulatory framework that attempts to enforce compliance in order to maintain some level of public confidence. Arnot (2009) argues that industry investment in building and maintaining social licence is not just the right thing to do, it is good business.

In the current environment, the livestock export industry is managing an erosion of social licence for livestock export and this is leading to a combination of mounting scrutiny of industry, increasing public pressure for more regulatory controls to be imposed on industry activities and calls for the

export of livestock to be abolished based on animal welfare grounds. When there is effective social licence to operate, it is possible for operators to move away from a more restrictive, regulatory environment towards a more relaxed operating framework with less regulation (Arnot 2009).

Industry funded research has over many years been directed at issues of direct relevance to productivity and welfare in northern beef herds. Examples include the Cash Cow study (McGowan *et al.* 2014) and the breeder mortality study (Henderson *et al.* 2013). Additional projects are now being planned to further investigate calf and cow mortalities in particular and implement intervention trials to reduce the risk of these losses occurring under northern conditions. These proposed studies will incorporate innovative methods for monitoring animals and managing performance data and will have ancillary benefits in facilitating performance monitoring and reporting. These activities will offer insight and options for industry to consider in developing welfare monitoring and reporting systems for key measures that will in turn contribute to strengthening social licence.

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Potential benefits of selecting for improved resilience in Northern beef cattle

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Introduction

Livestock face a variety of challenges from their production environment including exposure to infectious agents, abiotic extremes, social stressors as a result of herd hierarchy and mixing with unfamiliar animals and management induced stressors imposed by standard husbandry procedures and practices. Challenges vary between environments. For instance, in Northern Australia, beef cattle experience seasonal challenges from ticks and buffalo flies, extreme heat and humidity, variable feed quality and long transport distances to market. Following pasture backgrounding, many Northern Australian cattle are then finished through feedlots or are destined for live export exposing them to a new set of challenges. Identifying animals better able to cope with these unique challenges could 1) improve animal health and welfare 2) reduce reliance on the use of antibiotics and anti-parasitic drugs thus slowing the emergence of multi-drug resistance and 3) improve productivity. It is also important to consider the significant influence consumers can have on an industry.

Consumers are increasingly conscious of the health and welfare of the animals producing their food and are demanding the highest possible standards of animal welfare through purchasing choices. Consumers are also increasingly concerned with the use of drugs in food-producing animals and the potential residue issues they pose. Therefore, breeding strategies aimed at improving the health and welfare of animals and reducing reliance on drugs to treat disease are expected to improve consumer confidence, help maintain the social licence to operate and, improve industry profitability.

We define resilience as the ability of an animal to maintain productivity in the face of diverse environmental challenges. Livestock respond to challenges from infectious agents and other environmental stressors through immunological, physiological and behavioural defence reactions. These three modalities of host defence are highly integrated, acting together to minimise the impact of challenges on the host (Colditz *et al.* 2002). The resilience of individual animals can be predicted by combining measures of their general immune competence, stress responsiveness, ability to tolerate climatic extremes and behaviour or temperament (Fig. 2). Livestock management practices, such as weaning, social mixing and animal handling, provide opportunities to simultaneously assess the various components of host defence contributing to resilience. For example, yard weaning of beef calves provides an opportunity to simultaneously assess the ability of calves to cope with weaning stress, the ability of calves to respond to immunological challenges whilst under stress and assess their temperament.

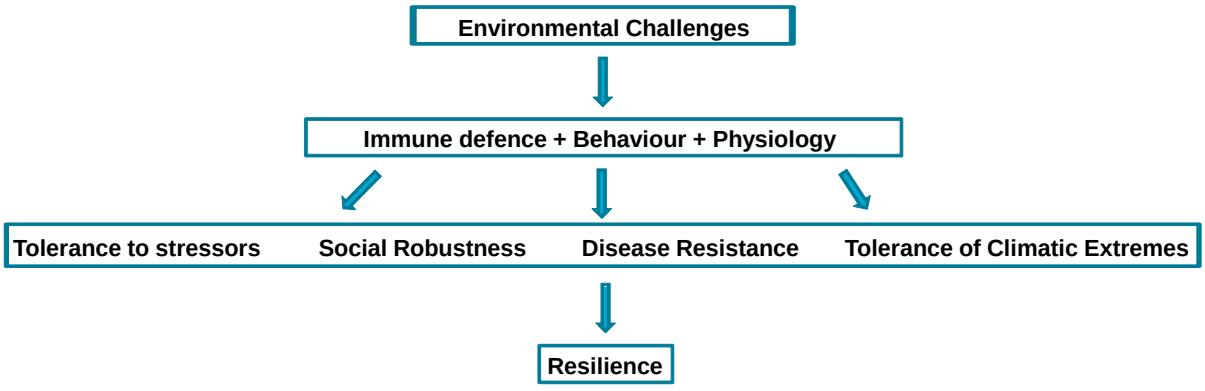

Fig. 2. Resilience can be considered as the ability of an animal to maintain productivity in the face of diverse environmental challenges. Measures of disease resistance, tolerance to stressors, heat tolerance and social robustness can be used in combination to predict an animal's resilience.

When assessing the resilience of livestock, the component measures used to define the resilience phenotype need to be tailored to the specific production environment. Here we propose a series of measures, which could be used in conjunction to define resilience phenotypes specifically tailored for beef cattle grazing in various regions of Northern Australia.

Heat tolerance

The trend toward increased hot conditions in the cattle production regions of Australia is clear. Howden and Turnpenny (1997) reported that for the Gayndah region (South East Queensland), the last 40 years has seen a 60% increase in days that cause heat stress in taurine cattle. With an intermediate warming scenario of an average temperature increase of 2.8°C by 2100, the number of heat stress days are estimated to increase to 139 days p.a. (as compared to the 58 heat stress days in the late 1990's). Furthermore, this region will face 92 days p.a. with high risk of heat related fatalities.

While the numbers and costs of cattle mortalities due to a discrete heat event can be calculated, total production losses over summers and on a national basis are difficult assessments. Sackett *et al.* (2006) estimated that Australian feedlots lose $16.5 million p.a. due to reductions in animal performance over summer.

The most obvious contribution to productivity loss in cattle from heat stress is decreased feed intake and subsequent slower weight gain. In beef cattle, there is a 0.4 kg/day average daily gain (ADG) depression for every 1°C increase in internal body temperature (Finch 1986). A less obvious impact is the lower reproductive performance (Wheelock *et al.* 2010). All stages of bovine reproduction are affected by heat load.

Any stressor will redirect endocrine and metabolic processes toward maintenance of homeostasis and away from growth. The overt characteristics of heat stress: reduction of feed intake, reduced appetite and lassitude are the accumulation of the interactions of systemic endocrine, metabolic and inflammatory changes. The reduced feed intake most commonly experienced during heat stress has clouded much of the research and interpretation of the endocrine and metabolic effects that can be solely attributed to heat stress. However, the metabolic changes in heat stress cannot be explained by reduced feed intake alone. Heat-stressed ruminants fail to enlist the glucose saving mechanisms used by underfed animals; i.e. do not consume their fat stores and become slightly insulin insensitive (Baumgard *et al.* 2011, Wheelock *et al.* 2010). It is likely, that to supply the glucose required for maintenance, protein in muscle is being catabolised to fuel gluconeogenesis in the liver.

There is now some evidence that the gut barrier function is disrupted in heat stress. The role of ruminal and intestinal dysfunction during heat stress in cattle was first proposed by Cronjé (2005). The disruption to gut function and integrity is a consequence of reduced blood flow to the viscera during heat stress, as the blood is directed to the skin and the mucosa of the respiratory tract for cooling. The lack of oxygen in the gut and liver, due to the reduced blood flow, compounds the situation thus setting off more inflammatory responses.

There has been research into different management tactics and tools with some adoption by producers and producer organisations (e.g. MLA 2006). Based on research and their own experience, beef cattle nutritionists have manipulated buffering capacity, electrolyte balance and roughage: grain ratios of summer rations. These adjustments have met with success in some instances and not others, but this inconsistency is not understood.

Many researchers point to genetic selection as a means to equip the industry with heat tolerant breeds (Gaughan *et al*. 2010, Howden and Turnpenny 1997). It is generally accepted that *Bos indicus* genotypes have greater heat tolerance than *Bos taurus* genotypes. There are exceptions. The Tuli, closely related to *Bos taurus* but tropically evolved, appears to have a high degree of heat tolerance (Hammond *et al*. 1998). This paper reported also that the rectal temperatures of Brahman cattle and

Angus cattle (40.0 and 40.9 °C respectively) were higher than the rectal temperature of Senepol cattle (39.6 °C) under the same conditions.

Selective breeding for heat tolerance is a long and imprecise process but needs to be part of the answer. However, tools for detecting economically competitive heat tolerant phenotypes are limited because it is not understood which physiological parameters are most appropriate. Furthermore, the technology to measure these parameters in large numbers of animals in production environments is still under development or not yet in the pipeline.

Our current focus is on feedlot cattle where we are investigating inflammatory and metabolic responses to high heat load in growing steers in collaboration with Dr John Gaughan and team (University of Queensland, Gatton) (MLA B.FLT 0157). While the end-goal is to develop new nutritional and/or management approaches for alleviating heat stress in the feedlot, we are hopeful of discovering new parameters to define the heat-tolerant phenotype in *Bos taurus* cattle. This will provide tools for selective breeding and for assessing the suitability of animals for feedlot entry.

Tick resistance

Cattle tick (*Rhipecephalus microplus*) and tick borne disease (*Anaplasma marginale, Babesia bigemina, Babesia bovis*) have the highest economic impact of all diseases experienced in cattle in the north of Australia. A recent review commissioned by Meat and Livestock Australia estimated annual costs in excess of $160 million and attributed this to a combination of lost productivity and treatments (B.AHE.0010). Typical strategies used to control the incidence and severity of tick and tick borne disease are genetic improvement, chemical control, vaccination and management practices. A search of the patent literature over the last 10 years largely confirms the focus on these control strategies but identifies the occasional unconventional candidate. A breakdown of the results revealed a total of 68 patents of which 55 patents describing potential novel acaracides, 6 for vaccine antigens, 3 genetic loci that could be significant for breeding approaches, and one each for probiotics, novel detection method, dsRNA (a form of chemical control) and freeze spraying (Derwent Innovation Index). Chemical control approaches have been highly successful when susceptible populations of ticks are targeted but increasingly ticks are showing high levels of resistance to acaricides. This issue has driven the ongoing search for new actives as identified in the patent search described above. Further complicating matters for producers are withholding times that must be applied following chemical application (limiting sale and movement of animals) and community concerns with the potential for residue contamination of foods and the environment.

Genetic control strategies are focussed on selective breeding programs that seek to include cattle that are tick resistant and / or eliminate those that are highly susceptible. This is largely achieved in industry by an indirect method through use of pure Indicine or crossbred Taurine and Indicine animals, as the Indicine breeds are reported to carry 5-10 times less ticks than taurine breeds (Jonsson 2014). Variation of resistance level within breeds does occur but it is difficult to take advantage of this fact as ranking animals for this trait in high numbers is not logistically or economically feasible. The main limitation being the intensive nature of recording tick levels on cattle, which is achieved via visual assessment of the animal. The tick burden is quantified as a score or as specific numbers of parasitising engorged adult ticks. Measurement of larvae is even more difficult given their near microscopic size and preference for difficult to access areas of the animal, that can place observers in harms way. The heritability of these traits is variable, ranging from 0.13 to 0.64 (Jonsson 2014), and this is most likely because the response mounted is complex, involves multiple functional pathways each of which may contribute at variable levels dependent on the different environmental or tick challenge methodology used.

The nature of host resistance to parasites is complex and involves many pathways (Campino 2006). The culmination of these pathways is reduced numbers of ticks, reduced viability or production of tick eggs. Resistance achieved via immunity is composed of both innate and acquired responses (Piper 2009, Kemp 1976). Antibody has been shown to be important in some studies but recent focus has been on the significance of the cellular response (Piper 2009). Genetic association studies have reinforced the importance of these pathways by identifying genes that are known to

function in development of immune responses or wound repair, such as RIPK2 (Porto Neto 2012). Behavioural responses such as grooming, which is mediated by licking are important (Verissimo 2016). Other structural features of significance for enhancing cattle resistance to ticks include colour, hair density, and skin thickness (Shyma 2015).

We suggest that recent advances in technology should facilitate development of automated approaches for quantifying tick loads on animals and that this could be a productive area for future research. It may also be possible to measure resistance indirectly through an associated trait. In this respect, blood based immune parameters provide a further option. We have recently reported the use of blood based parameters for identification of worm resistant sheep allowing animals to be ranked following a single blood test (Andronicos 2014). Confidence in the value of such tests is enhanced by the observation that test results correlate well with conventional methods of counting parasite load (WEC in the case of worms). Significantly these phenotypes are amenable to pooling studies which greatly reduce the cost of genotyping studies and the method has been devised in a manner that allows both genotype and phenotype to be collected from a single sample. Given the importance of cellular responses to tick resistance in cattle, we believe that application of a similar approach in cattle may have great value in defining a new phenotype that can be routinely measured.

Temperament

It is easy to recognize that cattle differ in their behavioural reactions, for instance, to humans and to isolation from a group. When a behavioural response is expressed consistently on multiple occasions and in different situations it likely reflects the temperament of the animal. Cattle were domesticated from a wild progenitor, the auroch, which was hunted for food by humans. For these animals, fear of humans would have improved their chance of survival. During the process of domestication cattle were unintentionally selected for docility (Larson & Fuller 2014); however, it was not until the 1970s that attempts were made to quantify the temperament of cattle and objectively breed for temperament traits. A number of methods for measuring temperament were explored including escape attempts of an animal isolated in a yard, flight distance when approached, and restlessness when held in a crush (Fordyce *et al.* 1982). The advantages of a standardised and automated method for measuring temperament led to the development of flight time, which is the time in seconds it takes an animal to travel a distance of approximately 2 metres when released from a crush (Burrow *et al.* 1988). The trait is moderately heritable and EBVs for flight time are available through Breedplan for Brahman and Santa Gertrudis sires while EBVs for docility, measured as restlessness in the crush or when held individually in a yard, are available for Limousins.

The behavioural responses we recognise as reflecting the temperament of the animal are accompanied by physiological responses such as release of the stress hormones cortisol and adrenalin. These hormones influence energy metabolism. It is therefore not surprising that favourable correlations exist between docile temperament (eg slow flight time), faster growth rate in the feedlot, more tender meat, and lower incidence of dark cutters (Kadel *et al.* 2006). Favourable temperament is also associated with a reduced occurrence of disease during feedlot finishing (Fell *et al*. 1999) but is not associated with resistance to internal or external parasites. In one study conducted during an AI program, more cows with a docile temperament were identified as in oestrus than cows with a poor temperament (reviewed by Haskell *et al.* 2014).

A second change in behaviour that is thought to have occurred early in the process of domestication was an increased capacity of cattle to habituate to the presence of humans and being handled (Wilkins *et al.* 2014). Whereas temperament is recognised by the consistency of a behavioural response over time, habituation is the change in response as the animal becomes accustomed to handling and to a new environment. A capacity to habituate underpins the training procedures used at weaning to teach young cattle to lead and move as a mob (Tyler *et al*. 2012). It has been proposed that genetic variation between animals in their capacity to habituate could be a valuable trait for selection (Wechsler & Lea 2007); however to date, standardised tests for quantifying the capacity to habituate have not been developed. Further exploration of the genetics

of habituation and its association with resilience of animals to environmental challenges is warranted.

Immune competence

Unfavourable genetic correlations exist between production traits and the incidence of many common diseases in livestock (Rauw *et al*. 1998). For example, the genetic correlation between milk production and the incidence of mastitis in dairy cattle has been estimated at between 0.15 to 0.37 (Lyons *et al*. 1991, Uribe *et al*. 1995, Van Dorp *et al*. 1998) and selection focussed on high productivity in pigs has led to an increase in susceptibility to stress and disease (Prunier *et al*. 2010). Such findings suggest that selection for production traits with little or no emphasis on health and fitness traits has the potential to increase the incidence of disease in livestock production systems.

The immune system is composed of tissues, cells and molecules which work together to protect the host animal against disease. Effective host defence is reliant on the immune system's ability to detect a wide variety of agents, to distinguish whether such agents are part of the body or foreign (self versus non-self), to determine whether non-self agents are commensals or threats, and to eliminate the potentially infectious agents or pathogens. Livestock, with the exception of those raised in specialised facilities, are exposed to a myriad of pathogens on a regular basis. Such pathogens possess an inherent ability to evolve rapidly, and as a consequence, adapt quickly to changes in the environment, and continually develop new strategies to avoid detection and elimination by the host's immune system. To detect and eliminate pathogens, the immune system has developed a diverse range of defensive responses that work together to protect the host. Immune competence can be considered as 'the ability of the body to produce an appropriate and effective immune response when exposed to a variety of pathogens'.

Animal health can be improved through both targeted management practices and the implementation of genetic selection strategies aimed at breeding animals with improved immune competence. In combination, these approaches have the potential to dramatically improve animal health. Health and welfare are intimately linked and therefore improving animal health is expected to result in improved welfare outcomes for livestock. The concept of breeding for 'general' disease resistance was first proposed by Wilkie and Mallard (1999) and has been used successfully to reduce the incidence of disease in pigs and dairy cattle (Mallard and Wilkie 2007, Mallard *et al*. 2014). This approach combines measures of both antibody-mediated immune responses (AMIR) and cell-mediated immune responses (CMIR) to assess 'general' immune competence (Figure 2). Extra- and intra-cellular pathogens are most effectively controlled by AMIR and CMIR, respectively, therefore individuals identified as having a balanced ability to mount both types of responses are expected to exhibit broad-based disease resistance. Based on this concept, Mallard *et al*. established a protocol to assess immune competence in dairy cattle which has enabled genetic selection strategies, aimed at breeding animals with enhanced 'general' disease resistance, to be developed and implemented in industry. We are currently developing a similar testing protocol, based on a different set of antigens to those used by Mallard, to assess 'general' immune competence in *Bos Taurus* beef calves in Southern Australia during yard weaning as part of a joint Meat & Livestock Australia and CSIRO funded project. As part of the project we are investigating the potential for genetic selection, aimed at improving 'general' immune competence, to reduce the incidence of disease in Australian beef cattle with a particular focus on reducing bovine respiratory disease (BRD) incidence in the feedlot environment.

Following extensive research to validate the benefits of breeding for improved 'general' disease resistance in dairy cattle, the global breeding company Semex Pty. Ltd. are now marketing semen from sires with estimated breeding values for immune competence (Mallard *et al*. 2014). Such advances are allowing dairy producers to place direct selection emphasis on traits aimed at improving the health and welfare of animals in their herds. We propose that the development of immune competence testing protocols specific for beef cattle in Northern Australia will allow beef

producers to select animals with improved general disease resistance, improving the health and welfare of cattle in their herds.

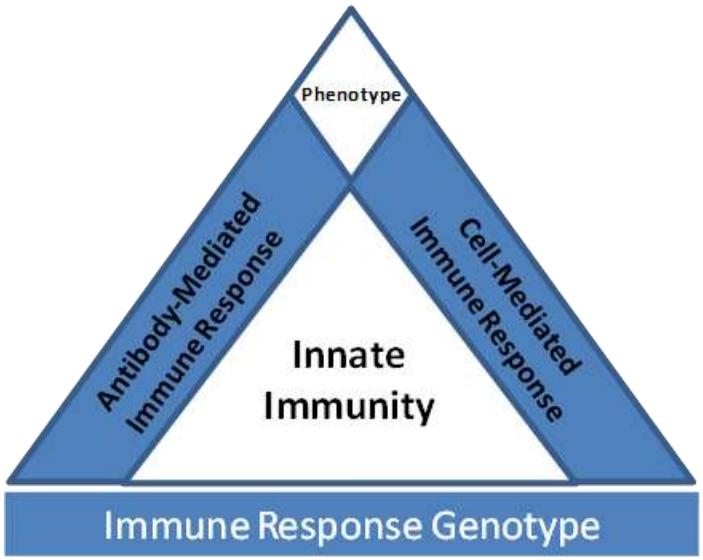

Fig. 2. Genetic variation in the ability to resist disease is due to a large number of additive genetic effects which together regulate innate and adaptive immune responses (Source: adapted from Wilkie and Mallard 1999)

Summary

Future development of a resilience selection index specific to Northern Australia beef cattle will allow Northern cattle producers who are aiming to improve the resilience of their herds to make genetic gains in resilience traits. If improved resilience is correlated with an improved ability to cope with the challenges imposed by the feedlot and live export environments, feeder and live export cattle which are the progeny of high resilience indexing sires are expected to attract a premium for cattle producers.

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Extensive sequencing of a tropically adapted breed – the Brahman Legends Sequencing project

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Introduction

The tropically adapted Brahman breed (*Bos indicus*) was developed from four Indian cattle breeds in the United States and are now widely used for beef production in harsh environments in Northern Australia, South Africa, Namibia, the United States and Columbia. Identifying mutations in Brahman genomes associated with adaptation, fertility, meat quality and growth rates would facilitate genome selection and therefore accelerate genetic gain for these traits in both Brahman cattle and composite cattle with Brahman ancestry. With this ultimate aim, fifty Brahman bulls were selected for sequencing.

Materials and Methods

Bulls for sequencing were selected using an algorithm that identified fifty bulls that captured the highest proportion of genetic variation in the breed, based on an analysis of an extensive Brahman pedigree and a stepwise regression procedure to avoid double counting of ancestral genomes and took into account whether DNA, extracted from semen straws or Ampules, was available for a bull or not (Druet *et al.* 2014). The selected bulls were sequenced on an Illumina HiSeq sequencer, at an average of 12.5 times genome coverage, and a range of 10 times genome coverage to 30 times genome coverage. Reads were mapped to the bovine genome (UMD3.1) with BWA and variants were detected in the sequence with a GATK pipeline. The variants included single nucleotide polymorphisms (SNP) and small insertion deletions (indels).

Results and Discussion

The 50 bulls selected captured 17% of the variation represented in the pedigree. Among the bulls selected, many were grand sires or great grandsires of very large numbers of bulls now used in the Northern Australian industry. The oldest bull in the sequence data set had a birth year of 1959. Initial analysis of the sequence data revealed the Brahman genomes had a much higher rate of polymorphism than that observed in *Bos taurus* breeds. This is likely a reflection of a larger ancestral population size for *Bos indicus* cattle than *Bos taurus* cattle (pre-domestication) and the fact there was some infusion of *Bos taurus* breeds into Brahmans during breed formation. The next step in this project is to link genome variation amongst the bulls to variation in key traits such as fertility and meat quality.

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Virtual connections leading to real results

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Introduction

The FutureBeef eExtension team delivers online services to graziers across the top half of Australia as part of the FutureBeef Program for northern Australia. These beef properties are geographically distributed across 4.3 million km^2, providing a formidable challenge for service delivery. While face-to-face engagement is ideal for building trust and rapport, webinars provide an innovative means to connect in real-time without anyone needing to travel.

FutureBeef pioneered the delivery of RD&E information to the beef industry via webinar and has been connecting audiences since November 2011. It has already delivered 27 public webinars, attracting 5400 registrations, 2360 live attendees and the recordings have received over 8000 views on YouTube. The webinars are now delivered as a collaboration between the Department of Agriculture and Fisheries (Qld), Meat & Livestock Australia and Beef Central.

Methods

An external evaluation (Coutts 2016) was undertaken using telephone surveys of 265 randomly selected FutureBeef eBulletin subscribers (from a total of 2931) of which 150 people completed the survey (a response rate of 57%). The respondents were producers (68%), public extension officers (16%), private advisors (13%) and corporate farm managers (3%). Secondary data included internal post-event surveys of each webinar.

Results

The FutureBeef webinars were described by respondents as being: “wonderful”, “brilliant”, “a great initiative”, and “well-presented and professional”. Several mentioned the webinars as providing valuable content for those who are too busy, isolated or unable to travel long distances, commenting, they are a good way of engaging people and 1 person said, “they are brilliant and it saves on travelling time and cost – very efficient” (Coutts 2016).

Across the 27 webinars, respondents found it relatively easy to register (9.6/10), join (9.0/10) and interact (8.7/10). They found the information useful (8.1/10), improved their knowledge (7.8/10) and were overall satisfied with the event (8.3/10).

Discussion

Face-to-face engagement is the best way to build trust and communicate complex messages, but when that is not feasible, electronic engagement can be a useful substitute. Webinars enable graziers to engage with specialists anywhere in the world and gain the latest information. Graziers with suitable Internet connections found it easy to participate with the webinars and valued the information provided. However, limitations of Internet access and data limits impede the wider adoption and use of this modern communication medium.

In the meantime, FutureBeef will continue providing this valued service to those able to access it. The webinars are an effective means to connect with a geographically dispersed audience and complement other engagement mechanisms.

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Update on cattle tick vaccine research

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Introduction

Cattle ticks and the diseases they carry have been estimated to cost Australian cattle industries up to $175m per annum in losses. During the Beef CRC (2005 – 2012), research to identify new cattle tick vaccine candidates as alternative(s) to the previous TickGARD vaccine was undertaken. TickGARD is known to need 3 to 4 boosts per annum to protect successfully, and worldwide TickGARD based vaccines are not protective against all cattle tick stains (nil protection in Argentina and South Africa and low protection in Brazil). These facts rendered TickGARD commercially unsuccessful in Australia. During Beef CRC research, mixtures of novel vaccine candidates demonstrated protection in tick challenge trials. Since 2014, Meat & Livestock Australia has supported on-going trials to determine the most effective single antigens for Intellectual Property protection.

Methods

Tick challenge trials are undertaken in tick pens at the Queensland Animal Science Precinct, UQ Gatton campus. Small groups of cattle (n=3) are vaccinated prior to infesting the cattle with tick larvae. After ~3 weeks, fully engorged adult female ticks which have 'dropped' off the cattle are collected from each animal daily (soft washing of pens into baskets). These ticks are cleaned, counted and weighed, and subsequently incubated to determine if they lay viable eggs. The percent effectivity of each vaccine is determined by comparing the number of ticks, the weight of eggs and the percentage of larvae emerging from the eggs – in comparison to the ticks collected with the control group of unvaccinated cattle.

Results

A total of 15 candidates have been tested in 3 trials to date. Effectivities have ranged from 20-60%, with 8 vaccines showing nil effectivity.

Discussion/Conclusions

A final 5 single antigens are being tested later this year. Future research will examine mixtures of the most successful vaccine candidates and also determine if long lasting immunity (annual boosting) can be achieved. The estimated economic benefit to the beef cattle industry was estimated at ~$98m with a potential international market value of a further $US100 million in vaccine exports per annum.

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What if beef industry recommended practices were Politically Correct?

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Introduction

Beef industry service providers at a workshop in 2014 were not satisfied with the low number of beef producers who had adopted recommended practices (RPs) for cattle herds and grazing lands. They proposed that wider adoption of RPs would occur if extension practices focused more on the values important to beef producers and less on the values important to service providers. This paper identifies two forms of 'Political Correctness' which in different ways influence the adoption of beef industry RPs.

Political Correctness that isn't Driving Adoption

Leading beef producers, beef industry organisations and service providers place great value on running beef properties as businesses, believing this to be the primary reason for adopting RPs. This has become the politically correct rationale for beef producer adoption of RPs, and one that very few beef producers would publically disagree with. However, running a property as a business may not be the highest priority for many beef producers, who instead, place more importance on personal aspects of their occupation, such as family, community, industry, landscape and livestock. Could adoption of RPs increase if they were aligned with these personal values?

Adoption Rates are Slow at Best

Some products, such as fridges, radios and landline phones, were almost essential during the 1900s but yet 30+ years passed before 90% of United States (US) households had these products. Non-essential but highly attractive products like a colour TV or mobile phone took 20 years to be adopted by 90% of US households. Brahman cattle genetics, first introduced to Queensland properties in 1910, represented only 10% of the herd by the late 1960s, and took another 30 years to reach 80%. All of these products had obvious benefits and were easy to use, but still took decades to be widely adopted.

Other products, like exercise bikes, electric cars and security cameras, stalled at below 20% adoption by a population. Adoption of practices can be similarly low, like the regular use of financial budgets by Australians, or beef producers who forage budget, pregnancy test or keep effective records. Marketing theory states that people who are late to adopt an innovation cannot be persuaded to adopt earlier, no matter how many times they are prompted to do so. Faster and wider adoption requires the innovation to be reinvented to make it attractive to more people.

If only Recommended Practices could be like a Personal Computer

Personal computers (PCs) were introduced in the late 1970s and by 1985 adoption by US households stalled at 15%. While being a highly useful office tool, most households did not want or perceive a need for them. Uptake of PCs then increased through reinvention which made them cheaper and easier to use and enabled them to be used for many purposes. Over 30 years, with improvements in operating systems, speed and memory, the rapid expansion of games and software applications and connection to the World Wide Web, household adoption rose to 80%. Similar reinvention occurred with mobile phones and also played a role in the widespread adoption of Brahman genetics in northern Australia. Brahman cross-breeds, including official breeds like Santa Gertrudis, appealed to increasing numbers of beef producers. For PCs and mobile phones it was personal applications rather than business applications which were responsible for the very high level of adoption. Can RPs be like PCs, reinvented to be cheaper and easier to use and serve more purposes?

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Standardised record keeping to improve beef business performance

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Introduction

Recent reports demonstrate significant opportunities for improvement in beef breeding businesses in northern Australia (McGowan *et al*. 2014; McLean *et al*. 2014). Comprehensive engagement with beef producers across the Burdekin River Basin has shown that very few keep adequate reconciling stock records, thus limiting their capacity to calculate current position. This reduces confidence and ability to realise the benefits of practice change. Many herd record keeping technologies and methods exist commercially however adoption rates are low. This activity focuses on practical methods to capture the most basic mob-level information required to perform business and cost benefit analyses.

Method

A producer group in the lower Burdekin basin, central Queensland, is developing and testing a simple standardised herd-recording system using field data captured to:

a. Complete a reconciling annual livestock schedule based on gender, age, number and live weight.
b. Perform herd and business analysis using the BRICK (Anon) as a diagnostic platform for identifying opportunities for practice changes.
c. Conduct economic analysis to determine the profitability of practice changes using Breedcow (Anon).

Results

The group has so far successfully developed and tested yard recording sheets that capture data to feed directly into an office-based paddock livestock schedule spreadsheet. Individuals within the group have gained confidence to examine management practice changes such as: moving to a controlled mating program; developing improved pastures to reduce sale age; and, undertaking a series of diagnostic measures to determine possible causes of below-expected cow performance.

Discussion and Conclusion

There was initial belief from the producers that their existing herd data was sufficient. After the first attempt to complete a reconciling annual livestock schedule, they acknowledged a need to improve their record-keeping practices. It was a simple exercise of reconciling livestock numbers that led producers to realise it is not possible to thoroughly evaluate their management and business, thus identify opportunities for improvement, without at least basic data.

Acknowledgements: We would like to thank the producer focus group for their continued dedication and support.

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"We remembered what you'd said so we changed what we did"

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Introduction

As a Research/Extension Officer there is no better compliment that makes your heart sing more than: "We remembered what you'd said, so we changed what we did."

Methods

Rangeland Management Courses are a travelling one-day course where Northern Territory Department of Primary Industry and Fisheries (DPIF) and Department of Land Resource Management staff join forces to present information about the rangelands to first and second year stockpeople. Participants typically range in age from 16 – 25, and come from the widest variety of backgrounds; some have been born and raised on cattle properties in Queensland and New South Wales, while others are straight from school in the inner city suburbs of Melbourne. But no matter where they come from, they all seem to learn something and become fascinated at how a natural ecosystem can support and function as the basis of a ten's-of-thousands head mob of cattle.

The topics covered in a Rangeland Management Course include:

- Pasture dynamics – species identification, good versus bad, the value of grasses and forbs, changes in quality and quantity as the year progresses
- Land condition – distinguishing criteria, the importance of good land condition, what degradation means to the carrying capacity of a paddock and how that impacts profit
- Ruminant nutrition – the role of microorganisms, pasture quality decline, the effect on reproduction and the roles of supplementation during the wet and dry seasons.
- Biodiversity – why it's important
- Poisonous plants – What the local species look like, how they affect the animal and the best management or prevention strategies
- Weeds – Identification of local species, treatment methods and demonstrations.

Between five and ten courses are run throughout the year, mostly on company owned stations right across the NT. Course presenters are always certain to accommodate different learning styles throughout the day by including activities, field trips, practical demonstrations and theory based information delivery. Discussion between participants focussing on previous experiences relating to the topics is encouraged at all times in alignment with andragogy principles. One of the most relished activities in the course is the station planning exercise which is held at the end of the workshop as a self-directed summary activity. In groups of three or four, participants are given a map of their current station of residence with only the land systems and boundary fence marked on it. Using the skills and information they have learnt throughout the day, participants work hard to plan fences and watering points, identify their most productive paddocks for animals requiring highest nutritional requirements, all while keeping in mind the characteristics of the land systems available. To date we have received positive feedback and will continue to deliver, develop and customise the course for as long as we are invited by station owners and managers.

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Cell grazing doesn't pay its way in the Northern Territory

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Introduction

Proponents of intensive rotational grazing (IRG) or 'cell' grazing suggest it will increase the productivity and profitability of northern grazing systems. This has garnered considerable interest at a time of declining productivity gains and high debt levels. We review the impacts of IRG compared to continuously grazed paddocks when trialled in the Northern Territory (NT).

Methods and Results

Table 1. Characteristics of the IRG systems in the NT trials.

Station, Region	Median rainfall (mm)	Trial duration (years)	Paddock size (km²)	Number of paddocks	Stock density when grazed (AE/km²)	Graze period (days)
Beetaloo, Barkly	450	4	2-25	46	846	2-5, some open gates
Newcastle Waters, Barkly	476	3	1-8	14	370	15 (1-116)
Pigeon Hole, Victoria River	650	3	1.2	25	404	5
Douglas Daly, Douglas Daly	1209	6	0.06	26	2773	1-3

Pastures did not stay in phase two growth during the dry season. IRG did not lead to improved pasture yield, composition or soil carbon in the short term. Smaller paddock size of IRG paddocks was associated with more even grazing with distance from water, but carrying capacity was the same as fully watered (within 3 km of water) continuously grazed paddocks. Diet quality and live-weight gain were never higher and were sometimes lower in IRG systems (Schatz 2016). The higher operating costs (1.5 to 1.8 times higher) and higher capital investment of IRG led to poorer economic performance compared to continuously grazed systems. At Pigeon Hole the minimum paddock size to maximize economic returns was between 20 to 30 km^2 (Hunt *et al.* 2013). Once paddocks are fully watered, addition of further waters and fencing did not lead to further increases in carrying capacity and reduced economic returns.

Discussion and Conclusions

Fully watered continuously grazed paddocks with appropriate stocking rates performed as well or better than IRG systems. NT findings are consistent with others (Hall *et al.* 2014; Briske *et al.* 2008). The lower or similar production combined with higher operating and capital costs of IRG make them less profitable at least in the short term. Unless IRG leads to higher carrying capacity, there is no potential for it to lead to higher profit given the higher costs.

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Nitrate supplementation of beef cows in the dry tropics

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Introduction

The Australian government has recently approved a GHG offset methodology allowing beef cattle producers to earn Australian Carbon Credit Units (ACCU) and participate in the Emissions Reduction Fund (ERF) by feeding nitrate as a substitute for urea when fed at an equivalent amount of nitrogen. The objective of this experiment was to determine effects on animal health and productivity when cattle were offered free choice nitrate lick blocks during the dry season.

Materials and Methods

Seventy six *Bos indicus* cows were stratified by liveweight (LW), parity and pregnancy status, then allocated to unrestricted access of lick blocks containing either nitrate (molasses based with 35% calcium nitrate; 60 g N/kg as fed) or urea (Rumevite 30% Urea + P; 150 g N/kg as fed) between June and November 2014. Cows grazed a common 467 ha paddock during the experiment at Fletcherview, Charters Towers, accessing both water and allocated supplement treatments via a remote automatic drafting unit. Herd scale supplement intake was determined by weekly weighing of lick blocks. Cattle were mustered monthly to determine LW, body condition score (BCS; 1-5 scale), diet quality via faecal near infrared spectroscopy (NIRS) estimates and blood methaemoglobin (MetHb) concentrations.

Results and Discussion

Herd scale estimated mean block intakes across the dry season were 72 and 93 g/cow.d for nitrate and urea blocks respectively. Faecal NIRS estimates during June (mean ± sem; 3.8 ± 0.1% CP, 52.5 ± 0.3% DMD) suggests forage quality was initially low and it declined progressively thereafter. There were no statistical differences in mean LW nor conceptus-free (CF) LW between treatments during the experiment. However cows supplemented with nitrate lick blocks demonstrated reduced CFLW change (-0.035 ± 0.03 kg/d; $P < 0.05$) compared to cows accessing urea blocks (0.019 ± 0.03 kg/d). Similarly, nitrate supplemented cows had lower mean BCS (4.17 ± 0.02; $P < 0.05$) than urea supplemented cows (4.27 ± 0.02) and the mean difference reached 0.3 BCS units during the late dry season ($P < 0.001$). Mean blood MetHb concentrations in urea supplemented cows were normal (0.36 ± 0.04%) and did not change over the dry season. In contrast nitrate supplementation was associated with greater mean blood MetHb concentrations (0.61 ± 0.04; $P < 0.001$). The intake of both urea and nitrate blocks appeared to increase markedly during October and November. This coincided with an increase ($P < 0.001$) in mean blood MetHb concentrations within nitrate supplemented cows (1.5 ± 0.3%) and maximum individual concentrations were 7.5% and 5.7% in October and November respectively.

Conclusion

The most probable cause of reduced CFLW change and BCS in nitrate supplemented cows was insufficient N intake from nitrate lick blocks to rectify the underlying RDN deficiency in the grazing diet. Although an increase in the consumption of nitrate lick blocks would increase N intake, it is likely to be accompanied by an undesirable increase in blood MetHb concentrations.

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Evaluating growth rates in Australian and Indonesian feedlots

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Introduction

Meaningful comparisons between reported growth rates of cattle in feedlots are difficult as often objective data and information on the history of the cattle are not available. Factors such as previous management and growth rate, transport method, vaccination history, and the ration fed can all affect growth rates in the feedlot. This case study documents the performance of steers sent from Douglas Daly Research Farm (DDRF), NT to a feedlot in Queensland and in Indonesia.

Materials and Methods

These observations are of 2 consecutive year groups of Brahman steers that grazed improved Buffel grass pasture at DDRF under similar management from weaning, and were sent to a feedlot at around 18 months old. On 12 July 2013, 25 steers were weighed after an overnight curfew and transported by road train to a feedlot in south east Queensland (Qld). The ~3,300 km journey was completed over 5 days with a quarantine inspection at Cedar Park (~100km) and then spelling twice after about 1,100 km and 2,300 km. The steers were inducted into the feedlot on 18 Jul 2013 and fed the normal commercial ration for 73 days. A pre-slaughter liveweight was not recorded to avoid bruising and was subsequently estimated using the hot standard carcase weight assuming a dressing percentage of 53%. Liveweight (un-curfewed) recorded at induction, a mid-point (54 days) and the calculated final weight were used to calculate ADG and weight loss in transport (from DDRF to feedlot induction).

In 2014, 30 steers that had been managed at DDRF in the same way as the previous year group were exported to a feedlot near Lampung (Sumatra, Indonesia). The steers were weighed after an overnight curfew at DDRF on 26 Feb 2014 before being quarantined at the Berrimah export yards for 7 days prior to departure from the port of Darwin on 6 Mar 2013. They went through the normal quarantine process in Indonesia, were inducted into the feedlot on 15 Mar 2014 and received the normal feedlot rations and management for 121 days. Liveweights (un-curfewed) recorded at induction, a mid-point (69 days) and at the end of the feeding period were used to calculate ADG and weight loss in transport (from DDRF to feedlot induction).

Results and Discussion

While average ADG over the period in the feedlot (Feedlot ADG) appears higher in the Qld feedlot, this is likely the result of recovery from a greater amount of weight loss in transport (Table 1). This is also likely to be a reason why the rate of ADG appeared to reduce over time in the Qld feedlot, ie. the apparent rapid initial growth (ADG to mid-point) was due to recovery from weight lost in transport. When ADG was calculated from initial weight at DDRF (curfewed) to the final feedlot weight, then ADG's at the different locations were similar. These observations show that the history of cattle (particularly weight loss in transport) should be considered when evaluating feedlot ADG's.

Table 1. Mean performance of NT steers sent to a feedlot in Queensland and in Indonesia.

Location	Initial weight at DDRF (kg)	Transport Weight loss (%)	ADG to mid point (kg/d)	Feedlot ADG (kg/d)	ADG from DDRF (kg/d)
Qld.	343.1	-8.5	2.04	1.82	1.29
Indonesia	312.9	-1.4	1.50	1.54	1.38

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Comparison of the growth of F1 Senepol x Brahman and Brahman steers in an Indonesian feedlot

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Introduction

Most cattle in northern Australia have a high *Bos indicus* (usually Brahman) content as they perform better in the harsh conditions than *Bos taurus* cattle. However, Brahmans from northern Australia often suffer price discrimination when sent to Australian domestic markets as they are regarded as having less tender meat than *Bos taurus*. Crossbreeding with Senepol bulls has been found to be a way of producing offspring from northern Australian herds that have higher growth rates and more tender meat than Brahmans (Schatz *et al.* 2014). However there is some resistance to adoption of crossbreeding in the north as there are concerns that crossbreds are discriminated against in the Indonesian live export market, which is a major destination for young northern Australian cattle, due to the perception that they don't perform as well as high grade Brahmans in the tropical environment. Therefore a study was conducted to compare the growth of Brahman (BRAH) and F1 Senepol x Brahman (F1 SEN) steers in an Indonesian feedlot.

Materials and Methods

Shortly after weaning in 2013 the male progeny of Senepol and Brahman bulls mated to similar Brahman cows were relocated to the Douglas Daly Research Farm (DDRF) where they were castrated and then grazed improved pasture together for about a year. The steers were weighed on 26/2/14 and steers >300 kg were selected for this feedlot study. The selected steers (32 BRAH and 54 F1 SEN) were exported from Darwin (NT, Australia) to Indonesia through the normal live export process and fed for 121 days in a commercial feedlot near Lampung (Sumatra, Indonesia). All the steers were fed in the same pen and received the normal feedlot management and rations. Liveweight was recorded at induction, a mid point and at the end of the feeding period when fat depth was also measured ultrasonically at the P8 site.

Results and Discussion

When the steers were weighed at DDRF on 26/2/14, 24% of BRAH steers and 57% of F1 SEN steers weighed >300 kg as a result of the F1 SEN having a heavier average weaning weight (+12.8 kg) and higher average post weaning growth (+15.6 kg). The average weights of the exported steers at feedlot induction were 312.3 kg (F1 SEN) and 308.5 kg (BRAH). The average daily gain over the feeding period was 0.17 kg/day higher ($P<0.001$) in the F1 SEN compared to BRAH (1.71 vs 1.54 kg/day). As a result the F1 SEN put on 21.6 kg more weight ($P=0.002$) over the feeding period. There was no significant difference between the genotypes in average fat depth at the P8 site at the end of the feeding period (F1 SEN = 10.5 mm, BRAH = 10.6 mm) despite the F1 SEN being 25.4 kg heavier on average. Two BRAH steers were euthanized due to illness in the feedlot. This study found that that F1 SEN steers performed better than BRAH in an Indonesian feedlot, and so the results should allow live export cattle buyers to purchase these types of animals (Brahman x tropically adapted *Bos taurus*) with confidence that Indonesian feedlotters will be happy with their performance.

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Effect of Phosphorus supplementation on the growth and fertility of Brahman heifers grazing Phosphorus deficient country in the NT.

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Introduction

Despite numerous studies demonstrating improved growth of cattle supplemented with Phosphorus (P) during the wet season when grazing P deficient country, there is almost no published evidence demonstrating that it improves reproduction in northern Australia (Winks 1990). This may contribute to why P supplementation is not as widely adopted as might be expected (Dixon *et al.* 2011). This study aims to determine the benefits of P supplementation of Brahman females grazing P deficient country in the NT, and this paper reports on results up until the end of the first mating.

Materials and Methods

Following weaning in June 2014, 180 Brahman heifers were, after stratifying for weight, randomly allocated to either a +P or -P treatment (average weight: +P = 174.5 kg, -P = 174.7 kg; n=90 per treatment). Treatment groups separately grazed neighbouring paddocks at Victoria River Research Station that were determined to be acutely P deficient (average Colwell P soil test results: 2.5 and 3.1 mg P/kg). Study heifers were managed in exactly the same way with the exception of their mineral loose lick supplement either containing P (+P) or not (-P). In May and October each year, weight (curfewed), BCS, hip height and P8 fat depth were recorded. Heifers were mated for the first time (as 2 year olds) between 5/1/16 and 6/4/16. Pregnancy diagnosis was conducted 7 weeks after the end of mating (on 24/5/16) using manual palpation and ultrasound to confirm non-pregnancy.

Results and Discussion

Despite similar growth during the 2014 and 2015 dry seasons, the increased growth of the +P treatment over the 2014/15 wet season resulted in a significantly heavier pre-mating weight (+32 kg, $P<0.001$) on 29/10/15 (+P = 270 kg, -P = 238 kg). Similarly, the +P treatment again grew significantly more (+ 33 kg, $P<0.001$) over the 2015/16 wet season so that after mating (on 24/5/16) the average weight of the +P treatment was 65 kg heavier ($P<0.001$), +3.3 mm fatter at the P8 site ($P<0.001$) and demonstrated greater skeletal growth (+3.8 cm hip height, $P<0.001$) when compared to -P. There was a 10% higher pregnancy rate for +P (70% vs 60%), which was not statistically significant ($P=0.18$). This difference was less than would be expected from the difference in pre-mating weights and analysis of the data found that pregnancy rates in the heavier weight ranges were lower in +P than -P. Investigations are underway to determine the reason/s for this, and ovarian ultrasound scanning on 21/6/16 determined that 23% more heifers in +P (87% vs 64%; $P<0.001$) were observed to have attained cyclicity (either pregnant or had a corpus luteum). The reasons for this discrepancy between the percentage pregnant and percentage attaining cyclicity are difficult to explain and are thought to be independent of treatment eg. differences in the incidence of disease or bull performance. If all cycling heifers had become pregnant then there would have been a statistically significant difference in pregnancy rates between treatments.

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Post-weaning phosphorus supplementation restores bone volume in pregnant cows independently of dietary metabolisable energy

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Introduction

Breeder cows grazing phosphorus (P) deficient rangelands in northern Australia are likely to be in low P status by late lactation and have difficulty restoring bone P reserves during the dry season. This study examined the ability of mature cows to recover bone P reserves in response to post-weaning P supplementation. A new tuber coxae bone biopsy method was used to identify histological changes in trabecular bone volume and mass, and thus P reserves, in response to dietary metabolisable energy (ME) and P. Trabecular (spongy) bone has a larger surface area and should demonstrate more rapid bone volume changes than traditional measures of rib cortical thickness.

Methods

Forty recently-weaned mature *Bos indicus* cross cows (mean foetal age ± SD, 12 ± 1.2 weeks) were fed *ad libitum* P-deficient diets of low or high ME with/without calcium phosphates in a 2x2 factorial design (HE-LP, HE-HP, LE-LP and LE-HP) in individual pens for 13 weeks. Diets were designed to represent high quality pasture in the mid-late wet season, or moderate quality pasture in the early-mid dry season, each without or with P, respectively. Bone biopsy samples were obtained at the commencement and end of the experiment.

Results

After 13 weeks cows fed both high P treatments (HE-HP and LE-HP) increased trabecular thickness and bone volume by *ca.* 23%. Cows fed low P diets (LE-LP and HE-LP) exhibited no change in bone volume and had less mineralised bone with thick osteoid (un-mineralised) seams (Fig. 1).

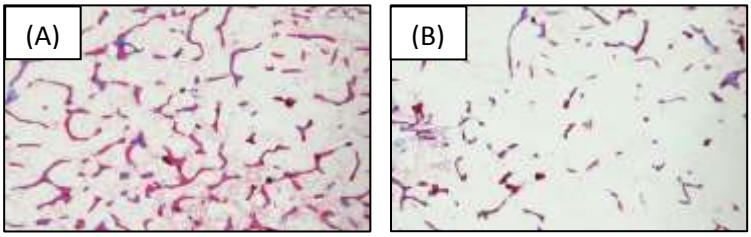

Fig 1. Examples of (A) high bone volume (HE-HP) and (B) low bone volume (LE-LP) in trabecular bone from tuber coxae biopsies after 13 weeks of treatment diets.

Discussion/Conclusions

On the high P diet, there were gains in trabecular bone volume during early-mid pregnancy and this was independent of dietary ME. This suggests that P supplementation will have benefits, in terms of bone volume, even when pasture ME is limited. Cows consuming low P diets post-weaning showed losses in mineralised bone and poor quality bone formation. This is an important period of bone replenishment following the losses of bone and mineral during lactation. Cows not receiving adequate dietary P post-weaning and during mid-pregnancy may miss out of the opportunity to accrue bone during this interval and before the next parturition.

This research was supported by Meat and Livestock Australia and the Qld DAF.

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Exogenous bovine somatotropin increases the concentration of Insulin-like Growth Factor-1 in plasma of *Bos indicus* steers fed low and high quality diets

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Introduction

The relationship between liveweight (LW) gain and skeletal growth in cattle is well established. Antari et al. (2016) established an *in vivo* model using bovine somatotropin (bST) and different dietary regimes to manipulate and understand the regulation of skeletal growth. bST is administered to dairy cattle every 14 days in the USA to increase milk production. The current experiment examined the validity of those dosage recommendations for young *Bos indicus* steers fed high (*Medicago sativa)* and low (*Astrebla* spp.) quality roughage diets. The concentration of Insulin-like Growth Factor-1 (IGF-1) in plasma was measured as an indicator of response to bST within a 14 day dosage period.

Methods

Bos indicus steers (n=30; 194 ± 10 kg LW, mean ± S.D.) were allocated to one of three dietary treatments [high protein (P)/high energy (E) intake (HPHE), high P/low E intake (HPLE), low P/low E intake (LPLE; n=10/treatment]. Within each dietary treatment, steers were administered bST (500 mg Sometribove zinc suspension, Elanco Animal Health; n=5) or saline (n=5) subcutaneously every 14 days for 98 days. Within one 14-day dose interval, blood samples were collected from the jugular vein of all steers prior to feeding on day 0 (pre-dose) and 1, 2, 5, 8, 12 and 14 days after bST or saline administration and centrifuged at 2250 *g* at 4^{o}C for 10 min. The concentration of IGF-1 in plasma was measured using an immunoradiometric kit (Beckman Coulter). Data were $\log_{10}$ transformed prior to analysis using a Mixed model in SAS which included Hormone, Diet, Day and interactions.

Results

The mean plasma IGF-1 concentration was higher (P<0.001) in steers injected with bST than steers injected with saline (275 and 107 ng/mL), and in steers fed the HPHE treatment (372 ng/mL) compared to steers fed HPLE and LPLE (80 and 63 ng/mL) treatments over the 14 day period. Plasma IGF-1 concentration was higher 1 day after bST injection and peaked 2 (LPLE) or 8 (HPHE, HPLE) days after bST injection, returning to pre-injection concentration 12 days after bST injection, regardless of diet. The proportional increase in plasma IGF-1 in response to bST was similar between diets (1.8-fold above baseline), albeit the absolute increase in concentration was higher in steers fed the HPHE treatment (387 ng/mL) compared to steers fed the HPLE and LPLE (82 and 51 ng/mL) treatments. Plasma IGF-1 concentration did not change within the 14 day period for steers injected with saline.

Conclusions

The dose rate and dose interval as recommended for commercial use in the dairy industry appear applicable for *Bos indicus* steers regardless of diet. However, a high energy intake is required to achieve maximal plasma IGF-1 responses to bST in growing steers.

Acknowledgements

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Evaluation of intensive rotational grazing on improved pasture in the NT

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Introduction

Several reviews of studies have found no conclusive experimental evidence of pasture or livestock production advantages from intensive rotational grazing (IRG) compared with continuous grazing (CG) (eg. Hall *et al.* 2014). However despite this, IRG has many strong advocates and several producers have reported benefits in financial performance and sustainability from adopting IRG (McCosker 2000). This study is being conducted to examine the effects of IRG on animal and pasture performance and soil carbon levels, although this paper just deals with animal performance.

Materials and Methods

The trial area is a block of 32 x 6 ha similar paddocks at Douglas Daly Research Farm. The pasture composition is predominantly Buffel grass (*C. ciliaris*). Cattle enter the study shortly after weaning and remain in it for about a year at which time they are replaced by the next year group of weaners. Brahman and Brahman cross weaners, after stratifying for weight, are randomly allocated to one of the following treatments: IRG, CG_C (CG where the stocking rate remains constant at 1.5 head/ha), or CG_V (CG where the stocking rate varies so that it is always the same as the effective stocking rate over all the IRG paddocks). The IRG rotates around 26 of the paddocks while the CG treatments (3 replicate paddocks per treatment) always stay in the same paddock. The amount of time the IRG group stays in a paddock depends on the time of year and stage of pasture growth, and ranges from 1 – 3 days. The number of animals in the IRG treatment each year varied according to assessment of pasture availability. Between mid-2009 and mid 2015 the stocking rate in IRG and CG_V ranged from 1.33 to 1.83 head/ha. The study was designed with advice from a leading cell grazing consultant.

Results and Discussion

Generally liveweight gain per head was highest in the CG treatment with the lowest stocking rate, and liveweight gain per ha was highest in the CG treatment with the highest stocking rate (Fig. 1 and 2), as in different years the stocking rate in CG_V was higher or lower than CG_C. In each of the 6 years of the study so far weight gain has been lowest per head and per ha in IRG. After consultation with the cell grazing consultant the CG_C treatment was discontinued from mid-2015 and these paddocks are now used in the IRG treatment to increase the number of rest days between grazes.

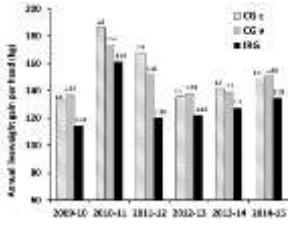

Fig. 1. Annual liveweight gain per head (SR (head/ha) above bars).

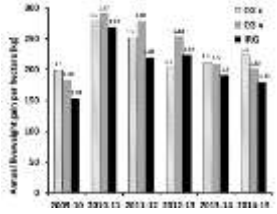

Fig. 2. Annual liveweight gain per hectare. (SR (head/ha) above bars).

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Development of an automated field based solution to quantify the drinking activities of northern Australian cattle grazing systems

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Introduction

Cattle require water for physiological processes associated with maintenance, growth, fattening, pregnancy and lactation. In extensive grazing systems water may not be freely available to cattle at all times. Cattle have a tendency to concentrate their activities around water points but the distance cattle travel from water varies. Observations of cattle in the northern rangelands suggest that the distance cattle graze from water points influences their watering behaviour (Low *et al*. 1981; Schmidt 1969) which may have may have important consequences on their productive and reproductive performance. This paper summarises a PhD project which aims to develop an automated method to record drinking activities of cattle as a means to better understand drinking activities in northern Australian grazing systems.

Drinking frequency effects on the performance of cattle

The first study will use a systematic review methodology to analyse the existing literature for drinking frequency effects on cattle performance. In this process, the following questions are being asked: (1) is there any evidence of an effect of drinking frequency on cattle performance? (2) what performance responses to drinking frequency have been documented? (3) how do performance responses vary according to environmental and animal factors?

Investigation of watering behaviour using remote weighing technology

The second study will utilise remote walk over weighing (WoW) systems to record the timing and frequency of cattle visits to the water trough. Three sites across northern Australia are being investigated: Belmont Research Station, Qld (breeders); Lansdown Research Station, Qld (steers); Brunchilly Station, NT (breeders and steers). The influence of animal physiological status and live weight on watering behaviour will be considered in addition to environmental factors such as weather, paddock size and water infrastructure.

Quantification of drinking behaviour using an accelerometer

The third component of the PhD aims to evaluate the posture and movement of the head and neck during drinking and validate an approach to record detailed drinking behaviour using an accelerometer mounted to a neck collar. The number and duration of drinks taken by individual animals is of primary focus. A method to predict water intake will also be explored.

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Stocktake and analysis of legume evaluation for tropical pastures in Australia

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Introduction

The addition of legumes to tropical pastures has the potential to have large benefits for the productivity and profitability of beef production enterprises in northern Australia. This has long been recognised and a large effort has been made in the past to develop forage legumes suited to a range of environments and production systems in northern Australia. Systematic evaluation and development of improved legumes has stalled over the past 10-20 years. At the same time as renewed interest in improving the range of legumes available in northern pasture systems, much of the past research was at risk of being lost and a great deal could be learnt from examining past legume evaluation efforts. This project aimed to collate and store tropical legume evaluation data and knowledge from past and current legume evaluation, and then review and analyse the information to identify priority genera, species and accessions that are candidates for further evaluation and/or potential commercialisation.

Method and Results

Past and current pasture researchers were brought together to prioritise and collate past evaluation data on legumes for tropical pastures into a common database that can be used as a resource to guide future legume development activities. Over 180,000 records of evaluation data of pastures legumes from 567 sites in the tropics and subtropics were collated. Initial interrogation of this database with high power statistical approaches across a range of past evaluation locations and conditions has revealed several tropical legume species that have higher productivity potential than commercially successful species. In particular, several *Desmanthus* species showed high levels of persistence and higher year 3 productivity than other species across a range of environments, indicating they many have wider potential for development. Some *Macroptilium* species also demonstrated wide potential, with *Macroptilium lathyroides* in particular, showing higher productivity levels in both year 1 and year 3 and performed relatively better than other species at locations with lower site yields. Further examination of variation within species or comparisons amongst individual accessions may reveal further information on genotype performance across the full set of evaluation experiments.

Using expert opinion, a legume gap analysis was also conducted across 12 production regions of northern Australia to identify where further legume development needs are greatest. This region by region gap analysis of 1) commercially proven legumes, 2) of adapted commercially but not successfully or of widely adopted, and 3) prospective species identified significant gaps in adapted and commercially proven legume varieties in western Qld, southern Northern Territory and northern Western Australia. However, the value proposition for legume development targeted to those low-productivity environments is likely to be low. In other regions, a limited set of well accepted options are available but gaps in these array of legumes are evident and/or agronomic constraints or limitations restrict their uptake or wider adoption. Highest priorities for further legume development identified were i) legumes that persist in competitive grass pastures in the subtropical semi-arid inland, and sub-humid coastal hinterland, ii) legumes for clay soils in northern tropical regions, iii) legumes for light soils (sandy and duplex) in inland subtropics, and iv) more robust ley legume options. Several species and accessions that have shown promise in past evaluation work and are thought to have attributes which improve on key limitations of commercial varieties but are not yet commercialized were identified in *Desmanthus*, *Stylosanthes, Macroptilium*, and *Aeschynomene*.

Overall, there is still appears to be potential for gains in the range and performance of legumes available for pasture systems in Northern Australia.

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Successful Pasture Development at Cungelella: A grazier, a researcher and a seed company's perspective

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Introduction

Cungelella is a NAPCO property located in Central Queensland's Brigalow Belt region between Springsure and Tambo. Mean annual rainfall is 598 mm pa the soils are typically low in N and P, have an alkaline pH and moderate to high clay content. The property is some 22,000 ha and mainly backgrounds NAPCO composite cattle for the company's feedlot. Pastures are predominately long established buffel grass which is rotationally grazed with strategic spelling.

Over many years a number of pasture legumes have been sown and trialed at Cungelella in an attempt to improve and enhance the sustainability of the buffel grass pastures and to improve live weight gains. To be successful in this environment a legume needs to be able to compete with buffel, survive and recover from prolonged dry and wet spells and put weight on cattle and be a good return on investment. However almost without exception the species sown to date have not met expectations. Species sown have included: Stylo's, butterfly pea, Clovers, Medics, Siratro and Burgundy bean, these species have not persisted with the buffel and the grazing regime.

Results and Discussion

In 2010 Progardes Desmanthus was the next species trialed as it had been evaluated and had persisted in old trial plots for many years in Central western and Northern Qld. Initially a 250ha old buffel grass paddock was renovated with a savannah plough and Progardes seed broadcast on the surface. Almost 6 years later this paddock is an excellent stand of Buffel and Progardes with the Progardes having a stable population of some 7plants/m^2. Cattle regularly gain an additional 40kg/hd compared to steers on adjacent buffel alone paddocks. The pasture has been well tested over recent years with full commercial grazing pressure and very dry and wet periods.

Since 2010 a number of other pasture establishment techniques have been utilized and some additional 2,500ha has now been sown to Progardes. Establishment techniques have included blade plough with seed drum or aerial seeding, blade plough followed by chain to create a finer seed bed tilth, cultivation with a Tilco and air seeder and very recently in an attempt to store soil moisture which is seen as critical in this environment for successful legume establishment has been to aerially apply Glyphosate herbicide and then aerial seed Progardes into the buffel litter. To date this method is proving to be successful as the competition from the buffel is initially greatly reduced; soil moisture is retained and available for the germinating and establishing Progardes legume. Later the buffel fully recovers from the herbicide and the legume has a well-established tap root system and competes with and complements the buffel. The pasture development methods undertaken at Cungelella and the resulting productivity are models that may well be applicable to large areas of the Brigalow region and beyond.

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Maximising beef production and profits using high quality forages

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Introduction

Northern beef producers continually need to find strategies to increase profitability (McLean *et al.* 2014). Targeted use of high quality forages has the potential to improve the profitability of northern beef enterprises through increasing enterprise turnover and productivity (Bowen *et al.* 2010). This study examined the key drivers of profitability for major annual and perennial dryland forage systems used for beef cattle production in the Fitzroy River catchment of Queensland.

Methods

Cattle liveweight (LW) gain and economic performance was measured for 6 forage types at 21 sites across 12 commercial beef cattle properties in the Fitzroy River catchment of Queensland during 2011 – 2014 (28 annual data sets in total). The forages were annual forage crops (oats (*Avena sativa*), sorghum (*Sorghum spp.*) and lablab (*Lablab purpureus*)), sown perennial legume-grass pastures (leucaena-grass (*Leucaena leucocephala spp. glabrata* + tropical grass (C_4) species) and butterfly pea-grass (*Clitoria ternatea* + C_4 grass species)) and perennial C_4 grass pastures.

Results and Discussion

The sown forages resulted in 1.2 – 2.6 times the annual cattle LW gain per ha compared to that measured for perennial grass pastures (Table 1.). However, there was no correlation between annual cattle LW gain per ha and gross margin. Furthermore, neither forage establishment and management costs nor cattle price margin (sale price less purchase price, range -$0.40 – 0.45/kg LW) were correlated with gross margin. In conclusion, trends in the data indicated that perennial legume-grass pastures, and particularly leucaena, on average resulted in greater profitability than annual forage crops or perennial grass pastures. Lower forage costs for these legume-grass pastures, compared to annual forage crops, combined with high productivity appear to be the primary factors.

Table 1. Key performance measures for cattle grazing forages on commercial properties

	Annual forages			Perennial forages		
	Oats	Sorghum	Lablab	Leucaena -grass	Butterfly pea-grass	Grass
No. of datasets (No. of sites)	8 (6)	5 (4)	2 (2)	5 (4)	3 (2)	5 (3)
Total cattle LW gain (kg/ha.year)	93	108	99	198	125	76
Forage costs ($/ha.year)[A]	194	142	144	39	26	3
Gross margin ($/ha.year)[A]	102	24	18	181	140	96

[A]Annual forage costs and gross margins for perennials were calculated by amortising establishment and maintenance costs.

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Effective extension delivery: the High Output Forages project

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Introduction

In central Queensland's Fitzroy River Catchment, grazing cattle on dryland forages systems is a strategy used by many beef producers to increase beef production. The research project 'High-output forage systems for meeting beef markets – Phase 2' (HOF), provided a better understanding of the expected forage, animal and economic performance of common forage systems in commercial beef enterprises. The applied, multidisciplinary nature of this project resulted in many recommendations for beef producers. Extension products were developed to support informed decision making with regard to forage use. These included a producer guide to forage use '*Feeding Forages in the Fitzroy'* and forage gross margin spreadsheets. A range of extensions activities were conducted as part of this project. This paper presents a summary of the activities which were undertaken and the associated producer feedback.

Results and Discussion

The communication of key recommendations from the HOF project has been extensive with a total of 2,144 people receiving direct information about the project at 121 events/contacts, including 29 field days or workshops (Table 1.). The overall acceptance and rating of project messages has been high with an average approval rating of 85% across all surveyed events and of 88% across the 7 dedicated extension events held after finalisation of the project results. The intended level of practice change as a result of project messages and recommendations was 66% across all surveyed events and 87% for the 6 full-day workshops held after finalisation of project results. Key aspects contributing to the effectiveness of these extension activities included: 1) involvement of beef producer co-operators in the project, 2) the multidisciplinary project team including technical, extension and economist expertise; 3) demonstration of the financial implications of recommended practice change, and 4) providing a pathway to adoption, including development and demonstration of extension tools. The high level of industry approval and intended adoption of project messages demonstrates the positive outcomes for industry from accessing multidisciplinary regional project teams with a strong focus on applied research and financial implications for producers.

Table 1. Summary of extension activities

	Level of achievement
Number of events or contact with project staff	121
Field day/workshop	29
Webinar	2
Conference/meeting	7
Property visit	17
Telephone or email enquiry	66
Number of participants receiving direct contact	2,144
All events:	
Approval rating of project messages	85%
Survey respondents intending to make practice change	66%
For 7 dedicated extension events after finalisation of project results:	
Approval rating of project messages	88%
Survey respondents intending to make practice change	87%

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Production versus weed risk – an innovative approach to assessing improved pastures for the WA rangelands

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Introduction

There is growing interest in intensifying beef cattle production in the rangelands of northern Western Australia through 'mosaic agriculture' to complement the extensive grazing of native vegetation. Irrigated fodder production and the introduction of improved forage plants (dryland) can broaden the feed base of rangeland grazing systems. With agricultural development there can be unwanted consequences and one of these is that some pasture plants have become agricultural and environmental weeds in certain situations (Lonsdale 1994). The challenge is to find the right balance between agricultural development and minimising the risk of weed invasion of high value environmental assets. Diversification permits are required to grow non-indigenous plants on pastoral leases in WA. The current assessment procedure includes a desktop assessment of weed risk by the state government departments involved. However, there is currently a paucity of field data from previous trials or agricultural developments to calibrate the desktop modelling.

Methods

Taking an innovative approach a series of field nurseries have been established in key environments (soil x climate) in the West Kimberley and Pilbara to obtain data on the persistence and/or spread of a wide range of commercial pasture and fodder grasses and legumes. Four sites have been established at Wallal Downs south of Broome, Birdwood Downs near Derby, at Woodie Woodie in the Pilbara and at Gogo Station in the Fitzroy Valley. All of the species being evaluated are commercial pasture and fodder options that are widely used in similar environments in the Northern Territory and Queensland. At each site, there are two replicated trials. The 'grass' trials have 23 entries and include a range of warm season (C4) annual and perennial grasses. Each entry has plus and minus (+/-) complete fertilizer sub-treatments and each combination is replicated three times. The 'legume' trials have 23 entries and include a range of tropical legumes, plus the temperate legume - lucerne (*Medicago sativa*). Each entry has +/- fertilizer and +/- rhizobia sub-treatments and each combination is replicated three times. In the WA rangelands the spread of weeds is often episodic so the field nursery trials were established under irrigation to simulate the worst case scenario, i.e. if plants establish and set seed following a tropical cyclone or an extremely high rainfall year. The irrigation was gradually turned off over the 'wet' season once the plants were well established.

Results and Conclusion

The key results to date and implications for agricultural development in northern Western Australia are summarised.

Acknowledgements

We acknowledge the financial support from the WA State Government's Royalties for Regions program and Meat and Livestock Australia Donor Company.

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Mosaic Agriculture – Fast-tracking a new frontier for beef production in northern Western Australia

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Introduction

Improved pastures are widespread in both north and central Queensland and in the Northern Territory, however to date beef production in the rangelands of northern WA is predominantly reliant on the grazing of native vegetation, as there are only minor areas of dryland or irrigated improved pastures and fodders. However, there is growing interest in intensifying agriculture in the WA Rangelands to encompass dryland or irrigated improved pastures and fodder crops to broaden the feed base of rangeland grazing systems. In particular, interest and investment in irrigated 'mosaic agriculture' is increasing rapidly. Recent regional-scale studies have identified large potential water sources for irrigated agriculture from groundwater (west Kimberley); surface water and groundwater (central Kimberley) and mine de-watering in the Pilbara.

Early adopters of mosaic agriculture have faced a number of challenges with respect to the: environment (birds, insects and extreme weather conditions); land tenure; agronomy and aligning intensive production with the extensive nature of the beef production system. In addition, there are the issues resulting from working in remote locations with a limited business support network.

The Royalties for Regions funded 'Northern Beef Futures Project' (NBF) is working with producers to overcome or minimise the impact of the challenges identified above and to determine the economics of finishing pastoral cattle on areas of irrigated pasture. The NBF project is also exploring opportunities for irrigated and dryland forage systems to transform the northern beef production systems. In principal, finishing pastoral cattle to slaughter-ready weights on irrigated pasture, in conjunction with other management changes, has the potential to increase production by 40-50 percent.

We are in the process of generating robust local data sets on fodder production and feed quality. This will enable the reliable economic modelling of the contribution of mosaic agriculture to a range of cattle production systems. Replicated agronomy trials have been established under centre pivot irrigation at Kilto Station (near Broome), at Woodie Woodie in the Pilbara and at Gogo Station in the Fitzroy Valley which are representative of key soil-climatic zones in northern WA. Local data sets are important due to the unique combination of soils and climate especially the extended periods of high to extreme temperatures in the build-up to and over the 'wet season'.

Close Liaison with industry is a priority and a recent workshop with key irrigators and industry representatives provided an opportunity for participants to share information as well as helping identify issues and barriers for the industry as a whole. A series of economic models are being developed and refined through the PHADI (Pilbara Hinterland Agricultural Development Initiative) and the La Grange projects. Preliminary economic analysis shows that when fodder is valued at $200/T a yield of 30T/ha is required to provide a moderate return on investment. The breakeven price for hay production (i.e. with no return on investment) is about $150/T assuming a hay yield of 30T/ha.

Some of the key results and implications for mosaic agriculture in northern WA are highlighted.

Acknowledgements

We acknowledge the financial support from the WA State Government's Royalties for Regions program directed through DAFWA in the Northern Beef Futures project and the Meat and Livestock Australia Donor Company.

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Increasing seeding rate does not improve legume establishment in undisturbed buffel grass pastures

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Introduction

Although good establishment is recognised as critical to the long term persistence of legumes, many producers don't think they can afford to use more expensive seedbed preparation to allow establishment. Several producers and advisors in the pasture seed industry have suggested that increasing seeding rates, but still sowing with no seed bed preparation, will improve the reliability of establishing legumes into sown grass pastures. This paper reports the results of a legume seeding rate trial.

Methods

A seeding rate trial was established near Wandoan on a brigalow grey clay soil with a buffel grass pasture. ProGardes desmanthus (various *Desmanthus spp.*) was sown at five seeding rates – 1, 2, 4, 8 and 16 kg seed/ha with 4 replicates. Seed was broadcast into undisturbed grass in February 2013. Legume plant numbers and size were recorded 5 and 9 weeks then 9, 15, 23, 25 and 38 months after planting.

Results and Discussion

The trial had a very dry spring and early summer leading up to planting with little grass growth. The site received close to average rainfall in the nine weeks after planting. The following 2 summers have been below average rainfall. All seeding rates had seedlings 5 weeks after germinating rain but almost all seedlings had died by 9 weeks. Seed that was sown had good levels of hard seed with some seed managing to germinate and survive in subsequent years; however by 38 months after sowing no seeding rate had adequate plant numbers (>4 plants/m^2). These results demonstrate that increasing seeding rate and planting directly into existing grass pastures is an unreliable approach to improving legume establishment into buffel grass pastures in inland areas of Queensland.

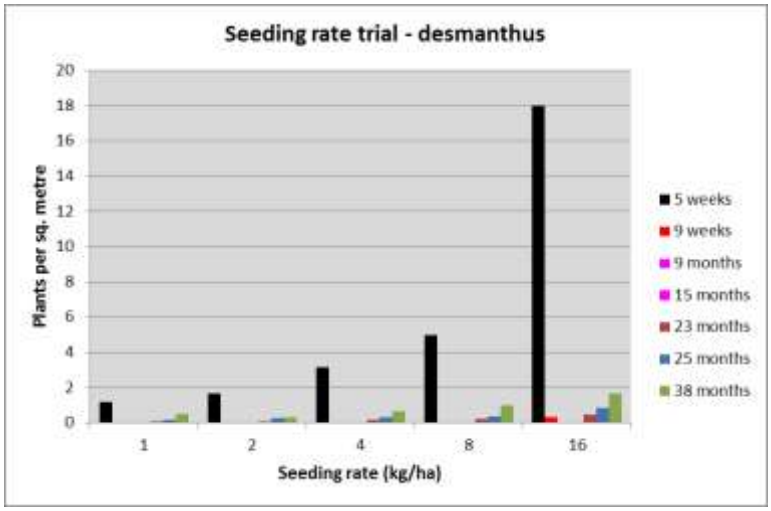

Figure 1: Desmanthus plant number over time for different seeding rates

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Stimulating Mitchell grass to respond to limited rain during drought

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Introduction

Mitchell grass (*Astrebla* spp.) becomes dormant during drought and often fails to respond to rainfall events of 25-50mm. In early 2006, tussocks failed to respond to rains in excess of 150mm and a similar lack of response was observed in 2016 following 50-100mm.

Methods

Forty-nine paired and grazing–gradient sites with contrasting *Astrebla* response were surveyed in 2006 and 2009 to assess tussock response (Phelps *et al*. 2011). Site history (e.g. grazing and burning) was obtained through semi-structured interviews with the owner/manager of each property. A rainfall/evaporation ratio (R/E) was used as a guide to the severity of soil moisture deficit, using climate data from Silo DataDrill (Phelps *et al*. 2011).

Results

In 2006, 12 paired sites of contrast demonstrated differences ($P<0.05$) due to burning or grazing and wet season spelling. *Astrebla* tussocks at sites where older, dead, tillers were present failed to respond, as did tussocks where sites continued to be grazed. Tussocks at sites where dead tillers were absent and also spelled did respond. At one spelled site, *Astrebla* tussocks went to seed and grew approximately 1,000kg/ha. The continuously grazed paired site where dead tillers were present grew less than 200kg/ha and tussocks failed to set seed. Sites experiencing at least one failed summer (R/E <0.15 for the summer growing season) had significantly lower *Astrebla* density and basal area, exacerbated by the presence of old, dead tillers.

Discussion

Removing dead tillers appears to promote the survival and response of *Astrebla* tussocks—even under conditions of low rainfall and high evaporation. Burning can stimulate *Astrebla* tillering, seed production and biomass (Phelps 2006). It is possible that fresh tillers are better able to survive drought, or perhaps modify hormone levels associated with the breaking of drought dormancy. Stimulating *Astrebla* to respond to limited rains during drought could improve animal condition for sale at a time when the quantity of feed is crucial to a grazing enterprise's viability. However, the removal of old tillers reduces ground cover, contradicts current best-management practices and increases the risk of land degradation (Phelps 2012). To date, the evidence is too limited to make recommendations that contravene established wisdom. Research is needed to provide advances in drought management for increased pasture production, and improved livestock condition and enterprise viability.

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Estimating the diet selected by grazing cattle using F.NIRS or faecal N

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Introduction

Knowledge of the diet selected by grazing cattle is essential to understanding nutrient intakes and to inform management. Regression relationships between faecal N concentration (FN) and diet crude protein concentration (D-CP), or FN and diet digestibility (D-DMD), have been used to estimate the diet of grazing cattle. However, due to a lack of robustness of the regression relationships across pasture systems, and between seasons and years within pasture systems, estimation of diet from FN may involve large error. Near infrared reflectance spectroscopy of faeces (F.NIRS) can be used to estimate many diet attributes, including D-CP and D-DMD. In this paper we compare the error in prediction of D-CP and D-DMD in cattle ingesting tropical forages using F.NIRS or with FN.

Materials and methods

Data for the development of F.NIRS calibration equations for cattle fed tropical forage diets was used to compare the F.NIRS and FN approaches to estimating diet. These data comprised diet-faecal sample pairs (n=1221 for D-CP and n=1052 for D-DMD) where cattle (generally 3-4 animals) had been fed 264 forage diets. Laboratory measurements were made of the D-CP and D-DMD of each diet, and NIR spectra of faeces were measured. D-CP and D-DMD were predicted from faecal measurements by 2 procedures: (i) using established F.NIRS calibration equations (Dixon and Coates 2009), and (ii) linear regression of FN with D-CP or D-DMD. The error of prediction was calculated as the residual standard deviation (RSD) of regression of the reference and predicted values.

Results and discussion

The errors in prediction of diet with F.NIRS were much lower than the errors with FN (Table 1). The RSD of D-CP and D-DMD predicted with F.NIRS were 58% and 60%, respectively, of the RSD predicted with FN. The RSD values provide an estimate of the prediction error; *ca.* 68% of predicted values will be within 1 SD of the actual value and *ca.* 95% within 2 SD of the actual value. Thus F.NIRS provides much more accurate and reliable estimations of D-CP and D-DMD than does FN. Commercial laboratories usually measure FN using the same NIRS procedures and instrumentation as used for F.NIRS to measure diet N and DMD (but with different calibrations). Thus continuing use of FN rather than F.NIRS to estimate the diet quality selected by grazing cattle is outdated.

Table 1. The error calculated as the residual standard deviation (RSD) in prediction of diet crude protein (D-CP) and diet DM digestibility (D-DMD) from NIRS analyses of faeces (F.NIRS) using northern Australian calibrations for forage diets, or from faecal total N concentration (FN).

Diet attribute	Population			Prediction with F.NIRS		Prediction with FN	
	n	Mean	SD	R^2	RSD	R^2	RSD
Crude protein (%DM)	1221	7.4	4.7	0.93	1.24	0.80	2.12
DM digestibility (%)	1052	54.7	5.8	0.88	1.99	0.68	3.33

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An innovative approach to derive long-term carrying capacity estimates for extensive grazing properties in Queensland

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Introduction

The extent that stocking rates are aligned with long-term carrying capacity (LTCC) has a major impact on resource condition, livestock production and grazing enterprise viability. Hence, knowledge of carrying capacity is essential to sustainable and productive use of Queensland's grazing lands. Calculating the number of animals that can be carried on a land system, paddock or property in the long-term (20 – 30 years) without any decrease in land condition requires estimation of forage production and a 'safe' level of forage utilisation. The grass production model (GRASP) (McKeon *et al*. 2000) has been used extensively to estimate LTCC across a wide range of climate and land types in northern Australian rangelands. An innovative approach that uses the GRASP model and GIS technology to provide long-term carrying capacity information for extensive grazing properties in Queensland is described.

Methods

Infrastructure (e.g. fences, water points), land types and foliage projective cover (FPC) are spatially defined; historical climate records are accessed; and areas grazed by stock based on distance to water are calculated for a property. The Cedar version of the GRASP model is used to simulate land type pasture growth for 15 FPC classes over a 100 year period. Calculation of long-term stocking rates (pasture growth x utilisation / animal intake) for tree cover and land condition is consistent with the Grazing Land Management (GLM) and Stocktake extension programs (see www.futurebeef.com.au). Long-term stocking rates are linked with spatial data (infrastructure, FPC, land type) to derive 'Potential' (land type x tree cover class) and 'Actual' (land type x tree cover class x distance to water) LTCC information for a property using the ArcGIS spatial software.

Results and Discussion

This innovative approach was recently used to provide LTCC information (tables and maps) for 20 grazing properties in Queensland (Whish *et al.* 2016). Carrying capacity estimates were greatly improved through the adjustment of model parameters to account for location and property-specific information. LTCC information can assist managers of extensive grazing properties in their planning and decision making.

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Inclusion of percentage normal sperm to the BREEDPLAN evaluation for improvement of reproductive performance of tropically adapted beef breeds.

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Introduction

Cow and bull fertility are important to beef cattle producers in Northern Australia to improve beef productivity. However, genetic improvement of cow fertility has been limited by low recording, due to low intensity of selection and selection occurring relatively late in life. Therefore, identification of early predictor/s of bull fertility that have high genetic association with cow reproductive performance, would be valuable in helping improve beef productivity in Northern Australia and was a major output of the Beef CRC's northern reproduction project (Johnston et. al. 2014). Percentage Normal Sperm (PNS) is measured as part of the bull breeding soundness evaluation (BBSE) at around eighteen months of age, as an indicator of bull and potentially cow fertility in Brahman (BRAH) and Santa Gertrudis (SANTA) cattle. This paper reports investigation of the value of adding PNS to the routine BREEDPLAN evaluation for genetic improvement of tropical beef breeds.

Materials and Methods

Data for PNS was collected as part of the CRC recording of BBSE for BRAH and SANTA over a 10 years period, from 2006. For animals with multiple PNS records, only the first record was analysed. A total of 1199 and 1468 PNS records for BRAH and SANTA, respectively, measured between 500 to 800 days of age, were used in the evaluation. Genetic parameters for PNS were estimated. A new BREEDPLAN module to predict breeding values for PNS was developed.

Results and Discussion

Raw PNS were 64% and 73% for BRAH and SANTA respectively, and heritability was 0.25 for both breeds. Trial EBVs for PNS of the animals with a record ranged from -20% to 16% for BRAH and SANTA (Table 1). However, EBVs for PNS of the two breeds cannot be compared as they were from two different analyses. It is expected the sires with higher (i.e. more positive) PNS EBVs will produce sons with higher PNS compared to sires with lower (i.e. more negative) PNS EBVs. Importantly, the Beef CRC results suggest that the PNS is low to moderate genetic correlation with female reproduction. The evaluation is now being expanded using additional data from SMART Futures Project and other breeds e.g. Droughtmaster.

Table 1. Descriptive statistics for EBVs of percentage normal sperm of animals with records and sire of animals with records in Brahman and Santa Gertrudis breeds.

Type	Brahman				Santa Gertrudis			
	No.	Mean	Min.	Max.	No.	Mean	Min.	Max.
Animals with records	1199	0.6	-20.2	16.7	1468	0.1	-20.3	16.2
Sires of animals with records	84	-0.1	-17.7	15.2	134	-0.1	-18.7	22.4

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Use of chilled bull semen in fixed-time artificial insemination in Australian *Bos indicus* cattle; methodology to increase pregnancy rate?

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Introduction

The increasing use of fixed time artificial insemination (FTAI) in the beef cattle industry has led to renewed interest in the potential use of fresh or chilled semen as a lower cost alternative to frozen-thawed (FT) semen. A recent case study in Nellore cattle found that the use of chilled semen can potentially increase pregnancy rate to FTAI (Crespilho et al., 2012). The objective of the current study was to compare the pregnancy rates to FTAI in *Bos indicus* (Brahman) cows inseminated with either chilled or FT semen and to examine the relationship with various *in vitro* measures of sperm function.

Methods

Semen from three Brahman bulls (A, B, C) was collected by electroejaculation. Each ejaculate was split and extended in Tris-egg yolk extender base with 2.4% glycerol for chilled (5 °C) storage and 7.0% for frozen (LN_2) storage. Fixed time artificial insemination was conducted simultaneously to *in vitro* semen assessment at 48 hours after collection and chilling or FT and re-warming. A total of 116 cows were inseminated with semen from Bull A, 114 with Bull B and 117 with Bull C. Semen was assessed *in vitro* for sperm motility, function and fertilizing ability.

Results

The *in vitro* fertilization rates were significantly lower for the FT semen (69.8%) compared to the chilled semen stored at 5 °C for 48 hours (79.3%). The majority of the sperm quality parameters were higher for the chilled semen, and the proportion of sperm that were viable, had stable non-fluid plasma membranes, intact DNA, and were not apoptotic were each significantly higher for chilled compared to FT semen. The computer assessed sperm motility parameters showed significant differences between storage treatments with respect to sperm velocities, beat cross frequencies, overall proportion of progressive motility. The overall pregnancy rates 63 days after FTAI were 31.60% and 53.18% for the chilled (n = 174) and FT (n = 173) semen, respectively.

Discussion and Conclusions

The study showed that it was possible to achieve satisfactory pregnancy rates in Brahman cattle FTAI with semen collected by electroejaculation on-property, extended with a simple commercial extender and stored chilled (5 °C) for 48 hours. *In vitro* fertilization was not predictive of in-field fertility, hence semen preparation after collection using electroejaculation and extenders needs to be further optimized based on sperm function measures. It is speculated that particularly the level of reactive oxygen species needs to be controlled in order to prolong sperm longevity in a chilled state.

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Delaying post-biopsy embryo development with a view to allowing more time for comprehensive genotyping prior to fresh transfer

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Introduction

Embryo bisection is currently used to take a genetic sample from bovine embryos in order to identify their gender. Theoretically, this technique could be expanded to investigate multiple genetic traits, through utilising platforms such as bovine genotyping arrays. However, bisection is an invasive technique, and as a result, bisected embryos are generally transferred fresh, rather than risking further damage by freezing and transferring later. This fresh transfer limits the time available for assessment to <48 hours, which is insufficient time for genotyping arrays. This project investigates the effect of refrigerating bisected embryos in order to delay development, with a view to extending the period from bisection to transfer to allow more time for comprehensive genetic assessment.

Methods

Embryos were produced by IVF. On day 8 after fertilisation approximately half the embryos were bisected. This was achieved by cutting through the centre of the blastocyst using a 27g needle. Bisected embryos were then returned to the incubator for 24hours. On day 9, embryos were split into 3 groups according to treatment or development - 1) bisected embryos (blastocyst and hatched blastocyst stage), 2) blastocysts (with diameter >200um) and 3) hatched blastocysts. Embryos were transferred to refrigeration media, consisting of Tissue Culture Media 199 (TCM199) with Hanks salts and containing 50% foetal calf serum (FCS), and 25mM HEPES. They were then loaded 5 per straw into 0.25cc straws and placed in a domestic refrigerator at 4°C. A total of 167 bisected embryos, 94 blastocysts and 98 hatched blastocysts were refrigerated. After 72hrs refrigeration, embryos were returned to culture for 48 hours, and re-expansion rates were recorded.

Results

The re-expansion rate for bisected embryos, blastocysts and hatched blastocysts was 68%, 56%, 94% respectively. This represents a significant (p=0.05) difference between bisected embryos and hatched blastocysts and between blastocysts and hatched blastocysts. The results for blastocysts and hatched blastocysts were pooled. This gave an average re-expansion rate of 76%, which was not significantly (p=0.05) different to that of bisected embryos.

Discussion/Conclusions

This study would suggest that holding bisected embryos at 4°C can delay development by at least 72hours without affecting embryo survival. However, the stage of development of IVF embryos is critical to their refrigeration tolerance. Previous studies have shown *in vivo* produced embryos to be more tolerant of refrigeration than IVF embryos (Ideta et al., 2013), therefore it is expected this result could be replicated using *in vivo* produced embryos. If so, this system might present a simple and effective method for extending the time between bisection and fresh embryo transfer, thus allowing more time to utilise comprehensive genetic screening in embryo transfer programs.

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Diagnosis issues for vibriosis (bovine genital campylobacteriosis)

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Introduction

Bovine genital campylobacteriosis (BGC) or bovine vibriosis is caused by the bacterium *Campylobacter fetus* subspecies *venerealis* causing embryonic loss or early term abortion. Existing diagnostic methods are not able to accurately determine the presence of pathogens in clinical samples and economic assessments cannot be undertaken reliably.

Methods

Bull prepuce samples were collected from a local abattoir and screened using the parA real time assay (McMillen *et al.* 2006) prior to culture isolation. Cultures were phenotyped according to OIE standards. PCR methods (molecular) used to screen the pure cultures were ISCfe1 (Abril *et al.* 2007), CstA/ParA (Hum *et al.* 1997), and NahE (van der Graaf-van Bloois *et al.* 2013). DNA sequencing of the conserved heat shock protein gene was undertaken to confirm isolate identities.

Results

Fifty-four *Campylobacte*r- like cultures were isolated and 15 isolates were positive in all methods. Culture identified a further ~15 isolates negative in PCR methods. One isolate negative by culture phenotyping was positive in the PCRs. Real time PCR positive bull prepuce lysates did not correlate with the subsequent isolation of *C. fetus venerealis*. DNA sequencing confirmed the identity of 16 *C. fetus venerealis* isolates (one identified as an *Arcobacter* spp. by culture), with the remaining false culture positives identified as: *C. hyointestinalis*, *Arcobacter cryaerophilus*, and *C. ureolyticus*.

Discussion/Conclusions

Culture phenotyping and molecular methods did not 'agree' for the identification of *C. fetus venerealis*. DNA sequencing revealed the presence of other pathogens not known to affect reproductive wastage. As boiled clinical samples cannot be used for diagnosis, currently the only way to identify the pathogen is to isolate the bacteria and to apply molecular methods to confirm identity. Research is needed to determine if other pathogens identified here are compromising cattle health.

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Calf vigour at birth and neonatal mortality

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Introduction

Most pre-weaning calf mortalities occur within the first week of life (Bunter *et al*. 2013). Elevated calf mortalities are mostly associated with high environmental and nutritional stress prior to and around calving (McGowan *et al.* 2014). These stressors may be confounded with effects of birth vigour on neonatal mortality. We aimed to measure the incidence of birth vigour, of neonatal mortality, and if there was an association between them, using data that was collected as part of MLA project, B.NBP.0759.

Methods

The data that were descriptively analysed included 478 and 328 tropically-adapted newborn calves born in late 2014-early 2015 at Spyglass (northern forest) and Brian Pastures (southern forest) beef research sites. Mortalities explained by dam death, stillbirths and birth trauma were excluded from descriptive analysis. Neonatal mortality was defined as occurring in the first week of life. Vigour at birth was assessed on a 6-point scale. Multivariable logistic regression of neonatal mortality was attempted with explanatory variables of birth vigour, location (research site), dam age, breed, sex, month of birth, and first order interactions of these variables with birth vigour.

Results

As a percentage of live births, neonatal mortality was 2.5% at Spyglass and 2.1% at Brian Pastures. The incidence of very low-low calf vigour was 0.74% (Fig 1). The low incidences of both precluded statistical analysis of neonatal mortality.

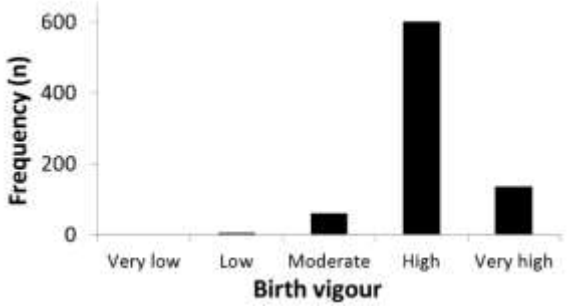

Fig. 1. Frequency of birth vigour scores for Spyglass and Brian Pastures calves born in 2014-2015

Discussion and Conclusions

The low frequency of very low-low calf vigour in this study demonstrates the vitality of newborn tropically-adapted calves in well-managed situations in northern Australia. Testing the association between low vigour of newborn calves and neonatal mortality requires a higher incidence of both.

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Bopriva™ as an alternative to spaying cattle in northern Australia.

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Introduction

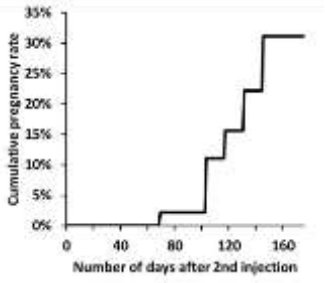
Spaying is widely used in northern Australia to prevent pregnancy in cows that are intended to be fattened and sold after a wet season as bull control is often poor. However, there is a desire to develop non-surgical methods of preventing pregnancy for both production efficiency and animal welfare considerations. This study was conducted to evaluate the effectiveness of using Bopriva™ for this purpose. Bopriva™ is a vaccine that reduces the effect of Gonadotrophin Releasing Factor (GnRF) in both males and females by generating antibodies against GnRF. Two vaccinations are required to supress GnRF activity to a level that will prevent pregnancy. A period of 4 months protection from pregnancy is expected if the second vaccination is administered 12 weeks after the first.

Materials and Methods

Ninety non pregnant cull cows of various ages (average = 9 y.o, range = 3.5 to 15 y.o) were weighed and allocated to either a SPAY or BOPRIVA treatment at Douglas Daly Research Farm on 1 Sep 2014 (day 0). The SPAY cows were spayed using the Willis dropped ovary technique and the first injection of Bopriva™ was given to the BOPRIVA cows. All cows were weighed and a second Bopriva™ injection given to the BOPRIVA cows 81 days later. Bulls were added to the cows at this time. Cows were weighed and pregnancy tested using real time ultrasound on day 206 and day 253 (12 May 2015) and date of conception was calculated from foetal age. All cows grazed together throughout the trial and all weights were recorded after an overnight curfew.

Results and Discussion

Two (4.4%) of the SPAY cows died following spaying. One (2.2%) of the BOPRIVA cows was pregnant on day 206 and 14 (31%) were pregnant on day 253. The cumulative pregnancy rate over time is shown in Fig. 1. There were no significant differences between treatments in average weight over time (P=0.67) (Fig. 2). Economic analysis found that use of Bopriva™ to prevent pregnancy became more cost effective than spaying when mortality rates were above 2.1%. In classes of females which tend to have higher mortality rates following spaying these results indicate that where pregnancy only has to be prevented for a period of 4 months and the process of administering 2 injections is not too inconvenient that Bopriva™ may be a cost effective alternative to spaying for preventing pregnancy.



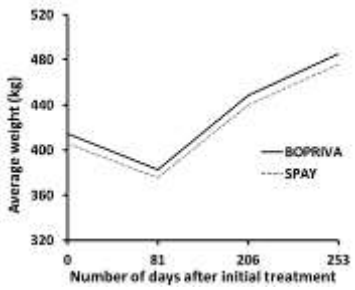


Fig. 1. Cumulative pregnancy rate of BOPRIVA cows. Fig. 2. Weight change, BOPRIVA (-), SPAY(--).

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Accelerating the impact of genomics on beef production

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Introduction

The efficiency of beef production systems underpins on-farm productivity, which consequently impacts on the sustainability of beef businesses. Genetic technologies can be employed to address efficiency gaps, for example in the reproductive output of cow herds. Genomic predictions, using DNA information to identify animals with high genetic merit, have underpinned a rapid increase in the rate of genetic gain in the dairy industry. With Northern Australian beef cattle, a number of factors have impeded the development of reliable genomic predictions. Amongst these are the multi-breed nature of the Australian beef industry, as well as the limited opportunities to collect phenotype information for grazing animals in extensive production environments.

Our group at CSIRO specialises in adapting and making use of recent advances in genetic technologies to address these roadblocks. For example, we have developed computational approaches to allow genomic predictions from a well-characterised breed of cattle to be used to rank selection candidates in another breed. We have also developed cost-effective methods to carry out genomic surveys of commercial animals to allow the ranking of sires without known pedigree connections to the commercial animals. We envisage that these innovative approaches will pave the way for genetic technologies to start making an impact on beef businesses even before highly accurate genomic predictions become available for every trait and every breed in the industry.

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Developing technologies to track cattle in remote areas

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Introduction

The cattle industry has the potential to provide essential income streams and livelihood options to indigenous communities in northern Australia. In this project, CSIRO partnered with an indigenous community that is a major land holder in the Archer River Basin, Cape York Peninsula. The community is keen to intensify or develop an existing (but largely unmanaged) cattle operation yet have multiple land management goals including the maintenance of cultural sites, protection of food resources, participation in a carbon economy and the protection of biodiversity. Although there has been significant research into movement in the landscape of domestic cattle, very little has been done on the movement of feral cattle and their ecological impacts on natural systems. Feral cattle represent a significant environmental threat and can reduce productivity by disrupting controlled herds and mating programs. This project was a preliminary attempt to test existing devices on an un-managed herd to represent feral cattle in natural systems in the mesic tropical savannas and to provide vital information for designing future cattle experiments in areas where stock are not controlled and are difficult to muster and locate (tropical rainforests, dune scrubs and gallery forest along major rivers).

Methods

Sixteen cattle (LW±SE 181±3.1 kg) mustered from open and wooded country 50 km south south-east of Aurukun far north Queensland (13.757^{o}S, 141.567^{o}E) were each fitted with a CSIRO ear-tag containing GPS, inertial measurement unit, battery, radio, solar panel and micro-processor unit in early August 2015. The electronics were encased inside a 3D printed ear-tag weighing 40 g that measured 40 x 75 mm. Once released the cattle were free to return to their home range. There is limited fencing in this area with rivers and the ocean forming physical barriers to cattle movement. The devices were programmed with a schedule to record the location of the animals every 4 hours. In early November 2015, the cattle were mustered, the ear-tags retrieved, the data downloaded, processed and analysed.

Results and Discussion

Of the 16 cattle ear-tags fitted, eight were retrieved four months later. All retrieved devices were operational. While deployed the devices had maintained battery charge through solar energy harvesting despite becoming dirty and being mounted on the ear. The majority of the cattle remained close to permanent water for the majority of the time, although periodically went on excursions to the east (Fig. 1).

Fig. 1. Locations of eight feral cattle in Cape York region over four months.

Conclusions

The experience gained during this study will help in the design of devices that are suitable for long-term deployment in remote natural areas.

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Diet selection influences cattle performance on tropical pasture

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Introduction

The performance of cattle on tropical pastures is influenced by season and pasture conditions, however, within any group, some individuals perform better than others do. While genetic differences can be important, we speculated that performance can be influenced by grazing selection.

Method

Eighty-nine Droughtmaster weaner steers (initial LW±SE 181±3.1 kg) were allotted to 276 ha of pasture comprising mixed tropical grasses and stylos on Lansdown Research Station (19.66^{o}S, 146.84^{o}E) in November 2015. Cattle were weighed as they entered the water points using a walk over weigher (WoW). Cattle were also mustered to the yards and weighed on 3 November 2015, 1 December 2015, 29 February 2016, 7 April 2016 and 2 May 2016. In addition, cattle had a faeces sample taken for near infrared (NIR) analysis and the pasture assessed for dry matter yield and legume content (BOTANAL technique) and NIR determination of crude protein (CP) and δ^{13}C (an indicator of the proportion of C3 plants in the diet including legumes) at three month intervals.

Results and Discussion

The number of records from cattle using the WoW was variable throughout the trial. During periods of rainfall and when there are sources of water other than the water point associated with the WoW, the number of cattle being recorded can be zero. At other times, the majority of animals are recorded daily. Walk over weigher and crush live weights were very similar during the trial with herd averages of 187, 203, 278, 321 and 352 kg recorded by the WoW and 203, 203, 276, 319 and 343 kg recorded when cattle were mustered to the yards and a static weight recorded on 3 November 2015, 1 December 2015, 29 February 2016, 7 April 2016 and 2 May 2016, respectively. The break of season occurred in late January resulting in increasing biomass and forage quality over the three sampling periods (Table 1). The CP of the diet was noticeably higher than that of the pasture, indicating a degree of selection, which was less apparent in February.

Table 1. Yield and composition of the pasture and composition of the diet.

	Pasture composition (NIRS)				Diet composition (FNIRS)			
	Yield (t/ha)	Legume (%)	*NDF* (% DM)	CP (% DM)	CP (% DM) Mean	Min	Max	δ^{13}C
Dec 1	1.39	33.7	75.1	5.55	8.81	6.23	11.2	19.2
Feb 29	2.94	20.6	61.0	10.4	11.5	9.41	13.7	18.0
May 2	5.68	30.8	68.9	7.36	10.0	4.34	12.7	21.2

Conclusions

Within this cohort of individuals, there was a large range in diet selection and LW change. However, we are unable to identify clear relationships between diet selection and LW performance. Ongoing measurements over the next 12 months and data pertaining to rumen function and grazing behaviour is yet to be analysed and may help to explain the variability among individual cattle.

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Precision Pastoral Management System: delivering on-ground benefits for beef producers

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Introduction

The Precision Pastoral Management Tools (PPMT) project has spent the past five years developing a "cloud-based" software system, the Precision Pastoral Management System (PPMS), to assist the northern beef industry. The PPMS can remotely monitor and analyse cattle and pasture production without any labour or skill inputs from beef producers. Over the past three years the system has been tested and its benefits assessed on five commercial cattle stations from the Northern Territory (NT), Queensland (Qld) and Western Australia (WA). The system has been found to provide financial, environmental and personal benefits for beef producers.

Benefits for Beef Producers

Financial benefits from the PPMS have been demonstrated at Glenflorrie (WA) and Newcastle Waters (NT) stations. At Glenflorrie, the PPMS detected liveweight change 5 weeks earlier than traditional paddock-based monitoring could. The station owner estimated that an early decision to supplement based on the PPMS data could have prevented a loss of 7% saleable liveweight, or a saving of $14,933 across the herd compared with later commencement of supplementation. Similarly, at Newcastle Waters, the PPMS provided the capacity to objectively evaluate their bull supplementation program. Data from the PPMS showed that supplementation could have been started earlier to better meet the target average bull weight of 400kg.

Environmental benefits can result from; matching stocking rates with current season feed on offer, wet-season spelling, and evenly spreading grazing pressure. Information from the PPMS allows more informed decision making for these management strategies. Implementing them generally requires infrastructure development to give the necessary control of grazing. At Undoolya station, the use of the Remote Livestock Management System prompted, a 13,300ha paddock to be split and wet season spelling implemented. This improved the pasture yield of the spelled paddock by 60%.

Personal benefits, whist difficult to quantify, are also accruing from the PPMS. Producers have related how the data from the PPMS has removed anxiety associated with making management decisions such as when to sell, adjust their stocking rates or commence supplementation. As stated by Murray Grey (Glenflorrie station), "*You can't argue with the liveweight data when it starts declining; it was a fact"*. The provision of the liveweight and pasture data has also provided producers with the opportunity to learn more about their production system, as stated by Ben Hayes (Undoolya Station), "*The weight gain and how good they can (grow), I have learnt a lot from that.*".

Conclusion

This paper has briefly outlined financial, environmental and personal benefits that the PPMS delivers for beef producers in northern Australia. A second NBRUC paper (Leigo *et al* 2016a) outlines how the PPMS was developed and can be used by beef producers in northern Australia.

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Precision Pastoral Management System: automated 'big data' for cattle and pasture production

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Introduction

Beef producers continue to search for technology that can increase production and reduce operating costs. On average, beef producers in northern Australia manage 7,000 head of cattle over 2,000 km^2 with 6.6 labour units (MLA 2015). To date, few properties collect and analyse objective data on pastures and cattle performance. Undertaking regular monitoring of cattle and pasture is currently expensive, time consuming and requires skills and knowledge that are not readily available in remote parts of the country. A tool is needed that can provide accurate, objective data on rangeland cattle and pasture production. The Precision Pastoral Management Tools (PPMT) project has over the past five years developed a "cloud-based" software system, the Precision Pastoral Management System (PPMS), to address these needs.

How Does the PPMS Work?

The PPMS receives and analyses cattle and pasture production data, produced by remote and automated systems customised to individual cattle stations. Beef producers log-in to their customised website to review their cloud-based data at any time. Cattle liveweight data is collected remotely via Precision Pastoral Pty Ltd's Remote Livestock Management System (RLMS) which uses walk-over-weighing technology. Pasture data is provided by satellite as sourced from the company Landgate. Both systems collect data daily and provide a weekly summary. Beef producers have been engaged in the development and trialling of the PPMS to maximise adoption. The project has sought to develop a simple, usable delivery of 'big data' as an effective decision support tool. Software development has followed action learning cycle, whereby the PPMS was planned for, a prototype developed, reviewed and adjusted. Key design elements of the PPMS were that: the data needed to be collected and analysed automatically with no need for producer input; and to be intuitive, with no need for training or user guides for the beef producer to use it. The PPMS has been trialled on five cattle stations across northern Australia for three years and a further four stations have commenced using the system. Beef producers have used the PPMS to assist with strategic decisions such as the optimal time to sell cattle, adjusting stocking rates, and implementing supplementation programs.

Conclusion

This paper has briefly outlined how the PPMS works for beef producers in northern Australia, a second NBRUC paper (Leigo *et al.* this proceedings) reports on the benefits received by beef producers using the system.

References

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Autonomous technology can record fertility traits in northern beef herds

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Introduction

Extended postpartum anoestrus periods are known to cause productivity losses in the northern beef industry. However, the key fertility traits influencing reproduction are poorly recorded with only 12% of commercial mating's in northern Australia having BREEDPLAN EBV's (Lee *et al.* 2015). Similarly, perinatal deaths result in substantial losses (5 – 7%) but the exact causes are not well known (Burns *et al.* 2010). Maternal parentage is a key parameter recorded by the seedstock industry but the methods currently used are both laborious and expensive. Our research objectives were to 1) provide technologies to determine maternal parentage and calving dates to enhance data capture by the seedstock industry and 2) locate calving sites so causes of perinatal loss could be ascertained.

Methods

Forty cows and their progeny were trained to use a Walk-over-Weighing (WoW) system and monitored from April 2015 to March 2016. The ability of radio frequency identification (RFID) sequencing to determine maternal parentage was assessed in April 2015. Daily weights using the WoW system, plus seven static weights, were recorded from 1 September 2015 to the end of the calving season. On 1 September 2015 the cows had a radiolocation device inserted intravaginally. Cows were monitored weekly from insertion to the start of calving and then daily throughout the calving season. The herd calved from 14 October 2015 through to 9 February 2016.

Results

The use of RFID sequencing from the WoW system resulted in 92% correctly assigned maternal parentage compared to manual mothering up. Preliminary analysis of the WoW data in relation to deriving date of calving has shown that 63% of calving events were determined and possibly another 16% will be resolved using different analytical techniques. The weight loss associated with calving could not be detected for the remainder of the herd. Preliminary analysis of the radiolocation device data shows 17.5% of devices had zero transmissions; 17.5% were expelled prior to calving; 20% could possibly be associated with calving dates; 40% weren't associated with calving dates and 2.5% didn't transmit until well after calving. In terms of deriving a calving site, 29% of devices provided a location but the location was generally not derived until two weeks after calving.

Discussion and Conclusion

The cost and complexity of recording fertility-related parameters is limiting their generation by northern seedstock producers. Walk-over-Weighing is proving to be an accurate and potentially cost-effective method of recording maternal parentage and date of calving, which could result in the production of more animals with Days to Calving EBV's. The radiolocation device evaluated in this study requires further refinement before it can consistently identify calving sitings.

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FORAGE: climate, pasture and cover information for grazing land management

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Introduction

Grazing land managers and industry advisors in the 21st century need quick and easy access to up-to-date, comprehensive information to support enterprise decision making. FORAGE is an online reporting tool (https://www.longpaddock.qld.gov.au/forage/) which offers a range of property-scale reports that contain information including: rainfall, pasture growth and biomass, seasonal rainfall and pasture growth outlooks, ground cover, soil erodibility, land types, tree density and climate projections – presented as time-series graphs, images and data analyses. The FORAGE system accesses a grazing systems model to simulate pasture growth and total biomass, using interpolated climate records with soil and pasture parameters. Remotely-sensed data from the Landsat satellites are also accessed to provide estimates of green and non-green (i.e. dead or senescent) cover and bare ground, as well as a ≈30-year time-series of ground cover values for a property or land type. The FORAGE web interface is a simple form where the user provides an email address and the property location (latitude/longitude) or the property Lot/Plan to request a report. Reports are emailed as PDF documents to the user within the hour, or within a few hours, depending on the complexity of the report.

FORAGE reports

Current FORAGE reports include:

- Rainfall and Pasture report
- Rainfall and Pasture by Land Type report
- Ground Cover report
- Minimum Ground Cover report
- Regional Comparison Ground Cover report
- Indicative Land Type report
- Foliage Projective Cover report
- Rainfall and Pasture Growth Outlook report
- Regional Climate Projections report
- Drought Assessment report
- Erodible Soils report (only available for the Burdekin region)
- Crop Frequency report (only available for the selected areas in southern Queensland)

New reports are currently under development, including a Fire History report, Climate Change Impacts on Grazing report and a Safe Carrying Capacity report. Enhancements and upgrades to existing reports are also planned to improve the user experience and information presentation.

FORAGE Report Applications

FORAGE reports can be used for a 'one-off' purpose such as property acquisition or infrastructure planning (Rainfall and Pasture, Indicative Land Type, Erodible Soils reports); for grazing management decisions (Rainfall and Pasture by Land Type, Ground Cover reports); or for periodic systematic monitoring and evaluation (Regional Comparison Ground Cover, Drought Assessment reports).

FORAGE has generated >7000 reports since 2011. The main users have been grazing enterprises, rural consultants, NRM groups and government agencies. FORAGE reports are currently being used to support the Reef Water Quality Science Program and Grazing Best Management Practice (BMP).

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Clermont Cattlemen's Challenge: Results from 2006/07 to 2014/15

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Introduction

The Clermont Cattlemen's Challenge is an annual competition in which local cattle producers enter 5 weaner steers for growing out and feedlot finishing for the 100 day grain-fed market. The Challenge aims to better understand cattle performance in the district. This paper compares the annual property performance for the last 9 years of the Challenge.

Methods

The weight gain results for the pasture phase (approx. 9 months) were collated from 38 properties for the past 9 years of the Challenge (2006/07-2014/15) and analysed using a technique developed by Finlay and Wilkinson (1963). Poor growth rates were experienced during two years and were not included in the analysis. For each year the average weight gain of cattle from each property was regressed on the average weight gain of cattle from all properties for that year (n = 12-17) to compare property performance over years and locations.

Results and Discussion

Variation in the performance of individual properties during good growth years was evident. The mean weight gain of steers from all properties and the regressions of two selected properties are shown in Fig. 1. Across most years Property 1 produced above-average weight gains whereas Property 2 produced below-average weight gains. The slope coefficient is greater for Property 1 (0.97) than for Property 2 (0.26) indicating Property 1 has a greater growth response than Property 2 to improved growth conditions. The intercept is greater for Property 2 (0.41) compared to Property 1 (0.07) indicating better performance by Property 2 when, on average, there is no growth. Reasons for the variation in property performance will be discussed with the producers in the Challenge.

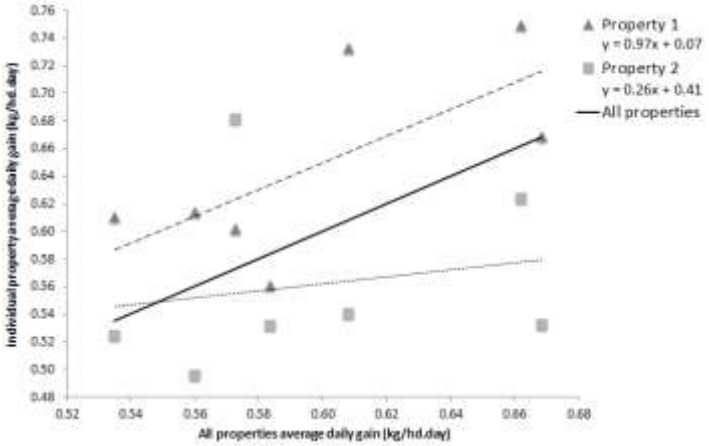

Fig. 1. Individual weight gain performance of two properties involved in the Cattlemen's Challenge

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FutureBeef: Working together to improve extension and adoption

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Introduction

The National Beef Production Research, Development and Extension Strategy (2010) provided a platform for federal and state governments, industry bodies, CSIRO, and the university sector to collaboratively target funding and resources into industry priorities for research, development and extension (RD&E), as determined by the Northern Australia Beef Research Council (NABRC), the Southern Australia Research Council and Cattle Council of Australia. A four-year coordinated extension and communication program ('FutureBeef') was launched in May 2012. The *FutureBeef Program for Northern Australia*, is a collaboration between MLA, DAF, NTDPIF and DAFWA.

Methods

A program management committee developed annual program strategic and operational plans, communication and social media strategies, and trialled a program monitoring, evaluation and reporting (MER) framework in Queensland. Investment into new projects supported the implementation of the NABRC Implementation Response; promoted extension activities and key messages around best management practice under the FutureBeef brand; developed and integrated new technologies, tools and engagement approaches as part of innovative extension delivery; will lift the extension and technical capacity of government, non-government and private extension providers in upcoming professional development opportunities; and later this year will conduct a program evaluation to determine achievements and industry impact.

Results

The program co-funded a comprehensive technical review of all EDGE*network®* workshop materials, encompassing over 10 years of R&D by a technical group of public, industry and private RD&E providers. New workshops and professional development opportunities will be rolled out in 2016. The FutureBeef website (averaging over 100,000 visits/year), staff intranet, webinar series (over 10,000 views on YouTube), eBulletin (3000 subscribers) and social media channels (around 3000 Facebook and over 3200 Twitter followers) were created, and the Stocktake Plus app was further developed and trialled (1600 registered users). Most extension activities across northern Australia, particularly in Queensland, were delivered under the FutureBeef brand and cross-promoted through the online events calendar, print and online newsletters and rural media features.

Discussion

Independent evaluations were conducted on the FutureBeef website, staff intranet, webinar series, eBulletin, social media and the Stocktake Plus app (see further NBRUC papers). Industry recognises the FutureBeef brand and sees value in these innovative extension and communication approaches. The acceptance and uptake of these to date has been comparable with other industry engagement figures and with improvements in internet access in future, these will be integral to the modern extension toolkit. Professional development opportunities for extension providers will be a key focus in the next six months, as well as integrating industry-funded tools and key communication messages into a suite of projects funded by MLA and other funding partners.

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Enhancing extension outcomes through the use of community-based social marketing

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Introduction

The Grazing Best Management Practice (Grazing BMP) program is a voluntary, industry led process which enables graziers to identify improved practices which can increase the long term profitability and sustainability of their enterprise. The web based benchmarking system covers five modules; people and business, soil health, grazing land management, animal production and animal health/welfare. The program has a focus on maintaining good ground cover in order to minimise soil erosion and therefore decrease sediment run-off impacting our water ways and the Great Barrier Reef. Additionally in time the program will allow the grazing industry to demonstrate environmental management to the wider community. Evaluation is showing that Grazing BMP continues to measure excellent results in the Burdekin and Fitzroy catchments where it originated. As the program migrates south into the Burnett Mary and South-East Queensland catchments, our question is "Can we enhance our extension outcomes through application of recent staff development learning's?"

Enhancing Extension Through Community-Based Social Marketing

Agricultural extension is the intermediate between research and the producer, encouraging the adoption of new knowledge to change processes within agricultural industries. Often extension revolves around supplying information based on OUR assumptions about customers and their needs. According to McKenzie-Mohr (2011) many costly community interventions have led to minimal behaviour change. McKenzie-Mohr (2011) endorses the well-defined five-step community-based social marketing approach (CBSM) to achieve greater adoption and behaviour change success. CBSM merges knowledge from the social sciences with knowledge from the field of social marketing. The CBSM approach offers an attractive alternative to traditional information-intensive extension approaches; moreover it has proved very effective at bringing about behaviour change (McKenzie-Mohr 2011). CBSM involves a five step approach; **1) Behaviour selection, 2) Identifying barriers and benefits** associated with selected behaviour/s, **3) Development of a strategy** that reduces barriers while simultaneously increasing the perceived benefits of the behaviour being promoted, **4) Piloting the strategy and 5) Implementation and on-going evaluation**

Conclusion

Using the CBSM approach as a tool to enhance extension of Grazing BMP in the Burnett Mary and South-East Queensland catchments will be a learning journey for all involved. The aim is to take a balanced approach integrating the CBSM approach within the traditional delivery of extension through workshops. In addition to providing staff with a valuable learning journey, this approach will hopefully result in extension being as effective as possible and gaining the best outcomes for the GBMP project.

References

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Connecting online with FutureBeef

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Introduction

The FutureBeef website, eBulletin and social media went live in January 2012, April 2012 and July 2013 respectively. Communication channels were independently evaluated to: a) determine the level of user satisfaction, the impacts on users' businesses, and whether their use contributed to improved profitability and sustainability, and b) recommend improvements based on user perceptions.

Methods

The evaluation involved a review of secondary data and a telephone survey of 265 randomly selected eBulletin subscribers (from a total of 2931) of which 150 people completed the survey. The response rate gave a 95% certainty that the true mean responses to survey questions lie between ± 8% for eBulletin subscribers. Respondents were: 68% producers, 16% public extension officers, 13% private advisors and 3% corporate farm managers. The secondary data was the subscriber and staff evaluation reports conducted in 2013 and the eExtension project annual report 2014-15.

Results

On average, survey respondents' ratings of the usefulness of the different communication channels were similar: FutureBeef eBulletin 6.6/10, FutureBeef newspaper features 6.8/10, Facebook 6.7/10, Twitter 6.3/10, multimedia 6.4/10, website 6.2/10 and the staff intranet 6.4/10. Most respondents preferred email to receive information and updates although newspaper features were also useful information sources for many. Overall respondents' satisfaction rating for FutureBeef information sources as a whole was 7.4/10. Thirty-four per cent of respondents used the information and resources to stimulate or support decisions and changes made to their enterprises or their advisory and extension services (Coutts 2016a; 2016b).

Discussion

The FutureBeef eBulletin, social media, webinars and website are an effective combination of ways to connect with industry that complement and enhance existing relationships. The eBulletin and newspaper features were cited as sources informing and prompting change. Social media use is growing with extension providers currently appearing to actively use these channels more than producers and industry. The website is viewed as a useful and evolving resource keeping visitors updated. It was also cited as a specific resource prompting or informing change.

Overall respondents had a reasonably high level of satisfaction with the usefulness, delivery and extension of FutureBeef information. The ease or difficulty of internet access has a significant impact on communication channels accessed by stakeholders. There are indications that FutureBeef information is positively impacting knowledge and understanding as well as productivity and improving the advice being given.

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Beeftalk newsletter celebrates 21 years providing valued information

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Introduction

The *Beeftalk* newsletter has been providing valued information to beef producers for 21 years. The Department of Primary Industries and South East Queensland Regional Beef Research Committee (RBRC) initiated *Beeftalk* as a cost effective way to connect with the large number of cattle owners and agribusinesses in South East Queensland (SEQ). It combined four smaller regional beef newsletters for more efficient production and greater distribution. At an early meeting, beef officers Dave Daniel, Russ Tyler, Damien O'Sullivan and others debated its name until the administration officer called out from the next room… "Stop your fussing boys, just call it *Beeftalk*". For 17 years *Beeftalk* was mailed twice a year, as a 24 to 32 page newsletter to 10,000 addresses in SEQ. In spring 2013, *Beeftalk* transitioned to a biannual 12 page feature within the *Queensland Country Life* (QCL) newspaper with approximately 21,000 copies per edition (42,000/year) distributed across Southern Queensland. Now covering east to west Queensland, sheep information is included with a two page *Flock talk* feature by the DAF Leading Sheep team at Charleville. *Beeftalk* collaborates with sister FutureBeef newsletters, *CQ BEEF* (in QCL) and *Northern muster* (in *North Queensland Register*), which combined cover all of Queensland.

The Aims of Beeftalk are to:

- give timely, topical and easy-to-read information in short articles referenced to a source;
- highlight beef projects undertaken by DAF, CSIRO, University of Queensland and other agencies through the umbrella of the RBRC;
- provide a cost effective conduit between DAF, beef producer households and the wider industry.

Beeftalk Evolution

1996	Editorial team formed consisting of a beef producer member and Beef Extension Officers based at Gympie, Gayndah, Bundaberg, Kingaroy, Brisbane and Ipswich
1996–2013	*Beeftalk* mailed to 10,000 addresses in SEQ. Winner of two DAF client service awards.
2013	*Northern muster* leads new delivery method with Fairfax Media
2013–15	*Beeftalk* and *CQ BEEF*, 12 page biannual feature in the *Queensland Country Life*
2014	*Flock talk* (sheep) joins *Beeftalk* in *Queensland Country Life*
2015 on	*Beeftalk* (6 page) plus *Flock talk* (2 page) triannual feature (63,000 issues/year) in QCL

Methods

The *Beeftalk* team consists of DAF extension officers plus a producer member. Three times a year the team call for, collate and write articles using producer feedback from previous editions guiding content.

Evaluation and Feedback

Producer feedback remains extremely complimentary including evidence of positive changes on farm. "We look forward to Beeftalk; it has been a great benefit to our operation." A recent review confirms that *Beeftalk* is highly regarded and valued by industry.

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Diminishing returns and profitable beef production

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Summary

Profit is maximised when marginal costs are (almost) equal to marginal returns, not when beef production is maximised.

Methods and Discussion

Diminishing returns is the phenomenon where increases in variable inputs to a production process results in declining increases in total outputs. Extra inputs will improve profit so long as the extra (marginal) returns exceed the extra (marginal) costs. Table 1 is derived from case study data for a beef property located in northern Australia. Each scenario represents a more complex bundle of inputs. Total grazing pressure is the same in each scenario.

Table 2. Predicted beef output and production costs.

Scenario	Liveweight sold (t)	Total fixed costs	Total variable costs	Total costs	Fixed costs per kg	Variable costs per kg	Total costs per kg	Marginal costs per kg
Minimal input	309	$441,637	$135,775	$577,412	$1.43	$0.44	$1.87	
Very low input	340	$441,637	$140,251	$581,888	$1.30	$0.41	$1.71	$0.15
Low input	403	$441,637	$170,055	$611,692	$1.10	$0.42	$1.52	$0.47
Moderate input	428	$441,637	$188,069	$629,706	$1.03	$0.44	$1.47	$0.72
High input	494	$441,637	$317,799	$759,436	$0.89	$0.64	$1.54	$1.97
High input + energy	512	$441,637	$449,409	$891,046	$0.86	$0.88	$1.74	$7.21

Profit is maximised in the short term when marginal cost is almost equal to marginal revenue. Marginal costs are defined as the change in total cost associated with a small change in output. As the level of output from this property will not impact on the prices received, the optimum economic level of inputs for this business will produce a beef output greater than 428 t but less than 493 t. Table 2 provides the performance of the investment at each level of inputs and shows that focusing on maximum beef production will reduce profit. Targeting the highest level of production reduces the gross margin by about $105,000 per annum. Although the “High input +energy” increases weaner numbers by 14% and beef production by 20%, it could decrease returns by more than 50%.

Table 3. Predicted beef output and investment returns.

Scenario	Liveweight sold (t)	Extra liveweight sold (t)	Beef output (kg/AE)	Number of weaners	Gross margin	Internal Rate of Return
Minimal input	309		88	1,357	$375,452	-0.75%
Very low input	340	30	91	1,470	$390,960	-0.42%
Low input	403	63	102	1,555	$470,827	1.07%
Moderate input	428	25	114	1,556	$479,360	1.17%
High input	494	66	130	1,697	$453,992	0.68%
High input + energy	512	18	134	1,776	$373,099	-0.78%

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Production costs, prices and profitable beef production

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Summary

The average level of production costs incurred by a beef business is not a useful indicator of the most profitable level of beef production. Consideration of marginal revenue (price) and marginal costs provides a much better indication.

Method and Discussion

Production costs are comprised of (1) costs that can be readily adjusted and vary with the level of output (variable costs) and (2) those more difficult to adjust in the short run (fixed costs). Variable costs plus fixed costs equals production costs. Another term used when discussing production costs is *marginal costs.* They are defined as the change in total cost associated with a unit change in output. So long as the cost of additional input (or marginal cost) is less than the value of the additional product (marginal revenue) it will pay to continue to apply more input. Case study data from a beef property in northern Australia was used to investigate the relationship between production costs, beef price and the most profitable level of beef production. Figure 1 shows the expected relationship between average variable costs, average total costs, marginal costs and average price for production scenarios with increasing variable inputs. The most profitable level of beef production is found near where the marginal costs curve crosses the price line – not at the point where average total costs are minimised.

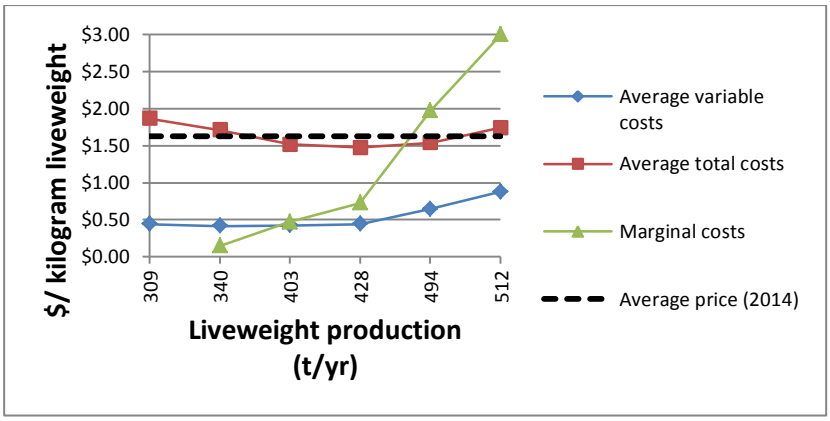

Fig. 1 Beef production, production costs and price.

Consider the impact of the recent rise in prices on the most profitable level of beef production for the case study property. The lowest point for average total costs will not change in the short term but the optimal level of output will now increase. Beef producers can contemplate additional expenditure to increase output as long as the marginal cost of the strategy does not exceed the marginal revenue. If they focussed on maintaining low total production costs, they could be up to $100,000 per annum behind where they should be. A focus on minimising production costs will lead to opportunities to improve profit being missed.

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Breed your own (BYO) bulls?

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Summary

The appropriate selection of replacement bulls from the breeding herd can significantly improve business performance. In this scenario, decadal investment returns were improved by more than 40%.

Method and Discussion

The potential economic impact of selecting breeding bulls from the male weaners of a commercial beef herd was tested using a model of a "typical" breeding herd of northern Australia. The herd model represented an "average" herd of the VRD/Sturt Plateau region, and was based on data available from recent industry surveys and the Kidman Springs Research Station as at the end of 2014. The model herd is about 6,500 Adult Equivalents with about 3,500 cows and heifers mated each year. The expected average reproduction efficiency of the breeding herd (weaners produced as a percentage of cows mated) is 55%.

With a joining percentage of 3%, about 105 herd bulls were used each year. Replacements enter the herd as two year olds with an average landed cost of $2,250. On average, herd bulls are kept for five years and the expected annual mortality rate is 2%. Approximately 21 replacement herd bulls are required each year.

The BYO Bulls scenario consisted of appropriately identifying approximately 42 male weaners, keeping them to yearling age when 50% would be culled and sold as yearling bulls to the abattoirs. The remainder would enter the breeding bull herd as herd bulls. Culled herd bulls are sold for the same average value in each scenario. The selection strategy was expected to at least maintain the reproduction and other performance parameters of the breeding herd and its progeny.

The selection process includes selecting yearling bulls which pass an examination for reproduction soundness, have a suitable temperament and meet other management criteria. The additional costs expected to be incurred by the selection process are $200 per weaner bull retained. Data recording and analysis costs were added to a portion of the breeding herd to cover the additional costs of selecting weaner bulls. Another cost identified for the BYO scenario is a loss of income due to the sale of the cull yearling bulls to the abattoirs. They were sold at $1.10 per kilo live compared to $1.90 per kilo live for steers.

The benefit of the BYO Bulls scenario was the saving on replacement costs for herd bulls ($2250/bull). The key assumption is that no aspect of herd performance (reproductive or growth) would be impacted by the change. Implementing an objective bull selection process could improve herd performance over time and should also eventually add to economic performance but such gains are unlikely to be apparent in the first decade after the change is made and have not been included in this analysis.

Over ten years the cumulative net cash flow of the modelled business was improved by 28% when compared to the net cash flow of the "without change" scenario.

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The relationship between economic response and reproduction rate

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Summary

The benefits of improving reproduction efficiency are property and enterprise specific. Some properties may gain significant economic benefits with minimal expenditure while others have limited opportunities to economically improve performance. Even so, there is no particular level of reproduction efficiency beyond which no further benefits are achievable. The ultimate decision criteria to judge a potential improvement to reproduction efficiency is the extra return on extra capital invested associated with the change.

Method and Discussion

A herd modelling exercise was undertaken to look at the possible economic response to improving reproduction efficiency. Reproduction efficiency is defined as the number of weaners produced divided by the total number of breeders mated expressed as an annual percentage.

The following conclusions were drawn about the value of improving reproduction efficiency:

1. Properties that have a low starting level of reproduction efficiency stand to gain the most (in both relative and absolute terms) from implementing well-targeted investments to improve reproduction efficiency.
2. Marginal returns reduce as the underlying performance of the breeding herd improves. The benefits gained by spending $20 per breeder in a herd with 50% weaning rate may be positive but spending the same amount when the herd already achieves an 80% weaning rate appears unlikely to provide net benefits.
3. Strategies aimed at improving reproduction efficiency that require a different pattern of spending, say where a large up front capital expenditure is required, need to be analysed using a process that accounts for patterns of costs and benefits incurred over varying periods of time to assess potential benefits.
4. The extra costs and extra benefits of improving reproduction efficiency are property and enterprise specific.
5. The extra costs and extra benefits associated with any management strategy is the critical consideration regardless of the current level of breeder herd performance.
6. Investment to improve reproduction efficiency may not be the best investment available to the manager and all opportunities to improve business performance should be included in any assessment of strategies.
7. Analysis of the impact of a change in the reproduction rate in a breeding herd must consider herd nutrition, mortality rates, growth rates, stocking rates, culling strategies and age of turnoff.

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The impact of the season of calving

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Introduction

The economic impact of having calves "out of season" was modelled. The underlying assumption is that uncontrolled (continuous) mating systems in northern Australia incur a cost due to calves being born in less favourable periods of the year.

Method and Discussion

Data for herds with uncontrolled mating was applied to bio-economic models to estimate the impact of preventing calves being born during what are seen as less favourable calving periods. A breeding herd with continuous (uncontrolled) mating was initially modelled using a "typical" enterprise of the Victoria River District (VRD) and Sturt Plateau of the Northern Territory. The data was sourced from NT DPIF research activities and the Cash Cow project (McGowan et al 2014). Once the base herd model was developed, "out of season" calves were prevented by varying the mating period in the model. The mating period was varied by removing bulls:

- from September to December
- from June to September
- from June to December.

Removal of the bulls prevented the cows that formerly conceived to calve "out of season" from doing so. They could still conceive at the next available opportunity. The economic and financial analysis undertaken considered not only the endpoint of the change but incorporated the impact of the implementation phase as well. Beef businesses located in a region with highly variable and generally low nutrition in northern Australia face a significant transition period if it want to move from year round mating to a system where "out of season" calving is prevented.

Where there is no reduction in operational costs, improvement in efficiency and/or conception rates, it is considered highly likely that a disruption to mating periods in a region where cows find it very difficult to re-conceive will diminish the economic and financial performance of the beef business over the following decade.

Although conception rates appear unlikely to improve with the change, the impact of a scenario that increased the re-conception rate to calve again within 12 months of all breeders by 10% was tested. None of the other performance parameters of the herd were changed. The measures of economic efficiency calculated for the segregated breeding herd with uncontrolled mating and the herd with controlled mating and 10% better conception rates indicated very small difference between the two mating systems over the life of the investment. Incurring any additional costs due to the restriction of the mating period would make the benefits minimal even if improved conception rates were expected.

Reference

McGowan (2014) Northern Australian beef fertility project: CashCow, Project code: B.NBP.0382, Meat & Livestock Australia Ltd. Available for download at: http://www.mla.com.au/Research-and-development/Final-report-details?projectid=15462.

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Estimating the value of individual strategies

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Summary

Unless a performance indicator or ratio takes account of the extra costs and benefits associated with strategies to improve a breeding herd and the time taken for extra costs and benefits to be realised, the measure is unlikely to identify the relative value of the strategies. Although some production ratios and indicators can be useful when assessing current herd performance, none are suitable when assessing the potential benefits of alternative management strategies.

Method and Discussion

A wide range of performance measures and ratios have been proposed as suitable when assessing strategies to improve the economic performance of beef breeding herds in northern Australia. Examples include: branding rate, mortality rate, weaning rate, growth rate, kilograms of output per hectare, per adult equivalent (AE), per breeder; income per AE or per ha, cost of production, cost of gain, operating margin, weaner production (kg/cow/year), lactation rate or liveweight production ratio. A number of these indicators were compared to the traditional economic and financial indicators of value to assess their capacity to appropriately reflect the potential economic and financial benefits of a change to herd management. Table 1 shows ratios for three example strategies for a property in northern Australia. The first strategy provided energy supplements to heifers to improve weaning rates; the second used genetically superior bulls to improve reproduction performance and the third invested in infrastructure to improve pasture utilisation.

Table 1. Performance, production and economic indicators

Strategy Indicator	Base herd	Base herd + heifer feeding	Base herd + genetic selection	Base herd + pasture utilisation
IRR (whole investment)	4.97%	4.66%	4.97%	10.73%
NPV (whole investment @ 5%)	($56,252)	($615,931)	($53,542)	$15,271,049
Closing cash balance	$15,180,060	$14,233,850	$15,084,853	$13,121,154
NPV (marginal return)		($559,679)	$2,711	$15,327,301
IRR (marginal return)		n/a	5.51%	28.51%
Weaning rate	51%	51%	53%	58%
Weaner production*	135	136	136	132
Live weight production*	172	172	172	174
Live weight production ratio*	0.57	0.57	0.57	0.58
Operating margin*	$0.64	$0.60	$0.64	-$0.05
Cost of production*	$1.15	$1.19	$1.14	$2.68

***** Average for the decade

Production ratios are incapable of appropriately identifying the relative economic or financial merit of the various strategies. Weaning rate also shows little relationship to the results of the economic and financial analysis. The traditional economic and financial criterion do not take much more time and effort to calculate than production ratios or other ratios and they better discriminate between the strategies. In fact, they are the only criterion able to appropriately differentiate between the strategies in terms of their value to the manager.

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Themes underpinning the economic improvement of northern beef herds

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Introduction and Method

A number of case studies were undertaken with beef breeding enterprises across northern Australia to identify the value of management practices aimed at improving beef business performance. Consideration of the case studies identified a number of important themes underpinning the economic improvement of northern beef herds.

Discussion

The case studies identified that for beef herds with relatively lower performance in northern Australia critical issues for improving performance are management skills/knowledge and property infrastructure development. The capacity of a manager to identify where and when expenditure on infrastructure is likely to pay dividends is critical. Such investments are targeted at improving the profitability of the beef enterprise and may or may not change reproduction efficiency. Focusing on investments aimed at improving reproduction efficiency alone will lead to better opportunities to improve the profitability of the business being missed.

The focus of managers in the nutritionally more difficult regions with more profitable systems could usually be summarised as “how do I use herd data and infrastructure to best manage the herd and the available nutrition?" Strategies such as herd segregation, controlled mating, supplementation and weaning were all seen as part of the overall choices available to manage the herd and herd nutrition.

Beef enterprises in the more favourable production regions that already have well developed infrastructure do not show significant economic response to such investments. The improvement of such herds appears to rely more on:

- the cost effective improvement of the nutrition of the steer portion of the herd
- identifying the most efficient enterprise and herd structure (which may or may not include a breeding component).

Where breeding is undertaken, pressure must be placed on the breeding herd to perform at its most efficient level - without incurring significant additional costs in doing so. The focus should be on effective herd and grazing management that:

- makes sure cows calve in an appropriate window
- weaning with minimal cost but maintaining (as much as possible) cow body condition
- selecting bulls and replacement heifers using objective measures
- culling cows on reproduction performance.

Breeding females located in the nutritionally more favoured regions are unlikely to need regular supplementation, and managers feeding regular supplements in such regions need to reconsider the economic value of their supplementation regime and their grazing management.

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Profit and profit drivers

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Summary

The term "profit driver" is often applied to factors such as rates of mortality, levels of reproduction efficiency and amounts of beef output. Ranking "profit drivers" on the basis of their impact on "industry average" gross margins or kilograms output of beef per adult equivalent or per hectare gives no indication whether an investment to change the factor will impact on profit. Identification of priority areas for improvement in any herd should be based on analysis of the expected extra costs and extra benefits of the proposed change in management.

Method and Discussion

A herd model developed to assess breeder herd performance in the VRD /Sturt Plateau region was used to identify the change in performance expected to arise from changes in key output indicators. The herd model represented an "average" herd in the VRD/Sturt Plateau region, and was based on data available from recent industry surveys and the Kidman Springs Research Station. The herd had about 6,500 Adult Equivalents in total and typically mated about 3,500 females each year. The expected average reproduction efficiency of the breeding herd (weaners produced as a percentage of cows mated) was 55%. Total mortalities as a percentage of opening herd numbers averaged about 4.5% per annum. Weight gain in steers ranged from 100-130 kg/year depending on the age of the steer and the season of birth. Weight gain in heifers ranged from 100-120 kg/year.

The output indicators chosen were a 1% improvement in reproduction efficiency, a 1% reduction in mortality rates and a 1% improvement in sale weight of all sale cattle. (A 1% improvement in sale weight is equivalent to a 1% improvement in growth rate). Table 1 indicates the gross and net changes in total beef output produced and the Present Value of the Benefits to the business when each factor was varied in the model. Equivalent grazing pressures were maintained in each scenario.

Table 1. Impact of changes to reproduction rate, mortality rate and sale weight.

Variable	Change (%)	Annual liveweight production (kg)	Extra liveweight per annum (kg)	Liveweight production (kg/AE)	Extra liveweight response (kg/AE)	Change in Present Value (PV) of Benefits
Base herd		588,130		87		
Increase weaning rate	+1%	592,608	4,478	88	0.72	$20,578
Decrease mortality	-1%	609,204	21,073	91	3.31	$203,894
Increase sale weight	+1%	591,455	3,325	88	0.48	$35,809

A 1% change in reproduction efficiency leads to a 0.7% increase in beef output and a 1% change in sale weight and leads to a 0.6% increase in beef output. It would be difficult to argue that these values are significantly different to each other although the PV of Benefits of increasing sale weight is almost double that of increasing weaning rate. Improvement in beef output due to a reduction in mortality rate relies upon the mortality rate of all classes of stock being reduced on average by 22%. The relationships shown in Table 1 are only of value when costs of achieving the change are accounted for. No decision to change herd management should be made from the relationships shown in Table 1.

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Strategies to improve reproduction efficiency and breeder herd economic performance

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Introduction

Strategies aimed at improving the reproduction efficiency and breeder herd economic performance of beef cattle in northern Australia have been investigated.

Summary

Strategies capable of improving the reproduction efficiency of beef businesses in northern Australia were identified. In terms of improving reproduction efficiency, it was found:

- Strategies are available to improve the economic performance of a breeding herd with poor reproduction performance.
- The potential benefit of any strategy to improve reproduction efficiency can only be assessed within the constraints of the beef business considering change. The net benefit of strategies will depend on the current performance of the herd and business.
- The implementation of supplementation, weaning, controlled mating, herd segregation and other herd management strategies must be done cautiously. The economic performance of an intensively managed and supplemented breeding herd run under low and highly variable nutritional conditions is not always better than the same herd run less intensively at a lower cost.
- The more problematic reproduction efficiency, the more necessary it is to use cow performance data to manage the breeding herd and the higher the level of management skill and timeliness required to bring about economic improvement.

The economic improvement of reproduction efficiency largely relies upon management having the skill and timeliness necessary to identify and implement strategies suitable for their particular herd, available resources and the industry constraints applying at the time.

The particular impediments that prevent a manager moving from their current management system to something else are very specific to the people, the skills and the resources available and it cannot be assumed that the current system is not achieving the owner's goals.

The key skills for managers are a clear understanding of the trade-offs and responses likely to occur when making an investment in their beef business, an ability to clearly articulate how much a change will improve their profit and a capacity to successfully implement the change.

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Improving productivity to reduce grazing pressure and increase profitability

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Introduction

Recent survey studies have reported on current management practices (Barbi *et al*. unpub) and the wide ranging productivity levels in beef breeding herds of northern Australia (McGowan *et al*. 2014). This paper presents an economic investigation of herds running at different productivity levels and the impact these have on profitability and grazing pressure.

Method

A property of 22,300 ha was modelled in Breedcow using the 50th and 75th percentile performance levels from the "Northern Forest" KPI data as reported in Cashcow (McGowan *et al*. 2014), the 313"C" Beef CRC template (Holmes *et al.* 2011) and the Grazing Management Practice Adoption Survey (Barbi *et al.* unpub). Cashflow was targeted to remain constant, meaning that the analysis could identify the impact of increased productivity on gross margin and grazing pressure.

Results and Discussion

The results show that enterprises operating at the top 25% (75th percentiles) achieved a ~58% increase in gross margin and run 28% less adult equivalents (Table 1). These results do not indicate the profitability of moving from one performance level to another, but rather indicate the profitability of operating at each level.

Table 1. Results of the steady state economic analysis.

Metric	50th percentile enterprise	Top 25% enterprise	Difference	%
Adult Equivalents Carried	3,369	2,422	-947	-28.11
Cattle Carried	3,650	2,675	-975	-26.71%
Net Cattle Sales (income)	$511,865	$511,815	-$50	-0.01%
Gross Margin - herd (after interest)	$174,041	$274,828	+$100,787	57.91%

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Practice change achieved by the Grazing BMP and Extension Support project

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Introduction

The Burdekin rangelands Grazing Best Management Practices (BMP) and Extension Support project aims to encourage beef producers to adopt practices that result in productive and profitable grazing systems and help reverse the decline in water quality entering the Great Barrier Reef (GBR) Lagoon. Within the 2014-2015 financial year, 308 beef businesses, 616 beef producers in the Burdekin rangelands have participated in project activities delivered by the Department of Agriculture and Fisheries (DAF). Surveys were conducted in May 2015 to provide evidence of practice change on property as a result of activities they had attended from 2011-2015.

Method

Face to face and phone surveys were conducted with 30 businesses by an independent consultant to determine the levels of management practice change as a result of field days, workshops and one on one activities they had participated in through the project. All producers who attended three or more events were surveyed and the remaining businesses were randomly selected until a significant number of businesses were in the survey pool.

Results

Results showed 83% of producers have made a practice change as a result of activities they attended from 2011 to 2015 (Figure 1), exceeding the target of 40% change. Grazing land management (GLM), animal production and business themed activities achieved 57%, 44% & 50% practice change, respectively. The results for individually themed practice change appear lower than overall practice change results due to multiple engagements by individual producers.

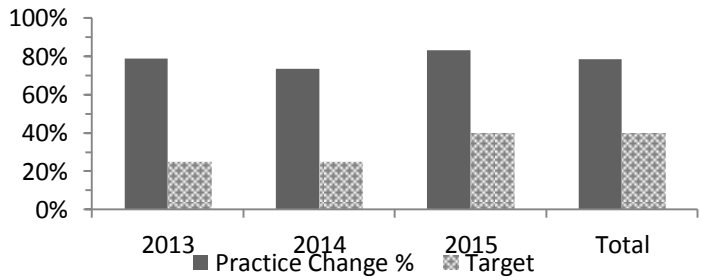

Fig. 2. Survey results (2013-2015) measuring % practice change by beef producers participating in the project.

The majority of producers surveyed (93%) undertook further research and felt more confident in making management decisions. 70% of producers scored an improved confidence rating of 4 or greater for GLM, 87% for animal production and 60% for business management.

Table 1. Producers with an improved confidence in decision-making 2015.

	Rating: 1 (no improvement in confidence) to 7 (great improvement in confidence)						
	1	**2**	**3**	**4**	**5**	**6**	**7**
GLM	13%	10%	0%	33%	23%	7%	7%
Animal	3%	0%	7%	30%	17%	37%	3%
Business	7%	10%	17%	17%	27%	13%	3%

Discussion/Conclusion

Results are consistent with the two previous surveys undertaken in 2013 & 2014, which achieved an average of 76% practice change. The M&E process has shown that producers who have engaged in project activities have improved decision making confidence and made changes to their practices.

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Grazing Best Management Practices
A benchmarking tool for productivity opportunities, extension and continuous improvement in grazing practices

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Introduction

Grazing Best Management Practice (Grazing BMP), a partnership comprised of the Fitzroy Basin Association, AgForce Queensland and the Department of Agriculture and Fisheries, have developed and piloted a set of sustainable production standards that demonstrate achievable, sustainable production and enhanced environmental and animal welfare outcomes to the broader community.

The Grazing BMP Program

Grazing BMP is a voluntary, industry led process that assists producers to identify improved practices that enhance the long term profitability of their enterprise. Grazing BMP helps identify the steps and training required to incorporate best management practices into current management. As Grazing BMP matures it will also assist farmers to identify opportunities and threats, as well as demonstrate sound environmental and ethical practices to the community. The standards within Grazing BMP are often already familiar practices to producers and information pertaining to each standard are available to give a more thorough context as to why the standard has been asked. When an assessment is completed at a workshop with a facilitator, the facilitator along with key presenters give key information ensuring that producers have a greater understanding of the standards. Additionally, 10% of accredited Grazing BMP producers are audited by an independent and external company to ensure integrity in the information provided, thus allowing the data to remain credible.

Benefits to Industry

Grazing BMP has created a process which ensures demonstrable and continuous improvement of grazing best management practices. This is complemented by a dynamic reporting tool that responds to community concerns with current, issue specific data, developed and ratified by independent industry professionals. The information supplied within the benchmarking tool has enabled an analysis of the productivity opportunities within the grazing industry. Through a breakdown of data into catchment regions, extension requirements are able to be identified to upskill graziers in areas of deficiency; this increases producer knowledge and also allows targeted extension by Grazing BMP staff whilst retaining anonymous data. Through a re-assessment process, conducted every 2 years, changes in producer's production is captured and this identifies which areas certain changes have occurred. This, in time, will allow for modelling of projected changes and how they affect the landscape, production and other farming practices.

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Mob based recording systems for beef cattle management

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Introduction

Intensive collection of complex data is not required to effectively manage beef herds. The issue is getting the right data and collecting it as part of the routine management program. This paper describes recording systems that enable mob based data to be collected effectively. A paint branding system for temporary cattle identification is also described.

Methods

Breeding cattle data

Critical information for managing breeding females is pregnancy status, body condition score and for maiden heifers liveweight. Pregnancy status data enables breeder performance to be assessed and problems identified (e.g. fertility diseases). Knowing what animals will calve when is valuable for grazing and nutritional management and planning branding and weaning. Body condition is the principal determent of breeder performance and consequently this data is crucial for assessing performance and planning management through to calving. Heifer liveweight data at pregnancy test is critical for assessing heifer pregnancy rates and the heifer management system. The Breeder recording sheets enable pregnancy status, body condition and liveweight to be recorded easily by anyone at the speed the cattle are being handled. The system has proven reliable when large numbers of cattle are being handled e.g. 1,000 head pregnancy tested per day. The sheets can be easily customised to suit the management group and can handle a number of breed and age groups.

Growing cattle data

For growing cattle knowing the distribution of the mob across weight ranges is as important as knowing the average weight. This data aids assessment of market options, sales planning and nutritional management. The Liveweight recording sheets enable animal numbers by liveweight ranges to be recorded for a number of breed and or animal classes.

Paint brands

Paint brands enable short term identification of animal groups. The “T, V, I” paint brands provide a clear easy to use identification system. Identifying groups is particularly valuable when there are limited drafting options at the crush. Up to 10 groups can be identified at the crush for later drafting in the drafting yard.

Summary

In commercial beef herds mob based recording systems can provide the data required to effectively monitor herd performance and guide management. Critically the system can collect data without affecting the speed or efficiency of the cattle work being undertaken. The system is based on a series of easily prepared and used recording sheets. The “T, V, I and N” paint brands system provides an effective short term identification system for drafting cattle into management and marketing groups.

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Recording coronet circumference as a possible alternative to the measurement of birth weight

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Introduction

Recording calf birth weight accurately allows producers to make informed decisions relating to breeding objectives. The most accurate and reliable method of obtaining birthweight requires the use of weigh scales, however a correlation has been found between coronet circumference and birthweight (Ko and Ruble 1990), which was used to develop and patent the CalfScale™ tape. This paper describes the data collected to examine the potential of using coronet circumference at birth and branding to predict the birth weight of calves thereby providing an alternative to weighing calves at birth.

Methods

During the 2015-16 calving season, birth weight and coronet circumference were recorded within 24 hours of birth during routine calf tagging and birth recording at Brian Pastures Research Facility (Gayndah, QLD), and Spyglass Research Facility (Charters Towers, QLD). However, collection of coronet circumferences only began late in the 2015 calving season. Calves were tagged with unique identification numbers, and birth weights were measured using hanging spring scales. Coronet circumferences were recorded by placing the CalfScale™ tape around the coronary band (the intersection of hoof and hair) with correct side for the sex of the calf facing outwards, pulling the tape firm, and reading the circumference indicated by the arrow. During routine branding operations coronet circumference was recorded at the branding cradle. A standard tape measure was used at branding, because at this age the CalfScale™ tape was not large enough. Records were taken as part of MLA project B.NBP.0759 and included three breeds: Brahman, Droughtmaster and Santa Gertrudis (Brian Pastures only). Numbers of records at each site are shown in Table 1.

Table 4. Number of records across locations and years.

Year	Location	Birth Weight Records	Birth Coronet Records	Branding Coronet Records
2015	Brian Pastures	346	-	319
	Spyglass	475	160	443
2016	Brian Pastures	676	675	636
	Spyglass	295	295	275

The records will be analysed to determine the relationships between branding and birth coronet with actual birth weight. This will provide an assessment of the suitability of using coronet circumference as an alternative measure to recording birth weight in tropical beef breeds.

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Establishment of the High Performance Recorded Beef Herd in South East Queensland

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Introduction

The Brian Pastures Research Facility located in the Central Burnett, Qld, is a typical example of beef production systems in the region, and is home to the DAF high performance recorded herd. The herd was established in 2003 and had a pivotal role in the Beef CRC program, consisting of tropical composite breeds. Since then it has incorporated Brahman, Santa Gertrudis and Droughtmaster breeds with cattle sourced from various seed stock providers, as well as herd progeny. The herd has a key role and has expanded further under MLA B.NBP.0759, which is focussed on accelerated genetic improvement of reproduction of beef cattle in northern Australia.

Methods

Brian Pastures is 2100ha in area with a combination of improved and native pastures, and leucaena, with land types representative of the area. The herd consists of 482 females and the breeder herd is managed as a single contemporary group. This unique design limits external variables that effect productivity, such as climate, infrastructure and nutrition, and precise performance measures that are difficult to record in a commercial system can be collected with greater integrity on an intense scale. Data is collected at key performance events based on protocols developed to meet project requirements. Table 1 outlines the performance measures collected. The resource herd contains large groups of high utility phenotypes, and has used a variety of both key influential and young elite sires. This allows direct comparison of strategically developed progeny and head to head comparisons across breeds. The high level of DNA sampling of this herd means a complete recorded history on parentage, genomics and poll/horn status of progeny from a multitude of sires.

Table 1. Current performance measures.

Heifer Data	**Calf Data**		
Age and liveweight at puberty, Lactation anoestrous interval (1st calf heifers) P8 fat depth, Hip height, Body condition score	***Birth (within 24hrs)*** Birth date, Birth weight , Sex, Calf Vigour, DNA Sample	***Branding*** Liveweight, Horn status, Coat score, Coronet circumference	***Weaning*** Liveweight Flight Time Coat score

Cow Data		
Into, Mid, & Out of mating	***Calving (within 24hrs)***	***Weaning***
Ovarian Scan, Hip Height, P8 fat depth, Body condition score, (EMA, Rib fat - into mating)	Calving difficulty, Mothering score, Body condition score, Teat & udder score	Cow weight, Foetal age, Cyclic/acyclic status, Body Condition Score, Hip Height, P8 fat depth, Lactation status

Conclusion

Higher reproductive efficiency can be achieved by improving environmental and management factors. However, improving our genetic selection systems will enable industry to further improve productivity, and provide tools to more accurately select traits to meet specific enterprise targets at an accelerated rate. Performance measures collected at Brian Pastures will facilitate this change.

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Performance recording an extensively managed beef herd in north Queensland

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Current performance recording

In 2012, the Queensland Department of Agriculture and Fisheries established performance recorded herds, including Brahmans and Droughtmasters at the Spyglass Research Facility (120km North of Charters Towers, Qld) as part of an ongoing MLA project (B.NBP.0759) developing enhanced evaluation of reproduction traits for tropically adapted breeds. The long term phenotypic recording on these herds has provided added value to current genetics research and will also add value for future beef research projects (Limburg et al. 2013). Technical officers are the key connection between what happens on the property and the team leaders. Current research involves technical staff recording daily measures on newborn calves in the field. The recorded herds are checked weekly throughout the year and officers are in attendance during AI programs, pregnancy diagnosis and natural mating programs with bull selection and monitoring. Commencing with 290 dams in 2012, the overall herd has grown to 490. Due to drought conditions (Fig. 1) on Spyglass, 200 head were agisted after the 2015 calving season.

This (2016) calving season technical officers will monitor 490 females. Data gathered includes calf date of birth, sex, colour, breed, birthweight and coronet circumference. Calves are ID tagged and tail hair sampled for DNA parentage and analysis. Dams are recorded for body condition, mothering behaviour and udder and teat conformations. Calving runs are completed by two operators in a side-by-side ATV.

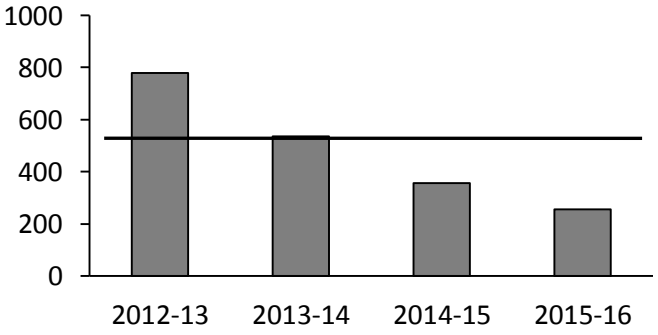

Fig.1. Spyglass annual July-June rainfall 2012 to 2016 vs long term median rainfall

Potential to expand performance recording at Spyglass

The Spyglass Research Station herds provide a unique opportunity for other potential research projects, including being a testing ground for new herd recording technology. Such technologies include Precision Livestock Management Technologies (PLMTs) (Swain et al. 2013). Spyglass is the ideal situation to demonstrate the value of PLMTs and other next generation technology to improve production in extensively managed beef herds.

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Strategies for replacement heifers in Northern Australia: Weaning weight

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Introduction

One of the major challenges faced by northern Australia producers is to increase productivity per animal. Early weaning is a widely recommended procedure to increase cow re-conception rates but is a nutritional challenge for calves. This experiment examined the effect of plane of nutrition in the first dry season and its long-term effect on performance of replacement heifers. It specifically examined whether any or what type of supplement was required.

Methods

The design of this experiment was a 2 x 5 factorial, which is composed by two weaning weight groups of heifers (WW) [130 ± 1.1 (EW) and 180 ± 1.0 (NW)] and five supplementation levels (0, 0.1, 2.5, 5 and 10 g/kg LW.day). Supplement composition was copra meal during the first 2 months, and copra meal plus cracked corn on a 50-50% mix until the end of first dry season. Heifers were allocated in pens of 4 (EW) and 5 (NW) head per pen, with three pen replicates per treatment. All pens had *ad libitum* access to sabi grass hay (*Urochloa mosambicensis*), Rumevite® 30% + P and water. Treatments were imposed during the first dry season (18/06/14 to 02/12/14), and after that all heifers grazed as one single mob (Victoria River Research Station, NT) and received a wet season supplement (mineral loose lick, 73g P/kg DM) and a dry season supplement in second dry season (mineral loose lick; 21g P and 700g CP/kg DM) and the same wet season supplement in the next second wet season.

Results and Conclusions

EW and NW heifers responded as predicted to level of supplement in the first dry season but the cumulative gain over the next 2 years was not affected by weaning weight (Table 1.). EW gained more weight than NW in the fist wet. Heifers that received the lowest levels of supplementation during the first dry season demonstrated compensatory liveweight gain over the wet season. During the second dry season, EW performance was also higher than NW heifers, but no difference was found in the following wet season. Despite the better performance of EW final weight was still lower than NW (323 *vs* 378 kg) and similar to the difference in weaning weight. Approximately 40% of the weight difference gained over the first dry, between un-supplemented and the highest level of supplementation group, eroded during the subsequent season. In Northern Australia, the use of mineral block lick with urea is a lower cost alternative suitable for weaners in the 130 – 180 kg range with no adverse effects on long term weight gain by heifers other than the initial weight.

Table 1. Cumulative liveweight gain (kg) of Brahman crossbreed heifers

	0		0.1		2.5		5.0		10		SEM	*P.1*	*P.2*	*P.3*
	NW	**EW**	**NW**	**EW**	**NW**	**EW**	**NW**	**EW**	**NW**	**EW**				
1st Dry	3.0 **e**	13.7 **de**	19.4 **de**	22.0 **de**	42.6 **bc**	34.0 **ab**	62.4 **a**	52.4 **abc**	62.8 **a**	54.9 **ab**	4.1	NS	NS	<0.001
1st Wet	60.8 **a**	59.5 **ab**	58.0 **ab**	51.6 **abc**	43.4 **cde**	58.6 **ab**	31.4 **e**	45.4 **bcd**	34.0 **de**	41.0 **cde**	2.8	0.001	0.002	<0.001
2nd Dry	2.9	6.2	0.1	2.5	-7.2	1	-4.1	3	-6.9	1.3	3.1	NS	0.003	NS
2nd Wet	97	104.1	103.8	109.5	112	107.2	106.1	103.3	103.7	98	4.4	NS	NS	NS

P.1: P-value WW x Sup. Level; *P.2*: P-value WW effect; *P.3*: P-value Sup. level effect; NS: Not significant

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Land resource information for the Spyglass Beef Research Facility (SBRF)

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Introduction

Detailed land resource information is required to support research programs being conducted in the beef industry. To address this need, a soil resources project has been conducted at SBRF. Components of the project included:

- Conventional land resource survey to provide an inventory and information compendium of the soils and land resources of the 38,000 ha property.
- Land suitability assessment of approximately 760 ha of land adjacent to the Burdekin River for potential irrigated agriculture activities.
- Digital Soil Mapping (DSM) products to provide continuous spatial mapping of soil attributes relevant to grazing and animal research.

Overview

324 soil sites across the property were described, and an additional 1,400 observation sites were recorded – documenting the geology, land zones and vegetation across the SPRF. 30 soil profile classes were identified and mapped at a scale of 1:50,000. Where possible, these have been correlated with those of existing broad scale soil maps in the region. The properties of each soil profile class were summarised and interpreted in terms of their attributes affecting land management and their landscape relationships. 103 surface soil samples were analysed for fertility, enabling trends across the property to be determined. Detailed descriptions and laboratory analysis were provided for representative soil profiles.

The conventional soils mapping was complemented by Digital Soil Mapping (DSM). This is an alternative approach that uses raster-based information systems, where the outputs are single attributes (e.g. soil pH, soil depth) predicted for individual cells (pixels) across a continuous 'surface' covering the whole property. These can be fully integrated with process models such as PaddockGRASP. Estimates of uncertainty are also routinely produced.

A feature of SBRF is its proximity to the Burdekin River and the potential to expand water utilisation to include irrigated cropping. A portion of the property was examined in detail for its potential to support irrigated cropping. In conjunction with another land evaluation project being conducted in the Charters Towers area, a regional land suitability framework is being developed for a wide range of irrigated crops and pastures.

Information pertaining to each of the 285 individually delineated soil map units is contained within the Queensland Government Soil and Land Information (SALI) database and is accessible for public use. The database includes all the laboratory data, along with the site descriptions and land suitability information where relevant. The digital soil mapping products are also freely available.

Conclusion

The SBRF soil resources project generated a series of reports, maps and foundational datasets that can be used to support beef grazing research, and more widely to support the beef industry in north Queensland.

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Improved photo standards for body condition scoring of beef cattle

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Introduction

Body condition scoring (BCS) is a visual assessment of an animal's relative body tissue (muscle and fat) mass. It provides an assessment of an animal's body reserves and nutritional status. Because BCS is a primary risk factor for cow performance, especially for pregnancy and lactation (McGowan *et al*. 2014), it is a valuable tool for assessing the status of animals and planning management. The 5-point BCS system (Gaden 2005) used by two large projects (Beef CRC, Cash Cow) is well known and regarded as the most suitable system for the extensive beef industry. While photo standards are a valuable tool for promoting BCS and training people to use it, the current photo standards use a number of breed types, which make it harder to calibrate body condition scores for a specific breed type.

Method

To develop better photo standards, animals from three common breed types (Brahman, Droughtmaster/Brahman cross and composite) were photographed in a range of body condition scores (Fig. 1). All photos were enhanced and cropped; brands and ear marks were removed to achieve anonymity.

Results

The standards will be available in hard copy and online at www.futurebeef.com.au. Image files will be available for presentations and publications.

Fig. 1. Brahman cross cows in the primary body condition scores.

Conclusion

Readily-accessible photo standards for BCS of three of the major breed types in northern Australia will increase consistency of assessments and assist learning the technique. Having one optimum system as a standard for body condition scoring will increase the ability to directly transfer information between industry groups.

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High prevalence of low body condition of north Australian cows

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Introduction

Productivity of cows in northern Australia is highly variable and a function of variation in the proportion of cows which become pregnant while lactating, foetal and calf loss, weaner weight and cow growth and mortality (McGowan *et al*. 2014). Sub-optimal body condition scores of ≤ 3 (BCS; 1-5 scale) was associated with low performance of these variables and therefore a useful indicator of herd productivity.

Method

The body condition of 25,000 cows that weaned a calf was determined at the first annual branding or weaning muster (Round 1 - mid wet-early dry season) and at the time of pregnancy diagnosis (Round 2 - early-mid dry season) on 72 properties across northern Australia (2008-2011).

Results

Almost 90% of northern forest cows that weaned a calf during the year had a BCS ≤ 3 at the first annual muster which coincided with the peak mating period (Fig. 1). Over 50% were in BCS ≤ 3 at the pregnancy diagnosis muster. Similar but less dramatic patterns of distribution of BCS occurred in the other country types.

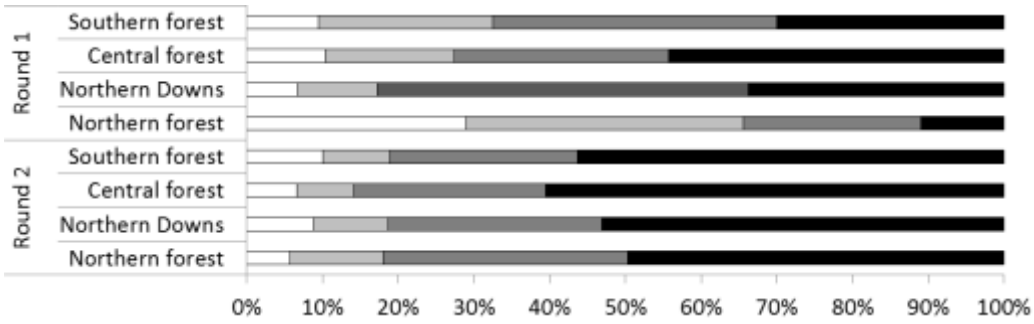

Fig 1. The distribution of body condition score (clear 1-2; light grey 2.5; dark grey 3; black 3.5-5) for cows weaning a calf during the year within country type at the first and second annual musters.

Discussion and Conclusions

High prevalence of low body condition score between calving and the end of peak mating is a feature of cow herds across northern Australia, and especially in the northern forest. Recovery of some body condition by mid-dry season occurs in many cows which weaned a calf. Independent of country types and rainfall effects, managing the feed base, lactation, and health and stress all impact on body condition. Therefore many options are available to improve body condition, thus leading to improvement in cow performance, productivity and potentially business incomes.

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Quality Graze Steer Challenge - Engaging Pastoralists in central Australia

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Introduction

The pastoral industry in the Arid Zone of central Australia has a number of strengths, which include the ability to achieve significant weight gain on fully cured native pastures while having access to premium quality beef markets. The production of finished steers for slaughter and premium prices through the Meat Standards Australia (MSA) grading system is one option to take advantage of these strengths. To encourage adoption of research recommendations and to disprove a perception that steers can only be prepared for premium markets in exceptional seasons in the Arid Zone, a Producer Demonstration Steer Challenge (Challenge) was implemented at Old Man Plains Research Station (OMP) near Alice Springs. This challenge encompassed the extension component of a long-term grazing trial, which tests different grazing strategies, based on a modelled carrying capacity, towards the consistent production of quality beef in central Australia while minimising the effect of a variable and unpredictable climate.

Materials & Methods

Seven central Australian producers representing popular cattle breeds and cross breeds supplied eight weaner steers (180 – 220 kg) each for the Challenge. All steers entered a two-paddock 12 month rotation with a capped variable stocking strategy based on a long term carrying capacity of 2.2 Adult Equivalent per km^2. Web based real-time performance updates on weights of individual animals as well as groups were made available to producers while steer performance data such as growth rate, condition score, P8 fat depth and skeletal growth were presented quarterly. At approximately thirty months of age, and with a target weight of 575 kg, the steers were sent direct to slaughter and MSA grading. Criteria such as steer performance, meat quality and price per kg were used to determine the winner of the Challenge. Qualitative data collected through a participant survey at the beginning and end of the project as well as discussions at field days and individual visits are being used to indicate changes in perception and thereby the effectiveness of this Challenge as a communication and research adoption tool.

Results & Discussion

Data showed that environmental conditions exerted a greater influence on steer growth rates than genetics. This emphasizes the importance of grazing land management. In an extremely variable and unpredictable climate this project also demonstrated that steers can achieve a weight of 575 kg with a P8 fat depth of >6 mm by thirty months of age which enables them to achieve MSA grading. The development of a website to provide producers with updated information about the Challenge, as well as other relevant research findings, improved communication and contributed to uptake of research recommendations.

Conclusions & Implications

The Challenge participants experienced how their steers met requirements to access premium markets through applying a grazing strategy and carrying capacity appropriate for the conditions. The Challenge has successfully engaged seven producers while approximately 25 percent of the Alice Springs region actively followed the progress of the Challenge. This was a significant engagement outcome with potential to increase research uptake.

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The effect of intensive rotational grazing on cattle production on the Barkly

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Introduction

Anecdotal evidence has suggested that rotational grazing may increase cattle production as compared to traditional extensive continuous grazing practices in Northern Australia. During the dry season most cattle need to return to water points to drink at least once a day. In large paddocks with few waters, this results in areas close to water being overgrazed and areas beyond the walking range of cattle being under-grazed. The subsequent decline in feed levels and land condition close to water is detrimental to animal production.

Methods

An intensive rotational grazing system was set up at Beetaloo Station on the Barkly Tablelands. The area is located on a black soil Mitchell grass plain, and was divided up into 36 paddocks averaging 4km^2 and an additional 10 paddocks averaging 16km^2, each paddock having access to two watering points.

The rotation herd (Brahman cross weaner bulls) which averaged 4,300 head throughout the dry season, were shifted on average every 3-4 days. A control mob (same class of stock, average 65 head) was set stocked in a single 4km^2 paddock, in the same area. Live weight performance was measured on three different cohorts of cattle between 2012 and 2015. In each case, the station staff selected and weighed between 70 and 100 weaners into both the continuous and rotation systems.

Results

Cattle weights were measured opportunistically to coincide with the sales program of the station. Treatments were not replicated and were not statistically analysed. The live weight performance in the rotation was very poor in 2013/14 (Table 1) because the cattle got caught on inundated black soils in February and lost weight which they weren't able to recover. Daily live weight gain per AE was similar between the two systems for the other two years. Live weight gain *per hectare* was superior in the continuously grazed paddock every year, due to the combination of better individual animal performance in some years, as well as higher stocking rates.

Table 1. Liveweight gain per AE and per hectare.

	kg/AE/day			kg/ha		
	2013	2014	2015	2013	2014	2015
Rotation	0.42	0.35	0.34	18.6	11.4	11.6
Continuous	0.41	0.53	0.37	22.8	19.9	14.0

Discussion

The results support the findings from other studies in northern Australia that stocking rate is the main driver of animal production rather than the grazing system per se. Regardless of the grazing system employed, it is important to match stocking rates to the long term carrying capacity of the land type in its current land condition if animal performance and land condition outcomes are to be optimised. The stocking rates for both grazing systems (average 14.5AE/km^2 rotation and 16.2 AE/km^2 continuous) were higher than the DPIF would recommend for the land type in its current land condition (average 9.5 and 11.2 AE/km^2 for rotation and continuous respectively). The poor live weight performance experienced in 2014 after cattle got caught on inundated black soils highlighted the importance of having higher country for cattle to use during the wet season.

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Some economic considerations arising from an intensive rotational grazing system in the Barkly region of the Northern Territory

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Introduction

Many producers in the Barkly region are keen to understand whether they should be investing in intensification. The NT DPIF compared the economic performance of an intensive rotation system and an extensive continuous grazing system for 3 years at Beetaloo Station, NT.

Methods

The rotation system and live weight gain (LWG) performance are described in Douglas *et al*. (2016). Net cattle revenue per head was determined by calculating the difference between their start and end weights and multiplying by a long-term average price of $1.60/kg. Direct costs (husbandry, freight and selling costs) came to $78 per head; the cattle in the trial were not supplemented. The grazing system operating costs (helicopter, labour, water supply management and vehicle costs) were calculated from figures supplied by the owners and came to $1.98/ha.year for the rotation and $1.36/ha.year for the continuous system (costs associated with moving the rotation cattle was the main difference). Stocking rates in both systems were set by the station owners each year based on experience. The figures above were used to undertake a simple analysis to compare the grazing systems on a per adult equivalent (AE) and a per ha basis. Note that data on the capital costs are not presented here but will be presented on the poster.

Results and Conclusion

The continuous system outperformed the rotation in 2 of the 3 years (Table 1). In 2013, LWG/AE was higher in the rotation but this benefit was negated by the higher running costs and lower average stocking rate (SR). In 2014 the rotation cattle had very poor LWG (Douglas *et al.* 2016) which resulted in a poor economic outcome. Despite higher LWG/AE in the continuous system in 2015, economic performance was better in the rotation because it had a higher average SR. On a per ha basis, the continuous system outperformed the rotation in 2013 due to superior LWG/ha and lower costs/ha. In 2014, costs/ha were slightly higher in the continuous system but the higher LWG resulted in better performance. In 2015, per ha performance was better in the rotation because the higher SR and slightly lower costs/ha overcame the superior LWG of the continuous system. The results highlight that the economic performance of a grazing system in any given year is determined by complex interactions between LWG, stocking rates, area of land used and costs.

Table 1. Economic comparison (not including capital investment, interest and depreciation).

	$ per adult equivalent			$ per hectare		
	2013	2014	2015	2013	2014	2015
Rotation	108.96	-0.79	61.62	15.40	-0.13	6.90
Continuous	117.93	86.22	54.32	20.81	16.10	6.67

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Grazing BMP - enabling better business management

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Introduction

Grazing Best Management Practice (BMP) is a voluntary online self-assessment tool designed to assist land holders improve the economic, environmental and social sustainability of their grazing enterprise. Since late 2010, over 1,300 businesses, managing in excess of 19 million hectares across Queensland have participated in the program. Guided by a team of industry representatives to design each of the assessment standards, the Grazing BMP program was developed through a partnership between Fitzroy Basin Association (FBA) AgForce and the Department of Agriculture and Fisheries (DAF).

Grazing BMP provides graziers with the opportunity to assess their current business management practises in relation to industry standards across five modules; soil health, grazing land management, animal production, animal health and welfare, and people and business.

What are the Benefits of the Program?

The program enables landholders to identify areas within their grazing business where advancing their skills or knowledge, or implementing a change of practice, would improve management and business performance. The program is currently delivered within the Fitzroy region in an 'accelerated' two day workshop format, which enables producers to network with peers and organisations such as FBA, DAF and external industry consultants. Grazing BMP assessment data, feedback and expressions of interest are used to identify and plan training events to meet the needs of producers to improve knowledge and skills.

Meeting Industry Needs

Not only are industry needs recognised directly through the Grazing BMP program but also as a result of continuous contact with landholders. Numerous Grazing BMP workshops in the Fitzroy region identified that many graziers felt unskilled in the use of the National Livestock Identification System (NLIS) database. This feedback was further supported by the high level of NLIS enquiries to local Biosecurity Queensland staff. Maintenance of individual accounts on the NLIS database is important in maintaining lifetime traceability of cattle to comply with market requirements and legislation.

As a result of this feedback, local extension officers developed NLIS training events in four locations across the catchment to enhance producer competency in maintaining their NLIS account. Topics covered at the workshop were; structure of the NLIS database, using scanning equipment, completing tag transfers, checking NLIS accounts and understanding account messages. The role of the database in marketing and biosecurity was also discussed.

The four workshops were attended by 80 producers. Producer feedback was positive with 88.4% of graziers reporting improved understanding of the benefits of better NLIS account management for biosecurity and marketing. Furthermore, all attendees enhanced their confidence in using the database, and many suggested they would maintain their account and complete PIC reconciliations more regularly as a result of attending the training day. A further three training events are planned for late 2016.

The Grazing BMP program has been highly effective in identifying and addressing industry skill gaps and improving management and business performance in grazing enterprises across the State.

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Grazing BMP – data endorses relevance

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Introduction

The Grazing BMP (best management practice) program is a voluntary, online self-assessment tool for the grazing industry. The objective of the program is to assist landholders to improve the economic and environmental performance of their grazing enterprises. The program is made up of 5 modules (Soil health, Grazing land management, Animal production, Animal health and welfare, and People and business) which are designed to present best practice technical information and management principles. Producers assess their current management practices against the 157 standards within the 5 modules. When conducting a Grazing BMP assessment, producers rate themselves as operating at 1 of 3 levels: 'above', 'at', or 'below' standard. Action plans are developed within the program to assist landholders to prioritise the most profitable and sustainable practices and to identify training requirements. Commencing in the Fitzroy River Catchment of Queensland in late 2010, Grazing BMP has expanded into 3 additional Queensland catchments: Burdekin, Burnett Mary and South East Queensland. This paper presents a snap-shot of data for the number of modules that have been completed and reassessed as part of the Grazing BMP program.

Results and Discussion

Table 1 gives a 3-month snap-shot of module assessments as compared to the project milestones for the 4 Queensland catchment areas, demonstrating that in just 3 months from January 2016, the target number of new modules completed, and of modules reassessed, have been exceeded by 96% and 59% for the financial year period respectively. Data collected in the Grazing BMP program is being used by the program partners, Fitzroy Basin Association, AgForce and Department of Agriculture and Fisheries, to promote the beef industry and organise extension activities targeted to producer requirements. Grazing BMP enables producers to demonstrate and document good land management and environmental stewardship through the Soil health and Grazing land management modules. The animal modules enable the industry to demonstrate to the wider community that they take animal welfare seriously, while the People and business module demonstrates that producers are willing to embrace new ideas to increase productivity through sustainable management pathways. Other groups outside the target catchments (e.g. OBE Beef) have seen the merit of the BMP program and are using it as a marketing tool. The high levels of participation in the Grazing BMP program demonstrate its relevance and value to the grazing industries.

Table 1. Comparison of 2015-16 delivery targets with actual Grazing BMP achievements for the four target catchments during 01/01/16-31/03/16.

	New modules completed	Modules reassessed	Property area of participating businesses
Target milestones 2015/16 financial year	916	331	-
Actual achievement	1,799	525	3,179,504

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Grazing Best Management Practices

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Introduction

The Grazing Best Management Practice (Grazing BMP) program is an industry-led, proactive and voluntary approach to demonstrate the uptake of good farm management practices and ethical and environmental stewardship. The program is a self-assessment system used by graziers to benchmark their management practices against standards set by industry and provides graziers with the tools to identify opportunities to refine their business practices, as well as provide a pathway to progress identified issues using the most current methods, tools and support available.

The program consists of 5 modules: 'Soil Health', 'Grazing Land Management', 'People and Business', 'Animal Production' and 'Animal Health and Welfare'. The modules have been developed by DAF technical staff and expert industry consultants with ongoing reviews to ensure the modules continue to remain applicable to all stakeholders. The model has distinct phases providing an escalating level of confidence and credibility for the producer, the industry and broader community.

Phase One - Self Assessment

The self-assessment phase requires graziers to benchmark their business against all 5 module standards and compare their position against industry performance. This can be undertaken in a variety of ways, such as attending a Grazing BMP workshop, through facilitator guided support, or online via the Grazing BMP website. Alternatively graziers can combine all 3 options.

Phase Two - Auditing

Auditing is initiated by the grazier nominating to have their self-assessment endorsed by an industry auditor. A Grazing BMP facilitator will work in conjunction with the grazier to review the evidence supplied against a predefined auditing checklist. Once the evidence required to meet the audit expectations is collected, the grazier can progress to having an accredited auditor conduct an on-property audit, usually taking around 3 hours to complete. Periodic, independent audits are also conducted by external auditors to review the effectiveness of the accreditation process and the audit procedures.

Certification

Graziers are recognised as 'Accredited producers' when 100 per cent of the core requirements across all 5 modules are successfully endorsed at Industry Standard by the auditor. Additionally, graziers can be recognised as an 'Advanced accredited producer' when all core requirements are successfully endorsed at above Industry standard by the auditor. Grazing BMP accreditation is valid for 3 years whereupon reassessment is required to formally review accreditation.

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DAF/MLA project B.NBP.0766: Independent assessment of new pasture plants for seasonally-dry Queensland: scope and progress

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Introduction

Breeder productivity (weaning and death rates) and heavier sale weights are key profit drivers for the northern beef industry (McLean *et al*. 2014). Previous research, mostly with *Stylosanthes*, has shown the use of sown tropical grasses and legumes can significantly increase the productivity and profitability of beef growing and breeding enterprises in seasonally-dry areas (Partridge and Miller 1991). However, many areas have few or no well-adapted grasses or legumes. Moreover, recently developed cultivars and promising lines have not been comparatively assessed across a range of land types (Cox 2014).

Project Scope and Implementation

In 2013, DAF researchers began a five-year experiment to compare the performance of new pasture plants with older cultivars on a range of moderate- to high-fertility soil types within the 600 to 900 mm average annual rainfall belt in northern and central Queensland. The aim is to improve animal nutrition within 'weaner' and 'grower' systems through the development of grass/legume pastures with moderate levels of management to encourage first year establishment. Thirteen research sites have been developed in a north-west to south-east arc between Normanton and Moura with up to 29 legumes and 30 grasses sown in replicated small plots at each site. Key genera include: (legumes) *Centrosema, Clitoria, Desmanthus, Leucaena, Macroptilium, Stylosanthes*; (grasses) *Bothriochloa, Brachiaria, Chloris, Dichanthium, Digitaria, Heteropogon, Panicum, Urochloa*. Measures include plant persistence, biomass production under grazing and acceptance to livestock.

Preliminary Results

A run of dry seasons required multiple sowings at some sites, but provided strong selection pressure at sites where establishment was successful. A number of more persistent, and well-grazed, 'best-bet' types are beginning to be identified for the duplex and basalt soil groups:

Legumes: (low rainfall) *Desmanthus virgatus* and *D. bicornutus* (Marc, ES203, Progardes), *Stylosanthes seabrana* (Primar, Unica), *S. scabra* (Seca , Siran plus newer types) and *Macroptilium gracile* TGS849; (moderate rainfall) as for low rainfall plus *M. atropurpureum* (CPI84989), *M. bracteatum* (Juanita, Cardaarga), *Clitoria ternatea* (Milgarra) and *S. guianensis* (ATF3308/3309S).

Grasses: (low rainfall) *Panicum maximum* (Massai and NuCal), *P. coloratum* (ATF714, green type) and *Digitaria eriantha* (Premier); (moderate rainfall) as for low rainfall plus *Brachiaria brizantha* (Toledo), *Brachiaria* hybrids (Mulato 2, S155), tetraploid *Chloris gayanus*, *Digitaria milanjiana* (Strickland, Jarra), *P. maximum* (Gatton and G2), *Urochloa mosambicensis* (TGS1012).

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A program to revitalise the Australian Pastures Genebank to develop new pasture cultivars for seasonally warm environments

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Introduction

The use of sown grasses and legumes imported into Australia from tropical and sub-tropical regions of the world comprise the key feed-base for the grazing industries in northern Australia, particularly within higher rainfall areas where economic benefits have accrued over some 50+ years (Walker *et al*. 1997). More recent roles include legumes for grazing leys in crop/graze systems, pasture plants for moderate rainfall environments and summer-active pasture plants for southern Australia. Well-resourced plant evaluation programs underpinned cultivar development, but reduced investment in sown pastures over the 1990s-2000s has limited recent progress (Cox 2014).

The Tropical Forages Collection

The Australian tropical forages genebank is a unique collection of imported tropical and sub-tropical pasture grasses and legumes which underpins cultivar development in Australia. The collection contained some 26,000 accessions prior to a reduction to 'priority germplasm' in the early 2000s. By 2002, the collection contained some 10,016 (614 species) warm-season grasses and 2,677 (255) legumes: ~25% of these had insufficient volume or viability to be useful (P. Lawrence *pers. comm.* 2002). With funding from the Grains Research Development Corporation, we completed the regeneration of 2000+ seeds of 380 grasses (81 species) and 609 legumes (91) over 3.5 years beginning in 2005; a success rate of 89% for grasses and 94% for legumes (Cox *et al*., 2009). However, regeneration was ceased until the federal and state governments and primary industry development corporations endorsed a national model for germplasm management.

A New Regeneration Program

The new model saw the transfer of tropical collection to a national pastures collection (Australian Pastures Genebank, Waite Campus, Adelaide) in 2014. A four year regeneration program, with a stronger industry focus than previously, was resumed at Walkamin in 2015. Approximately 120 accessions are being regenerated each year, targeting the production of 5 000 to 15 000 seeds per line. The initial focus is on pasture legumes for moderate rainfall environments (*Centrosema*, *Desmanthus, Macroptilium*), but also pasture legumes for the higher rainfall areas (*Centrosema*, *Vigna*), high-quality grasses (*Brachiaria*, *Digitaria*, *Panicum*, *Urochloa*) and ley legumes (*Clitoria*, *Lablab*). Variation within species is being measured to aid future plant development programs, with data to be accessible to the public through a new searchable database currently under construction.

There has been sound progress to date. In the first year, 114 of the 120 lines (90 legumes and 30 grasses) were successfully regenerated and described and the seeds and data transferred to the national collection. This year another 120 lines, plus the previous failures, have been established and seed harvesting and plant characterisation had begun by March.

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Modelled long-term productivity of buffel grass pastures with and without legumes in central Queensland

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Introduction

Pasture productivity benefits of sowing legumes with buffel grass have mainly been measured 3 to 5 years after establishment and only in a few environments. Simulation models allow the extrapolation of trial results in time and space. Site data collected from 2 locations in central Queensland were used to simulate the productivity of grass only and grass with legume pastures that were established approximately 15 years previously.

Methods

Pasture trials at Wandoan and Moura were established into paddocks that had a history of cropping. Each trial had 10 ha sown to buffel grass and 10 ha sown to buffel grass and a legume. The Moura site was sown with *Caatinga stylo* (cv. Primar and Unica) early in 1997 and the Wandoan site was sown with Desmanthus early in 1995. Detailed pasture production measurements were collected from the sites over 2 years (2011-2013) and used to calibrate the pasture growth GRASP model.

Results and Discussion

Legumes increased total pasture productivity by 23-35% at the Moura site and by 113-170% at the Wandoan site over the two years of sampling (Fig. 1). Key biological and physical pasture processes were well represented in the calibrated grass only and grass plus legume GRASP models for both trial locations. The degree to which 'resetting' the sites impacted on the growing points of stylo and buffel plants and the adequacy of the trial sites to represent broader buffel grass and buffel plus legume pastures needs to be determined. However, the calibrated models can extend and improve estimates of long-term pasture productivity benefits of sowing legumes with buffel grass within central Queensland.

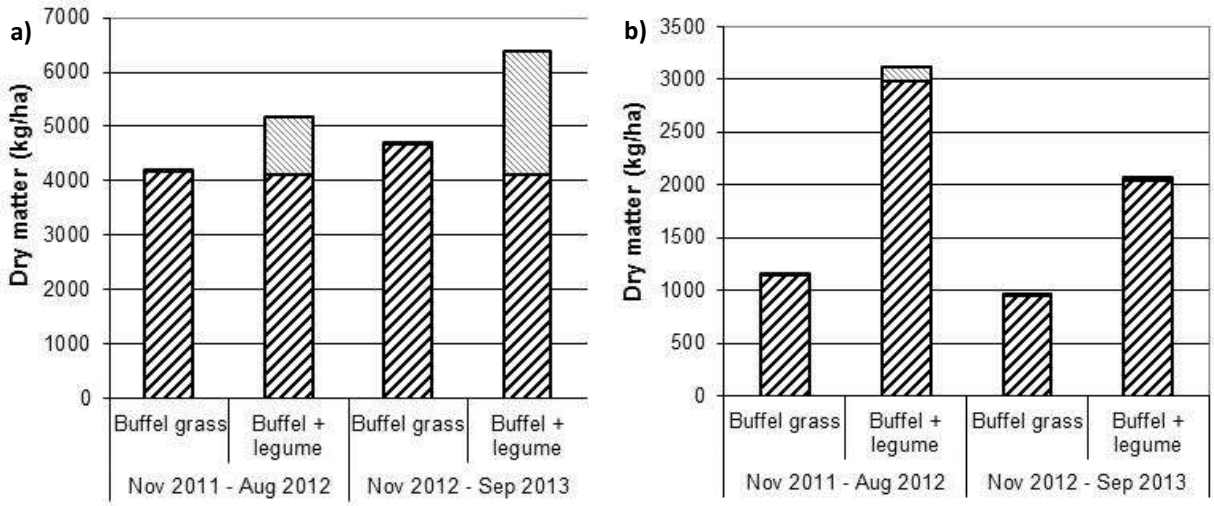

Fig. 1. Peak dry matter production (kg/ha) for each year of sampling between 2011-2013 for buffel grass only and buffel grass with legume pastures at a) Moura and b) Wandoan sites. Dicots ■ Legume ▨ Grass ▨.

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Graziers: Legumes are the best option to address sown pasture rundown

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Introduction

Sown pasture grasses are very productive when planted after clearing or into fertile cropping soils. However, over time dry matter production and animal performance decline as soil nitrogen availability to pasture grasses declines, a phenomenon often described as "pasture rundown" or more correctly "nitrogen tie-up". This paper discusses the large industry interest in this issue and the management options graziers deem to be the most appropriate for dealing with nitrogen tie-up.

Methods

Graziers and industry personnel were engaged at a range of forums where information about nitrogen tie-up was delivered. At workshops outlining causes, costs and management options, demographic information was collected including area of sown and native pastures and numbers of stock managed. Further, insights as to what graziers assess as the most appropriate way to improve productivity of pastures suffering from nitrogen tie-up on their own properties was collected.

Results and Discussion

A total of 465 people, managing over 820,000 ha of sown and 895,000 ha of native pastures with more than 291,000 head of cattle, attended workshops between 2011 and 2016. An assessment of intended methods to address nitrogen tie-up were collected from 237 attendees, and indicated that graziers consider increasing nitrogen supply as the most appropriate strategy. Increasing nitrogen supply through the use of legumes is clearly the most commonly intended management technique, followed by mechanical renovation to increase nitrogen cycling. Applying nitrogen fertiliser was more popular than changing grazing management, possibly because reducing stocking rates is regarded as not addressing the underlying cause (Table 1).

Table 1. Grazier assessment of the intended strategies and techniques to deal with nitrogen tie-up.

Overall strategy	Management technique	% of respondents
Accept rundown and lower productivity	Break up new country if available	2
	Purchase more land	1
	Reduce stocking rates	5
Increase nitrogen cycling	Mechanical renovation	35
	Chemical renovation	2
Increase nitrogen supply	Apply nitrogen fertiliser	27
	Introduce legumes	84

Conclusion

These engagement activities confirm that productivity decline due to nitrogen tie-up in sown grass pastures is a significant problem across large areas of southern and central Queensland. Large numbers of graziers are seeking information, and the majority identify introducing legumes as the most appropriate way to increase productivity.

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Robust legume hays for dry-season cattle feeding in north-west Queensland

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Introduction

Beef enterprise profitability in north-west Queensland is strongly influenced by the amount and quality of dry-season feed. Legume hays, particularly *Centrosema pascuorum* and *Clitoria ternatea*, can provide high-quality feed for livestock in seasonally dry areas (Nulik *et al*. 2013) and others (*Stylosanthes guianensis*) have performed well on the Atherton Tablelands (Cox *et al*. 2012). The production of irrigated, high-quality fodder in 'mosaic' farming systems has recently been identified as way to improve the productivity and resilience of beef enterprises in this area (Grice *et al*. 2013). A pilot study was undertaken to test promising legume hays in this environment.

Method

Two varieties of the short-lived legume *Centrosema pascuorum* (Cavalcade and Bundey) and one variety each of the perennial legumes *C. brasiliana* (Oolloo), *Clitoria ternatea* (Milgarra) and *Stylosanthes guianensis* (Nina) were grown for hay on a deep, fertile (pH=5.8; Colwel-P = 12 ppm; sulphate-S = 4.3 ppm) alluvial soil near Georgetown. The legumes were sown in January 2014 into fertilised (200 kg/ha single superphosphate and 100 kg/ha muriate of potash) replicated plots (100 x 4m) and weeds controlled using imazethapyr and haloxyfop at label rates. Irrigation was applied to supplement rainfall. Plant populations 4 weeks after sowing were measured. Herbage samples (4-6 quadrats per plot, 5 cm) were collected immediately before cutting, drying and baling with commercial equipment. Eight-ten weekly cycles were targeted. The samples were dried (70^{o}C) to constant weight, weighed and subsamples ground and submitted for full nutrient analysis.

Results

All legume species established exceptionally well and produced moderate (Oolloo 1505 kg DM/ha, Milgarra 1810) to high (Nina 2380, Bundey 2952, Cavalcade 3187) biomass yields 10 weeks after sowing. The quality of the hays was excellent: crude protein 14-19%; lignin 9.5-11.9%; metabolisable energy 7.8-9.1 MJ/kg. All had high relative feed values (90-117 (100 is typical lucerne hay)), with Cavalcade and Bundey the highest, and Nina stylo the lowest overall. The growing conditions were challenging thereafter as kangaroos and pigs damaged the crops (despite the farm being pig-fenced) during the dry season and irrigation was applied less than optimum due to shortages of water and breakdowns. Cages were installed to exclude grazing animals. The *C. pascuorum* varieties all but died out by November, but the perennial species survived producing up to 1300 kg DM/ha (Nina). Growth of the legumes during the third cycle (10 December to 12 March) was affected by grasshoppers and water shortages. Despite this, Milgarra grew exceptionally well, producing 2987 kg DM/ha (others < 700 kg/ha) and persisted thereafter, proving to be a most resilient and productive legume for hay production under difficult conditions.

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Leucaena toxicity — a new management strategy

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Introduction

Leucaena (*Leucaena leucocephala*) is a high quality ruminant forage that can cause toxicity due to the presence of mimosine and its breakdown product, dihydroxypyridine (DHP). The identification of the rumen bacterium (*Synergistes jonesii*), discovered in 1982, led to the development of a commercial inoculum based on rumen fluid containing *S. jonesii* which was thought to offer complete protection when properly administered. However 20 years later, extensive monitoring of cattle consuming leucaena has indicated lower than expected efficacy of the inoculum. This led to an intensive research program (2010 to present) that has provided new understandings concerning the role of *S. jonesii* and suggests an alternate method for DHP detoxification.

Recent findings regarding *S. jonesii* and DHP metabolism

Recent analyses of rumen fluid and urine collections contradict the originally described detoxification pathway, and are summarised below:

- *S. jonesii* is indigenous across all ruminant species, including non-ruminant species, but is always present in the rumen at low levels, regardless of amount of leucaena in diet.
- High levels of urinary DHP are often seen in healthy animals consuming high leucaena diets, despite being positive for *S. jonesii*; these animals lack clinical signs of toxicity.
- Discrete mutations (SNPs) have been detected in *S. jonesii* 16S rDNA gene sequences which indicate genetic diversity at the species level; these differences can be associated with geographical location and ruminant species, and may indicate varying ability to degrade DHP.
- Since 2003, 2,3-DHP has been reported as the dominant isomer excreted (Halliday *et al.* 2014), contradicting the notion of 2,3-DHP as a transitory isomer.

These findings suggest that *S. jonesii* is not capable of degrading all DHP in ruminants, especially in those consuming high leucaena diets. Beginning in 2014, analysis of large numbers of urine samples collected from animals on 100% leucaena diets, and retrospective re-analysis of many past samples, has revealed that a large proportion of DHP is excreted in conjugated form: bound as a glucuronide. Conjugation has a two-fold benefit: (a) it increases the polarity of the molecule, allowing the toxin to be rapidly excreted (Smith 1971); and (b) it binds to an hydroxyl group on the pyridine ring, reducing both the anti-thyroid affects (Christie *et al.* 1979) and the affinity to chelate with essential minerals (Smith 1971). As such, high levels of conjugated DHP do not appear to affect animal performance.

New management paradigm

These findings have the potential to dramatically change the way in which animals consuming leucaena world-wide are managed. Best-practice appears to involve a gradual introduction to leucaena allowing animals to adapt by firstly degrading mimosine to DHP; then allowing the induction of liver enzyme pathways responsible for conjugation of DHP to complete the process of detoxification.

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Perennial legume-grass forages maximise beef production

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Introduction

In the seasonally dry tropics the growth and nutritive value of pastures is highly variable both within and between years so that the forage available to cattle usually varies widely in quality and quantity. This creates challenges for beef producers to consistently meet market specifications and limits output of cattle. Targeted use of high quality forages has the potential to increase beef output. This study measured the forage and cattle production for major annual and perennial dryland forage systems used for beef production in the Fitzroy River catchment of Queensland.

Methods

Forage biomass production (cut quadrats and Botanal), diet quality (F.NIRS) and cattle liveweight (LW) gain was measured for 6 forage types at 21 sites across 12 commercial beef cattle properties in the Fitzroy River catchment of Queensland during 2011-2014 (28 annual data sets in total). The forages were annual forage crops (oats (*Avena sativa*), sorghum (*Sorghum spp.*) and lablab (*Lablab purpureus*)), sown perennial legume-grass pastures (leucaena-grass (*Leucaena leucocephala spp. glabrata* + tropical grass (C_4) species) and butterfly pea-grass (*Clitoria ternatea* + C_4 grass species)), and perennial C_4 grass pastures.

Results and Discussion

All sown forages resulted in higher diet quality (crude protein and dry matter (DM) digestibility) than perennial grass pastures (Table 1). Diet quality was highest for cattle grazing oats. Tropical annual and perennial legume forages also resulted in high quality diets. The sown forages resulted in 1.2 – 2.6 times the annual cattle LW gain per ha of that for grass pastures. The very high forage sorghum biomass was not converted efficiently to cattle LW gain. In conclusion, trends in the data indicated that perennial legume-grass pastures, and particularly leucaena, on average resulted in greater annual cattle LW gain than annual forage crops or perennial grass pastures. The sustained, high quality diet provided to cattle, combined with high annual stocking rates, appear to be the primary factors.

Table 1. Forage and cattle production on commercial properties in central Queensland.

	Annual forages			Perennial forages		
	Oats	Sorghum	Lablab	Leucaena-grass	Butterfly pea-grass	Grass
No. of datasets (No. of sites)	8 (6)	5 (4)	2 (2)	5 (4)	3 (2)	5 (3)
Forage biomass (t DM/ha)[A]	4.6	12.2	6.0	G 3.8, L 0.4	G 4.6, L 0.5	3.7
Stocking rate (AE/ha)[B]	1.0	1.7	1.0	0.76	0.58	0.37
Total days of grazing per annum	116	107	107	284	181	224
Diet crude protein (g/kg DM)	123	88	115	120	97	66
Diet DM digestibility (%)	63	55	59	59	59	55
Total cattle LW gain (kg/ha.year)	93	108	99	198	125	76

[A]Measurements made in the grazed paddock. Values are the peak biomass for annuals and the average biomass over the annual cycle for perennials. Values for leucaena biomass represent only the edible material (i.e. leaves and stems <5 mm in diameter). 'G' and 'L' represent the grass and legume components, respectively. [B]Average over grazing period for annuals but over 365 days for perennials.

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The effect of tree density on biomass production of *Leucaena leucocephala* and *Chloris gayana* using a Nelder fan design

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Introduction

Leucaena leucocephala (leucaena)-grass pastures are widely used for beef production in tropical and subtropical Queensland, where it is recognised as a productive, profitable and sustainable feeding system (Shelton and Dalzell 2007). There is limited information regarding how plant density of leucaena affects competition between tree and grass components of the pasture.

Methods

A Nelder fan design with 10 different leucaena densities (from 100 to 80,000 trees ha^{-1}) growing with and without Rhodes grass (*Chloris gayana*) was established at Gatton, Queensland in November 2013 (Pachas *et al,* 2015). The above-ground biomass was determined 4 times within 386 and 412 day growth periods for Rhodes grass and leucaena, respectively, during 2014 and 2015.

Results and Discussion

The individual yield of leucaena plants was negatively affected by increasing leucaena plant density expressed as $\log_{10}$ (trees/ha). Maximum individual yield (23.7 kg DM tree^{-1} year^{-1}) was obtained at a density equivalent to 100 trees ha^{-1} without grass competition and was reduced by 68% with grass competition. However, total leucaena and Rhodes grass biomass expressed as kg DM ha^{-1} year^{-1} was positively correlated to $\log_{10}$ of tree density (R^2=0.99) reaching 32,800 kg DM ha^{-1} year^{-1} at the highest density tested (80,000 trees ha^{-1}). The yield of Rhodes grass was negatively correlated with increasing leucaena plant density (R^2=0.99). Maximum grass yield of 24,260 kg DM ha^{-1} year^{-1} without tree competition declined to 1,420 kg DM ha^{-1} year^{-1} at a leucaena plant density of 8,618 trees ha^{-1}. The contribution of leucaena and grass to total forage production varied with tree density; leucaena forage constituted 10%, 50% and 90% of total edible biomass at tree densities of 210, 1,457 and 8,618 trees ha^{-1} respectively.

Conclusions

Leucaena biomass yield was significantly reduced (>50%) by grass competition at low leucaena plant densities (100 to 4,100 trees ha^{-1}). At high leucaena plant densities (>5,000 trees/ha), double the amount of leucaena biomass forage was produced but grass growth was minimal. At high leucaena plant densities, grass/roughage would need to be provided from adjoining paddocks or as a supplement to deliver a balanced diet to grazing cattle.

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Grazing preference of the psyllid resistant *Leucaena* inbred cv. 'Redlands' compared to the commercial *L. Leucocephala* cvv Cunningham and Wondergraze

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Introduction

An MLA-supported breeding program was initiated in 2002 to develop an interspecific psyllid-resistant *Leucaena* variety derived from crossing the susceptible species *L. leucocephala* with the resistant species *L. pallida* (Dalzell *et al*. 2013). In 2013, cv. Redlands was selected for release to industry based on high levels of psyllid resistance, in-vitro digestibility, yield, branchiness and fertility. A previous preference trial had shown that, when undamaged, Cvv Cunningham and Wondergraze were preferred' but all were ultimately consumed. The objective of this program was to compare the grazing preference of Redlands, and three similar breeding lines, with existing commercial cultivars following a period of high psyllid pressure.

Methods

The experiment was located on Whitewater Station (18°S, 144°E, 628 m asl) owned by Tom and Christine Saunders. Treatments were 6 leucaena genotypes planted in 2 independent 15 m rows, 10 m apart, with 4 replications. Seedlings were planted in February 2014 and the entire area fertilized with sulphur at 30 kg/ha and Gran-Am at 50 kg/ha; while gypsum at 150 kg/ha was applied at the base of the trees. Some dripper irrigation was used as needed, especially in the dry season and weeds were controlled. Psyllids had damaged the commercial varieties in early April 2016. The trial was grazed in mid-May 2016 by 15 – 24 steers and cows (4 – 500 kg); yield of leaf before/after grazing was measured. Grazing behaviors were observed using a 180° day/night time-lapse camera mounted on a pole attached to a forklift.

Results and Discussion

Overall, there were no major differences in preference among the varieties. All were well eaten with approximately 10% of leaf remaining at the end of grazing period (Fig. 1). Given that there was more leaf on the breeding lines at the beginning of the trial, the cattle spent more time grazing these lines (data not presented). A video of grazing behaviour over the period of the trial can be viewed by accessing the QR code below (Fig. 2).

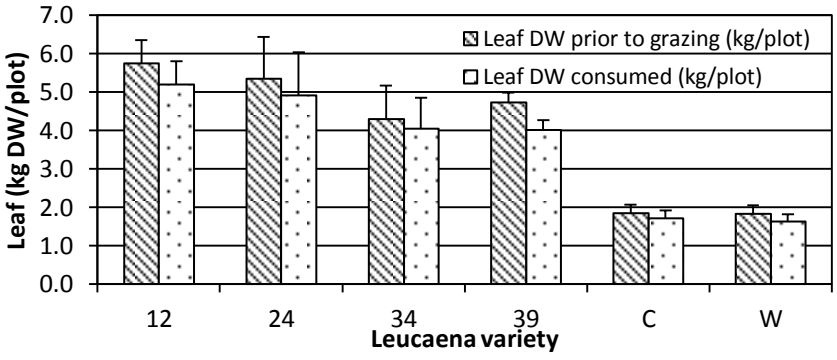

Fig. 1. Dry weight of leaf/plot before and after grazing

Fig. 2. QR code-grazing video

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Better agronomy improves the reliability of establishing legumes into existing grass pastures

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Introduction

Commercially, small seeded legumes have not established reliably in sown grass pastures. Although good establishment is recognised as critical to the long term productivity and persistence of legumes, most producers use low-cost and low-reliability establishment techniques such as broadcasting after either no or minimal pasture disturbance (e.g. fire) or severe soil disturbance and a rough seed bed behind a blade plough. This paper reports results from 6 legume establishment trials.

Methods

Six trials across three districts (Wandoan, Goondiwindi and St George) and two soil types (grey cracking clays and loamy surfaced soils) have been conducted over 4 years to test the impact of better agronomy on establishing small seeded legumes into existing grass pastures. The trials are designed with 5.5 m wide by 20 m long plots with grass strips (either 4.5 or 2.5 m) left between each plot. Clay soil trial sites were sown with Progardes desmanthus (various *Desmanthus spp.*); the Wandoan loam soil sites were sown with fine-stem stylo (*Stylosanthes guinensis var. intermedia*); Goondiwindi and St George loam sites were sown with Caatinga stylo (*Stylosanthes seabrana*). Treatments are a combination of fallow period (i.e. period from first treatment to control the grass until sowing); seedbed preparation; and post-emergent weed control as follows:

- No disturbance of the grass pasture.
- Grass pasture disturbed at plant through: slashing; cultivation with a deep ripper, tynes or off-set discs; herbicide spray.
- Short fallows of 2-4 months using herbicide (i.e. zero tillage (ZT)), cultivation or both.
- Medium fallow of about 4-6 months using either ZT or cultivation.
- Long fallow of about 4-6 months using either ZT or cultivation.

Within the fallow treatments there were also with and without post emergent weed control treatments. There were 30 treatments in total, with most treatments also having split plots in which seed was either drilled with a single disc opener planter or broadcast. Not all treatments were included at each site. Legume plant numbers and pasture biomass were measured for up to 3 years post sowing.

Results and Discussion

The sites had a variety of seasonal conditions during the trials: Wandoan was average in the year of sowing but below average overall; Goondiwindi was below average (driest 20-30% of years); St George was very dry (driest 10% of years). At all sites the most common commercially used techniques of no disturbance, slash and cultivate at plant treatments failed to produce adequate legume numbers and should not be recommended to graziers for establishing legumes into competitive existing grass pastures. Storing soil moisture and reducing competition from the existing grasses through fallows dramatically improved legume seedling survival and in turn plant numbers and growth. Fallow length had the major impact on legume establishment with relatively small differences between ZT and cultivated treatments. Post emergent weed control increased plant numbers and growth especially in the long fallows and at sites with higher weed loads. Drilling seed improved emergence on soils with a firm or crusted surface compared to broadcasting seed. Drilling

produced negative results on soft soils most likely due to difficulties in controlling sowing depth with the machine used.

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Phosphorus fertilizer offers a huge opportunity to increase productivity and profitability of sown pastures in northern Australia

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Introduction

The Brigalow Belt bioregion of Queensland is an important part of the northern Australian beef industry as it supports a large proportion of the sown pastures and cattle herd with relatively high stocking and growth rates. Clay soils were widely thought to have adequate plant available phosphorus (P) levels for sown pastures leading to extremely low rates of fertiliser use. Recent studies show large and increasing areas of low plant available soil P and large responses by pasture legumes to P fertiliser precipitating a review (Peck *et al.*, 2015) which this paper summarises.

Methods

A review of current knowledge was conducted involving review of literature and un-published trial results; bio-economic analysis and identifying research, development and extension priorities.

Results and Discussion

The Brigalow Belt carries approximately 30% of the northern Australian beef herd on 15% of the grazed land area, largely due to sown grass pastures growing on relatively fertile soils in a moderate rainfall zone. The productivity of the majority of sown pastures has declined by approximately 50% due to nitrogen being tied-up in soil organic matter – a process commonly called 'pasture rundown'. Incorporating pasture legumes has been identified as the best long term solution to improve the productivity of rundown sown grass pastures, however they require adequate P to grow well and fix large amounts of N. Graziers and farm advisors have traditionally thought that P fertiliser is not required on sown pastures on Brigalow soils which has led to extremely low rates of fertiliser use (which contrasts to southern Australia). This widely held view is inaccurate with low P levels being common; a review of 3 soils databases reveals that only ~30% of soils have adequate P for all legumes (Colwell >25ppm), 20-30% of soils have Colwell P levels <10ppm a level at which all legumes are likely to respond and animals maybe P deficient.

Research trials have demonstrated legumes used in the sub-tropics respond strongly to P fertiliser. Economic analysis indicated strong returns are likely (internal rates of return of 9 – 15% with P fertiliser when establishing legumes into grass pastures on low P soils, 12 – 15% when adding P fertiliser to already established grass/legume pasture and 15 – 30% when establishing legumes into grass pastures on high P soils). RD&E is required for industry to increase P fertiliser from the current almost nil use. Specific R&D requirements include quantifying plant, animal and economic responses to P fertiliser; quantifying P requirements and responses of legume varieties; quantifying the extent of other nutrient deficiencies (e.g. sulphur and potassium). Development and extension activities are required to demonstrate the commercial impacts of applying P fertiliser to legume based pastures.

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Phosphorus fertiliser boosts grass-legume pasture yields up to 4 years after application

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Introduction

Legumes can significantly boost animal diet quality and supply nitrogen for companion grasses. However sufficient numbers of well grown legumes are needed to obtain these benefits. A moderate to high soil phosphorus (P) supply is required to obtain the productivity potential of legumes suitable for clay soils (e.g. desmanthus and Caatinga stylo) (Peck *et al* 2015). However there is a lack of experimental data on the biomass responses of these legumes to fertiliser on low P soils.

Methods

Two fully fenced trials were set up in existing long-term grass-legume pastures on low P status soils (~5 mg/kg Colwell P at 0-10 cm): Site 1 near Moura with buffel grass (*Pennisetum ciliare*) and Caatinga stylo (*Stylosanthes seabrana*); Site 2 near Wandoan with buffel grass and desmanthus (*Desmanthus spp.*).

At both sites, five rates of P (0, 10, 20, 50 and 100 kg P/ha) were applied during September 2012 and replicated 4 times. These treatments also received a basal rate of potassium (K), sulfur (S) and zinc (Zn) to eliminate other potential soil nutrient deficiencies. A sixth treatment of 100 kg P/ha without K, S, Zn was applied to investigate the responses without these nutrients.

Pasture biomass (grass, legume and total) was measured annually. After each biomass assessment, both trials were reset (by slashing) for the following summer growth season.

Results

Large increases in pasture biomass with increasing P rates were recorded at both trial sites, peaking at 50kg P/ha. The responses were measured in most, but not all years across the two sites. Legume biomass increased with applied fertiliser by approximately 4 fold at Wandoan and 2 fold at Moura in the first year. At Moura, the high legume growth in the early years resulted in greater grass growth in subsequent years, but to date this effect has not been observed at Wandoan. Pasture biomass was higher with K, S and Zn at Wandoan, but no response was recorded at Moura.

Conclusion

Desmanthus and Caatinga stylo are highly responsive to P fertiliser on soils with low P supply resulting in higher total pasture productivity. Higher short term legume yield from applied fertiliser resulted in increased grass biomass at Moura in the third and fourth years following application. This is likely to have been due to increased N supply from the legume component of the pasture. Further research is required to identify how often P fertiliser should be applied to maintain pasture responses and to determine whether fertiliser should be broadcast on the surface, drilled or banded into the soil.

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Is variable stocking more profitable and sustainable than fixed stocking in a variable climate?

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Introduction and Methods

Varying stocking rates with rainfall could be more productive and sustainable in managing climate variability than fixed stocking at long term carrying capacity (LTCC). We tested the performance of variable and two fixed stocking strategies over 18 years at the Wambiana grazing trial, Charters Towers. Stocking rates in the variable (VAR) strategy were adjusted annually based on available forage, with the fixed strategies run at either a moderate (MSR: 8ha/AE) or heavy stocking rate (HSR: 4ha/AE). Rainfall varied markedly over the trial with 2014/15 (243 mm) the fourth lowest year on record (Fig. 1a.).

Results and Discussion

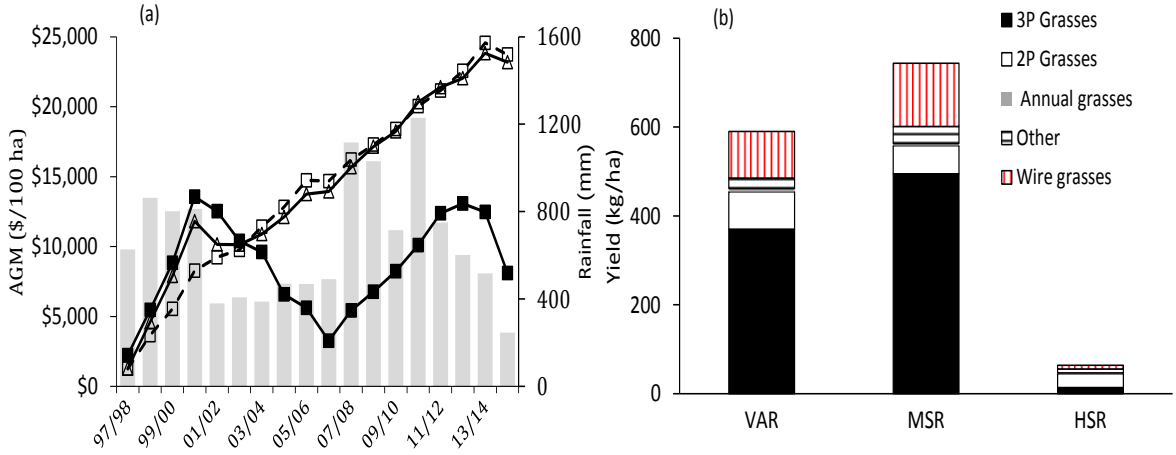

Fig 1. a. Change in accumulated gross margin per 100 ha (AGM) for variable (△), heavy (■) and moderate (□) stocking versus rainfall from 1998 to 2016. b. Pasture composition in May 2015 after 18 years of treatment application.

The VAR and MSR strategies were equally profitable over 18 years with both being far more profitable than the HSR (Fig.1a). Pasture yield and composition were also far lower in the HSR than in the VAR and MSR (Fig. 1b). However, pasture condition was noticeably better in the MSR than in the VAR: this a legacy of overgrazing in the VAR immediately before the 2001/02 drought. This critical adaptive management lesson emphasised the need for constrained, risk-averse changes in stocking rate. Variable stocking appears to be no more profitable and is possibly less sustainable than fixed stocking at LTCC. However, this conclusion may be premature: with the current severe drought the relatively heavy stocking rate in the MSR (8ha/AE) compared to the VAR (16 ha/AE) could precipitate significant degradation in the former treatment with long term impacts on profitability. We look forward to reporting future developments.

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The effect of fire on the long term dynamics of Currant bush

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Introduction and Methods

Carissa ovata (Currant bush) is a major native woody weed widespread in the Burdekin and Fitzroy catchments that significantly reduces carrying capacity through competition. Fire suppresses *Carissa (*Back *et al.* 2005) but there is no long term data on its efficacy as a control mechanism. To investigate this issue, 8.8 km of permanent monitoring transects were established on the box, brigalow and ironbark soil types on the Wambiana grazing trial, Charters Towers (O'Reagain and Bushell 2011). The site was burnt in October 1999 and again in October 2011. *Carissa* canopy cover was measured pre- and post-fire, as well as in 2015. Rainfall was above average before and after both fires, but rainfall in the 2001-2007 and 2014-2015 seasons was well below the long term average.

Results and Discussion

Both the 1999 and 2011 fires resulted in a large reduction in canopy cover of *Carissa* (Fig. 1a: data for box soil only). However, plants re-sprouted and grew rapidly post-fire, as shown by the increases in canopy cover in later years. Overall, *Carissa* cover increased markedly on the Box (+70%) and Brigalow (+40%) land types over the 17 year study despite the application of two intense fires (Fig.1b). Thus by 2015 significant portions of the Box (23%) and Brigalow (14%) were covered by *Carissa.*

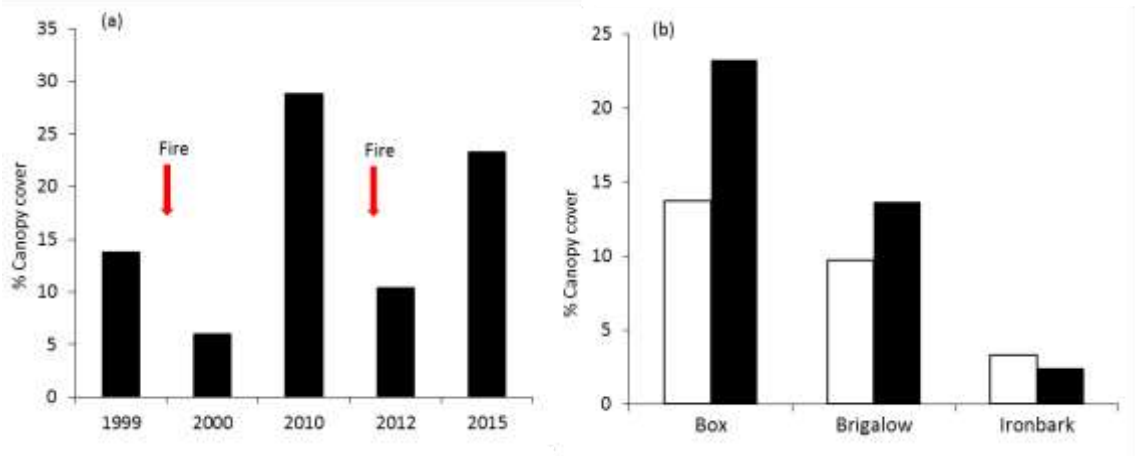

Fig 1. a. Percent canopy cover of *C. ovata* on the box land type pre- and post-fire between 1999 and 2015. b. Canopy cover of *C. ovata* on different soil types in 1999 (□) and 2015 (■).

These results show that more regular fire is required to suppress *Carissa,* that it is almost impossible to eliminate once established without chemical or mechanical intervention and finally there is need for more detailed research in understanding and controlling this significant native weed.

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Influence of currant bush (*Carissa ovata*) on soil organic carbon

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Introduction

Currant bush (*Carissa ovata*) is a native sprawling spiny shrub in the grazed woodlands of Queensland. Currant bush is generally regarded a weed by landholders and has been increasing in cover in many regions (Grice *et al.* 2000; O'Reagain *et al.* 2016). However, currant bush provides some environmental benefits through protecting the soil surface from disturbance by livestock, providing areas of enhanced water infiltration (Fraser 2013) and habitat for native wildlife and improves shrub biomass carbon stocks (Bray *et al.* 2014). However, the impact of currant bush on soil organic carbon (SOC) stocks is unknown. This paper investigates the SOC stocks beneath the currant bush canopy compared with distances away from the canopy.

Methods

Soil cores were extracted on a grid sampling design at the long term Wambiana grazing trial 80 km south of Charters Towers in Queensland. Each sample location was classified by soil type (sodosol or vertosol) and position relative to the canopy (under the canopy, within 1 m of the canopy and >1 m of the canopy). Soil was sampled at 187 locations with 30 soil cores under the canopy, 75 cores within 1 m and 82 cores >1 m of the canopy. Soil was processed as described in Bray *et al.* (2016). SOC stocks were calculated for two depth layers 0 – 0.1 m and 0 – 0.3 m. The effects of soil type and currant bush canopy on SOC stock was assessed using residual maximum likelihood analysis.

Results and Discussion

SOC stock in the 0 – 0.1 m depth layer was significantly higher under the currant bush canopy (11.3 t C/ha) compared with away from the canopy (8.8 and 8.7 t C/ha, within 1 m and >1 m respectively). In the 0 – 0.3 m soil layer, SOC stock under the canopy (22.8 t C/ha) was significantly higher than within 1 m of the canopy (18.4 t C/ha) but not different from soil >1 m from the canopy (20.5 t C/ha). These data indicate that with the observed trend of increasing currant bush cover in the grazing lands of Queensland (Grice *et al.* 2000; O'Reagain *et al.* 2016), SOC stock is also likely to increase providing some environmental benefits. However, there will be a trade-off in livestock productivity due to the competitive effects of the shrub on pasture production.

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Soil erodibility of Burdekin and Fitzroy River Basins

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Introduction

The Soil and Land Resources Group within DSITI has been contracted to produce a dataset showing the inherent erodibility of soils throughout the Burdekin and Fitzroy Basins. Cane growing areas in the Lower Burdekin were excluded. The project is part of a number of priority water quality science projects being funded by the State Government via the Department of Environment and Heritage Protection. The project is focused on grazing areas within these catchments and the results are being used by government to guide their response to the Reef Plan and by Department of Agriculture and Fisheries, Queensland Government grazing management extension programs.

Methods

The soils are being classified using a soil erodibility classification scheme that has been specifically developed for this project (Zund in prep). The scheme considers soil texture, soil sodicity, soil salinity, cation ion balance and clay type and is a simple decision tree model with critical values for each soil attribute. The classification scheme interpolates surface soil stability (4 classes), subsoil dispersibility (4 classes) and overall soil erodibility (17 classes). The scheme does not consider landscape features, land cover or land use and hence the classification scheme does not produce risk or hazard data. The classification scheme is applied to maps developed for each of the required soil attributes. The attribute maps are derived digitally using soil data from sites throughout the catchments and environmental covariate maps derived from a digital elevation model (Gallant and Austin 2015), radiometric data (Minty *et al.* 2009) and satellite imagery. The spatial data is used in a geospatial digital soil mapping model that interpolates soil attribute values across the catchments.

Results

The project has so far produced GIS data for the Burdekin which is freely available via www.data.qld.gov.au. A simplified version of the data for properties within the Burdekin can be viewed in a specially made 'Erodible soils report' within the FORAGE section of the Queensland Government LONG PADDOCK website.

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Effect of root-zone salinity on tropical and subtropical perennial pasture species

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Introduction

It is anticipated that 3.1 million hectares of Queensland will be salt affected by 2050 (Great Artesian Basin Consultative Council 1998). The following study aimed to investigate the effects of increasing root-zone salinity on Rhodes grass (*Chloris gayana*), butterfly pea (*Clitoria ternatia*), desmanthus (*Desmanthus virgatus*), leucaena (*Leucaena leucocephala*), burgundy bean (*Macroptilium bracteatum*), lucerne (*Medicago sativa*), shrubby stylo (*Stylosanthes scabra*) and caatinga stylo (*S. seabrana*).

Methods

Species were grown in sand culture and compared for growth and mineral concentrations at 8 levels of salinity ranging from 1-21 dS/m. Treatments were established with both NaCl and additional Ca^{2+} to prevent Na^{+} induced Ca^{2+} deficiency. In Experiment 1, the calcium activity ratio of the bulk solution (CAR_x) was maintained $\geq CAR_{0.03}$, and increased to $CAR_{0.05}$ in Experiment 2 to observe the effect of a higher CAR on salt tolerance (Kopittke and Menzies 2005). Plants were grown for 10 weeks before salinity treatments were imposed incrementally until the desired treatment level was attained. Salinity impacts on plant growth were assessed based on relative total dry matter (RTDM) over 100 and 103 days compared to control plants (Deifel *et al.* 2006). Plant tissue analysis was conducted on root material and on 27-day-old and 34-day-old whole shoots (WS) in Experiment 1 and 2, respectively. Leucaena was an exception: mineral concentrations were measured in the youngest fully expanded leaf.

Results and Discussion

Average RTDM declined with increasing salinity for all entries except Rhodes grass cv. Reclaimer. Other diploid cultivars of Rhodes grass (Finecut and Toro) were rated very tolerant to salinity, based on salinity tolerance thresholds described in Maas and Hoffman (1977). The salt tolerance of the legume species ranged from sensitive to very tolerant. In Experiment 2, electrical conductivities (dS/m) that reduced legume yield by 50% were: 8–>21 (lucerne cvv); 5–16 (leucaena cvv); 12 (*Stylosanthes* spp); 12 (butterfly pea); 5 (desmanthus); and 4 (burgundy bean). Salinity thresholds for cultivars of lucerne were, on average, 2 times higher when the CAR was maintained ≥0.05. This was associated with better Na^{+} exclusion from shoots and maintenance of shoot Ca^{2+} concentrations. Nevertheless, salinity typically increased concentrations of Na^{+} and Cl^{-} in roots and shoots of the tropical and subtropical pasture species. The legumes tended to accumulate high Cl^{-} concentrations in shoots, while largely excluding Na^{+}; this was particularly true for the most salt tolerant legumes. Information obtained from this study will enable salt tolerant pasture species to be utilized in areas of southern Queensland where marginal quality water is available for irrigation and/or saline soils are present.

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Pasture rehabilitation on eroded D-condition scalds

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Introduction

In the cattle grazing lands of central and northern Queensland, landholders have attempted to rehabilitate bare, eroded, D-condition scalded areas with limited success. These unproductive areas have been caused by episodic climatic events associated with continuous grazing on the more fragile soils, such as frontages and fertile loam soils across the landscape. This paper describes two successful commercial scald-rehabilitation approaches in central Queensland.

Methods

Site 1. The first rehabilitation method was to fence the cleared brigalow forest, originally sown to buffel grass pasture, into a cell grazing system of multiple paddocks of 85 ha each. The clay-loam soil had developed scattered scalded, eroding patches. Only these scalded patches were deep-ripped on the contour and sown to a mix of introduced pasture grasses and legumes. Over the first four below-average rainfall years, the renovated cells were lightly grazed for short periods to encourage the pasture to establish and seed. These treated paddocks were left out of the cell rotation as necessary to benefit the new pasture.

Site 2. The second rehabilitation method, blade ploughing, was applied to a 1000 ha clay soil, native pasture paddock, which had been cleared of brigalow and Eucalypt trees. Scalded patches were extensive in the mid-slope. Blade-ploughing was applied to 95% of the whole paddock and narrow strips were undisturbed. The paddock was sown to a pasture mix of exotic perennial grasses and legumes. Light grazing pressure was applied after the first summer when there was a good establishment of the sown grasses, legumes and silk sorghum. The pasture was grazed continuously at a conservative pressure during the following two years after a summer rest period that allowed the pasture to grow well and seed.

Results

At Site 1, after four low rainfall years with limited grazing, ground cover of 50% was produced. Full rehabilitation was achieved over the following three years of average or higher rainfall. The remainder of the paddock supported the original buffel grass pasture. Grazing management was short-duration with long rest periods within the cell system, and the timing and grazing pressure were dictated by the state of the renovated pasture patches. At Site 2, the first three years received average or higher rainfall, producing 80% pasture cover. Both rehabilitation methods produced buffel grass-dominant, productive, mixed-perennial grass and legume pastures yielding 3000 kg ha-1, a basal area over 3%, and ground cover over 80%. Also, water infiltration was increased, and runoff water quality was improved by reducing sediment by an average of 90%, nitrogen by 91% and phosphorus by 89%. Undisturbed areas remained unproductive with <100 kg/ha herbage yield.

Conclusions

Both the deep-ripping and blade ploughing methods have successfully rehabilitated scalded patches in cleared brigalow and Eucalyptus communities on clay and clay-loam soils in central Queensland. This success is attributed to: seeding with a well-adapted, exotic pasture species mix; long-term grazing management of three to seven years, to suit the pasture growth stage; and average or higher rainfall years.

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Dead patches in Mitchell grasslands—a 30 year mystery solved

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Introduction

Since at least the 1980s landholders in the Mitchell grasslands of central-western Queensland, have reported relatively small circular patches (0.1-5ha) of dead Mitchell grass *(Astrebla* spp*)* in their pasture. Typically, observations have been most frequent during above-average rainfall years.

Investigation

Despite landholders and DAF staff investigating these dead patches over decades, the cause has never been documented. There was speculation that it may be areas of older grass dying amongst younger plants, patches of shallow soil with reduced moisture availability, or fungal infection.

In August 2012 an enquiry from owners of a property near Winton provided a promising lead, where patches of Mitchell grass were discoloured and withering amongst otherwise healthy pasture. Field investigation revealed Mitchell grass and star grass *(Panicum decompositum)* tussocks were easily pulled from the ground. There was also evidence of ground disturbance from wild pigs digging under tussocks. Affected tussocks were infested with a white curl grub (1-3.5cm in length, with a brown to orange head and translucent body) in the soil, obviously feeding on the roots. These beetle larvae had consistently severed the roots at 10-15cm depth, which appeared to be limiting access to moisture and nutrients and leading to the death of the tussocks. Interestingly feathertop *(Aristida latifolia)*, which is unpalatable to livestock, was untouched by the larvae.

Photographs of the site, tussocks and larvae were taken. Larvae were collected and grown to pupal stage over a 6 month period within moist clay soil growing a mix of commercially available millet and sorghum. After 12 months the pupae had not emerged from their soil cocoons and adults were not available for identification.

Whilst the larvae were obviously a curl grub (or cockchafer) and a member of the scarab beetle family (Scarabaeidae), they could not be positively identified to genus, but may be *Rhopaea* sp. which is an intermittent pest of pastures in southern Australia (Goodyer and Nicolas 2007). Scarabaeidae breed in wooded areas, rather than open grasslands, and it is possible that the infrequent observations of dead patches is due to adult beetles only migrating into western Queensland occasionally when conditions are right (such as easterly winds to carry beetles from forest country). Documented impacts of curl grubs in northern pastures are limited (e.g. Turner and Shaw 1969).

Summing Up

Curl grubs in southern states cause significant damage to crops, pasture and lawns. The infrequent nature of reporting of small dead patches of Mitchell grass suggests curl grubs cause minimal damage. Nevertheless, this phenomenon has been a mystery for decades, and further investigation of the species and life cycle of curl grubs in western Queensland would be of interest to many landholders, extension officers and scientists.

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Diet selected and growth of steers grazing buffel – centro pasture

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Introduction

The benefits of legumes with grasses are well known. However, knowledge of the diet selected by cattle grazing tropical grass-legume pastures is limited. Near infrared reflectance spectroscopy of faeces (F.NIRS) to measure diet attributes was used to evaluate the diet selected by cattle grazing a buffel grass (*Cenchrus ciliaris*) – centro *(Centrosema brasilianum)* legume pasture.

Materials and Methods

Three year groups of young cattle grazed a buffel grass - centro pasture through 3 annual cycles at the Douglas Daly Research Farm, NT. Replacement year groups entered the experiment in July each year shortly after being weaned (average initial liveweight (LW) = 162 kg). Lick blocks provided supplementary N and phosphorus. Pasture was evaluated with Botanal, LW was measured monthly and diet was measured using F.NIRS at 2 – 4 week intervals. Dry matter (DM) intake was calculated from steer LW gain and feeding standards (CSIRO 2007).

Results and Discussion

During the trial the seasonal break occurred on 19 October, 7 November and 10 November and annual rainfall ranged from 1,201 – 1,965 mm. The Botanal method was used to estimate forage DM on offer at the end of the wet season as ≥ 5.9 t/ha and legume comprised 9 – 19% of DM on offer. Legume made a small contribution to the diet during the wet season (average 6%) but a substantial proportion (20 – 30%) during the wet-dry transition and dry seasons (Table 1). This is consistent with observations of other species of tropical legumes. Diet DM digestibility (DMD) and diet crude protein (CP) were highest shortly after the seasonal break and then declined linearly through the wet and transition seasons by 0.072 and 0.046 percentage units per day, respectively. Annual average LW gain was 179 (range 159 – 209) kg. LW gains declined through the wet and transition seasons and averaged only 0.13 kg/day during the dry season. Near infrared reflectance spectroscopy of faeces allowed detailed examination of the relationships between changing diet quality, nutrient supply and LW gain.

Table 1. The average diet selected and average daily LW gains of 3 drafts of steers grazing buffel-Centro pasture during the wet season (WS), wet-dry transition season (TS) and dry season (DS).

Season	Diet selected (% DM)			Voluntary DM intake (g DM/kg LW.day)			LW gain
	Legume	DMD	CP	Legume	Grass	Total	(kg/day)
WS	6	68	15.7	1.6	25.7	27.3	0.83
TS	28	59	9.7	7.5	18.5	26.0	0.57
DS	21	56	6.1	4.1	16.5	20.5	0.13
Prob	***	***	***	***	***	***	***

***. P<0.001.

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The effect of nitrate supplementation on *Bos indicus* cattle after exercise

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Introduction

The potential to reduce methane emissions in ruminants is attractive to Australian agriculture. The Australian government has now endorsed an abatement methodology based on feeding nitrate to rangeland cattle. It has been proposed that nitrate salts could replace urea in supplements to provide an ammonia source for microbial growth while decreasing methane emissions from grazing ruminants. Dietary nitrate provides an alternative electron sink in the reduction of nitrate to nitrite and supports ruminal ammonia concentrations. However, nitrate in the diet can also be toxic to ruminants. In situations where there is inadequate degradation of nitrate to nitrite, increasing blood nitrite concentrations will oxidise haemoglobin to methaemoglobin (MetHb). Increased MetHb causes a decrease in the ability of the blood to transport oxygen to active tissues and hypoxemia results. In northern Australia, cattle walk long distances when grazing or being mustered and the animal's capability to endure physical activity will be compromised if the animal is hypoxemic. Therefore we questioned the effect a nitrate supplement would have on the arterial blood gases and heart rate of steers when exercised.

Materials and Methods

Bos indicus steers (mean body weight ± SEM , 397 kg ± 10.84 kg) fed a Flinders grass (*Iseilema* spp.) hay *ad lib* were used in this experiment to investigate the effects of three dose rates of nitrate salts (0, 30 or 50 g of nitrate/d) on arterial blood gases, methaemoglobin concentration, carboxyhaemoglobin concentration, oxyhaemoglobin concentration, total haemoglobin concentration, heart rate, and respiratory rate after exercise.

Results and Discussion

Increasing the dose rate of nitrate resulted in a decrease in the partial pressure of oxygen (P = 0.004) in blood. Steers treated with 50 g/d nitrate had a decrease in oxyhaemoglobin concentration (P = 0.001) and a concomitant increase in methaemoglobin (P = 0.001) and carboxyhaemoglobin (P = 0.001) compared with steers treated with 0 or 30 g/d nitrate. Steers dosed with 50 g/d nitrate had significantly (P > 0.05) increased heart rates immediately after exercise (175 ± 10 beats/min) compared with steers dosed with 30 g/d nitrate (116 ± 39 beats/min) or no nitrate (105 ± 28 beats/min). There was no difference between treatments for respiratory rate (P = 0.673) after exercise. The fraction of carboxyhaemoglobin in the blood was approximately double the concentration for the 50 g/d nitrate treated steers compared with other treatment groups. This reflects a further inhibition of the oxygen carrying capacity of blood for cattle consuming nitrate. An important consideration is that the increase in carboxyhaemoglobin with the largest dose of nitrate in the present study is indicative of oxidative stress through production of heme oxygenase-1. Feeding nitrate to *Bos indicus* steers resulted in a decrease in the oxygen carrying capacity of blood. When 400 kg steers consume 50 g/d nitrate and experience mild exercise, there is a significant load placed on the cardio-respiratory system. It is likely that doses of nitrate greater than 50 g/d for this class of animal could induce hypoxic trauma especially if exercise is imposed after consuming a nitrate supplement.

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Bacterial composition of a mixed microbial inoculum for reducing the toxicity of the ruminant fodder shrub *Leucaena leucocephala*.

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Introduction

The leguminous drought-resistant shrub *Leucaena leucocephela* is widely cultivated in tropical and subtropical regions to provide a high protein fodder for ruminant livestock but contains the toxic amino acid mimosine. Cattle grazing Leucaena can suffer adverse health effects including reduced live-weight gain, hair loss and goitre and death. To prevent these problems, a fermentor produced rumen-derived, mixed microbial inoculum capable of degrading mimosine and its pyridine alkaloid fermentation by-products (3,4- and 2,3-DHP) has been produced by the DAF since 1995 and is administered under an APVMA permit in Australia to ruminant livestock. This study determined the microbial composition of the mixed microbial inoculum, which to date has been poorly characterised. Archival samples spanning 13 years of production were used as well as eight, two day sequential samples from a single fermentation, which were monitored for changes in microbial composition and the presence and population levels of *Synergistes jonesii*, a known DHP-degrading bacterium.

Methods

Samples selected from fermentations conducted between 1999 and 2012, were chosen to determine if there had been changes in bacterial composition due to changes in the starter culture (passage effect), and the type of fermentor system used. Samples were also selected from eight time points taken during a single fermentation (Run 79, 27/6/2012) - days 2, 3, 5, 7, 9, 11, 13 and 15. DNA was extracted from 1 mL aliquots of fermentor liquor which had been pelleted by centrifugation at 16,000 x g for 10 minutes and the supernatant removed prior to storage at -20 °C. The microbial community was characterised using barcoded amplicons of the V3-V4 region of the 16S rRNA gene generated using high fidelity DNA polymerase and 454 pyrosequencing of pooled amplicons was conducted using the Roche 454 GS FLX Titanium platform (Macrogen, South Korea). A *S. jonesii* specific quantitative PCR was developed to determine numbers of *S. jonesii* present in samples.

Results

Microbial community analysis established that the mixed microbial inoculum produced in the fermenter system encompassed less microbial diversity than that normally found in cattle rumens with an estimated 300-400 bacterial species (taxa) observed. The mixed microbial inoculum was predominated by bacteria of the phyla normally associated with the rumen including Bacteriodetes (43.5%), Firmicutes (45.9%), Proteobacteria (1.8%), Tenericutes (1.1%) and Synergistetes (3.2%) with a core microbiota retained between successive fermentations. *S. jonesii* was present in all batches of the inoculum and stabilised at levels over 1 x 10^6 cells/mL after day eight of fermentation.

Discussion/Conclusions

This study used modern sequence-based methods to show that the mixed microbial inoculum produced by DAF for over 20 years, has maintained a diverse yet stable microbial community, collectively responsible for the degradation of the toxic pyridine alkaloids. The population levels reached by *S. jonesii* within the mixed bacterial inoculum remained similar between fermentations regardless of different starters used (number of passages) or the type of fermentor system used.

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Using F.NIRS to determine diet quality and justify liveweight gain results

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Introduction

Producers conducting on-farm supplementation trials involving multiple paddocks are susceptible to obtaining bias results due to paddock effects. Use of tools such as Faecal Near Infrared Reflectance Spectroscopy (F.NIRS) can assist to better understand the difference in diet quality and liveweight gain results across paddocks. This paper describes a Climate Clever Beef Project supplement trial in 2014.

Materials and Methods

A mob of 364 homebred mixed sex weaners were weighed at Ninderra, Injune in Southern Qld on 29 June 2014, averaging 252 kg, and split into 2 buffel grass paddocks of a similar brigalow-belah land type. The Lower Bullock paddock comprised of approximately 60% Biloela buffel and 40% Gayndah buffel, whereas the Brigalow paddock was 95% Biloela buffel. The control group of 173 head (120 steers and 53 heifers) received no dry lick in Lower Bullock for 82 days, whilst 191 head (80 steers and 111 heifers) were provided with ad lib dry lick in Brigalow over the same time period. The dry lick initially contained 10% urea and was gradually increased to 30% by day 43. Dry lick intake and rainfall was routinely measured. Dung samples were collected 3 times during the trial (8 July, 15 August and 17 September) and analysed using F.NIRS, mainly to attain crude protein (CP) and dry matter digestibility (DMD) levels. The cattle were weighed and the trial concluded on 19 September 2014 due to the paddocks receiving 59 mm of rain from mid-August to early September. Post-trial liveweight gain was monitored by weighing animals again in mid-April 2015.

Results and Discussion

At the end of the trial (19 September 2014) there was no significant difference in the average liveweight gain of the two mobs, with the control mob averaging 0.28 kg/day and the dry lick treatment 0.29 kg/day. F.NIRS results showed that the CP and DMD were similar across the 2 paddocks at both the first and third dung collection (8% and 54% respectively). The 15 August collection however showed the CP was 11% and DMD 56% in Lower Bullock compared to 6% and 53% respectively in Brigalow paddock. This difference may help to explain why the non-supplemented cattle performed equal to those supplemented. It is unknown if the cattle which received the supplement would have performed worse without it. The ratio of DMD:CP exceeded 8 in August, indicating that a response to a protein supplement would be likely, however the 38mm of rain in August soon reduced the ratio below 8 and the average daily dry lick intake reduced from 200 g/day to 100 g/day. The amount and intensity of rain received by the 2 paddocks was similar and thus is unlikely the cause of the difference in CP levels. It is suspected that the cattle in Lower Bullock favoured the shorter sward height Gayndah buffel over the Biloela buffel, which has been previously noted in this paddock. Both mobs gained the same liveweight over summer and thus the control animals did not experience compensatory growth. As a result of this trial, the property owner now has a better understanding of how to use F.NIRS to monitor diet quality and changes in liveweight. Future plans involve splitting up paddocks to better manage the Biloela and Gayndah buffel and supplementing strategically.

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Genomic analysis of the rumen *Streptococcus bovis/Streptococcus equinus* complex: How do they grow so quickly?

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Introduction

The *Streptococcus bovis/Streptococcus equinus* complex (SBSEC) is a group of animal and human-derived commensal bacteria, found in the rumen and gastrointestinal tract. *S. bovis* is a fast-growing organism which can over-proliferate in the rumen sometimes causing rumen acidosis when cattle transition too quickly from forage to high grain diets, such as those employed in the feedlot industry. SBSEC strains are also opportunistic pathogens impacting on the health of ruminant livestock, having been associated with mastitis in dairy cattle and laminitis in cattle and horses. In this study the genome sequences of 13 SBSEC strains, originally isolated from the rumen of Australian cattle and sheep and archived within the DAF culture collection, were interrogated to determine how the genetic make-up of these isolates compared to other SBSEC strains and identify the mechanisms these organisms may be using to over-proliferate within the rumen.

Methods

The complete genome sequences for a total of 42 rumen-derived SBSEC isolates (representing *S. bovis, S. equinus, S. henryi, and S. gallolyticus*) were examined to identify genes involved in carbohydrate catabolism and bacteriocin production. Between-strain differences, including bacteriophage (prophage) sequences were also identified and the production of viable bacteriophages confirmed using electron microscopy.

Results

Analysis of genome sequence data revealed that although the genetic make-up of the SBSEC contained a core set of genes involved in cell growth and metabolism there were strain specific genes present in some SBSEC. The majority of SBSEC examined possessed genes coding for enzymes within the glycosyl hydrolase families 5 and 16, capable of breaking down complex plant carbohydrates. The bacteriocin genes identified were primarily bacteriocin classII lantibiotics, however strain-specific bacteriocin genes were also noted. In addition, many SBSEC genomes contained previously unreported prophage-like elements, with 22 strains encoding a sufficient complement of genes to be designated as “intact” prophages.

Discussion/Conclusions

This study has led to the identification of novel prophages and provided new insights into how bacteriophages infect rumen-associated SBSEC strains. It has also used microbial genetics to understand how SBSEC populations may be sustained in the rumen, and how these organisms can effectively break down plant carbohydrates whilst inhibiting the growth of other rumen bacteria.

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The concentration of phosphorus in plasma and serum collected from *Bos indicus* crossbred steers over a wide range of phosphorus intakes

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Introduction

Cattle grazing across much of northern Australia are likely to be consuming diets that provide insufficient phosphorus (P) to maximise annual liveweight (LW) production unless supplementary P is provided. The concentration of P in plasma or serum appears to be the most immediate and stable indicator of P intake of growing cattle. Previous studies examined the effect of sample site, blood fraction and time after feeding (Teleni et al. 1976; Monteil et al. 2007) on the concentration of P in plasma or serum of cattle, but both studies used lactating cattle consuming P adequate diets. The current experiment examined differences in the concentration of P in plasma and serum collected from the jugular and coccygeal veins of steers over a wide range of P intakes.

Methods

Bos indicus steers (n=30; 228 ± 2kgLW) consumed increasing amounts of P (4 to 21 g P/day) in a diet representative of early wet season pastures in northern Australia (110 g CP and 9.3 MJ ME/kg DM). After 172 days, blood samples were collected prior to feeding from the jugular and coccygeal veins of each steer into lithium heparin vacutainers (plasma) and from the jugular vein into a SST^{TM} vacutainer (serum). Samples were centrifuged at 2250 *g* at 4^{o}C for 10 min and the inorganic P concentration in plasma and serum determined on an Olympus AU400 auto-analyzer.

Results

The concentration of P in the plasma from the jugular vein of steers ranged from 0.8 to 2.8mmol/L. There were linear relationships between plasma (X) and serum (Y) inorganic P collected from the jugular vein (Equation 1) and between plasma inorganic P collected from the jugular (X) and coccygeal (Y) vein (Equation 2) of steers over a wide range of P intake.

Equation 1. $Y\ (mmol/L) = 0.93X + 0.10\ (P<0.01, R^2 = 0.97)$

Equation 2. $Y\ (mmol/L) = 1.06X + 0.02\ (P<0.01, R^2 = 0.97)$

Discussion and Conclusions

The concentration of P was lower in serum compared with plasma and lower in the jugular compared with the coccygeal vein of steers over a wide range of P intakes. The equations generated in this experiment may be used to adjust circulating P concentration to a common reference point. Issues surrounding the timing of collection (relative to diet quality), animal class, sample collection and processing methods and the development of crush side tests require further validation if blood P is to be used to inform producers of the likely response of a mob of cattle to P supplementation.

Acknowledgements

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Differential expression of intake regulatory genes in the hypothalamus of sheep

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Introduction

Feed intake is controlled by the hypothalamus in response to physical, nutrient and hormone signals from the peripheral tissues. The integration of these signals occurs primarily through the arcuate (ARC) nuclei of the hypothalamus, which in turn regulates the appetite-stimulating (Lateral, LAT) and appetite-suppressing (Ventromedial, VMH) centres of the hypothalamus. The abundance of intake regulatory genes were measured in the ARC, LAT and VMH of sheep to understand the potential mechanisms that depress intake when ruminants consume low crude protein (CP) forages.

Methods

Merino wethers (n=35; 26 ± 2 kg LW; mean ± S.D.) were fed one of four diets with different CP content for 28 days, euthanased and the ARC, LAT and VMH were dissected from the hypothalamus. Total RNA was extracted from each region, reverse transcribed and real-time PCR of genes were conducted on a 48.48 Dynamic Array Chip (Quigley et al. 2012). Data presented is the region of hypothalamus (main effect) only from the overall statistical model (region, diet and interaction).

Results and Discussion

Differential abundance of candidate genes in different regions of the hypothalamus support possible roles in stimulating or inhibiting feed intake in ruminants (Table 1). Interventions that target specific genes or regions of the hypothalamus may mitigate the reduction in feed intake that occurs in ruminants consuming diets deficient in CP.

Table 1. Relative abundance of mRNA of intake regulatory genes in the lateral (LAT) and ventro-medial (VMH) compared with the arcuate (ARC) regions of the hypothalamus in sheep[1].

Candidate gene[2]	ARC	LAT	VMH	CI	Proposed role in intake regulation[3]
AgRP	100b	99b	75a	4	Stimulatory
CART	100a	109a	239b	20	Inhibitory
MC3R	100b	12a	82b	9	Stimulatory
MC4R	100a	505c	359b	17	Inhibitory
MCHR1	100b	46a	171c	10	Stimulatory
NPY	100c	7a	70b	8	Stimulatory
PMCH	100a	15666b	1867a	999	Stimulatory
POMC	100b	32a	324c	147	Inhibitory

[1]Back transformed means with 95% confidence intervals (CI) expressed relative to the ARC (%); different letters across a row indicate a significant difference (P<0.05). [2]Agouti-signalling peptide (AgRP), cocaine-amphetamine regulatory transcript (CART), melanocortin 3 receptor (MC3R), melanocortin 4 receptor (MC4R), melanain concentrating hormone receptor 1 (MCHR1), neuropeptide Y (NPY), pro-melanin concentrating hormone (PMCH) and proopiomelanocortin (POMC). [3]Rodent and human models.

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In vitro evaluation of the antimethanogenic potency and effects on fermentation of individual and combinations of marine macroalgae

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Introduction

Methane (CH_4) is a potent greenhouse gas with a global warming potential 28 times CO_2. Agriculture and waste management accounts for 62% of global anthropogenic CH_4 emissions with rumen fermentation responsible for 58% of agricultural contributions. Up to 15% of feed expenses are lost as CH_4 and with feed a primary expense for producers, consequently depleted feed utilization efficiency is a foremost problem. Previously demonstrated, red macroalgae *Asparagopsis spp.* reduces enteric CH_4 production by up to 99% *in vitro* and 80% *in vivo* with as yet unquantified benefits to production. *Asparagopsis* metabolites interrupt methanogenesis at the vitamin B_{12} dependent terminal step of CH_4 production. However, environmental technologies must deliver economic benefits before system changes will be adopted. Other macroalgae with less potent antimethanogenic capability have been shown to improve rumen fermentation and may complement the inclusion of *Asparagopsis* in livestock feeds by assisting in more efficient use of feed energy otherwise lost as CH_4. It was hypothesized that macroalgae previously demonstrating improvements to fermentation *in vitro* would maintain antimethanogenesis when combined with the highly potent *Asparagopsis* and would enhance rumen fermentation. The aim was to create a ranking order of best candidates and establish which performed best in the combinations and hence be most beneficial and profitable as a livestock feed supplement.

Materials and Methods

This study used 72 h *in vitro* fermentations with rumen inoculum to characterize effects of 7 species of marine macroalgae included at 5% of substrate organic matter (OM). The collective species represent the primary categories of red, brown, and green macroalgae. Candidates previously demonstrated variable levels of antimethanogenesis and improvement to fermentation. They were included individually for ranking (n=4) and paired (n=4) with the potent antimethogenic *Asparagopsis* to evaluate beneficial effects on fermentation. Combinations were included in fermentations at 5% of OM for the 7 candidates paired with *Asparagopsis* at 2%. Total gas (TGP), CH_4, digestibility (IVDOM), and volatile fatty acids (VFA) production were used to evaluate effects on fermentation.

Results and Discussion

When tested individually at 5% of OM, the 7 macroalgae candidates induced minor but not significant improvements in VFA profiles after 72 h, however minimal effect on TGP, CH_4, and IVDOM, and thus no clear justification for a ranking order was demonstrated. When tested in combination with *Asparagopsis*, the results were dominated by the presence of *Asparagopsis* with near elimination of CH_4, however no further benefits were demonstrated. Therefore, *Asparagopsis* remains the only macroalga inducing dramatic reduction of CH_4 both *in vitro* and *in vivo*, unfortunately benefits of combinations with the other macroalgae evaluated in this study was not demonstrated. However, combination with high protein macroalgae is proposed to provide productivity enhancement during seasonal lows in grass quality and thus reducing CH_4 emissions intensity and providing a stronger conduit for environmental responsibility while increasing productivity. Since *Asparagopsis* is unrivalled as a safe natural antimethanogenic agent in rumen fermentation further improvements in feed quality and utilization efficiency by addition of a second macroalga or other natural additive is highly desirable. [C]Corresponding author: rob.kinley@csiro.au

Changes in liveweight of cows after relocation to NT floodplain

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Introduction

It is expected that females culled from breeding herds will contribute a significant proportion of the animals slaughtered at the recently developed Darwin abattoir. A potential supply chain for this market is fattening culled cows on floodplains in the Daly and Darwin regions prior to being slaughtered at the abattoir. Whilst there are anecdotal reports of good average daily gains (ADG) (e.g. 500 g/d) for cows grazing floodplains, some aspects of maximising performance require further investigation. Of particular interest is the reported liveweight (LW) loss of cows during their adjustment to the floodplain and its impact on net live weight gain between arrival and sale. The aim of this study was to provide objective information on the LW changes of culled cows during their transition and induction onto the floodplain and its impact on net live weight gain between arrival and sale.

Materials and Methods

Fifty non-pregnant Brahman cows recently removed from multiple breeding management groups for either age or sub-fertile performance averaging 8.8 yrs, 394.3 kg LW and 2.7 BCS (1-5 scale) were relocated from Victoria River Research Station (VRRS; 16.12^{o}S 130.95^{o}E) to Beatrice Hill Research Farm (BHRF; 12.65^{o}S 131.32^{o}E) on the 24/6/2016 (0d), approximately 650km. Cows were transported overnight with LW recorded before leaving VRRS, following a 12h off-feed on-water curfew, and on arrival at BHRF on the 25/6/2016. At BHRF cows grazed on black soil floodplains typical of the Koolpinyah Land System which were pastured by Pangola, Gamba, Tully, Para, and Amity Aleman grasses, and Olive hymenachne. Interim LW was recorded on days 13, 34 and 61 within an hour of mustering. A final LW was recorded on the 9/12/2016 following a 12h on-water off-feed curfew.

Results and Discussion

The overall ADG observed for cows grazing floodplain pastures at BHRF was 0.21 kg/day from the LW recorded at VRRS prior to transport and 0.29 kg/day from the LW recorded on arrival at BHRF. The observed changes in LW were generally consistent with current knowledge, with cows on average losing 3% (11.8 kg) during transit between VRRS to BHRF. Cows lost a further 1.2kg (95% CI; -8.7-6.2) between days 0 and 13 and afterwards continually increased in LW with ADG decreasing across time. The highest ADG was observed between days 13 and 34 at 1.83 kg/d, which reduced to 0.27 kg/d between days 34 and 61. An ADG of 0.04 kg/d between days 61 and 167 was observed although is likely to be an underestimate due to differences in curfew method. The changes in LW during transition onto the floodplains can likely be attributed to changes in gut contents and potentially have little effect on carcass weight, as cattle previously grazing pastures of low nitrogen content can experience decreases in gut contents during a transition to a higher quality pasture (McLean *et al* 1983). These findings further highlight the potential misleading nature of using LW alone to evaluate cattle performance and production systems, and the significant confounding effect of gut contents. On average cows gained 48.6 kg over 5.5 months after arriving on the floodplain and this increased their sale value by approximately $163/head, due to their heavier weight and the higher price (+$0.25/kg) paid by the meat works for heavier cows.

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The metabolic and inflammatory challenges of summer in the feedlot

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Introduction

In cattle production systems, summers are commonly associated with reduced growth, reduced weight gain, and poor reproductive outcomes. While reduced feed intake is part of the reason for this loss in productivity, it is only part of the story. The altered physiological responses to increased summer thermal load that contributes to the underperformance is poorly understood.

Method

We followed 80 growing steers in research feedlots over 2 summers (summer 1: 2013-14 and summer 2: 2014-15) and a winter (2014). Weekly live weights were recorded and weekly blood sampling enabled analyses of blood biochemistry, full blood cell counts, and inflammatory status. The trials were conducted at the University of Queensland QASP facility at Gatton, Queensland.

Results

The three feedlot studies gave different growth trajectories. The winter trials experienced near linear growth throughout, while final weights of both summer trials were significantly lower than the winter finishing weights. The summer 2 growth trajectory was slower and not surprisingly, achieved the lowest mean average daily gains, with no gain or slight loss of weight during weeks 7 – 8 on feed. The live weights after 90 days-on-feed were 585 ± 50 kg, 557.± 32 kg and 532 ± 69 kg for the winter, summer 1 and summer 2 studies respectively. The major pro-inflammatory cytokines were increased in blood during both summers, regardless of heat load. Furthermore, many blood metabolites are changed in summer relative to winter. The summers were very different also. The 2013-14 summer was very mild relative to the following summer in terms of heat load and accumulated heat load in the steers. When we compare the various parameters between the two summers, the physiology and metabolism of the steers in each summer are quite different. The blood bicarbonate (blood pH buffering), triglycerides, and leptin were lower in the hotter summer 2, whereas the fatty acid levels were higher in the cooler summer 1. The hotter summer induced higher average cytokine levels.

Conclusions

Preliminary data show that summer is inherently inflammatory, at least in the feedlot context. Also there is clear seasonal (winter vs summer) impact on metabolism and blood cell numbers. Besides a 25 kg difference in live weight (having started at very similar average weights), the different summer conditions saw altered the metabolism and inflammatory status of these rapidly growing steers. During the hotter summer 2, more animals developed an inflammatory state. Many of the cytokines are pyrogenic (fever inducing) and appetite supressing in their own right. The higher levels of the appetite supressing hormone, leptin, over summer 2 may have contributed to decreased feed intake. The decreased plasma NEFA suggests that despite lower ADG over hot periods, the steers were not mobilising their fats reserves to provide energy. The lower blood bicarbonate reflects increased respiratory rate common in animals attempting to reduce high heat load. As we unravel the complexity of response to summer heat stress we anticipate providing informed and testable interventions for feedlot diets and animal management to increase productivity and welfare.

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CTX-1 as a diagnostic marker of bone mobilisation in *Bos indicus* cows

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Introduction

Phosphorus (P) deficient cattle must mobilise body P reserves to maintain physiological functions. There is high demand for both calcium (Ca) and P in lactating cows for milk production and this demand is partly met by increased bone mobilisation. To better understand the capacity of mature *Bos indicus* cows to mobilize skeletal body P reserves to ameliorate a diet P deficiency during lactation, measurements of a bone mobilisation marker carboxy-terminal telopeptides of Type I collagen (CTX-1) were made in this study. These peptides are the degradation products of type I collagen, the major organic component of the bone matrix. During bone mobilisation, osteoclasts dissolve mineralised bone and degrade the collagen matrix producing CTX-1 fragments in blood.

Methods

Thirty-two *Bos indicus* cross (Droughtmaster) cows (6 – 11 years, live weight 474 ± 57 kg; body condition score 3.5 ± 0.6) initially in high P status were housed in individual pens from calving. For 14 weeks the cows were fed *ad libitum* diets high (H) or low (L) in P and/or Ca: HP-HCa, LP-HCa and LP-LCa. A fourth diet comprised LP-LCa with inclusion of ammonium chloride to provide a negative DCAD diet (LP-LCa-DCAD). The diet Ca/P ratios were *ca.* 2:1, 4:1, 2:1 and 2:1 respectively. CTX-1 was measured in plasma using Crosslaps ELISA (ImmunoDiagnosticSystems).

Results and Discussion

At calving, cows were in adequate P status (PiP 1.93 ± 0.10 mmol/L), with low plasma CTX-1 concentrations (0.32 ± 0.02 ng/ml) indicative of low bone mobilisation. CTX-1 concentrations markedly increased (P<0.05) in early lactation (Fig. 1.). In the HP-HCa diet, CTX-1 reached a maximum at 3 weeks (2.08 ± 0.49 ng/ml) and then declined. In all low P diets, CTX-1 further increased and remained higher (P<0.05) than the HP-HCa diet from 4 to 8 weeks post-calving. The highest CTX-1 concentration was observed in the LP-LCa-DCAD diet at 6 weeks (5.72 ± 0.44 ng/ml), although overall there were no differences among LP diets. CTX-1 in blood is a valuable marker to diagnose bone mobilisation in *Bos indicus* cattle. Mature Droughtmaster beef cows calving in high P status and then fed P-deficient diets during lactation have the capacity to mobilise substantial amounts of bone P for milk production and calf growth.

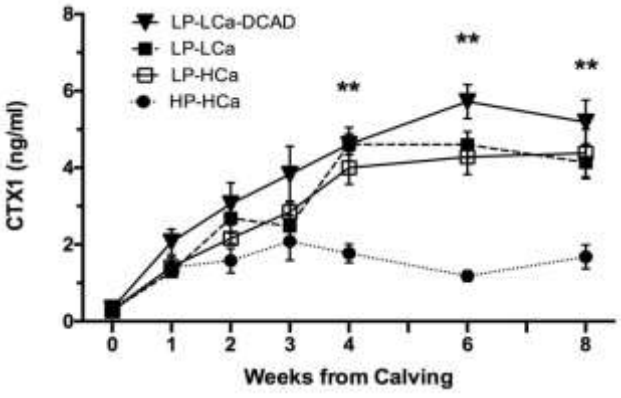

Fig. 1. Plasma CTX-1 concentrations during early lactation. **P<0.05 for all LP diets compared to HP-HCa diet.

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Using the P-screen test to evaluate P deficiency in grazing cattle

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Introduction

Effective management of P nutrition in grazing cattle requires diagnosis of P deficiency. The P status of cattle depends primarily on diet P intake but also on P mobilized from the skeleton and soft tissues. Indicators of P deficiency are the class of country, vegetation, local experience, reduced productivity of cattle, bone chewing and, in the extreme, pica. Past research has shown that dietary P status of cattle is best evaluated from samples of blood and faeces. This is available as the "P-Screen test" through Qld DAF laboratories, but has not been widely used. The main response by P deficient cattle to P supplements is a large increase (e.g. by 40-80 kg) in wet season liveweight gain.

Using the P-Screen test

Phosphorus deficiency in cattle is generally most severe during the wet season when the metabolisable energy and protein content of the pasture are high. Dry season testing is not recommended because protein and metabolisable energy intakes are relatively low and thus P requirement is low. Testing, and what this means for cattle performance, consists of:

1. Grazing a small 'sentinel' group (25-30 head) of growing steers or heifers well below mature frame size in the paddock(s) which best represent the property, or the land system, or where P deficiency is suspected. This sentinel group needs to graze the paddock through the wet season and this is the best way to evaluate a breeder herd. It is important that no P supplements are fed.
2. The sentinel herd have to be tested after they have been grazing wet season pasture for at least 3 months in the paddock being tested. The reason - after several months the performance and the results in the sentinel cattle are less likely to be biased by the mobilization of body P reserves.
3. A P-screen kit is available from DAF and other labs and contains 20 specially prepared blood sample tubes, other containers, and instructions. Cattle (20) need to be blood sampled and kit instructions followed to carefully put a measured amount of blood from each animal into a separate tube. A 'bulk' herd sample of faeces is needed and placed in the supplied container.
4. The kit is sent to the laboratory. The laboratory reports whether the sentinel cattle are likely to be deficient, marginal or adequate for P.
5. If growing cattle are P deficient then breeders should respond to P supplements. However the response may be as increased body condition rather than necessarily increased branding rate or weaner weight. However, breeder body condition and productivity usually improve together.
6. The P-screen test report may be just as important to know when less P supplement (or no P supplement) is needed to reduce costs as well as for deciding whether to provide P supplement.

Improving the P-Screen test

1. F.NIRS estimation of diet quality will be more reliable and informative than faecal nitrogen.
2. Faecal P concentration is an important additional measurement.
3. An agreed system to describe and record the cattle and pasture (as used for F.NIRS) is needed.

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Using faeces to estimate diet P concentration in grazing cattle

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Introduction

Management of phosphorus (P) nutrition in grazing cattle requires assessment of the intake of P. The concentration of P in faeces (FP) has been used as a guide to the concentration of P in the diet. This has been extended to using the ratio of FP/diet N concentration or FP/diet metabolisable energy content of the diet measured with F.NIRS (Jackson *et al.* 2012). In this paper the usefulness of FP concentration is re-evaluated with information from recent research.

How reliably can diet P be estimated from FP and F.NIRS in cattle grazing tropical forages?

- Research available 5 years ago for cattle in northern Australia indicated a good relationship between the FP and the diet P concentration (R^2=0.80; Dixon and Coates 2011).
- As the dataset was increased by the inclusion of samples from other projects, the relationship between the FP and the concentration of P in the diet was found to be poor (R^2 = 0.50).
- If measurements of both FP and F.NIRS in faeces were used then prediction of diet P concentration for young cattle in *ca.* maintenance was substantially improved (R^2=0.70).

How might it be possible to improve the reliability of estimating diet P from faeces?

- The amount of P excreted in faeces must equal the amount of P ingested less P stored in the animal (as liveweight gain or conceptus growth) or excreted in milk. Further, large gains or losses may occur with net P deposition into bone or net P mobilization from bone.
- The amounts of P needed for liveweight gain (or available from liveweight loss), conceptus growth and per kg milk production can be confidently estimated. The ratio of faeces to diet DM can be calculated from DM digestibility measured with F.NIRS.
- The net mobilization of P from bone, or deposition into bone, cannot be readily estimated but current research is addressing this.

A spreadsheet calculator is being developed to predict DP from FP with adjustments for P flows to/from the animal tissues and bone, and P excretion in milk.

Conclusions

- Diet P concentration in young cattle at *ca.* maintenance intake can be predicted with moderate accuracy and reliability from measurements in faeces of P and F.NIRS.
- Current research should improve the reliability of estimating diet P from faeces and correct for the effects of lactation, growth etc. in the animal.
- An agreed system is needed to describe and record the cattle and pasture (as used for F.NIRS).
- Measurements of FP and F.NIRS are useful as a guide to whether diet P deficiency is likely.
- The P-screen test still provides the most reliable assessment of the diet P status of cattle but requires sampling of blood as well as faeces.

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Effects of diet phosphorus and energy intake during late pregnancy on performance of Droughtmaster heifers

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Introduction

Phosphorus (P) deficiencies commonly occur in grazing cattle in the rangelands of northern Australia and elsewhere. This study examined the effects of P nutrition (adequate or deficient) on performance of heifers during late pregnancy at sub-maintenance energy intakes.

Materials and Methods

Forty-two Droughtmaster heifers were housed in individual pens during the last 3 months of pregnancy and were fed restricted amounts of wheat straw and molasses-urea. In a 3x2 factorial design heifers were fed diets of high (HE), medium (ME) or low (LE) metabolisable energy together with high (HP) or low (LP) phosphorous. The amounts of metabolisable energy intakes provided were calculated to provide conceptus-free liveweight (CF-LW) maintenance (HE diet), moderate CF-LW loss (ME diet) or substantial CF-LW loss (LE diet). Heifers were initially (mean ± SD) 419 (±31) kg of CF-LW and 3.9 (±0.27) body condition score.

Results and Discussion

Phosphorous concentration in the diet affected plasma inorganic P (PIP; P<0.001) irrespective of energy treatment (Table 1), and indicated that LP and HP cows were P deficient and adequate respectively. For LE and ME treatments there was no effect of diet P on energy intake or CF-LW change (P>0.05) suggesting that energy was the first limiting factor affecting animal performance on these diets. In contrast, P limited voluntary intake and performance of the heifers in the HE treatments. The HELP diet resulted in greater weight loss than the HEHP diet. Despite the significant differences in energy intake and CF-LW change between treatments there was no effect on calf birth weight (P>0.05).

Table 1. The responses of heifers (n=7) fed diets with high (H), medium (M) and low (L) energy intakes (EI) combined with H or L phosphorous (P) during the last 3 months of pregnancy.

Measurement	LELP	LEHP	MELP	MEHP	HELP	HEHP	s.e.m	E	P	ExP
PIP (mmol/L)	1.0	2.1	1.0	2.0	0.8	2.1	0.09	0.88	<0.001	0.35
EI (MJ/hd.day)	40	40	49	50	53	69	1.97	<0.001	<0.001	<0.001
EI (kJ/kg LW.day)	96	97	116	113	117	152	3.9	<0.001	<0.001	<0.001
CFLW change (kg)	-50	-52	-31	-25	-27	-6	8.46	0.01	0.07	0.63
Calf LW – birth (kg)	26.9	25.4	27.1	30.8	29.3	28.2	1.46	0.423	0.823	0.11

Conclusions

We conclude that diets with sufficient energy can result in CF-LW maintenance only when sufficient P is provided. Further investigation will determine if these P adequate diets result in the replenishment or maintenance of skeletal P reserves irrespective of weight loss. This research was supported by MLA and the Queensland Department of Agriculture and Fisheries.
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Effects of diet P intake during late pregnancy and early lactation on performance of mature Droughtmaster cows

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Introduction

Nutritional deficiencies of phosphorus (P) are widespread in grazing cattle in northern Australia and often reduce breeder performance. An experiment examined the effects of P deficiency during either late pregnancy or early lactation, or during both these intervals, on mature breeders.

Materials and Methods

Mature Droughtmaster breeders were group fed either P deficient (LP)(*ca.* 65% of requirements) or P adequate (HP) diets for the last 3 months of pregnancy, and then P adequate or P deficient diets for 3 months of lactation. Thus there were 4 diets: LP-LP, HP-LP, LP-HP and HP-HP. During pregnancy the cows grazed small paddocks and were fed molasses-urea supplements (± P), and during lactation were housed individually and fed mixed diets. Cows were initially (mean ± SD) 465 (±44) kg conceptus-free liveweight (CF-LW) and 3.6 (±0.59) body condition score.

Results and Discussion

During pregnancy PIP concentrations were lower in LP than HP cows but LP cows were not severely deficient, and there was moderate loss of CF-LW (mean 29 kg) in all treatments. During lactation both the LP-LP and HP-LP cows were severely P deficient, had a lower voluntary intake, and lost on average 33 kg LW. Conversely the LP-HP and HP-HP cows were P adequate and gained 23 kg during lactation. Feeding the HP diet during lactation increased calf growth so that calves were 10 and 17 kg heavier than the calves of cows fed the HP-LP and LP-LP diets. Thus feeding HP during pregnancy had a small effect on calf growth. In conclusion cows P deficient during late pregnancy cows mobilized sufficient body P to avoid adverse effects. During 3 mo of early lactation diet P deficiency reduced feed intake and cows lost 33 kg rather than gaining 23 kg. Furthermore P deficiency reduced calf growth although P adequacy (HP diet) in late pregnancy alleviated this effect.

Table 1. Effect of P deficient and/or P adequate diets during late pregnancy and/or during early lactation on CF-LW, BCS, plasma inorganic P (PIP), DM intake and calf LW gain.

Diet	CF-LW change (kg/day)		BCS change		PIP (mmol/L)		DMI (g/kgW)	Calf LW
	Preg	Lact	Preg	Lact	Preg	Lact	Lact	gain (kg)
LP-LP	-0.25	-0.40	-0.1	-0.8	1.7	0.6	16.8	0.75
HP-LP	-0.32	-0.34	-0.2	-1.0	2.1	0.4	17.4	0.83
LP-HP	-0.37	+0.26	-0.4	+0.1	1.8	1.7	21.1	0.96
HP-HP	-0.23	+0.25	0.0	-0.1	2.1	1.7	21.5	0.92
P (Preg)	n.s.	n.s.	n.s.	n.s.	***	n.s.	n.s.	n.s.
P (Lact)	-	***	-	***	-	***	***	***

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Bone mineral in steers: effect of diet phosphorus status, liveweight and age

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Introduction

Nutritional deficiencies of phosphorus (P) in cattle grazing northern rangelands are widespread and often severely reduce the growth rates of cattle (Winks 1990). It is established in dairy cattle, sheep and goats that the adverse effects of low diet P intakes may be alleviated by mobilization of P from body reserves, including from the large reserve of P in the skeleton. This experiment reports the changes in bone mineral, and thus of P, during P deficiency in growing *Bos indicus* cross steers.

Materials and Methods

At Lansdown near Townsville in the seasonally dry tropics the effects of severe and prolonged diet P deficiency on liveweight (LW) gain, on bone growth and mineralization in tail bone (Cy9), and on cortical bone thickness (CBT) of rib bone were examined in groups of P supplemented (P_{adeq}) and unsupplemented (P_{defic}) Droughtmaster steers of two ages grazing P deficient pasture. Steers in groups 1 and 2 were initially 20 and 8 months of age, and treatments were imposed for *ca.* 12 months. The bone mineral density (BMD) at the proximal end of Cy9 bone was measured at *ca.* 2 mo intervals using single photon absorptiometry (SPA) (Coates *et al*. 2015), and rib bone CBT was measured at the end of the experiment when the steers were *ca.* 32 and 20 months of age.

Results and Discussion

Measurements of LW change, plasma inorganic P concentrations (PIP) and rib CBT confirmed that the P_{adeq} and P_{defic} treatment steers were adequate and deficient, respectively, in P. During the 12 months of measurements adequate diet P increased steer LW gain from 77 to 187 kg in Group 1, and from 98 to 182 kg in Group 2 steers. PIP in P_{defic} steers averaged <30 mg P/L. The BMD in P_{adeq} steers increased with LW and age from *ca*. 0.275 g/cc (20 months, 300 kg LW) to *ca*. 0.34 g/cc (32 months, 490 kg LW), while in P_{defic} steers BMD decreased progressively to *ca.* 0.23-0.24 g/cc after 6 months. The absence of any decrease in BMD during the last 6 months of P deficiency suggested a physiological limit to further reduction in tail-bone BMD beyond a critical level. Although BMD decreased with P deficiency, in P_{defic} steers the volume of Cy9 tail bone continued to increase and there was some net bone deposition in the Cy9 (4% and 18% in Groups 1 and 2, respectively). Thus during P deficiency some bone growth continued but with reduced mineralization of the bone. In both age groups at the end of the experiment rib bone CBT and tail bone BMD were *ca.*40% lower in P_{defic} than in P_{adeq} steers. Tail-bone BMD and rib CBT at the end of the experiment were correlated (r = 0.93). In conclusion severe and prolonged P deficiency in growing steers severely reduced LW gain and was associated with low PIP concentrations, reduced mineral density of tail bone and reduced rib CBT. SPA could be used on-farm to diagnose P deficiency in young growing steers.

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Effect of diet phosphorus deficiency on liveweight and bone in breeders

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Introduction

Nutritional deficiencies of phosphorus (P) are widespread in cattle grazing rangelands in northern Australia and often reduce breeder herd productivity (McCosker and Winks 1994). An experiment examined the effects of severe P deficiency in breeder cows during pregnancy and lactation.

Materials and methods

At Springmount Station near Mareeba the effects of severe diet P deficiency (± P supplements) during pregnancy and lactation on the performance of mature Brahman cross breeder cows were examined. Measurements were made of changes in liveweight (LW), plasma inorganic P (PIP), and skeletal P reserves. Bone mineral density (BMD) in Cy9 tail bone was measured in late pregnancy (September), mid-lactation (March) and post-weaning (May) using single photon absorptiometry (SPA) (Coates *et al.* 2015), and cortical bone thickness (CBT) in rib bone at the end of the experiment.

Table 1. Effect of diet P-status (treatments P_{defic} and P_{adeq}) on LW, tail bone BMD and rib bone CBT in breeder cows. Calf LW gain was from mid-Jan to weaning in April.

Diet	Liveweight (kg)				Cy9 tail bone BMD (g/cc)			CBT	Calf LW
	Jun94	Sept94	Mar95	July95	Sept94	Mar95	May95	(mm)	gain (kg)
P_{adeq}	420	446	373	440	0.35	0.35	0.36	3.69	103
P_{defic}	430	434	350	363	0.33	0.30	0.31	2.58	92
Prob	n.s.	n.s.	n.s.	<0.01	n.s.	0.05	<0.05	<0.001	<0.01

Results and discussion

PIP concentrations indicated that that the P_{adeq} breeders (*ca.* 50 mg P/L) were adequate, while the P_{defic} breeders (*ca.* 20 mg P/L) were severely deficient, in diet P. During the late dry season (Oct-Jan, late pregnancy and early lactation) cows in both treatments underwent large LW losses (109 and 81 kg, respectively). During mid-lactation and post-weaning (mid-Jan to early July) LW gains were much greater ($P < 0.01$) in P_{adeq} than in P_{defic} cows (106 and 20 kg, respectively). Tail bone BMD was lower in P_{defic} than P_{adeq} cows in mid-lactation (Mar 95) and after weaning (May 95), but only by 14-15% (Table 1). Rib bone CBT was 30% lower in P_{defic} than in P_{adeq} cows ($P < 0.001$) and was thus much more responsive than tail bone BMD to severe prolonged diet P deficiency in mature breeder cows.

In conclusion, changes in bone indicated that the P_{defic} cows mobilized substantial skeletal P which presumably had some effect to alleviate a diet P deficiency. SPA could be used on-farm to diagnose severe P deficiency in breeders but was a less sensitive indicator than changes in rib CBT.

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When are Phosphorous supplements needed in Central Queensland?

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Introduction

The importance of phosphorous (P) in beef production across northern Australia is widely known. What is not well known is the prevalence of P deficiency in the central Queensland region. Some graziers may be foregoing production potential by not feeding P while others may be feeding P when they need not do so. The P-screen test using blood and faecal samples from dry growing stock was used at 3 sites in central Queensland at the end of the 2016 wet season to determine P status.

Methods

Appropriate stock (growing non-lactating cattle in their 2nd year) grazed potentially P deficient paddocks, over the 2016 wet season. Blood and faecal samples were taken at the end of the wet season at 3 properties, those being close to Bauhinia, Springsure and Alpha.

Results and Discussion

The blood samples from all 3 properties had blood inorganic P (Pi) concentrations above 50 mg P/L (Table 1). Indicating the cattle tested were in adequate P status and would not have responded to P supplements (Jackson *et al*. 2012). The faecal total nitrogen (FN) concentration on the Bauhinia property paddocks (1.6 and 1.8 %FN) indicated fair pasture quality. The concentrations of 1.4 %FN at Alpha and Springsure approached the threshold of 1.3 %FN when the stock are likely to be only maintaining and would likely respond to urea supplement. At Bauhinia and Alpha it is planned to resample for P in the early dry season. Allowing for more growth of the cattle should further reduce body P reserves and provide additional information on P status. A bigger wet season may affect P dilution in grass and change pasture species composition which may affect Pi concentrations in cattle, thus retesting of paddocks may occur. Graziers are encouraged to test paddocks to gain a better understanding of the P status, which is critical information for supplement management.

Table 1. P-screen results from 3 properties. The Bauhinia property was sampled in 2 paddocks.

Location	Land type	Sampling date	Mean blood Pi (mg/L)	Range blood Pi (mg/L)	Faecal nitrogen (% DM)	P status
Bauhinia 1	Bulloak country, box flats	24/02/16	56	44-67	1.8	Adequate
Bauhinia 2	Box flats	3/03/16	67	41-88	1.6	Adequate
Springsure	Mountain Coolibah woodlands	6/04/16	70	57-85	1.4	Adequate
Alpha	Silver-leaved ironbark	11/04/16	58	47-68	1.4	Adequate

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Blood sampling for P Screen – Tail versus Jugular

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Introduction

Phosphorous (P) is a major limitation to cattle production in many rangeland regions. Because blood inorganic P concentration is highly responsive to diet P intake it is considered the best indication of diet P intake. Usually the coccygeal (tail) vein is sampled on-farm but the jugular vein during research. We investigated the relationships between the concentration of inorganic P in blood in samples obtained from the coccygeal (tail) vein and jugular vein, and between serum (SIP) and plasma (PIP) in cows.

Methods

Two herds (each n =24) of mature *Bos indicus* cross (Droughtmaster) cows in late pregnancy grazed small paddocks and were fed molasses-urea supplements (± additional P) to provide either P adequate or P deficient diets. After 12 weeks jugular and coccygeal (tail) blood samples were obtained from all cows on each diet using vacutainers (BD) to provide samples for plasma inorganic phosphorous (PIP) and serum inorganic phosphorous (SIP) analysis.

Results and Discussion

Coccygeal PIP and SIP in cows fed the P deficient diet were in the range 1.18 - 2.07 mmol/L while those on the P adequate diet were 1.26 - 3.07 mmol/L. For all cows there was a strong relationship between PIP and SIP (R^2 =0.95) with plasma values being only 2% higher than serum but statistically different from 1:1 (P<0.05) (Fig 1A). There was also a strong relationship (R^2 =0.88) between jugular and coccygeal plasma samples with coccygeal P values parallel to the 1:1 line (i.e. slope not statistically different from 1) but with an offset of 0.3 mmol/L higher than jugular values (Fig. 1B). In conclusion tail serum or plasma yield similar results and only minor allowances need to be made when comparing these results with jugular PIP.

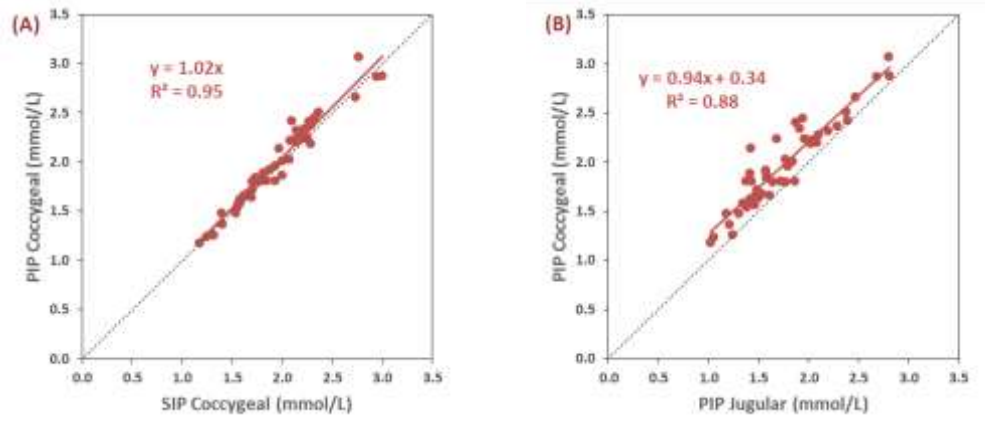

Fig 1. Coccygeal plasma inorganic phosphorous versus (A) coccygeal serum inorganic phosphorous and (B) jugular plasma inorganic phosphorous in breeder cows in last month of pregnancy.

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Effects of diet phosphorus on milk production in mature breeders

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Introduction

Phosphorus (P) deficiency in northern Australian rangelands has a major effect on production of beef cattle (Winks 1990). The effects of diet P on the performance of mature cows in early lactation were investigated; through milk output, milk quality, and calf performance.

Methods

Thirty-two *Bos indicus* cross mature breeders (6-11 years of age, liveweight (LW) 474 ± 57 SD; body condition score 3.5 ± 0.55 SD) were fed in individual pens for 3 months from the day of calving, on straw-flour-sugar based diets. The cows were fed *ad libitum* a diet high (H) or low (L) in P or calcium (Ca): HP-HCa, LP-HCa and LP-LCa. A fourth diet also comprised LP-LCa, with inclusion of ammonium chloride to achieve a negative DCAD diet (LP-LCa-DCAD). Cows were milked at fortnightly intervals over a 3 month period were collected using a milking machine system (Fig. 1). Each cow was milked twice at the beginning and end of a 4-6 h interval while the calf was separated from the cow. Oxytocin (2 ml) was injected into the jugular vein for milk letdown. Milk quality was measured in each milk sample as protein, lactose, fat and P concentrations. Birth weight was measured (30.1 ± 5.2 SD). Subsequent growth rates of the calves were measured weekly.

Results and Discussion

Neither average milk production (kg/day) nor P concentration of milk differed between diets (P>0.05) but both decreased (P<0.05) through lactation. Milk energy was lower (P<0.05) for LP-HCa than for the other diets. Calf growth rate over the 3 months ranged from 0.58 kg/day for the LP-HCa diet to 0.70 kg/day for the HP-HCa diet, but did not differ (P>0.05) among diets. The growth rate of the calves and estimated milk energy output were more closely correlated during months 1 and 2 of lactation than for the entire 3 months. This was in accord with Holmes *et al.* (1968) who reported a correlation with r=0.78 over 0-4 months of lactation.

Fig. 1. Milking procedure, Day 14.

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Diagnosing phosphorus status of beef breeding herds using sentinel steers

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Introduction

Management of phosphorus (P) deficiency in grazing cattle requires diagnosis of the P status of cattle and evaluation of likely responses to P supplements. The most reliable indicator of the P status of cattle is the P-Screen test (McCosker and Winks 1994) using growing, non-lactating animals without access to P supplements for at least 4 weeks prior to testing. Where possible, a group of sentinel steers or heifers grazing with a breeder herd is recommended to evaluate the P-status of the breeders (Jackson *et al.* 2012).

Method

A P-Screen test was used in a breeder paddock on a central Queensland property with anecdotal reports of peg leg. The practicality of using a sentinel group of young steers to evaluate phosphorus status of breeder paddocks was examined. Twenty yearling Brahman cross steers weaned in July 2015 were moved to a breeder paddock the following October. The mixed age cow mob were continuously mated with conservative stocking rates to match the predominantly low fertility land type. Routine property management continued throughout the study. In mid-March 2016, following a late break in the season, standard P-Screen methods were followed which involved taking blood from the tail and faecal samples per rectum from each of the steers during the mid to late pasture growing season.

Results and Discussion

The sentinel steer's mean blood inorganic Phosphorous (Pi) was 1.69 mmol/L and the faecal nitrogen was 1.93% (DM basis). The established standards used for P-screen indicated that the sentinel steers were in adequate phosphorus status. Therefore P deficiency of the breeder herd was very unlikely to be the cause of any lower-than-expected performance and a response to P supplementation would not be expected. The higher than adequate Pi levels were unexpected given the apparent low fertility land type; however there may be small proportions of more fertile areas within the paddock supplying sufficient dietary P to maintain the sentinel steers in adequate phosphorus status; this will be investigated. The property owners easily managed the inclusion of a sentinel group grazing with the lactating cows but cautioned that recently weaned animals may resume suckling which could affect the results.

In conclusion using young non-lactating sentinel animals and the P-Screen test was considered a useful method to determine P status of breeder paddocks and likely response to P supplements.

Acknowledgements

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A northern Australian strategy to deliver a multibreed genetic evaluation

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Introduction

Prolonged post-partum anoestrus interval and age at puberty in *Bos indicus* and *Bos indicus* infused breeds are two primary factors impacting reproductive efficiency in north Australian herds. The northern Australian commercial beef industry is increasingly focused on crossbreds and composites. Although crossbreeding is a valid strategy to improve herd reproductive performance and maximise production, adaptation traits (e.g. heat tolerance and parasite resistance) may be lost. Consequently, genetic analysis needs to accurately compare purebreds, crossbreds and composites and include primary performance and adaptation traits. Genomic technologies to assess genetic potential early-in-life for hard- and costly-to-measure, sex-specific traits and lifetime traits require quality phenotype information on these breed types. Industry does not provide this type of data.

Objectives

1. To further evaluate, validate and demonstrate genetic and genomic methods from the Beef CRCs while developing government multibreed Tropical Genetic Resource Herds (TGRH) genetically linked to collaborating Industry Brahman, Droughtmaster and Santa Gertrudis TGRH seedstock herds;
2. Specifically address the MLA Priority area of 'Rapid dissemination of superior genetics' and preserve the connectedness with Industry Next Gen Beef Breeding Strategies Industry TGRH.

Methods

BREEDPLAN TGRH established on government research facilities (Queensland and Northern Territory) using a range of breeds and their crosses and managed across a diversity of environments, will provide 'head to head' multibreed data for these industry-relevant traits. These herds must be genetically linked to strategically-located BREEDPLAN Seedstock TGRH to reflect current industry genetic potential and allow more rapid dissemination and adoption of research results into industry. High quality female and male reproductive performance, growth, carcass and adaptation data will be collected in 'head to head' comparisons of purebred, crossbred and composite animals that will help to generate the phenotypes and genomic information required. Specific reproductive traits/ measurements will include scrotal size and percent normal sperm in young bulls, age of puberty and a reproductive tract real-time ultrasound scan after removal of the bull/s in heifers and a reproductive tract real-time ultrasound scan after removal of the bull/s in lactating cows. Analysis of this multi-breed data will enable breed differences and heterosis effects to be estimated for the wide range of production and adaptation traits that will enable a true 'northern multibreed genetic analysis'.

Planned Outcomes

The main economic outcomes will include – 1. Improved productivity, efficiency and profitability of northern Australia's tropical beef seedstock herds in the short term through 'accelerated genetic improvement' of breeds via collaborating herds, improved reproductive performance and improved gross value of beef production; and 2. Development of 'head to head' phenotypic and genomic breed comparison and multibreed data to enable a true multibreed genetic analysis for the northern industry, in the longer term.

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Genetics of reproductive traits in tropically adapted beef herds

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Introduction

Reproduction is well established as a key driver of herd productivity and profitability in northern Australia beef herds (Burns *et al.* 2016). Limited information on genetic parameters of reproductive traits was available prior to research conducted in Beef CRC II and III. This research in Brahman and Tropical Composite breeds demonstrated that key component traits of reproductive performance (multiple measures - age of puberty, post-partum re-conception interval, scrotal circumference and percent normal sperm) are at least moderately heritable and that key traits in males are genetically correlated with female traits. However, many of the traits identified in the Beef CRCs remained untested under commercial management and in other tropical breeds.

Methods

A Next Gen Beef Breeding Strategies Project was developed to implement Beef CRC II and III research findings in the 3 largest tropically adapted breeds in northern Australia, using leading GROUP BREEDPLAN seedstock herds. Genetic and genomic methods of increasing herd reproductive performance in these breeds were evaluated, validated and demonstrated. A number of the Beef CRC reproductive traits were modified, through reduced measurement and tested in Brahman (3 herds - 1753 bulls; 2003 females), Droughtmaster (2 herds - 730 bulls; 1241 females) and Santa Gertrudis (2 herds - 1631 bulls; 1920 females) seedstock herds under commercial management. Measurements included - 1. A full Bull Breeding Soundness Evaluation in young bulls at 600 days of age, and 2. Reproductive tract real-time ultrasound scans in heifers (at 600 days of age before mating and 4-5 weeks after bull out) and lactating cows (4-5 weeks after bull out). This strategy was used to estimate the value of and the association between these modified traits and existing BREEDPLAN measures of reproductive performance.

Results, Discussion and Conclusions

Heritabilities, correlations and Estimated Breeding Values clearly show that opportunity exists for genetic improvement of male and female reproductive traits by selection of superior breeding animals. A DNA Bank was developed and a selection strategy used to identify the most 'informative' females and sires across the collaborating breeds for future genotyping and use in subsequent genomic selection strategies; 3,854 females have been genotyped (20K SNiP chip). Collaborating herds are being encouraged to continue recording lifetime productivity of females to better evaluate the early-in-life traits against overall lifetime fertility. These collaborating herds will form a valuable resource of phenotypic and genetic/genomic information for tropical beef cattle in future years.

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Increased accuracy of the Poll DNA marker test for Australian beef cattle

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Introduction

The Poll DNA marker test is used to determine the poll genetics of an animal, given the alleles observed within the poll locus. This paper describes improvements made to the commercially available Poll DNA marker test, to capture more variability, enable predictions that are more accurate and clarify uncertainty of polled probabilities.

Results and Discussion

Previously, haplotypes from 10 microsatellite markers were estimated once; animals with multiple possible pairs of haplotypes were omitted (Henshall *et al.* 2014). Haplotype horn/poll assignment was estimated using an MCMC sampler, providing each haplotype with a polled probability (Henshall *et al.* 2014; Piper *et al.* 2014). Improvements include estimating haplotypes 100 times for each animal, instead of once, thereby capturing variable haplotype estimations. Also, rather than omitting uncommon haplotype pairs, their varied and/or multiple haplotype probabilities are accumulated over the 100 chains and the mean polled probabilities reported. These improvements result in an increase in the number of animals assigned polled probabilities, and the number of haplotypes used has increased from approximately 1,600 to over 1,900. Despite the increase in haplotype variability, the first 200 haplotypes account for approximately 85% of assignments within the test; the remaining 1,700 haplotypes while only accounting for 15% provide a more accurate assignment of polled probability, and results in less animals with no polled probability assignment. Currently there are more than 35 breeds and over 13,000 animals tested, and their relative proportions can be seen in Figure 1. Brahman, Limousin, Hereford animals make up 50% of all animals submitted thus far, which is not surprising given these breeds were targeted in the development of the test.

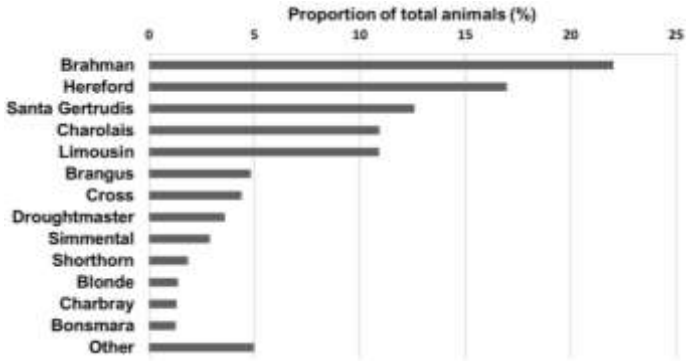

Fig. 1. Current proportions of breeds included in the Poll DNA marker test

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Repronomics Project update – enabling genomic selection for reproduction

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Introduction

Reproduction is a key profit driver in northern Australia and genetic improvement is a key tool for increasing commercial weaning rates. To enable tropical beef breeds to develop the capacity to drive genetic change in reproduction a new MLA funded project (MLA *B.NBP.0759*) was established, known as the Repronomics Project. This large breeding project is now in its third year and has generated significant numbers of calves and recorded a large number of females for age at puberty, lactation anoestrous interval, calving and weaning rates, along with many other traits. These records are being combined with DNA chip genotyping on all project and industry animals to enable genetic improvement of female reproduction through genomic selection.

Locations and Breeds

The project is using 3 breeds (Brahman, Droughtmaster, Santa Gertrudis) and a combination of research facilities (Brian Pastures, Gayndah; Spyglass, Charter's Towers; DDRF, Douglas Daly) and industry seedstock herds located throughout Queensland. The Douglas Daly Brahman herd is part of long term selection experiment utilising yearling mating. The Brian Pastures and Spyglass herds are DAF owned herds. All breeds are fully BREEDPLAN recorded, and at a location, breeds run together. Key linkages exist to the Beef CRC, Brahman BIN and Next-Gen projects and to industry herds.

Numbers, Female Recording and DNA Testing

To date the project has generated approximately 2,200 calves. Breeding is by natural mating for maidens and 1st calvers. Older cows have been used for AI (2 rounds fixed time) to generate progeny on high importance industry sires. Given adverse seasonal conditions, very good AI conception rates have been achieved. The project is using real-time ultrasound to do ovarian assessments on all females to accurately determine the follicle development and presence of a corpus luteum (CL) which is used to determine the age at puberty, and for lactating first calvers, their return to cycling post-calving. At Douglas Daly heifers are exposed for yearling mating. To date more than 1,500 heifers have been recorded for age at puberty and almost 1,000 first-calf cows for lactation anoestrous interval. To enable the development of genomic selection all females have been DNA parent verified and genotyped with a 25K chip, and all project sires genotyped with an 80K indicus chip. Industry sires have also been genotyped, including cooperator industry herds (2-3 herds / breed) and sires with high accuracy Days to Calving EBVs in the Brahman and Santa breeds.

Conclusions

The project is well underway and achieving its targets in generating females and intensive recording of reproduction. Recording of the project generated heifers will be increasing in coming years. All the data is feeding into new BREEDPLAN evaluations and will enable tropical breeds to make genetic change in improving female reproduction rates.

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Practical impact of adoption of genetic improvement

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Introduction

Using a combination of BREEDPLAN technology, Beef CRC outcomes (Johnston *et al*. 2013) and the Bull Power project outcomes (Holroyd *et al*. 1998), Lisgar Droughtmasters at Home Hill in North Queensland, and similarly managed properties, have adopted the technologies and increased productivity and profitability through using the basic BREEDPLAN traits in addition to Bull Breeding Soundness Evaluation fertility measures.

Methods

Over 10 years, genetic improvement has ensured ongoing improvement in the business and taken advantage of property and pasture development. Each property has defined minimum fertility standards with all bulls exceeding 70% normal sperm and passed other aspects of a full Bull Breeding Soundness Evaluation annually. A balance of above average growth (200, 400 and 600 day) and scrotal size traits, dam breeding history and carcase traits to meet market specifications is targeted. As fat cover and marbling are important to the higher priced markets, rump, rib and intramuscular fat and eye muscle area traits are incorporated in the herds' 'Breeding Objectives'.

Results

In the Lisgar herd, selection pressure on 600 day growth has resulted in herd results higher than breed average (Fig. 1.). Further, through selection pressure on percent normal sperm and scrotal size of bulls, the percentage of females pregnant in the first 2 cycles after exposure to bulls is increasing, thereby decreasing the calving interval and spread. Slaughter weights have been increasing while age at turnoff has decreased over 7 years. The gross margin in the Droughtmaster herd has increased from $209.48 – $244.73/AE from 2007 – 2012, demonstrating the benefit of applying the above technologies.

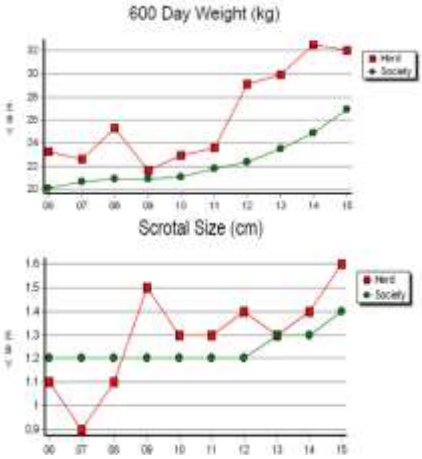

Fig. 3. Key Lisgar BREEDPLAN Estimated Breeding Value changes over time.

Discussion/Conclusion

The impact of using existing and emerging technologies over the last decade has been shorter mating periods, fewer bulls required, tighter weaner weight range and more compact turnoff groups within specifications for markets. The impact on females has included heifers cycling at a younger age and tighter breeding patterns.

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Muscle glycogen of rangelands cattle at slaughter varies with carcass traits

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Introduction

Low muscle glycogen in beef cattle at slaughter has been associated with insufficient decline in meat pH, resulting in dark meat ('dark cutting') (Gardner *et al*. 2014). Reduced incidence of 'dark cutting' is related to increasing carcass weight, rib fatness and marbling, as well as decreasing ossification scores (McGilchrist *et al.* 2012). Thus it is hypothesised that post-mortem muscle glycogen will increase as carcass weight, rib fatness and marbling increase, but decrease as ossification increases. A study to show consistency of those relationships with the known association between muscle glycogen and meat colour, may inform management to reduce 'dark cutting'.

Methods

Following co-grazing on mixed arid rangelands of central Australia, 97 Droughtmaster-cross steers (27–30 months old) were transported to South Australia (~1,590 km) for processing. A muscle sample from the *M. longissimus thoracis* of each carcass was collected 40 minutes post-mortem and stored at -20^{o}C until analysed for glycogen and lactate. A general linear statistical model was used to analyse relationships of muscle glycogen with average daily weight gain (*data not shown*) and carcass traits as continuous variables. Breed type and paddock of origin were fixed effects.

Results and Discussion

Rib fat (RF) depth was positively correlated with muscle glycogen (P<0.05); as RF increased by 10 mm, glycogen increased by 0.12 ±0.06 g/100 g muscle (Fig. 1). Although not statistically significant (P=0.051), hot standard carcass weight (HSCW) tended towards being negatively correlated with muscle glycogen; for each 100 kg increase in HSCW, glycogen decreased by 0.16 ±0.08 g/100 g muscle (Fig. 1). Marbling and ossification score had no impact on muscle glycogen (P>0.05).

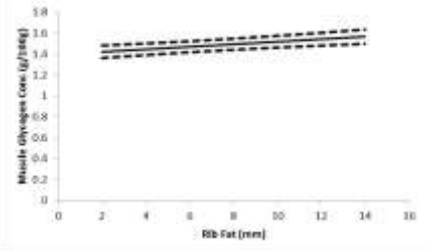

Fig. 1. Relationship between a) rib fat and muscle glycogen; b) carcass weight and muscle glycogen; ≡-≡ linear correlation +/-se.

These results indicate that fatter animals have increased glycogen storage, which supports the hypothesis and the findings of McGilchrist *et al.* (2012). However the negative correlation between HSCW and muscle glycogen challenges the hypothesis by showing that heavier animals may, after long-distance transport, have lower muscle glycogen stores. The cause of this relationship is unclear, but could involve increases in either fatigue or maintenance requirements in transit.

References

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Accuracy assessment of live animal ultrasound carcass measurements

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Introduction

The Clermont Cattlemen's Challenge is an annual competition in which local cattle producers enter 5 weaner steers for growing out and feedlot finishing for the 100 day grain-fed market. The Challenge aims to better understand cattle performance in the district and provide an avenue for group learning. This paper presents findings from a demonstration of the measurement accuracy of crush side ultrasound scanning of carcass traits.

Methods

After 100 days on grain 1 steer from each property group (n=16; live weight = 615 kg) was selected for slaughter and carcass measurement. Three days prior to slaughter the eye muscle area (EMA), intra-muscular fat (IMF), rump (P8) and rib fat depth of each steer was assessed using a Pie Medical Aquila scanner. P8 fat depth was also measured with an UltrAmac® fat depth scanner. One technician operated both machines. Carcass measures were taken at the Kilcoy Pastoral Co abbatoir.

Results and Discussion

There was a strong positive linear correlation (r =0.921; p = <0.001) between the Pie and UltrAmac® measures of P8 fat depth (Fig. 1). The relationship between UltrAmac®, Pie and carcass measures of P8 fat depth were on par (Table 1). Both machines correctly predicted P8 fat depth to be within or outside optimal specifications (8–12 mm) in 14 steers. Correlations between Pie and carcass measures of EMA and IMF were weaker but significant. Despite differences in individual measures the steers ranked similarly for these traits e.g. the top and bottom two steers were the same for Pie and carcass EMA. Pie and carcass measures of rib fat depth were not significantly correlated. Differences between measures could be due to probe pressure, hide pulling technique, variation in the actual measurement site and cooler shrinkage.

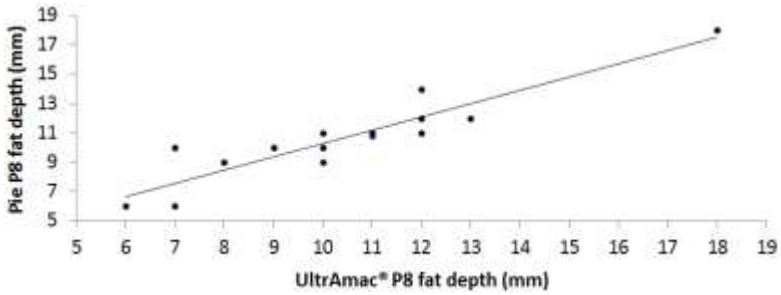

Fig. 1. Correlation between Pie and UltrAmac® measurements of P8 fat depth (mm) in 16 steers

Table 1. Descriptive statistics and correlation coefficients of ultrasound and carcass measures

Carcass measurements	*N*	*Mean*	*SD*	*Correlations*	
				Pie	*UltrAmac®*
Eye muscle area (cm^2)	16	75.3	3.9	0.60*	
Marbling (0-6)	16	1.3	0.4	0.52*	
Rib fat depth (mm)	16	9.4	3.6	0.41	
Rump (P8) fat depth (mm)	16	10.6	3.8	0.72*	0.72*

* $p < 0.05$; Pie IMF % is compared to marbling score

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Modified management to minimise calf loss at muster

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Introduction

The extent of cattle reproductive loss in northern Australia is clarified by a recent review (Burns *et al*. 2010), based on reports between confirmed pregnancy and weaning (3.4 to 26.5%). In the first year of an observational study on Old Man Plains Research Station (OMP), south of Alice Springs, reproductive loss (17.9 +/-7.1%) between confirmed pregnancy and weaning for a representative paddock management group (n = 112 mixed-age Droughtmaster cows) exceeded the sum of benchmarks proposed by Fordyce *et al*. (2006) for loss of a foetus (3%), neo-natal calf (5%), and post-natal calf (1%). The study aimed to identify reasons for reproductive loss on OMP, and thereby help develop management strategies to minimise foetal and calf loss.

Methods

Retrospective assessment of foetal and calf loss in a representative paddock on OMP for the first year of the study was based on muster data collected at tagging, branding and weaning of calves, plus field data collected during twice-weekly calving inspections and opportunistic post-mortem inspections. This indicated that 3 (17.6%) of the 17 peri-/ post-natal calf deaths were associated with muster activity in the middle of the calving period (October). Consultation with the cattle managers identified opportunity to modify muster activity and reduce the risk of calf loss. A 'package' of modified muster activities was adopted for the next two years of the study. These activities included: no overnight trapping; no yarding of cows with large udders if 'running back to the paddock for a calf'; drafting calves to process rapidly through the race; and holding cows and calves outside the yard to 'mother up' afterwards.

Results

Assessment of foetal and calf loss in the representative paddock for the second and third years of the study (n = 75 and 99 cows respectively) indicated 9 peri-/ post-natal calf deaths in each year (12% and 9% calf loss respectively), but no peri-/ post-natal calf deaths were associated with modified muster activity at subsequent musters.

Discussion

Although the OMP research herd is control-mated, a muster during the calving period models some of the challenges that central Australian properties have when they muster their continuously-mated, year-round calving herds. Reduced calf loss in a representative paddock on OMP was associated with modified muster activities; this suggests that similar activities could be used by commercial properties to minimise calf loss.

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Excuse me madam, is this your calf?

[A]*Whitney Dollemore*

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Introduction

The process of "mothering up" is practised in a number of cattle herds in northern Australia and is a basic requirement within the stud industry to establish parentage for calf registrations. "Mothering up" is the process of designating a calf to a dam based on the observance of behavioural cues (suckling, body positioning and grooming without agitation). The DPIF "Selected Brahman" breeder herd, located at the Victoria River Research Station, NT, is "mothered up" at weaning. These results are then confirmed by DNA parentage verification. This study aimed to investigate the rate of miss-mothering and identify factors affecting maternal matching.

Methods

In 2013, 2014 and 2015 two "Selected Brahman" paddocks were mustered and walked to the yards. In the late afternoon calves were drafted from their dams and kept in a separate yard overnight. The following morning calves were re-introduced to the cow group and observed by people on horseback until claimed by a dam. The cow/calf pairs were then cut from the group for joint processing and their identification information was recorded and collated with birthdate. Tail hairs collected from each calf and sent to the Animal Genetics Laboratory for DNA parentage verification. The data for cow/calf pairs established by mothering up were compared to parentage established by DNA testing to determine if mothering up had established parentage correctly. Cow and calf age, sex, weaning weight, and date of processing were investigated against the incidence of miss-mothering using logistical regression and chi-squared test in R software.

Results

On average mothering up was found to correctly identify 92% of cow/calf pairs (8% average rate of miss-mothering) (Table 1). This dataset was unable to identify any significant determinants of miss-mothering; calf age (χ^2= 4.4, p=0.22), weight (p=0.19), sex (p=0.88) and age of dam (p=0.2).

Table 5. Overall summary of miss-mothering

Muster date	No. cows	Percent miss-mothered	95% Confidence Interval	
			Lower	Upper
10-May-13	86	10.5%	5.5%	19.0%
23-May-13	64	10.9%	5.3%	21.4%
7-May-14	72	4.2%	1.3%	12.3%
9-May-14	84	13.1%	7.4%	22.2%
12-May-15	79	5.1%	1.9%	12.8%
14-May-15	72	5.6%	2.1%	14.0%
Overall*	**457**	**8.3%**	**5.1%**	**13.3%**

*includes clustering for muster date.

Discussion and Conclusion

None of the factors assessed had a statistically significant effect on the incidence of miss-mothering but there was a tendency for less miss-mothering in older dams. These results show that mothering up is a reasonably accurate method of identifying cow/calf pairs, but if correct parentage is important (eg. for studs on Breedplan) then DNA parentage testing should be used.

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Using performance recording to breed herd bulls on an extensive cattle station in the Northern Territory

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Introduction

Adoption of genetic evaluation and selection tools across the northern beef industry is low. This study was part of a Producer Demonstration Site which aimed to increase adoption by demonstrating the use of performance recording and selection tools to breed herd bulls on an extensive cattle station in the Northern Territory (NT).

Method

Performance recording records were used to select mature Brahman and Brahman x Charbray cows for a bull multiplier herd (n=510) on Helen Springs station, NT. Cows were selected if they had successfully reared a calf for 5 straight years and were due to calve between September 2012 and January 2013. The cows had been mated to purchased Brahman and Charbray bulls. Calves were tagged and weighed soon after birth and birth date, gender and dam ID were recorded. Weight was recorded at weaning on 26/4/13 and male calves were segregated in a separate paddock. Weight and scrotal size were measured at the end of post-weaning dry season on 22/10/13. On 17/7/14, at approximately 20 months of age the bulls were weighed and visually assessed and those not excluded on the basis of temperament, sheath score, deformities and conformation were evaluated for suitability as herd bulls using Bull Breeding Soundness Examination (BBSE) and semen testing.

Results and Discussion

Table 1 summarises the performance data of the bulls that were either selected or not selected for use as herd bulls. The average growth from weaning to 20 months of age was 208 kg (0.47 kg/day) for selected bulls and 182 kg (0.41 kg/day) for those not selected. Of the original 203 male calves weaned, 21 went missing over the 2013/2014 wet season, leaving 182 bulls to be assessed at 20 months. Of these, 118 were deemed unsuitable based on visual assessment, leaving 64 for BBSE and semen testing. One bull failed the BBSE and semen could not be collected from another. Of the 62 bulls semen tested, 14 (23%) failed the semen morphology test (having < 50% normal sperm), 18 (29%) had 50-70% normal sperm and 30 (48%) had >70% normal sperm. As a result 48 of the 203 (24%) male calves weaned were selected for use as herd bulls. A selection index using birth weight, growth, scrotal size, sheath score and semen morphology was developed to rank bulls.

Table 1. Average performance data of young bulls that were or were not selected as herd bulls.

	No. of animals	Birth date	Birth weight (kg)	Weaning weight (kg)	Weight at 20 months (kg)	Scrotal size at 11 months (cm)	Scrotal size at 20 months (cm)
Not selected	134	9/11/2012	34.9	188.9	368.1	19.9	-
Selected	48	13/11/2012	36.6	193.5	400.4	20.5	30.5

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Mating outcome effect on live weight production and efficiency of beef cows

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Introduction

Income from beef herds is primarily determined by annual live weight production (LWP), which for a cow is the change in her live weight between weaning times plus the weight of calf weaned. For a breeding herd, it is a function of weaner numbers and weight, and cow growth and survival. A major question is what is the impact in extensively-managed herds in the dry tropics of failure to conceive ***(E)*** and foetal and calf loss ***(L)*** on live weight production compared to weaning a calf ***(W)***.

Method

Brahman and Tropical Composite females (n=2,127) were first mated at 2 years of age and monitored between 2.5 and 8.5 years of age (Johnston *et al*. 2014). The four age groups of cattle were mated for three months annually on the four major country types in Queensland. LWP ratio (an efficiency measure) was calculated for the 11,566 mating outcomes as annual LWP divided by the average live weight of the cow-calf unit over the year (indicator of feed intake).

Results

Average annual live weight production of cows was:

- 150±43 kg on northern forest, 163±77 kg on northern downs country and 186±69 kg in central and southern Queensland.
- 152±60 kg in the year after first mating and 181±72 kg subsequently.
- 199±59 kg, 125±42 kg and 71±50 kg in ***W, E*** and ***L*** cows, respectively. ***E*** cows started the year in lower body condition (2.6±0.8; 5-point scale) than ***L*** and ***W*** cows (3.2±0.7).
- 190±71 kg, 152±75 kg and 150±62 kg for ***W***, ***L*** and ***E*** previous mating outcomes, respectively.
- 222±53 kg and 132±63 kg in cows that raised six and three calves in six years, respectively. Body condition at weaning (2.8±0.5 *v* 2.5±0.6) and calf weaning weight (208±37 kg *v* 201±36 kg) were higher in the former. Cumulative live weight production was linear in both classes.

Average live weight production ratio was 0.34±0.10 kg/kg of cattle for ***W*** cows compared to 0.26±0.09 and 0.14±0.10 kg/kg of cattle for ***E*** and ***L*** cows, respectively.

Conclusions

Calf loss has a larger impact on LWP of breeding cows than non-pregnancy does, partly because non-pregnant cows are in lower initial body condition. Cows that wean a calf every year appear to have much higher ability to produce live weight from available pasture than low-fertility phenotypes, as indicated by their higher LWP, heavier weaners, better body condition at weaning and higher LWP ratio. A live weight accounting concept was supported, whereby cows with low calf-rearing ability lose live weight over one or more breeding years that must be recovered in non-breeding years to support re-conception and be a bank for future calf rearing. High genetic variation for ability to conceive in tropically-adapted cattle (Johnston *et al*. 2014) may be associated with variation in LWP.

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Reduced costs when using recommended bull to female mating ratios

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Introduction

The Bull Power project (Holroyd *et al*. 2000) concluded that multiple-sire mating using tropically-adapted bulls that are reproductively sound at a rate of 2.5% of cycling females will not jeopardise herd fertility under most conditions in extensive parts of northern Australia where it is still common for producers to use 4-5% bulls. An opportunity to assess the recommended mating ratio arose within a heifer productivity demonstration study north of Charters Towers (Qld).

Methods

Pre- and post-mating monitoring of 334 two-year-old Brahman and crossbred heifers grazing a 2600 ha undulating paddock included pre-mating ovarian scanning and live weight. All bulls used had passed a full BBSE including sperm morphology, had above breed average scrotal size for their weight and were vaccinated against vibriosis. Heifers were sampled for BVDV antibody. Four-month mating commenced in mid-January 2014. Rather than using previous practice of a bull:heifer ratio of ~4% (Option A, Table 1), 2.5% bulls to cycling heifers was used.

Results

Average pre- and post-mating heifer live weights were 291 kg (190-389 kg) and 397 kg (298-512 kg), respectively. Pre-mating (December) ovarian scanning indicated 51% of heifers were cycling or about to cycle, with the expectation that more heifers would cycle as they grew. Bulls mated equated to only 1% of heifers (Option B, Table 1). No adverse effect on pregnancy rates occurred with 70% achieved, similar to preceding years: 65-70%. Nil pestivirus activity was recorded.

Table 6. The financial impact of reduced bull power.

	Option A	Option B
Number of bulls mated	12 (~4%)	4 (1%)
Capital cost @ $3,000/bull	$36,000	$12,000
Net annual bull cost ($434/yr)	$5,207	$1,736
Bull cost per pregnancy	$21	$7

Discussion and Conclusion

Reducing the bull number to mate 2.5% of cycling females appeared to have had no negative impact on pregnancies and a saving of $14 per pregnancy. The business also realised a major short-term saving through reduced capital expenditure on bulls ($24,000) by being able to reduce their bull herd without risk. In addition, a significant reduction in bulls fighting and broken fences associated with an ease in handling were noted. This demonstration supports recommendations from the Bull Power research and where implemented can achieve substantial short- and long-term savings in costs.

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Using the Stocktake Plus mobile app to manage grazing pressure and optimise Grazing Best Management Practices

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Introduction

The FutureBeef Stocktake Plus app is a grazing monitoring and management decision support tool for graziers and advisors predominantly located in northern Australia. It has been developed following the success of the Stocktake workshop, and to maintain pace with an ever changing digital environment. The app is a mobile tool assisting grazing best management practices by helping users to (1) monitor land condition, (2) calculate short-term forage budgets, and (3) balance stock numbers to pasture availability. Since the app's launch in 2013, the 1083 downloads from the relevant app stores have exceeded expectations, and almost three-quarters of them by beef and/or sheep producers.

Methods

A DAF led multi-skilled project team worked with Meat & Livestock Australia and Now Communications Group Pty Ltd (the app development company) using an initial scoping and design analysis in conjunction with developmental and extension phases to construct and promote the app. An external evaluation confirms the app's direction and development (Coutts J&R 2016), and the app continues to be rigorously tested and refined to ensure it is technically functional, reliable, robust and practical for graziers in northern Australia.

Results

Feedback indicates that the app has influenced the decisions of many users regarding property changes, with those having attended Stocktake workshops (or similar) appearing more likely to have done so (Coutts J&R 2016). Changes to managing carrying capacity and stocking rates were the most common, while other changes included increased and improved pasture monitoring, and changes to the timing of rotations, all which support the principles of Grazing BMP. Improved record keeping, particularly the ability to digitally store photos and information all in one spot, was a benefit already observed and valued by a number of users. Other benefits included an increased interest and understanding of pasture management; validation of current practices; and help meet Grazing BMP accreditation requirements.

Discussion

There is generally a positive response to the app by producers and extension officers. The app is widely seen to have value in helping to streamline producer operations and to help in decision making to ensure grazing best management practices are adopted. The data from this review highlighted that the app can effectively help improve landholders' understanding around the concepts of carrying capacity and stocking rates. The app has shown to have potential to contribute to improved land management, helping producers to make the transition to being "grass managers, rather than "cattle managers", as one producer expressed clearly.

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Using climate forecasts to predict pasture growth and live weight gain of cattle

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Introduction

Dynamical seasonal climate models have significant skill in predicting El Niño Southern Oscillation (ENSO) phase, but minimal skill at forecasting the details of daily local rainfall. This questions the possible utility of dynamical models in providing any further useful information to agricultural industries, beyond an ENSO forecast. Here we explore what climate features a dynamical climate model should aim to forecast reliably if they are to be useful in farm management decisions.

Methods

A case study is conducted for the extensively-grazed cattle enterprises in Dalrymple Shire, where predictions of pasture growth can be critical. Pasture growth in this region is dependent upon the interaction of rainfall, temperature, radiation and soil moisture. Forecasts of these variables can be obtained from seasonal climate models and used to generate forecasts of pasture growth.

Results

While ENSO phase is a dominant feature over the crucial wet season (November to March) time period, there are many other factors that contribute. These include: the number of rain days that fall when the soil is dry; the moisture content of soil at the beginning of the season; the likelihood of an "early break" that results in late winter and/or spring rainfall creating a longer than usual pasture growth season; and the interaction of ENSO with other climate modes such as the Indian Ocean Dipole and Australasian monsoon. Climate models cannot predict the details of extreme events, however we find that the impact of a high rainfall event compared to a moderate one is insignificant once the soil is saturated.

Discussion/Conclusions

Ultimately, the potential growth of cattle is the required knowledge and this relies heavily on the seasonal distribution of pasture growth which may be more readily obtainable from a dynamical model than a statistical one. Dynamical seasonal climate models have potential skill in predicting many of these factors, suggesting that they have a role in farm management decisions.

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A novel way to measure Leucaena coverage in the Fitzroy

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Introduction

Leucaena (*Leucaena leucocephala*)-grass pasture is important to the central Queensland grazing industry as it can approximately double beef production and gross margin across a range of land types (Bowen *et al.* 2015). It was estimated that over 150,000 ha of Queensland was planted to leucaena, and is projected to reach 3 – 500,000 ha by 2017 (Shelton and Dalzell 2007). However, no quantitative analysis of leucaena coverage has occurred. This work trials a novel method to quantify the area currently planted to leucaena in central Queensland based on statistical analysis of high resolution satellite imagery.

Methods

We assessed the 1,566,900 ha of the Fitzroy Basin Association (FBA) region. The region was gridded into 10 ha quadrats and 5,691 quadrats (3.58%) were randomly selected for analysis. Using Google Earth Enterprise, the quadrats were visually assessed in sub-meter satellite imagery (2012-2014). Planted leucaena is quite distinct from other crops; having darker green evenly spaced rows typically 5 – 10 m apart. Leucaena coverage in each quadrat was mapped and the area calculated in GIS software. The mean area across all quadrats was then estimated.

Results

Of the 5,691 quadrats assessed, 79 (1.37%) contained planted leucaena, with an average coverage of 67 m^2 per quadrat. Extrapolating these results gives an estimated 106,225 ± 29,212 ha (95% C.I.) currently planted to leucaena across the FBA region.

Discussion

Our work provides a practical and repeatable means of quantifying planted leucaena area. Given the FBA region is the major leucaena adoption region in the state, it suggests previous approximations of adoption (Shelton and Dalzell 2007) could be overestimates. Potential future work includes expanding the current survey, re-monitoring the same sites with newer high resolution imagery and overlaying the results of our sampling on potential leucaena areas (e.g. Dalzell *et al*. 2006) to better understand adoption gaps and target extension activities to close those gaps.

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Utilising Electroconductivity mapping to assess pasture establishment potential in pulled Blackwood soils

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Introduction

The amount of soil variability across a farm and within a field is important for determining potential benefits of adopting precision farming (King *et al*. 2005). However, little is known about the degree of within-field spatial variation in grassland and pasture production (Serrano *et al*. 2010). The grey/brown clays which typify the pulled Blackwood regions of the Belyando and Suttor represent a significant area of grazing for many beef production enterprises. High soil chloride levels have long been noted as an issue in the establishment and persistence of sown pastures on these soils. However, the variability of salt across this land type gives potential for some areas to be more conducive to sown 3P species than others. Using Electroconductivity (EC) mapping we were able to objectively assess these soils paddock by paddock for opportunities to improve the pasture environment and therefore production outcomes.

Methods

A Veris 3100 EC soil mapping unit was utilised to map 30 ha of pasture. Electromagnetic induction readings were recorded in a grid like pattern across the paddock with a GPS location. Runs were no more than 15 m apart in order to maintain good correlation between point data. Readings were taken at 0 – 30 and 0 – 90 cm soil depth for comparison. Four thousand five hundred geo-referenced data points were amalgamated into soil maps using the GIS program Manifold. Areas of high, intermediate and low EC were identified and ground truthed with soil cores taken at 0 – 20 and 30 – 60 cm.

Results

Soil chloride levels varied across the paddock from 40 – 3,200 mg/kg. As a result the EC (1:5) values also varied from 0.43 – 1.92. These areas were accurately identified by the mapping and confirmed through ground truthing. The result was an accurate picture of the production potential of the paddock that could be easily utilised by producers.

Discussion

Our work provides a viable and effective method to gauge the variability of soil chloride levels in an extensive pasture environment. This information can assist primary producers to identify and prioritise areas of their properties for pasture renovation. From the mapping layer, an algorithm might be formed to extrapolate soil salinity across the whole property utilising reflectance imagery. Long-term monitoring of these soils may also show rainfall driven fluctuations in salt levels, and identify additional opportunities to establish pastures in more favourable years.

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