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FOREWORD

It is again my great pleasure to introduce these proceedings for the 2013 Northern Beef Research Update Conference (NBRUC). In so doing I'm acutely aware just how precious are each of the contributions made to the improvement of the northern Australian beef industry. These contributions are made all the more precious by the continued decline in R,D and E capability amongst our leading provider organisations and the gradual ageing of our R,D and E and producer populations.

The North Australia Beef Research Council continues to be a force for collaboration and change to enable the greatest benefit to be achieved from our collective effort. This NBRUC is an opportunity to share our ideas and research outcomes and to celebrate our shared vision and passion for the northern beef industry. May it also be an affirmation to those who work tirelessly for the industry, and in the pursuit of progress. I certainly wish to take the opportunity to thank you all for your contribution, not only to this conference, but to a better tomorrow.

My thanks to the committee which has made this conference happen under the Chairmanship of Michael Lyons.

It remains for us to hope that the results presented at and derived from this conference will make a significant positive impact on how the industry operates in these most trying of times, and show producers struggling in those times that much has been and will continue to be done with their best interests at heart.

Once again, my congratulations and thanks to all concerned.

Ralph Shannon
Chairman
North Australia Beef Research Council

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Is there a place for intensification of northern beef production systems?

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Abstract. Intensification of agricultural industries refers to deliberately increasing input costs through a change in the type, or an increase in the number, of inputs with the aim of producing sufficiently higher returns to justify the increased costs. Examples in the beef industry include fencing and watering point development as well as diversification options such as small scale irrigated agriculture. Currently, there is much research activity investigating various forms of intensification of the northern beef industry, at both enterprise level and regional or industry levels. The impetus for intensification is coming from government, rural communities and the grazing industry itself. Federal and State level initiatives have included the Northern Australian Land and Water Taskforce and the consequent Northern Australian Ministerial Forum. At a more local level, graziers in the Flinders and Gilbert catchments of the Gulf country have been enthusiastically encouraging government to support the release of water for the development of irrigated agriculture on their beef properties. This has been championed by local government and by regional economic development organisations. Northern agricultural development has been espoused for over 100 years yet, to date, the beef industry remains the most successful, large scale agricultural industry in the north. A feature of the current enthusiasm for intensification is that government is supporting the process through funding scientific research rather than allowing development to proceed in the absence of science. Furthermore, that science is considering a large range of factors in an integrated way, including bio-physical, social, economic, environmental and cultural. This paper summarises the context for the science agenda supporting northern development and considers a portfolio of projects that are investigating the natural, human, infrastructure and supply chain resources that might be available. There is no doubt that a range of intensification options are possible. Soil and water resources are available but intensified use of these will require trade-offs and careful consideration of the risks involved.

What 'intensification' means

Intensification, at least in terms of pastoral activities, is a loosely defined term. It refers to any change in activities that requires higher inputs than are currently used. Livestock grazing in northern Australia has traditionally been an extensive, low input system. Intensification suggests a more closely managed system, with the expectation of higher outputs to justify the higher input costs. The term is typically used at two scales; enterprise and industry.

Intensification of infrastructure and the production system at the enterprise scale is perhaps most evident on those properties where cell grazing has been introduced but also includes reducing paddock size and providing more watering points in order to intensify the use of the available grazing land. It also includes more intensive management practices such as early weaning followed by intensive post-weaning nutrition and management. Intensification can also include substantial alterations to the enterprise, such as growing hay or forage using small scale irrigation, or even various types of tourism activities associated with the beef enterprise.

Intensification is also used beyond the enterprise scale to reflect the whole industry, or parts of the industry. For example, graziers in an area might independently develop small scale irrigation as adjuncts to their existing beef enterprise, leading to a loosely defined precinct that benefits the industry as a whole. Improved road, rail, port and yard infrastructure and the building of abattoirs are examples of corporate or government investment in intensification that is of direct benefit to the broader beef industry.

Of course, there is nothing new about intensification. Livestock grazing in Australia's northern rangelands has been intensifying since cattle were first brought into the region and properties moved from simply harvesting cattle to more intensive production systems. Fencing, roads, watering points and today's high technology precision pastoralism are all examples of intensification in the industry.

There is now, renewed and current interest by government, industry and the research community to investigate the potential for a range of intensification options for the northern beef industry. The interest stems from a number of factors including declining productivity gains, declining profitability from traditional forms of cattle production especially those targeted at live export, a willingness to diversify beef production systems from their traditional base and a stated agenda from both major sides of politics to develop industries and increase populations in the north.

Changes in pastoral use

Traditionally, cattle stations ran cattle and beef cattle were the source of almost all of the on-farm income. Government jurisdictions managed pastoral land to run livestock and had little interest in activities that were not directly pastoral related. Indeed, land tenure arrangements across the north actively militated against other land uses on pastoral land either through the land tenure and associated regulations themselves (Productivity Commission 2002) or through making it difficult to access capital because of the insecurity of the leasehold tenure.

That is not to say that there was no interest in using pastoral land for other purposes. There are many examples of profound moves away from beef cattle land use where alternatives existed. Pastoral leases were resumed in the Kimberley to develop irrigated agriculture, both to create Lake Argyle and to provide the cultivated lands of the Ord River Irrigation Area. The Katherine-Douglas-Daly Area has been, and continues to be, developed. Several large privately developed irrigation schemes were tried, for example, the Camballin Irrigation Area which in terms of planned rice production was to be second only in size to the Murrumbidgee Irrigation Area (Yuhun 2001). Nature conservation has also driven land use change. A number of National Parks and other forms of conservation tenure were created from pastoral leases (*e.g.* Litchfield National Park; Kennedy Range National Park). More recently conservation organisations like Australian Wildlife Conservancy and Bush Heritage Australia have bought pastoral lands for private conservation reserves. Indigenous people have also acquired pastoral lands for their own uses. Mining companies have bought pastoral leases for security of access to their mineral resources and to simplify the logistics of mine operations. Lang Hancock was a Pilbara pastoralist who diversified into iron ore. Both farm-stay and more sophisticated tourism (*e.g.* El Questro Station in Western Australia) have profoundly changed a number of pastoral leases.

This trend for change in land use of what was once an unbroken vista of pastoral lands has been termed the "Multifunctional Transition" by Holmes (2010). By quantifying the types of changes outlined above Holmes showed substantial change in tenure, ownership, management and use of pastoral lands in Australia's tropical savannas between 1976 and 2006. This trend continues in Western Australia at least (van Etten 2013). About 20% of the arid and semi-arid pastoral lands from the Pilbara south are now managed by new landholders with interests in mining, conservation and Indigenous use. In many areas, pastoralists now earn much of their income from off-property activities such as earthmoving or mining employment and lifestyle decisions can determine the extent to which livestock production is relied upon to maintain income.

A feature of these examples above was that there was a change in land use, rather than an intensification of existing, pastoral, land use. Increasingly, there is an enthusiasm to intensify production from northern beef cattle enterprises, but in a way that reflects that the intensification is part of, or an adjunct to, the underlying beef cattle operation.

There are several examples across northern Australia where individuals have added irrigated agriculture to their beef enterprises to increase and diversify their income stream. In some cases the additional agricultural production has allowed them to vertically integrate their production, allowing different turn-off strategies and access to different markets. Where once this was seen as inconsistent with a pastoral beef enterprise in both a regulatory and social sense, it is increasingly being seen as just another part of the development of northern Australia into a more heterogeneous production landscape.

From an institutional perspective, the idea of promoting intensification of the northern beef industry was given significant impetus by the Northern Australian Land and Water Taskforce which reported to the Commonwealth Government in late 2009 (NALWT 2009). The Taskforce foresaw a significant increase in the gross value of agricultural production from the north. This growth would be helped by improved transport infrastructure, harmonisation of regulatory frameworks across jurisdictions and changed agricultural systems. For the pastoral industry the Taskforce saw a real opportunity for beef enterprises to implement small scale irrigation systems, mosaic agriculture, to provide increased feed, different turn-off strategies and diversification of income.

The Taskforce recognised that there were a number of improvements that could be made to help this process. They included: governance arrangements; land tenure reform; infrastructure upgrades; intensification of the pastoral industry; carbon markets; increases in the total irrigated land (either through mosaic irrigation or larger precincts); and investment in Indigenous pastoral businesses.

One of the government's responses to the Taskforce's report was the formation of the Northern Australian Ministerial Forum (NAMF). The Forum is convened by the Commonwealth Minister responsible for regional development and includes the relevant primary industry or regional development ministers from WA, Qld and the NT. The Forum meets frequently and is active. It is supported by an Expert Advisory Panel and a panel of Indigenous experts with interests in sustainable economic development.

The NAMF has established the Northern Australia Sustainable Futures (NASF) program that contains a number of projects aimed at fostering the development of northern Australia with many of the projects aimed at developing the northern beef industry through some form of intensification. For example, ABARES was commissioned to report on the risks and opportunities for the northern beef industry across a range of topics including marketing, meat processing, productivity and diversification (Gleeson *et al.* 2012).

Of course, the Northern Australian Land and Water Taskforce was not the only driver of change affecting the northern beef industry. To a large extent, it was already happening. Rural communities were looking to provide a stronger economic base to support the pastoral industry. In the Gulf country of north-west Queensland there were grass-roots proposals for an irrigated agriculture precinct in mosaic style with institutional support from organisations such as the Mt Isa to Townsville Economic Development Zone (MITEZ). The Burton family in the west Kimberley were looking for ways to add to their existing beef enterprise through irrigated agriculture and meat processing (The Australian, 17/12/11) and companies involved in the northern beef industry were looking to intensify the value chain and diversify production. For example, AACo was looking to both develop irrigated agriculture on its properties in the Flinders catchment and make a large investment in a new abattoir just south of Darwin (http://www.aaco.com.au/operations/meat-processing-facility/). Rio Tinto is currently developing irrigated agriculture on its Pilbara properties with the aim of producing 25,000 tonnes of hay each year, as a means productively using mine water (The Australian, 19/1/12, page 17).

Government strategies looked to the development of more agricultural land in the north (NT 2030 Strategic Plan) and state government departments which had been primarily interested in pastoral land use on pastoral lands have been actively proposing intensified use (Chilcott 2009; Strategic Design and Development 2010). Pastoral land tenure was traditionally a barrier to intensification of land use (Productivity Commission 2002) but all three jurisdictions (Qld, WA and the NT) have a land reform process in train which would allow for greater diversity and intensification of use on pastoral lands (*e.g*. Department of Regional Development and Lands 2011; Northern Territory Government 2011). Regulation and legislation in others areas is also being considered. For example, in May 2013 the Queensland parliament passed the Vegetation Management Framework Amendment Bill with the aim of making it easier for landholders to clear land for high value agricultural purposes.

Research for intensification

The North Queensland Irrigated Agriculture Strategy (NQIAS)

In December 2011 the Queensland Premier, Anna Bligh, and the Minister for Regional Development, Simon Crean, announced the NQIAS. This was a $10m strategy designed to assess the scale of opportunity for irrigated agriculture in the Flinders and Gilbert catchments of the Gulf area of north Queensland. While it was recognised that a range of crops and forages including cotton, peanuts, pulses, hay and even tree crops might be produced, the strategy was deliberately focused on irrigated agriculture as an adjunct to existing beef enterprises, rather than a separate irrigation development in its own right. The Strategy was a collaborative initiative of the Australian Government's Office of Northern Australia and the Queensland Department of Agriculture, Fisheries and Forestry and is part of NAMF's Northern Australian Sustainable Futures program. The strategy was launched in response to local community efforts to build the case for investment in irrigation in both the Flinders River catchment (Mt Isa to Townsville Economic Development Zone, undated) and the Gilbert River catchment (Gulf Savannah Development 2009). The NQIAS announcement coincided with enthusiasm from local graziers (*e.g.* the Flinders River Agricultural Precinct) for the Queensland State Government to release water from the "General, unallocated water" category of the Water Resource (Gulf) Plan (2007). A release process for this water was announced in July 2012 and the actual allocation of water to beef producers was announced in May 2013.

The CSIRO was contracted within the NQIAS to assess the prospects for sustainable land and water development in the two catchments. This project will finish in late 2013 and has a number of activities that include land suitability mapping, river modelling, aquatic ecology, groundwater analysis, Indigenous water values, enterprise and regional scale economics, flood mapping and modelling, agronomy and crop modelling (Petheram *et. al.* 2012). Together these activities provide a resource assessment, an assessment of economic viability and an assessment of sustainability. While the project is focused on the Flinders and Gilbert catchments the intention is that the research techniques used will provide a model for assessment of other northern Australian catchments. For example, new techniques of digital soil mapping were applied to create land suitability maps for the area and automated processes have been used to identify potential dam site locations.

The case for mosaic agriculture

The Taskforce made a strong case for research to investigate the potential for small scale irrigated agriculture to supplement northern beef enterprises. The case was made on the basis that available water and soils limited the opportunity for large scale irrigated development in much of northern Australia but sufficient water and arable soils could be found in pockets across the north. Moreover, the beef industry was well established and had the capacity to diversify into small scale crop and forage production to both enhance existing beef enterprises and provide a new income stream. This led to a project within the NASF program investigating the constraints and opportunities for mosaic irrigation across the north. The research, to conclude late 2013, includes soil and land suitability mapping, assessment of water resources, whole farm modelling of the impacts of mosaic irrigation on the beef enterprise, a consideration of legislative and regulatory issues and the environmental impacts associated with mosaic irrigation.

Identifying and improving supply chains and transport logistics

Intensification of the beef industry will only be successful if markets are in place and supply chains are efficient. ABARES and CSIRO, supported by a consortium of institutional stakeholders, are investigating the long term outlook for agricultural commodities, including bulk commodities, high value small volume commodities and emerging products and industries. Six case study regions across northern Australia are being examined for their opportunity.

Improved value chains for the northern beef industry will only be able to realise their full potential if transport logistics are in place to support them. Unlike southern Australia, the north is characterised by a sparse road network and long distances to processing facilities, markets and ports. These supply chains are often cut during the wet season High logistics costs associated with getting products to market make the viability of many expanded or diversified production systems difficult. The logistics are further complicated by driver fatigue, animal welfare and biosecurity regulations as well as differing jurisdictional arrangements.

A further project under the NASF program has worked with meat processors, other beef industry stakeholders and the WA, Qld and NT Governments to identify possible solutions to transport logistic problems (Higgins *et al.* 2013). The project has developed a suite of models including a transport logistics model for the entire northern beef industry as well as more localised models which can be used to optimise the location of new infrastructure or to look for efficiencies in transport movements within the 'catchment' of a particular port or abattoir.

Other intensification research

Much of the beef research in the north contains elements of intensification, although not always explicitly identified this way. Two example projects that explicitly looked at intensification options were the Pigeon Hole project which investigated the potential for intensification through on-property infrastructure development (Petty *et al.* 2012) and a project that sought to identify where the largest research and development gains could be made in the industry (Ash *et al.* 2013).

Risks

Opportunity and risk are close associates. Realising opportunities for northern agricultural development is not, as history has shown, without its challenges (Cook 2009; Yuhun 2001). It is not uncommon for new enterprises to require ongoing government support; development can negatively impact Indigenous and some non-indigenous people (Stoeckl *et al.* 2013); intensification may increase some environmental risks; the distribution of economic costs and benefits is not always clear or favourable.

Fortunately, the current enthusiasm for northern Australian intensification is being supported by integrated and co-ordinated science that is helping to scope and quantify many of the opportunities and risks. Social, cultural and bio-physical research is being used to examine the resources that are available and what the impacts of development might be, thereby allowing the community at large, through government, to make decisions about the trade-offs and synergies inherent in the intensification of use of our natural resources. The comprehensive nature of the NQIAS is an attempt to address the criticism (*e.g.* Cook 2009) that previous research for northern development failed to address long term sustainability issues, Indigenous interests, economic viability and environmental consequences. Moreover, it has been established in direct acknowledgement of the National Water Commission's position statement on "Water management in northern Australia" whereby a number of principles have been designed to ameliorate this risk.

Conclusion

The intensification of the northern beef industry offers an opportunity to fundamentally change its outlook on the future. Unlocking significant new investment in intensified beef production requires confidence about the scale of opportunities and the risks that attend them. We are fortunate that there is currently the will and ability to identify and quantify both opportunities and risks, and their distribution amongst stakeholders.

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Extension: what works well?

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Introduction

Extension: what works well? While seemingly a simple question it is actually quite complex to facilitate change given the variety of situations and the highly contextual nature of extension. The critical factors that determine how successful extension is depend on the objectives of any particular campaign and the organisation that is the driver for change. This paper seeks to stimulate discussion and debate on what extension works well by dividing the debate. Firstly that extension is primarily about the technology being "right" and secondly that it's about the structures underpinning the extension process being adequate. After providing some insight into these two components and summarising the principles, an overarching discussion is provided on what works well. In, conclusion, it's a combination of ensuring that both the technology process and the structures underpinning the process are equally accounted for in any extension strategy and importantly, that the roles in the extension process of the various stakeholders are clear and there isn't duplication or confusion in the market place.

Extension and the multiple roles of the process

A widely accepted definition of extension is provided by the State Extension Leaders Network (SELN, 2006):

> *Extension is the process of enabling change in individuals, communities and industries. It improves practice in two significant areas: increasing the sustainability of production, and enhancing natural resource management.*

As a process, it is a critical component to the research and development continuum. With more than AU$78 million invested into red meat production and environmental research and development (R&D) last year (MLA, 2012) by Meat & Livestock Australia (MLA) alone, the imperative for extension to be effective in ensuring this investment has maximum impact has never been so strong.

Defining exactly what effective extension is depends on the role and objective of the process along with whom or what is driving the process. In general, the driver can typically be an organisation such as a research and development corporation (RDC) that is seeking to ensure the R&D achieves broad industry good and has an impact on industry performance. The role an RDC plays in the extension process is largely based on ensuring the RD&E continuum is maintained, and the platforms for delivery to industry are maintained. This includes:

- understanding the needs of producers to build profitable, productive sustainable businesses;
- packaging R&D outputs into a product or process that enables producers to engage with it and build knowledge, skills and potential adopt an innovation;
- aligning producer needs with the extension package and ensuring there are multiple mechanisms for producers to be made aware of the opportunity and engage with it;
- ensuring there are systems to measure and evaluate the impact of R&D uptake (or extension) at the regional and national level; and
- develop partnerships with extension delivery organisations within the public and/or private sector.

Public good extension is still carried out by the State departments of agriculture, with a level of regulatory extension delivery roles (e.g. biosecurity), but also an industry good role in building industry productivity, profitability and sustainability. Public investment in extension has been a key 'lever' that Australian governments have used to promote agricultural productivity growth (Sheng *et al.* 2011). However, notwithstanding Australian governments' commitment to increasing productivity, debate continues over the role governments should play in funding agricultural R&D and extension **(**Productivity Commission 2011).

Along with public sector R&D investment, extension investment has also declined, from 24 per cent of total public agricultural R&D and extension in 1952–53 to around 19 per cent in 2006–07 (Sheng *et al.* 2011). This decline reflects the withdrawal of state and territory governments from providing extension services and has been accompanied by increasing private sector involvement in some jurisdictions. The implications of this means the role that the public sector has in extension is becoming increasingly unclear at a national level.

Private good extension is driven by producers themselves. The extension process might be an individual working directly with a consultant or group of producers that drive the extension process with their own agenda and objectives for building their own knowledge, skills or confidence in a particular area of their business, or trialling and potentially adopting an intervention. An example of this is the Birchip Cropping Group, a not-for-profit agricultural research and extension organisation led by farmers in the Wimmera, Victoria.

Does it work well when extension is driven by the technology?

Typically, adoption or non-adoption of a particular technology or innovation provides the basis to the extension objective and process. The commentary for generations has espoused what constitutes good extension, as demonstrated by particular trends and innovations in methodology. Pannell *et al.* (2006) conclude an innovation needs to be 'adoptable' and prove to be sufficiently attractive to the target audience in order to be implemented. They established that adoptability, is driven by a dynamic learning process that involves becoming aware of the opportunity and then trialling and adapting the innovation to decide whether to adopt or not. It is also driven by social, cultural and personal influences.

Commonly, it's Rogers (2003) five factors that influence adoption of a technology or practice that is used to determine adoptability:

- *Relative Advantage* – is the degree to which the innovation is perceived as better than the idea, practice or object that it supersedes. It is measured in terms of economics, social prestige factors, convenience and satisfaction. It does not matter so much whether an innovation has a great deal of objectively measured advantage, but rather whether the individual perceives it as advantageous. An innovation that an individual perceives as providing relative advantage is more likely to be adopted by that individual.
- *Compatibility* – is the degree to which an innovation is perceived as being consistent with the existing values, past experiences and needs of potential adopters. The adoption of an incompatible innovation requires the adoption of a new value system compatible with the innovation, which is typically a very slow process. The more compatible an innovation is with an individual's values, past experience and needs, the more likely it is that the individual will adopt that innovation.
- *Complexity* – refers to the degree to which an innovation is perceived as being difficult to understand and use. The more simple an innovation is to understand and use, the more likely that it will be adopted.

- *Trialability* – refers to the degree to which an innovation may be experimented with on a limited basis. Innovations that can be trialled on a limited basis before an adoption decision is made are more likely to be adopted.
- *Observability* – is the degree to which the results of an innovation are visible to others. The easier it is for individuals to see the results of an innovation, the more likely they are to adopt that innovation.

Pannell *et al.* (2006) concluded the two main characteristics of a technology or practice that determines its adoption or non-adoption is its relative advantage, usually dominated by profit drivers and trialability which is impacted on by factors such as cost and lag time until results can be viewed. Barnett (2006) adds to this and concludes there are two other factors that affect the rate and extent of an innovation being adopted:

- *Communication Channels* – are the mechanisms through which information on the innovation is delivered to target adopters at various stages of the adoption decision process
- *The Social System that is targeted by the innovation* – refers to the culture, structure and customs of the target market.

From this, one could then argue that extension works well when it is driven by the technology, if these key factors in the adoption process are accounted for in the design of any extension program. However, this assumes that the platform for delivery is well organised, has appropriate levels of resources, and there is clarity in the roles and responsibilities of organisations involved in the extension process.

So is it all about the structures underpinning the extension process?

Structures that underpin the extension process refer to how well the platform for delivery is organised. Fundamentally, this includes key components to extension strategy development, execution and evaluation:

- Where the extension process is linked with R&D (as opposed to a biosecurity campaign), extension is planned from the outset of the R&D project development.
- Clear extension strategy development with defined hierarchy of objectives, key performance indicators, methodology that aligns with the objectives and evaluation measures.
- The extension strategy is developed in collaboration with all organisations that will co-invest in the process. This usually includes public sector representatives, private sector deliverers and producer representatives who will assist to regionalise the process and ensure relevancy.
- Any strategy is underpinned by a thorough situation analysis that helps to shape the compelling argument for engagement. This data should provide an assessment of the issues impacting producer business performance but also understanding the skill base of producers.
- Exploration of innovative models of delivery e.g. e-extension and ensuring there are multiple mechanisms available to appeal to a wide variety of learners.
- The roles in the extension process are clearly defined and maintained. This refers to having the right delivery organisations delivering the right programs e.g. public good programs are delivered by the public sector and private good activities delivered by the private sector.
- Ensuring there is enough, well trained deliverers available to provide the level of service required for any campaign to be effective. This may require capacity building activities that involve a large proportion of service providers that work with producers in a region e.g. agribusiness, banks; and
- Ensure there is a robust monitoring and evaluation strategy that tracks the economic, social and environmental impacts of the extension investment.

Overall this suggests extension should work well where there is a collaborative strategy in place that accounts for each of the above points. However, in reality it is rarely achievable to account for all these aspects largely due to limited resources and robust structures that enable appropriate strategy development to occur and overall confusion on who the driver should be of the extension process.

Extension: what works well?

Extension works well in theory when there is a good combination of ensuring that both the technology driven process and the structures underpinning the process are equally accounted for in the planning and execution of any particular campaign. In reality it is difficult to achieve this, as nationally there is still much confusion on the roles of different organisations in extension, exacerbated by the changing roles of the public sector across jurisdictions.

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Managing 'rundown' in grass pastures

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Abstract. Productivity decline in sown grass pastures is widespread in northern Australia and has been estimated to reduce production by approximately 50%. The economic impact of the decline has been estimated at over $17B at the farm gate over the next 30 years. Buffel grass (*Pennisetum ciliare*) is the most widely established sown species in northern Australia (>75% of plantings). The decline in pasture productivity with age is directly attributable to a lack of available nitrogen (N) in the soil as the nitrogen and other nutrients become 'tied-up' in soil organic matter, roots and crowns of old grass plants. This lack of available nitrogen limits dry matter production and may be exacerbated by overgrazing that can lead to reduced pasture condition and land degradation. Industry has used a variety of management options to cope with rundown in grass pastures that fit into one of the following groups: (a) accept lower pasture production, (b) increase the rate of N cycling or (c) add additional N to the pasture. The most commonly used management practice has been to accept lower pasture production and reduce stocking rates to maintain land condition and animal performance through either not adopting or having poor results from other options. Some management options used by industry provide marginal returns. The best economic return and most sustainable long term option is to establish well adapted legumes. However commercial results from legumes established into grass pastures have been mixed with notable successes but many failures. Consultation with industry, scientific literature and economic analysis has confirmed that legumes provide the best option for improving productivity of rundown sown grass pastures. Research, development and extension priorities are therefore predominantly about improving the reliability and performance of legumes sown into grass pastures. R,D&E priorities include: (1) Improved use of existing management options (*e.g.* improved understanding of causes, costs and options by industry); (2) Improve the reliability of establishing legumes and rhizobia into existing grass pastures; (3) Improving production from legumes (*e.g*. through plant nutrition, rhizobia effectiveness, N fixation rates and grazing management); (4) Legume adaptation (*e.g*. improved understanding of the adaptation limits of commercially available legumes and targeted evaluation for better varieties); (5) Legume seed supply constraints. Industry needs to address the apparent market failure in availability of legumes if large areas are to be established; (6) Improved understanding of buffel grass physiology, genetics and productivity.

Sown pastures in northern Australia

Well adapted sown pastures enable higher productivity and profitability in grazing enterprises because they can produce more feed, of a higher quality, for a longer period of the year than native pastures . They have been widely sown in northern Australia and continue to improve production and economic returns from grazing, especially the beef industry (Walker *et al.* 1997).

Of the total area planted to sown pasture in northern Australia, 70% has been sown only with tropical grasses with buffel grass (*Pennisetum ciliare*) being the most widely adapted and planted sown species comprising over 75% of the area sown to tropical grasses (Walker *et al.* 1997; Walker and Weston 1990).

Pasture rundown

Sown pasture grasses are very productive when they are planted after clearing virgin forest or into fertile cropping soils. However, the productivity of these pastures typically declines with time, a phenomenon often described as "pasture rundown" (Myers and Robbins 1991). The annual dry matter production from sown grass pastures can decline by 50 – 60% within five to ten years of establishment across a range of soil and seasons (Graham *et al.* 1981; Myers and Robbins 1991; Radford *et al.* 2007). Animal production shows a similar trend with a linear decline of 20-70% in live weight gains over the first five years of pastures when stocking rates are held constant (Radford *et al.* 2007; Robbins *et al.* 1987). However, individual animal performance may be maintained if stocking rates are reduced (Burrows 1991; Radford *et al.* 2007). The economic impact of pasture rundown to Queensland's grazing industry has been conservatively estimated at over $17 B at the farm gate over the next 30 years (Peck *et al.* 2011).

The majority of soil nitrogen (N) is in organic forms; however plants can only use mineral forms of N in the soil. The decline in pasture productivity with age is directly attributable to a lack of plant available nitrogen in the soil as the nitrogen and other nutrients become 'tied-up' in soil organic matter, roots and crowns of old grass plants. The large quantities of dry matter produced initially when pasture grasses are established is a response to the high levels of available nitrogen and water that accumulate on fertile soils during a fallow prior to planting. However, dry matter production and subsequent animal performance decline as the available N reserves decline and become less available to pasture grasses (Graham *et al.* 1981; Robbins *et al.* 1987). The reduction in dry matter production can result in overgrazing if stocking rates are not adjusted accordingly, which in turn can lead to poor land condition and land degradation.

Land condition and pasture rundown clearly interact and a reduction in land condition will exacerbate the rundown process, however land condition and nutrient tie-up are separate processes. Land condition can change independently of the amount of available nitrogen and nutrient tie-up occurs even when land condition is maintained at a high level. The remainder of this paper will discuss pasture rundown, which is nutrient tie-up, independent of land condition.

Management options for rundown sown grass pastures

The reduction in productivity of sown grass pastures as they age is due to a reduction in the supply of available N in the soil. With age since sowing, more of the mineral N is incorporated into organic material and its subsequent availability for plants each growing season is governed by the rate of mineralisation. Strategies for mitigating the impact of pasture productivity therefore need to either:

- Accept the reduction in pasture productivity and adjust management of other aspects of the farm business to maintain animal, environmental and economic performance.
- Increase the rate of N cycling. N is mineralised and made available to pasture plants through the decomposition of organic matter, therefore those practices that increase the rate of decomposition increase the rate of N supply *e.g.* mechanical renovation.
- Add addition N to the pasture sward through either fertiliser or biological N fixation (*i.e*. legumes).

Table 1 summarises specific management practices into their mode of action described above. Graziers have tried a wide range of mitigation strategies to reduce the impact of pasture rundown (Peck *et al.* 2011), the most commonly used approaches are:

- Live with rundown and accept lower production. In effect this is the most common strategy used with graziers reducing stocking rates to maintain land condition and animal performance through either not adopting or having poor results from other mitigation options.
- Mechanical renovation ranging from single cultivations (*e.g.* chisel ploughs, ripping or blade ploughing) through to short term cropping or crop/pasture rotations has been used by industry. However, the most commonly used mechanical renovation treatment used has been blade ploughs used primarily for woody weed control with the side effect of stimulating the release of N from soil organic matter.
- Legumes for improved feed quality and nitrogen fixation. These benefits are recognised through improved land prices for established leucaena but not for other legumes. Producers reported mixed results from legumes with notable successes but also many failures. The most common point of failure of legumes is poor establishment, however industry routinely

uses low cost, low reliability establishment techniques when establishing legumes into grass pastures (except for when establishing leucaena).

Table 1. Management practices for mitigating the impact of pasture rundown group by mode of action. Adapted from scientific literature, focus group workshops and phone surveys across southern and central Queensland (Peck *et al.* 2011).

Accept lower pasture production	Increase nitrogen cycling	Increase nitrogen inputs
Reduce stocking rates	Mechanical disturbance (regrowth control)	Legumes
Supplement stock	Mechanical disturbance (cultivation)	Fertilizer
Develop another paddock	Crop/pasture rotation	
Buy more land	Herbicide renovation (?)	
Invest in other aspects of the business	Grazing management (?)	
(*e.g*. water, genetics, fences, off-farm)	Slashing (?)	
Plant grasses more tolerant of low	Biological treatments (?)	
fertility	Tree rotations (?)	
	Fire (X)	

Notes: The most commonly used management options by graziers are underlined. ? – practices that has marginal or no improvement in production or has not been well studied; X – tested in trials and showed no improvement in pasture growth over a whole growing season.

Peck *et al*. (2011) conducted whole farm economic analysis to compare 12 strategies that industry has used to increase productivity on ageing buffel grass pastures across four districts of inland Queensland (Peck *et al.* 2011). Mitigation strategies were dry season protein supplements, nitrogen fertiliser (2 rates), mechanical renovation (3 methods), renovation with herbicides and legumes (leucaena and other legumes established 4 different ways). Mechanical renovation appears viable only for high production pastures (*i.e*. higher rainfall districts and higher fertility soils). Returns from mechanical renovation can be improved significantly if used to successfully introduce a legume. Herbicide renovation does not seem to be viable from this analysis. Nitrogen fertiliser was not viable at any location unless repeated fertiliser applications results in a build up in soil N levels. Dry season protein supplementation provided marginal returns at all locations. Legumes were identified as the most cost effective mitigation option with the potential to reclaim 30-50% of lost production providing whole farm returns of up to $1,300/ha over 30 years, and benefit:cost ratios of 4 -10.

Legumes have been identified as the best long term option for improving the productivity of rundown sown grass pastures. Legumes can improve production of rundown grass pastures through biologically fixing atmospheric N and thereby improving diet quality directly through providing higher quality forage and indirectly by improving the growth and quality of companion grasses from increased N availability. However, commercial use of legumes has achieved mixed results with notable successes, but many failures. The production potentials of many legumes recorded from research trials is often much higher than what is generally achieved commercially. There is significant opportunity to improve commercial results from legumes using existing technologies; however, there is a need for targeted research to improve the reliability of establishment and productivity of legumes.

Research, development and extension priorities

Consultations with industry (graziers, seed industry and researchers), scientific literature and economic analysis have confirmed that legumes provide the best opportunity for improving productivity from rundown sown grass pastures. However commercial results from legumes have been mixed and their potential needs to be considered relative to other management options. R,D&E priorities therefore focus on improving results from legumes in buffel grass pastures with the following topics identified:

1. Improved use of existing mitigation technologies. Specific areas for investment include building graziers understanding of causes, costs and options for managing rundown pastures; assess, compare and demonstrate the commercial results from different management options; and developing management packages for the most promising emerging legumes.
2. Improving the reliability of establishment of legumes and rhizobia in existing grass pastures. Agronomic practices developed for cropping and leucaena need to be adapted for use with small seeded legumes. Rhizobia establishment (not just the legume plant) is critical for successful legume pastures and improved establishment methods are required especially for small seeded legumes planted in summer.
3. Improving production from legumes. Plant nutrition; rhizobia effectiveness; N fixation rates; and grazing management all have a role to play in improving productivity from grass/legume pastures and are not well understood for most tropical legumes.
4. Legume adaptation. For legumes to be successful they need to be persistent, productive and well adapted to the environment (soils and climate) where sown pastures occur. There are well adapted legumes for many environments but there remain significant gaps (e.g. light soils in southern inland Queensland). The adaptation limits of commercially available legumes used with buffel grass pastures is not adequately described.
5. Legume seed supply. Seed of several of the most promising legumes is often in short supply. Industry as a whole needs to address this apparent 'market failure' if large areas of legumes are to be established.
6. Buffel grass ecology, physiology, genetics and productivity. Buffel grass is the most economically important sown pasture species in northern Australia, however its physiology and production characteristics are not as well understood as most crop species.

There are a number of current projects addressing several of these R,D&E priorities, however a sustained effort will be required to assist industry in improving productivity of rundown sown grass pastures.

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Pasture legumes in Queensland – a new wave?

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Abstract. The beef industry has contributed significantly to the Queensland economy for more than 150 years. The productivity of beef enterprises depends primarily on the availability of high-quality feed. The use of sown legumes to supplement sown and natural grasses is a well-accepted method to increase ruminant growth, through increasing feed intake and the uptake of nutrients by grazing livestock. Nitrogen fixation by legumes can also promote growth of companion pasture plants. A considerable investment by (mostly) federal and state government agencies, often co-funded by research and development corporations, contributed to the development of pasture legumes prior to the mid-1990s. Comprehensive programs resulted in the importing and evaluation of thousands of potentially useful legumes, some of which were released as cultivars, and the development of a globally significant genetic resources collection. Legumes, including *Aeschynomene, Centrosema, Chamaecrista, Desmodium, Leucaena, Macroptilium, Macrotyloma, Neonotonia, Stylosanthes* and *Vigna* and, in later years *Arachis, Clitoria* and *Desmanthus* were released. These provided well-adapted, (mostly) perennial pasture legumes for many grazing environments in Queensland. However, reviews completed by researchers in the 1990s emphasised the need to identify well-adapted and productive legumes for certain pasture zones, particularly the brigalow/gidgee, northern bluegrass (clay soils) and *Bothriochloa/Aristida* communities. Other high priority areas included developing disease-resistant *Stylosanthes* and insect-resistant *Leucaena* and legumes to address nitrogen run-down in dry-land cropping soils. The capacity for government agencies to develop new legumes has declined markedly over the last 15 years. New, less resource-intensive methods have been used by governments, universities and seed companies to identify and develop new legumes. These benefit significantly from previous research efforts, and include: development of promising lines identified by (often retired) researchers or from recently developed forage selection tools and selection of plants from old plant evaluation sites. Some breeding and selection is being conducted by universities and seed companies. There remains good collaboration between the public and private sector and there are indications of a revival in sown pasture development in Queensland. The development of a new *Desmanthus* cultivar for seasonally dry environments in central and northern Queensland is presented as an example of recent approaches to legume development.

Introduction

Beef production has a long productive history in Queensland. Beginning in the 1840s, the beef herd rapidly increased to about 10 M AE by 1895 and, except for a period of rapid decline between 1895 and 1903 associated with drought, pest and weed damage to grasslands, steadily increased to about 11 M AE by 1990 (Walker and Weston 1990). The beef industry contributes significantly to the Queensland economy and is valued at ~AUD 3 280 M today (Queensland Government 2011).

Vast native grasslands historically provide the principal grazing resource of the beef industry in northern Australia. These total about 172 M ha in Queensland alone (Walker and Weston 1990), and include sub-coastal and inland areas containing beef breeding and growing operations. The grasslands have been categorised into broad pasture communities, these in turn influenced by soil-type and annual rainfall. Their capacity to produce livestock has been estimated as well as their state of 'health' under grazing and weed pressure (Tothill and Gillies 1992). Important beef finishing operations have also been developed in higher rainfall areas, particularly on the wet coast and tablelands where sown grass and legume pastures are used on cleared land.

Legumes sown in combination with sown grasses or native grasslands today comprise the core feed-base for the beef industry in Queensland. Most were introduced into Australia from Africa (most grasses), central and southern America (most legumes) and, to a lesser degree, Asia. Plants were sourced from overseas because it was perceived that Australian native pastures, where present, did not produce sufficient high-quality biomass for sufficiently large periods of the year to provide satisfactory animal growth rates and reproductive performance. Indeed, the adoption of sown pastures has been associated with a trend of decreasing age of cattle at slaughter, from 3-5 years in the past to 2-4 years in 'recent' times (Walker and Weston 1990). It should be noted this is a combination of using more productive plants and tree clearing.

Reviews were periodically conducted to estimate the value of sown pastures to the beef grazing industry. By the mid-1990s, the net present value to the beef industry in north Australia was estimated at AUD 712 M with an annual gross benefit of AUD 80 M (Walker *et al*., 1997). Significantly larger benefits were estimated in another review (Chudleigh and Bramwell 1996).

The 'first wave' of pasture legumes

The growth of beef livestock, if otherwise healthy, is primarily based on feed intake and digestibility of feed (McLennan *et al.* 1998). Sown legumes in pastures can improve total usable nutrient supply to the grazing animal, through (1) providing higher levels of dietary protein (although much may be degraded in the rumen) combined with similar or higher digestibility than provided by grasses for significant periods of the year, and (2) through the fixation of atmospheric nitrogen and cycling of nitrogen so it is available for the growth of companion plants (like grasses). Legumes increase dietary intake of energy and protein through providing nutrients otherwise limiting rumen activity. These factors increase supply of metabolisable energy and protein to the intestines.

The benefit of developing new legumes to compliment sown and natural grasses has long been recognised in Queensland. Here, we consider the first wave of legumes to be the period prior to about the mid-1990s, when large-scale industry co-funded programmes effectively ended in Queensland. Large, well-resourced teams of federal and state government and university researchers identified deficiencies in pasture systems, completed targeted collections of legumes (and grasses) from overseas, generated seed required for evaluation, completed field evaluation and progressed useful types to cultivar status. The process was usually highly coordinated, with a strong emphasis on scientific rigour, publication and peer review. Most varieties went through a structured release protocol overseen by the North Australia Pasture Plant Evaluation Committee (NAPPEC), a group of government and university researchers and seed company representatives, prior to release. Most were public cultivars, but a number of proprietary cultivars were released during the 1990s.

Cultivars were developed using a variety of routes, sometimes 'in-house' and sometimes in coordinated plant development programs, usually with co-funding from the beef and/or dairy industries. Some of these programs involved assessment of a wide range of grasses and legumes across a range of soils and environments (Pengelley and Staples 1996), while others targeted the development of legumes for specific purposes (Bishop and Hilder 2005; Clem and Jones 1996). By 1997, 130+ grass and legume cultivars had been released in Queensland (Hacker 1997), although many are not in use today. Collections of genetic material (seeds) and root-nodule bacteria were developed concurrent to, and acted as a key resource for, these programs (Hacker *et al.* 1997).

Unlike for temperate zones where a small number of genera and species are used for beef and dairy pastures, a wide range of genera and species are used as pasture plants in Queensland. Key genera developed included *Aeschynomene, Centrosema, Chamaecrista, Desmodium, Leucaena, Macroptilium, Macrotyloma, Neonotonia, Stylosanthes* and *Vigna* and, in later years *Arachis, Clitoria* and *Desmanthus* were added (Hacker 1997). Short-term pastures or green manures (*Lablab*) and important genera otherwise used in cooler areas (*Medicago, Trifolium*) were also developed.

The impact of legumes on enterprise productivity and profitability has been measured over some 30 years in various experiments, mostly conducted by government and university research staff. Benefits include increased rates of animal growth, reproductive performance and stocking rates. The impact of *Stylosanthes* in north Queensland provides a good example. In a producer demonstration site conducted on lighter soils near Georgetown (1987 and 1994), the inclusion of *Stylosanthes* in native pastures improved weaner liveweight gain (of weaners provided the same supplements) between May and August by 45% if fertiliser was not applied at sowing and by 90% if fertiliser was applied (Anon 1994). This enabled a tripling of stocking rate and increase in annual liveweight gain from 60–120 kg/ha on native pastures to 120-160 kg/ha with fertilised *Stylosanthes*.

Priorities for sown pasture development were reviewed in the mid-1990s, preceding a reduction in investment by the federal and state governments during the 2000s. The capacity for current legumes to meet the needs of the beef industry (Queensland Beef Industry Institute 1998) and priorities for future plant development were identified (Walker *et al*. 1997). Overall, it was considered there were at least one or two well-adapted, productive legumes for beef enterprises on most pasture communities in high and moderate rainfall areas. In sub-coastal areas, which carry much of the beef herd, there was said to be legumes for the tropical tallgrass, northern speargrass and southern bluegrass areas, but few for the southern speargrass, brigalow/gidgee, northern bluegrass (clay soils) and *Aristida/Bothriochloa* zones. There was concern over the nitrogen-fixing capacity of some emerging legumes and the persistent threat of disease (*Colletotrichum gloeosporioides*) to *Stylosanthes* and insect pests to other legumes of strategic importance like *Leucaena*. Other priorities included developing ley legumes for dry-land cropping systems in central and southern Queensland to address declining soil nitrogen (Hacker *et al*, 1997; Walker *et al* 1997).

In a previous review (Walker and Weston 1990) it was noted that about 70% of sown pastures were grass-only and these are only productive for 4-10 years after sowing before productivity declines, mostly due to the 'tie-up' of available nitrogen. Reversing this decline through altered management, including the use of legumes, would be of considerably benefit the beef industry.

Recent development of legumes in Queensland

Efforts to develop new legumes over the last 10 or so years have been characterised by (1) a reduction in the number developed by federal and state government agencies, reflecting a marked reduction in the capacity of the public sector to develop new pasture plants and, (2) an increased number of routes to legume development, including more involvement by universities and the private sector (Table 1). The period has also seen the demise of NAPPEC and the Tropical Grasslands Society and uncertainty over the future of the ATFC.

To maintain momentum in the development of new pasture plants, public and private agencies have (mostly) employed less resource-intensive methods to identify and progress new legumes than in the past. Most of these rely on information or resources developed during the comprehensive programs of the 1980s and 1990s. For example, knowledge retained by (mostly) retired government researchers has been used by Queensland Government and private companies to identify potentially useful *Arachis, Macroptilium* and *Stylosanthes*. Information captured in the *Tropical Forages* website, a web-based selection tool developed to capture international knowledge before it was lost, was also used to identify high-performing international lines for use in northern Australia (*Desmanthus, Stylosanthes*). The selection of pasture legumes from disused government plant evaluation sites, mostly on commercial properties, is a recent method employed by university and state government researchers to identify persistent pasture legumes for areas where few, if any, are available. These include *Desmanthus* for central and northern Queensland (see below) and *Stylosanthes* for southern and central Queensland. The maintenance of plant evaluation records, through the Queensland Government QPastures database, has proven useful for this approach.

Table 1. Examples of legumes recently progressed in Queensland.

Legume species	Period	Route of development[1]	Potential role(s)
CSIRO			
Clitoria ternatea *Desmanthus* spp. *Lablab purpureus* *Macroptilium* spp. *Vigna* spp.	Late 1990s to early 2000s	ATFC > QGS > CSIRO	Leys in cropping systems. Domestic and international application.
Queensland Government			
Arachis pintoi and *glabrata*	Late 2000s to present	ATFC+RS(U) > QGS > SC?	Perennial legume hay alternative to lucerne in north Queensland
Desmanthus virgatus	Mid 2000s to present	Imported > QGS > SC	Drought-tolerant pasture legume for loam and clay soils
Stylosanthes guianensis	Mid 2000s to present	Imported > QGS > SC	Disease resistant pasture and hay in higher rainfall areas
Stylosanthes spp. (*scabra*)	Early 2010s to present	RS > QGS > SC?	Pasture legumes for light-textured soils in central/south Queensland
Private companies			
Macroptilium atropurpureum	Early 2010s to present	ATFC > QGS > SC	Pasture legume for soils with moderate fertility
Macroptilium bracteatum		BS > QGS > SC	Leys in cropping systems
Macroptilium gracile		ATFC > QGS > SC	Leys in cropping systems
Vigna parkeri		ATFC > QGC > SC	Pasture legume, high rainfall areas
Universities			
Desmanthus bicornutus + D. virgatus+ D. leptophyllus (	Late 2000s to present	RS > QGS > CSIRO>U>SC/U	Drought-tolerant pasture legume for loam and clay soils (composite)
Leucaena spp.	Early 2000s to present	BS(U) > SC/U	Psyllid-resistant browse legume for seasonally dry areas

[1] ATFC = Australian Tropical Forages Collection; BS = breeding/selection QGS = Queensland Government Seed Unit; RS = selection from old plant evaluation sites; SC = seed company; U = university collaboration.

There remains good collaboration between the various parties enabling sensible use of limited resources. In general, promising lines are identified (mostly) independently of the other parties, seed increase is completed at the Queensland Government seed production facility at Walkamin in north Queensland, and this seed returned to the party for evaluation. Where deemed suitable to progress further, the seed is further increased at the Walkamin facility for commercial adoption by the Queensland seed industry, based mostly in north Queensland.

Following is an example of a recent approach to develop desmanthus, a perennial legume for seasonally dry areas in central and north Queensland.

The development of Progardes desmanthus and future potential within *Desmanthus*

The need for tropical pasture legumes for beef production in northern Australia's extensive areas of alkaline clay soils has long been recognised. These soils present major challenges for establishing and growing legumes including surface-sealing, seasonal shrinking/cracking and alkaline reaction. The loss of forbs and poor persistence of legumes under grazing has been a key problem in these areas (Pollock (cited by Burt 1993); Orr and Phelps 2013). Such losses must be detrimental to ecosystem function and long term sustainability of the grasslands, and therefore to animal production (Tothill and Gillies 1992). In the semi-arid, seasonally dry (up to 6 months) regions of northern Australia, grass pastures decline considerably in nutritive value resulting in poor growth of livestock with subsequent consequences on herd productivity and profitability. The introduction of suitable legumes adapted to such environments could enhance grassland function and productivity of beef enterprises within this region. Such legumes could also play an important role in ameliorating 'run-down' in buffel grass pastures (Peck, this conference).

In the wetter, eastern clay soil areas of central Queensland's Brigalow region *Clitoria ternatea, Macroptilium bracteatum, and Stylosanthes seabrana* were released in the 'first wave' of legumes, with varying degrees of success. 'Jaribu' desmanthus, a blend of *D. leptophyllus*, *D. pubescens* and *D. virgatus* was released in the early 1990s (Cook *et al*. 1993). However, west of the 500 mm isohyet (and in the Gulf) comparatively little research and development of pasture legumes had occurred yet these are important beef and sheep producing regions.

The development of Progardes desmanthus has its origins in the first wave of legume development. Plant collection trips by federal and state government researchers were undertaken to the Americas, seeking pasture legumes suitable for (but not only) clay soils and seasonally dry environments. *Desmanthus* was one legume genus targeted, with, for example Reid (1983) noting that *Desmanthus* often occurred with buffel grass (*Cenchus ciliaris*). Introductions of ecotypes were completed (discontinuously) between the 1950s and 1990s. CSIRO and the Queensland Government established 6 legume evaluation sites, containing some 20 species of legumes, across the semi-arid, cracking clay region of north and western Queensland. *Stylosanthes* accessions initially appeared successful, but when revisited two decades later only accessions of *Desmanthus* remained at each site. Since establishment in the 1980s, these plants had persisted under grazing and survived pests, frost, drought and floods. This was considered potentially beneficial for the grazing industry.

James Cook University (JCU) researchers collected seeds of the best survivors at sites in the Mitchell Grass Downs Bioregion (on cracking clays and associated soils and land types such as Gidgee) and selected promising types. Seed increase was conducted at JCU and the Queensland Government facility and further small-plot evaluations of these, and other accessions from other abandoned sites in trials across north and western Queensland, led to further selection and the development and release of Progardes (www.progardes.com.au) by Agrimix Pty. Ltd., JCU's commercialisation partner. Progardes is a blend of *D. bicornutus*, *D. leptophyllus* and *D. virgatus* accessions with a range of growth habits (herbaceous decumbent to erect types) and flowering times (early to late). In its first commercial season, (2012/13) some 10,000 ha was sown across north Queensland. Progardes is showing promise as a pasture legume over a very broad range of environments from northern NSW to the brigalow and north and western districts of Queensland.

There is considerable potential within *Desmanthus* to develop more legumes suitable for the beef industry. The genus includes some 24 species (Luckow 1993) with very considerable diversity in morphology and environmental tolerances (Reid 1983). The ATFC holds some 400 accessions of *Desmanthus* from 14 species. Examples of the potential within this genus are provided by *D. bicornutus*: an accession has persisted in Townsville (1150 mm AAR) in open *Eucatyptus* woodland on duplex soils for some 20 years while another persisted for 25 years in an arid environment in western Queensland. This genus could significantly benefit future farming/grazing systems.

A new wave?

New legumes have been developed in recent years, but progress has mostly built on evaluation programs conducted prior to the mid-1990s or from the continuation of long-standing research programs at universities (*Leucaena*). Pleasingly, much of the work addresses the industry priorities noted in the mid-1990s, perhaps reflecting activity and mentoring by the same personalities, but the effort has been small overall. New plants are being developed to provide persistent pasture legumes on heavy and light textured soils in areas of moderate rainfall and disease (*Stylosanthes*) and pest (*Leucaena*) resistant types have been pursued. There has also been continued effort to develop legumes suited to crop/graze systems and work is has been conducted to refine the management of some of the legumes developed toward the end of the 'first wave'. For example, Queensland Government staff is assessing management of *Stylosanthes seabrana* to optimise nitrogen fixation.

An emerging concern is the lack of coordinated, independent assessment of the value of the various legumes to beef producers. Although a certain amount of useful information can be gained during cultivar development, experiments under grazing in representative areas (soil type and climate) need to be conducted to compare the performance of new legumes with the older ones (where present). These can be resource intensive and expensive to conduct.

So, a new wave? Probably not. However, there are encouraging signs of a renewal in tropical pasture plant development. Seed companies, universities and government agencies are completing (often) complementary activities and the collaboration of the past is continuing. Meat and Livestock Australia have also recently increased funding into the management and development of pasture legumes, particularly for moderate rainfall areas of Queensland, and regeneration and characterisation of the ATFC is mooted to begin in the next few years enabling targeted development of new legumes. The next stage will be to re-build the human capacity required for the development and management of legumes to meet evolving industry needs. A new beginning? Possibly.

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Early dry season or two-yearly fires are not so hot in grazed savannas: fire impacts on pasture species

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Abstract. Fire is an integral component of tropical savannas, but is often actively excluded from commercially grazed systems in northern Australia. The Victoria River Research Station (VRRS) fire experiment in the Victoria River District, NT, was established in 1993 to assess the impact of fire management on woody cover and pasture condition. The experiment is replicated on grazed red (calcarosol) and black (vertosol) soil sites, with experimental plots burnt early or late in the dry season, every two, four or six years, compared to unburnt controls. There were directional changes in species composition across both soil types regardless of fire treatment, suggesting grazing or seasonally driven trends. However fire did have some influence on composition. On the red soil site, *Heteropogon contortus* yield increased through time across all treatments, but less so for more frequently or early burnt treatments, while the percent *Gomphrena canescens* yield was higher with more frequent and early fire. *Brachyachne convergens* yield was higher on burnt plots, but *Brachyachne* and *Enneapogon* spp. yield both decreased through time on the red soil plots. *Aristida latifolia* yield increased through time on all treatments, but less so on more frequently burnt sites, while *Iseilema* spp. yield was highest on the biennially burnt treatments. Although early dry season fire is recommended to reduce greenhouse gas emissions and impacts on biodiversity in fire prone areas of northern Australia, in a commercially grazed environment where fire frequency is currently low, early fire resulted in a decline in pasture condition. Late dry season fire every four years provided the best outcomes for pasture condition and woody cover.

Introduction

Low fire frequency on pastoral land has been implicated in woodland thickening (Lewis 2002), and reduced pasture production and carrying capacity (Dyer and Stafford Smith 2003). The Victoria River Research Station (also known as 'Kidman Springs'), fire experiment has been in place for twenty years, and is now providing clear evidence for optimal fire regimes for woody cover (Cowley *et al.* 2011) and pasture management (Cowley *et al.* 2012), and there is growing interest in using the site to understand carbon sequestration implications of fire in grazed savannas. This paper reports individual pasture species response to fire treatments in the first 17 years.

Methods

The study sites are located in the semi-arid tropical savannas in the Victoria River District, NT (median rainfall 679 mm). Two sites were established in 1993 on a calcareous red earth (calcarosol) initially described as an arid short grass community (68% of total yield composed of *Enneapogon* spp*.*, *Brachyachne convergens*, *Dichanthium fecundum* and *Sporobolus australasicus*); and on a grey cracking clay (vertosol) initially classed as a Ribbon-Bluegrass community (79% of total yield composed of *Chrysopogon fallax*, *Dichanthium fecundum*, *Iseilema* spp. and *Aristida latifolia*). Sites cover 0.44 km^2 and are located within larger paddocks (black soil 10.2 km^2 and red soil 14.7 km^2).

Eight treatments varying in fire frequency (fire recurrence intervals of 2, 4, 6 years and unburnt) and season of burning (early – June and late dry season - October) were randomly allocated in a completely randomised block design to each site, with each treatment replicated twice within blocks. Each plot has four parallel transects running north to south, with 15 1 m^2 quadrats assessed along each transect at approximately 6 metre intervals. Only once (in 2007) have the fire treatments not been implemented due to a combination of low fuel loads and June rain.

Total dry matter pasture yield and percent species yield were visually estimated using the Botanal method from June 1994 onwards. Defoliation has been assessed from 2007 onwards. Sites were assessed annually from 1994 to 2001 and biennially thereafter.

The impact of season burnt and frequency of burning on major species yield was analysed using repeated measures ANOVA. ANOVA was used to test the effect of fire season and recurrence interval on grazing score for each year separately. *Post hoc* pairwise means comparisons were carried out using Tukey's HSD tests. Where required, dependent variables were transformed to meet ANOVA assumptions. All error bars on graphs are 95% confidence intervals of the sample mean.

Results

Rainfall was usually at or above the long term median in all but four years (2003, 2005, 2007 and 2010) (Fig. 1). Average total yield across all treatments varied through time, but was particularly low (<1000 kg/ha) in 2003 and 2007 (Fig. 1).

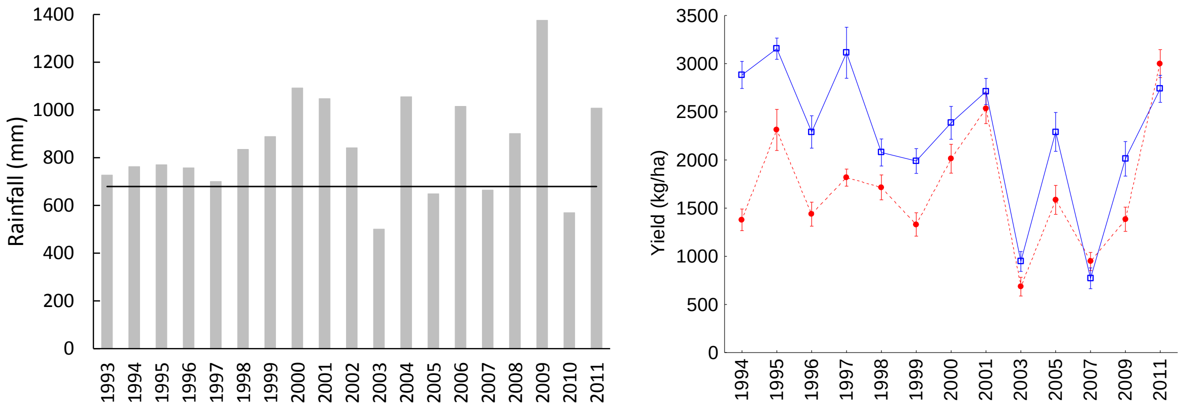

Fig. 1. Annual financial year rainfall (left) and yield (right) - VRRS fire trial 1993-2011. The black horizontal line is the long term median rainfall. Source BOM rainfall station 14847. Filled circle with dashed line - Red soil; open square with solid line - Black soil.

Only major species, or species that were significantly affected by fire are shown. Species yield varied most with year (Table 1), responding to variable rainfall. However, frequency of fire and to a lesser extent season of fire, were also significant factors affecting species yield.

Table 1. Effect of season burnt, burn frequency and year of burn on species yield at the red soil and black soil sites of the VRRS fire trial 1994-2011. (ANOVA: *P<0.05, **p<0.01, ***p<0.001, ****p<0.0001, dash indicates no significant difference, df indicates degrees of freedom for factor).

Site (soil type)	Species	Season Burnt	Burn Frequency	Year	Year by Season	Year by Frequency
		(df=1)	(df=3)	(df=12)	(df=12)	(df=36)
Red soil	*B. convergens*	*	*	****	*	****
	Enneapogon spp.	-	-	****	-	****
	% *G. canescens*	*	*	****	***	***
	H. contortus	-	-	****	****	****
Black soil	*A. latifolia*	-	*	****	-	****
	C. fallax	-	-	****	-	**
	D. fecundum	-	-	****	***	****
	Iseilema spp.	-	***	****	*	****

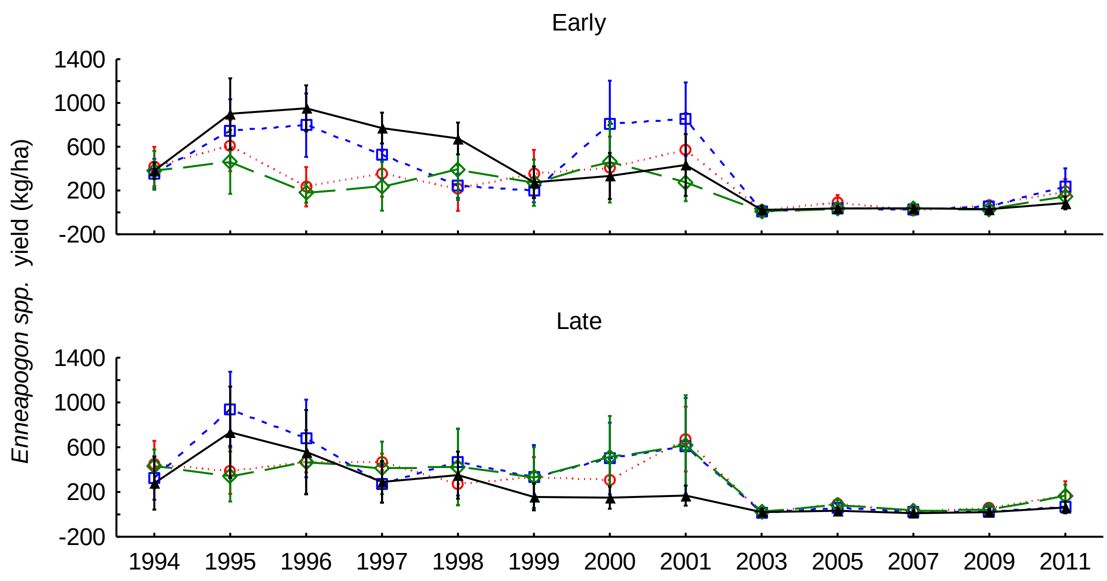

Fig. 2. Effect of fire treatment on yield of Enneapogon spp. through time at the red soil site VRRS. Open circle with dotted line - 2 yearly burns; open square with short dashed line - 4 yearly burns; open diamond with long dashed line - 6 yearly burns; filled triangle with solid line - control.

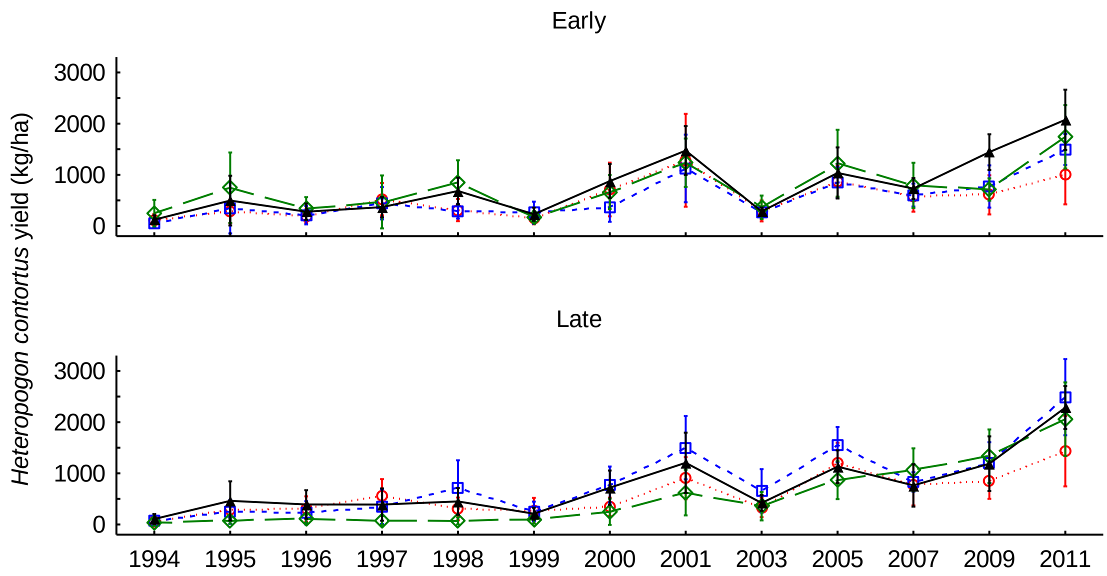

Fig. 3. Effect of fire treatment on *Heteropogon contortus* yield through time at the red soil site VRRS. Open circle with dotted line - 2 yearly burns; open square with short dashed line - 4 yearly burns; open diamond with long dashed line - 6 yearly burns; filled triangle with solid line - control.

On the red soil site *Enneapogon* spp. (Fig. 2) and *Brachyachne convergens* (not shown as similar pattern to *Enneapogon*) yield declined through time across all treatments, while *Heteropogon contortus* increased (Table 1, Fig. 2 and Fig. 3). *Brachyachne* yield was higher on all burnt plots than the controls, but only 6 yearly burnt plots were significantly higher than the controls (average 267 vs. 118 kg/ha, $p<0.05$, Table 1).

H. contortus yield increased less through time on early and more frequently burnt plots, while percent *Gomphrena canescens* yield was higher on early season (3% vs. 6% on early vs. late burnt, $p<0.05$) and more frequently burnt plots (2% for unburnt vs. 8% on 2 yearly burnt, $p<0.05$) (Table 1).

On the black soil site *Chrysopogon fallax* (Fig. 4), *Dichanthium fecundum* (similar trends to *C. fallax*, not shown) and *Iseilema* spp. yield all declined through time (Table 1), although *D. fecundum*

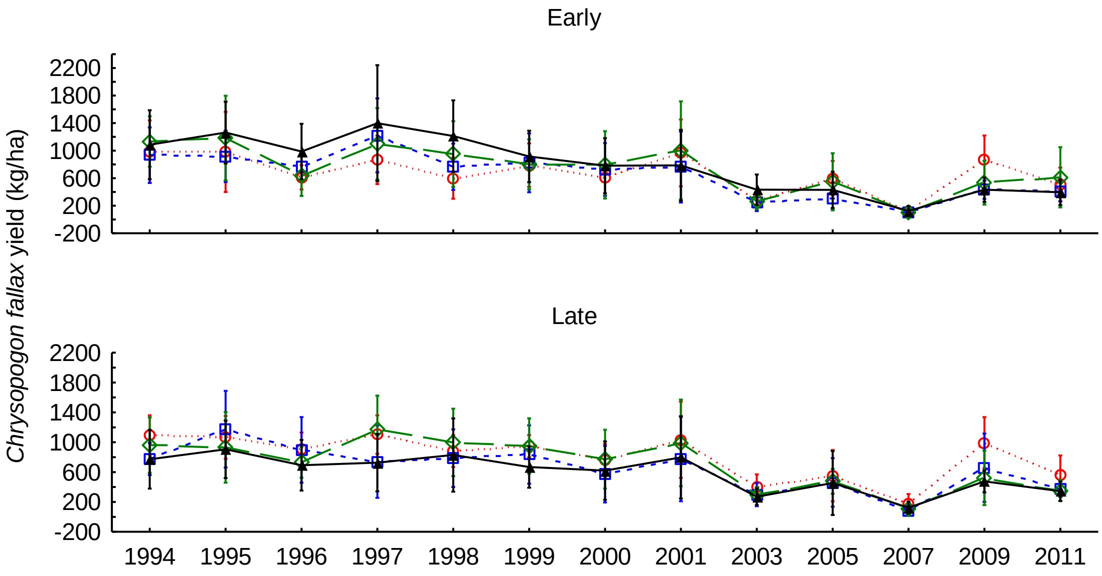

Fig. 4. Effect of fire treatment on yield of *Chrysopogon fallax* through time at the black soil site VRRS. Open circle with dotted line - 2 yearly burns; open square with short dashed line - 4 yearly burns; open diamond with long dashed line - 6 yearly burns; filled triangle with solid line - control.

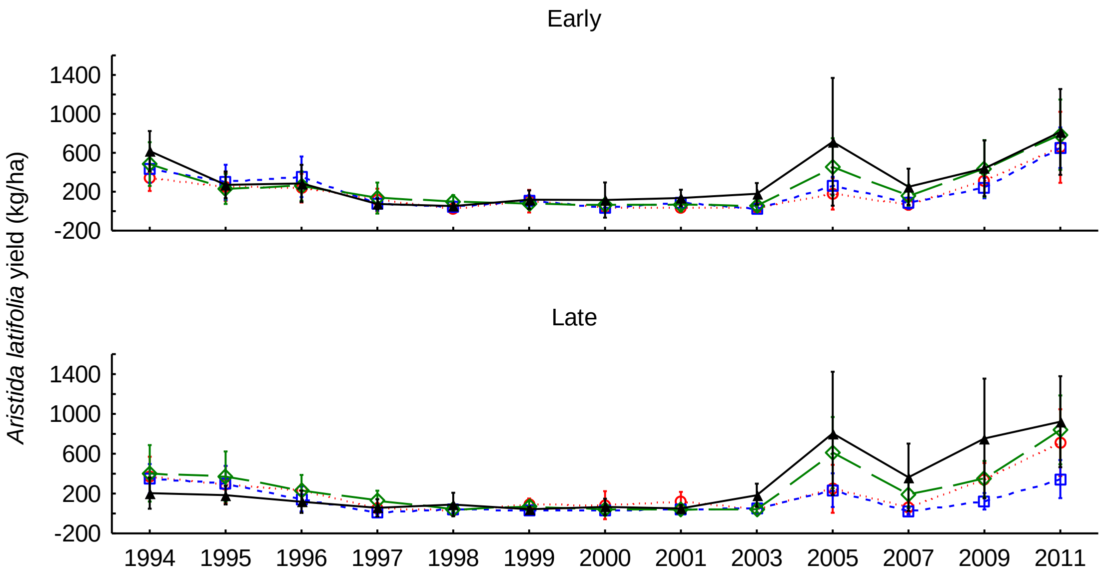

Fig. 5. Effect of fire treatment on yield of *Aristida latifolia* through time at the black soil site VRRS. Open circle with dotted line - 2 yearly burns; open square with short dashed line - 4 yearly burns; open diamond with long dashed line - 6 yearly burns; filled triangle with solid line - control.

and *C. fallax* yield started to recover from 2009 onwards. More frequent fire was associated with higher *Iseilema* spp. yield until 2003 (not shown), and from 2003 onwards, lower *Aristida latifolia* yield (Table 1, Fig. 5).

Defoliation was significantly higher on the black soil site on more frequently burnt plots in 2007 (frequency $F_{3,56}$=4.3, p=0.008) and on early season burnt plots in 2011 (season $F_{1,56}$=4.1, p=0.047).

Discussion

Seasonal or grazing mediated shifts in composition. There were compositional changes at both sites that were unrelated to fire treatment, and were more likely to have been rainfall or grazing pressure driven. For example, the red soil site is no longer the arid short grass community that was present at the beginning of the experiment. The conversion from an *Enneapogon* spp. dominated community to one dominated by the perennial *H. contortus* has been observed previously inside and outside grazing exclosures on VRRS (Bastin *et al.* 2003) and elsewhere in north western Australia (Watson and Novelly 2012), and interpreted as a change in vegetation state where grazing pressure has been reduced. This is consistent with the steadily reduced stocking rates in the paddock from 14 AE/km^2 in 1997 to 5.5 AE/km^2 in 2011 where the long term safe carrying capacity was estimated at 11 AE/km^2 (Cowley and Bryce 2004).

The decline of the palatable perennial grasses *C. fallax* and *D. fecundum* on the black soil site occurred when stocking rates were higher than recommended levels. Between 2002 and 2007, stocking rates averaged 21 AE/km^2 against the estimated safe level of 15 AE/km^2 (Cowley and Bryce 2004). The combination of these elevated stocking rates with the poor seasons in 2003, 2005 and 2007 may have contributed to the observed decline in perennial grass and *Iseilema* spp. yields. Conversely, the lower stocking rates since 2008 combined with the run of above average rainfall years (average stocking rate of 12 AE/km^2 from 2008 to 2011) may have contributed to the slight recovery of *C. fallax* and *D. fecundum* yields since 2009.

Fire frequency. Two-yearly burns tended to promote disturbance-tolerant annual grasses and dicots (Cowley *et al*. 2012), such as *Iseilema* and *Gomphrena* at the expense of longer lived grasses such as *A. latifolia* and *H. contortus*.

In the absence of grazing, fire increases *H. contortus* yield in south east Qld (Orr *et al.* 1991), and increased fire frequency has been speculated to be the driver of increased *H. contortus* frequency in the Kimberley region (Fletcher 2011). However in this study *H. contortus* yields increased most where there was *less* frequent fire. The lower *H. contortus* yield in more regularly or early burned sites may reflect higher grazing pressure on burnt areas, as *H. contortus* is sensitive to high utilisation (Orr *et al.* 2010), but also probably reflects less carryover material on more recently burnt sites.

Similarly for the black soil site, *A. latifolia* (a less palatable, short lived perennial) yield increased across all treatments after 2000, but less so with more frequent fire. When grazing and fire are applied separately, they both reduce *A. latifolia* yield (Phelps 2006). In this study burnt plots were also exposed to grazing, which may have compounded fire impacts on *Aristida*. Although lower yields of *A. latifolia* may seem a positive outcome for more frequently burnt sites, this was at the expense of lower total yields, with more annual grass, and an increased proportion of dicots (Cowley *et al.* 2012).

Season of fire. Early dry season burnt sites had higher annual grass yields and lower total yields on black soils (Cowley *et al.* 2012), and a reduced increase in perennial grasses (*H. contortus*), and higher proportion of dicot yields (such as *Gomphrena*) on red soils. This suggests that in grazed systems *late* dry season burns may be better for pasture condition than early dry season fires, particularly if paddocks are grazed post-fire before the wet season. Late dry season fire is also better for controlling woody cover, as late season fires are hotter (Dyer 2001) and have a greater impact on woody plants than early season fires on the red soil site (Cowley *et al.* 2011).

This contrasts with recommendations for early dry season burning on conservation and indigenous land, where frequent late dry season fires are implicated in declines in biodiversity and higher greenhouse gas emissions (Russell-Smith *et al.* 2003). However pastoral land already has a much lower fire frequency (Russell-Smith *et al.* 2003), so late dry season fire reduction strategies are less relevant.

Drivers of fire related species changes - post fire grazing pressure. There was some evidence from the black soil site that grazing pressure was higher on early and more frequently burnt sites one-and-a-half to two years post fire, but immediate post fire grazing impacts are unknown. However other studies in the region have found that despite lower total yields in recently burnt areas, cattle grazing is higher on burnt areas in the first few months after fire compared to surrounding unburned areas (*e.g.* Andrew 1986), as cattle seek out the higher quality regrowth.

To prevent preferential grazing post fire it is recommended that burnt areas are spelled, or burnt patches are large enough and stocking rates low enough to reduce the impacts of preferential grazing on burnt areas (Dyer *et al.* 2001). Although other parts of the experimental paddocks were frequently burnt to reduce post-fire preferential grazing at the experimental sites, this was not always done in drier years, when pasture (and fuel) was limiting. Hence grazing impacts may have sometimes been extreme. Negative trends in pasture composition on early burn sites are likely to be driven by the longer period of preferential grazing they are exposed to in the lead up to the next wet season.

Conclusions

This study indicates two-yearly fires should be avoided unless required to promote rapid change in woody cover, because of the deleterious effects on pasture condition. While early fires are recommended on conservation land to reduce damaging late season fire frequency and extent, on grazed pastoral land, early fire was associated with declining pasture condition probably due to the longer exposure to post fire grazing on early burnt sites. Four-yearly late season fires were the most effective for managing woody cover whilst maintaining pasture condition. Early dry season fires require careful post fire grazing management to reduce negative effects on pasture composition.

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Growth paths and meeting market specs

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Abstract. Whilst meeting market specifications (specs), especially for the higher quality domestic and export markets, will not be the major priority for a significant proportion of northern Australian beef industry, it will present economically-viable opportunities in the future for some as demand for meat of reliably high eating quality increases. In many cases meeting specs for these markets will require some modification to intrinsic growth paths of cattle in the region. Several approaches have been considered. The first involves selecting the cattle; specifically targeting the older, heavier weaners for nutritional intervention to reduce the shortfall between current growth rate and that required to meet the weight-for-age target. Another key consideration is the time of intervention in the growth path between weaning and slaughter with the variable effects of compensatory growth having a major bearing on which age group to feed. The various principles of manipulating growth paths were considered in 2 separate case studies. In the first, situated in the northern speargrass pasture community of the Intermediate zone, steers followed either a low-input industry baseline growth path to eventual slaughter at about 3.5 years or received treatments of high-input molasses-based mix in the first and second, or only the second, dry seasons post-weaning or were transferred to leucaena/grass pasture for finishing. All these modifications to the low-input growth path allowed the steers to be slaughtered at least 12 months earlier. Feeding only in the second year produced a similar final carcass weight to feeding in both years but with 22% less supplement intake. These results though were highly season dependent. Hormonal growth promotants provided varying improvements in growth across treatments but virtually precluded compliance with Meat Standards Australia specs. An economic analysis showed that all growth path modifications failed to increase the net value added relative to the low-input system although on a whole herd model analysis, leucaena grazing improved the gross margins relative to all other treatments. A second case study for the Endowed zone explored the use of a high-input molasses-based mix to finish steers in a deteriorating dry season scenario. Feeding the supplement resulted in a profit of $101/steer relative to selling the steers ‘unfinished’. It was concluded that with the current high cost of supplements feeding to reduce the age at slaughter will usually not be profitable except for opportunity feeding where turning off steers at premium prices is possible. However, improved pasture options provide some scope to profitably improve weight-for-age at slaughter and pasture options based on leucaena and plants suited to drier areas demand further research attention.

Introduction

The priority for any beef producer should be to find the most profitable option for their enterprise within the scope of the existing resources. Those options will vary according to a wide range of factors including regional location, land type and productivity, stage of property development and available markets. Although manipulating the growth path of cattle to meet a highly specific, high-value market may not improve the profitability of some producers, for others the most profitable production system and mix of inputs will include such manipulations of the growth path.

For this discussion our main focus will be on producing high quality, high value beef in northern Australia. The starting premise is that the demand for carcasses of reliably high eating quality will continue to increase, especially for domestic and some export markets, and that producers will continue to receive a realistic premium for these higher quality carcasses. In other words, quality will be important and will continue to receive a higher price. Our focus therefore is on how these market specs could be profitably met under grazing conditions encountered in northern Australia.

One of the most reliable methods of improving meat quality is to reduce the age of cattle at slaughter. However, such a goal is not congruous with the intrinsic low productivity of much of the extensive grazing lands of northern Australia, a product of low fertility soils, native tropical pastures of low nutritive value and the highly seasonal nature of the climate. These conditions vary widely though across the north and for convenience the region has previously been broadly divided into 3 production zones of 'Harsh', 'Intermediate' and 'Endowed' (Anon 1991). There are changes in the seasonality of animal production across the 3 zones, going from the typical 'saw-tooth' pattern of animal production in the Harsh and Intermediate zones to a more year-round production system in the Endowed zone. Large numbers of properties in the Intermediate zone continue with a breeding and fattening system (Bortolussi *et al.* 2005) and the improvement of production and profitability on these properties has been the main focus of recent work. Two case studies will be considered. The first will consider how the target can be met in the Intermediate zone whilst the second will explore opportunistic feeding for the Endowed zone.

Designing the growth paths

Our focus here is on the period between weaning and slaughter as the pre-weaning phase for calves born under extensive conditions in northern Australia predominantly occurs during the wet season when manipulation of growth of the calf is difficult to achieve.

Having established a target weight-for-age at slaughter, and with knowledge of the liveweight (LW) of the calves at weaning, simple mathematics provides a required annual growth rate which can be compared against the intrinsic (measured or historical value) annual LW change of steers for the area involved. The difference in LW between that which is currently achieved and that required represents the annual shortfall that needs to be overcome if the target is to be met. Strategies for meeting any shortfall then become part of the designed growth paths. Although this process for charting the growth paths seems elementary, we suspect it is one often not undertaken in practice.

As an example, for a final LW target of 550 kg, steers weaned at 200 kg LW will need to grow at 175 kg/year in order to finish at about 2.5 years of age, similar to the target of 180 kg/year suggested by English *et al.* (2009) for MSA compliance. This will be much more easily achieved in the Endowed zone where annual gains without intervention might be in the order of 160 kg compared to the Intermediate zone where the expected annual gains might only be 120 kg or the Harsh zone where expected gains may be less than 100 kg. Some other aspects worth consideration are discussed below.

Liveweight of calves at weaning

Not all (male) calves produced in any year will be suitable for early finishing. A major selection criterion will be weight at weaning, which will largely be a function of age. A high proportion of properties in northern Australia do not control mate or do so over a relatively long mating period so the calves are also born over an extended period leading to a wide range in LW at weaning. Work in NSW under more intensive grazing conditions (Greenwood and Cafe 2007) has shown that lighter calves at weaning do not necessarily grow at a faster rate than their heavier counterparts. Much of the LW difference at weaning, which is often just age related, will persist to the time when the heavier calves are sold for slaughter. This relationship is expected to be maintained under northern Australian conditions. In most cases it will be important therefore to stratify the weaners on weight at weaning and consider different production systems (growth paths) for different weight groups, with the heavier calves preferred for high weight-for-age targets. Mathematics indicates that a 100 kg difference in weaning weight will mean that the lighter calves will have to gain an extra 100 kg over their productive life, or 50 kg extra per year for slaughter at common weight at about 2.5 years. Where there are already difficulties in achieving the necessary high growth rates with the heavier calves, the lighter ones may pose too difficult and too costly a challenge and be better suited to other markets.

Type and timing of nutritional treatments

Age of cattle and response to improved nutrition. As indicated above, targeting younger turnoff of steers will generally require that 2 dry seasons and possibly 2 wet seasons are included in the growth path and the key question is: when should treatments be applied to achieve the most cost-efficient outcome? Where supplements are the preferred strategy for increasing annual gains, they will usually be fed during the dry seasons except where wet season phosphorus (P) supplementation is used in P-deficient regions. Dry season supplementation options are primarily in the first dry season when steers are at weaner age, in the second when yearlings, or a combination of both. This question introduces a further consideration, viz., do cattle of these different ages have the same requirements for nutrients for growth and second, do they respond similarly with the same nutrient intake? In theory younger steers should use additional nutrients more efficiently for liveweight gain than their older counterparts since in relative terms they are depositing a higher proportion of protein to fat and LW gain is greater per unit of protein deposited compared with fat (CSIRO 2007).

Two pen feeding studies were recently carried out to answer these questions (McLennan 2013). Steers from the same herd and genetic origin but of different ages (*i.e.* weaners) (10-12 months; *ca.* 200 kg LW) and mature-aged steers (33-36 months; *ca.* 430 kg LW) were fed low-quality tropical grass hays (<4.5% CP) plus a range of supplements fed at various levels in a response-surface design. The supplements included cottonseed meal (CSM; no additives) and barley/urea mix (barley/salt/limestone/molasses/water/Rumensin100; 94.3/0.94/0.94/1.9/1.9/0.05 parts, w/w as fed) plus urea/S (Bar/U) in the first study, and Bar/U and a molasses-based mix (MUP; molasses/urea/copra meal/salt/di-calcium phosphate/Rumensin100; 86.9/2.6/8.7/0.87/0.87/0.04 parts, w/w as fed) in the second.

The results were evaluated in 2 ways. First, when supplement intakes and LW gain were both expressed as a function of LW of the steers, the expected principles of young steers using the added nutrients more efficiently for growth than their older counterparts were confirmed (results not illustrated). However, when both intake and growth rate were expressed in absolute terms (kg/day; see Fig. 1) the responses by the older steers were similar to those of their younger counterparts, reflecting that both gained the same LW per unit (kg) supplement consumed. This finding, which is of greatest significance to the beef producer, suggests that from a nutritional point of view the age of feeding within the overall growth path is not of major importance. However, compensatory growth can have a major impact on the eventual outcomes of feeding at different ages as is discussed below.

Type of supplement. The other interesting observation from these studies is that the responses declined in order of CSM, Bar and MUP for both age groups. From a practical point of view, the low performance of MUP is a concern. In north Queensland it is often the production supplement of choice because molasses is readily available in coastal regions and mixes based on molasses combined with a protein source, including urea, can be fed with relative safety under extensive grazing conditions. The lower energy value and inferior animal performance with molasses compared to grains has been demonstrated previously (Lofgreen 1965; Gulbransen 1985) and whilst in the past this was countered by the much lower cost of molasses, increasing molasses cost in recent years has largely reduced the gap between these energy sources when compared on cost per unit energy supplied. Nevertheless, the risk of acidosis with feeding grains will continue to limit their use in extensive grazing situations. Protein meals are usually much more expensive than the other supplements described above but can be fed with relative safety and the high responses from protein meals compared to the 'energy' sources, especially at low intakes, suggest they deserve further consideration in a production feeding context.

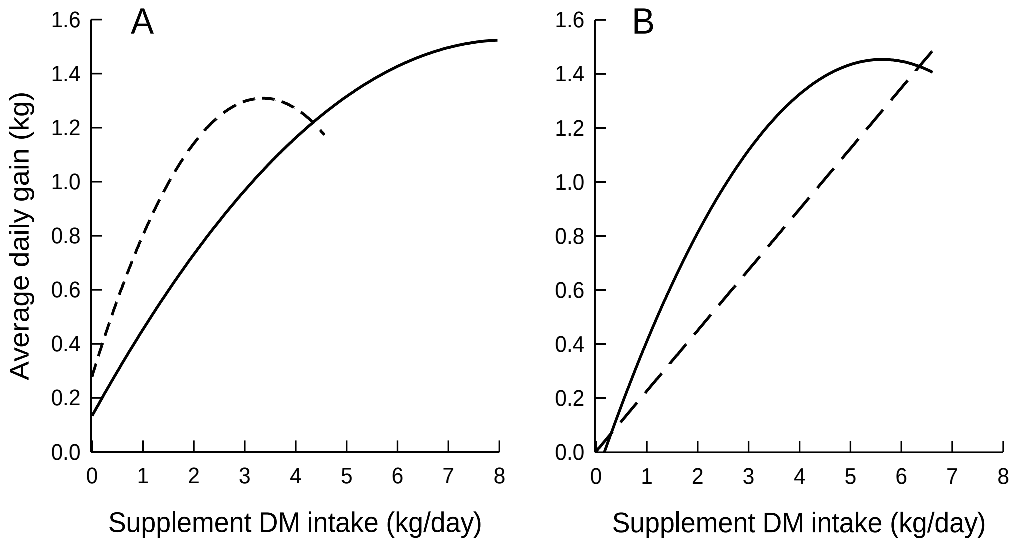

Fig.1. Effects of intake of (A) barley/urea mix (solid lines) and cottonseed meal (short-dash) in Experiment 1 and of (B) barley/urea mix (solid lines) and molasses/urea/protein meal mix (MUP; long-dash) in Experiment 2, on the average daily gain of young and old steers fed low quality tropical grass hay *ad libitum.* Differences between young and old steers were not significantly different in either experiment.

Compensatory growth effects. The phenomenon of compensatory growth is the other integral component of northern production systems that impacts on the efficiency with which nutrients supplied in the dry season are ultimately used by grazing cattle, and thus on eventual profitability. Responses realised during any particular dry season are eroded to varying degrees during the following wet season. Despite abundant evidence of its effects, the extent of compensatory growth remains largely unpredictable and could vary from 0 to 100% (Winks 1984). Ryan (1990) listed some of the main factors contributing to compensatory growth as the age at which restriction to growth is applied and the severity and duration of the restriction, but the relative contribution of these factors remains elusive. Thus although the earlier section indicated that similar responses to additional nutrients could be achieved with weaners during the first, and yearlings during the second dry season post-weaning, these results need to be considered in the context of likely impact of compensatory growth. It is possible that growth responses achieved in the first dry season are eroded over not just 1 but 2 subsequent wet seasons. This aspect is also discussed in Case Study 1.

Case study 1 (Intermediate zone)

Setting the target

An ambitious target was set - namely a finished *Bos indicus* crossbred steer with 4 permanent teeth or less achieving a final liveweight (LW) of between 540 and 620 kg at about 2.5 years of age for a final carcass weight of between 280 and 320 kg, meeting Meat Standards Australia (Anon 2007) specs and with boning group 10 or less. The choice of breed was based on the northern herd predominance of *B. indicus* derived cattle for reasons not related to meat quality, but the influence of genetics on meat quality is recognised (McKiernan *et al.* 2009).

Growth paths

To test the viability of meeting the target, a grazing trial was carried out in the northern speargrass region at “Swans Lagoon” Research Station near Ayr. This district is considered to be representative of the Intermediate production zone. The steers used began the trial at 200-210 kg (at weaning) and were followed through to slaughter up to 36 months later. The baseline growth path was a low-input system, considered the industry standard, in which the steers received a salt/urea/S dry lick (US) in the first dry season and then no further supplement (L-nil) and were slaughtered at about 3.5 years of age. Two other groups received the US treatment in dry season 1 and then one was fed MUP (see above) *ad libitum* in dry season 2 (L-H) whilst the other was transferred to a leucaena/grass pasture at "Brian Pastures" Research Station, Gayndah for finishing (L-leuc). A fourth group, the high-input treatment, received MUP at high intake in both dry seasons (H-H). Both groups fed MUP at some time were slaughtered at about 2.5 years and the leucaena steers about 3 months earlier. Half the steers in each treatment group were implanted with hormonal growth promotants (HGPs) of Compudose origin, with continuous pay-out from weaning until slaughter. There were 2 drafts of steers used but the emphasis here is on the first draft.

Results

The effects of the different growth paths on LW change (Draft 1) are shown in Fig. 2. At the end of the second wet season the L-H and H-H steers fed MUP were suitable for slaughter (533 kg average) but not those on the low plane treatment (L-nil) which were only 464 kg at the same time; they weighed 604 kg at slaughter 12 months later. Steers transferred to leucaena gained at the high rate of 0.8 kg/day over about 8 months and were slaughtered (532 kg) about 3.5 months earlier than those fed high-input MUP at Swans Lagoon. Thus by using high-input supplement or leucaena as part of the growth path the age at slaughter was reduced by at least 12 months. In addition, steers fed only in the second dry season (L-H) achieved the same final LW as those fed in both years (H-H) with 22% less supplement intake, largely through compensatory growth by the former. Over both drafts the response obtained in the dry season to feeding the high-input MUP supplement was eroded through compensatory growth by between 33 and 47% in the following wet seasons.

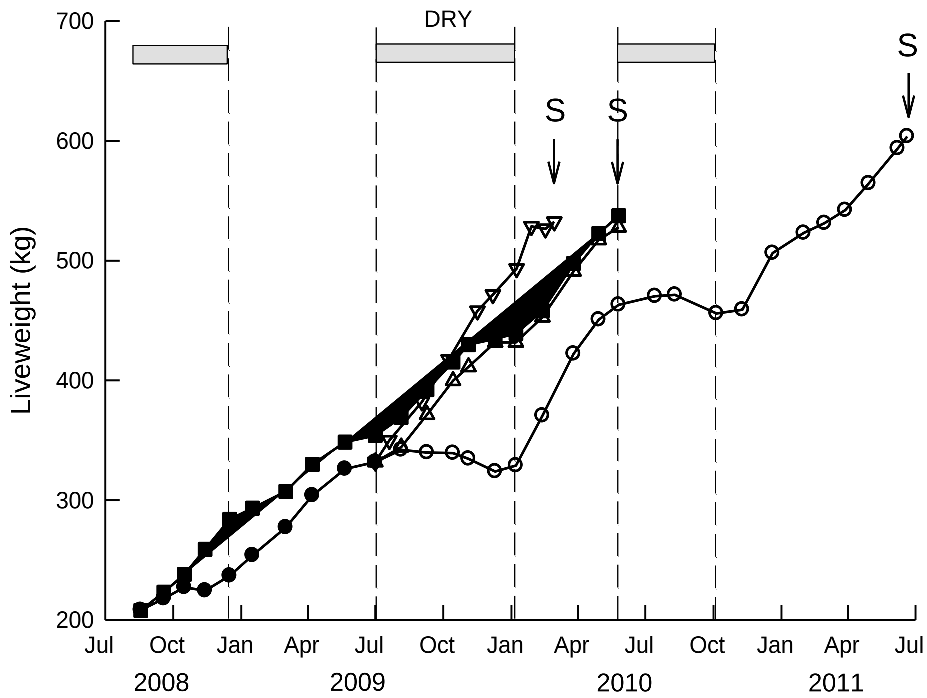

Fig.2. Changes in the liveweight of steers from Drafts 1 following the L-nil (open circle), L-H (upright triangle) and H-H (closed square) growth paths at Swans Lagoon and the L-leuc (inverted triangles) growth path at Brian Pastures. Data are averaged and represented by a single plot (closed circle) for treatments L-nil, L-leuc and L-H for the first dry and wet season post-weaning and individual plots are shown thereafter. Values are pooled across HGP treatments. An arbitrary delineation between dry (shaded) and wet (unshaded) seasons is indicated by the dashed vertical lines. "S" indicates slaughter.

The intakes of supplement by the different age groups and their LW responses (both drafts) are shown in Table 1. In the case of the weaners the response recorded was relative to steers receiving US, not an unsupplemented control. In contrast to the pen studies described earlier, there was a small difference between the conversion rates for weaners vs yearlings in this field trial perhaps because the yearlings were starting to fatten. Regardless, for both age groups the cost of extra gain was relatively high ($1.95-2.59/kg).

The most consistent effect was from the use of HGPs. To the end of the second wet season when the high-input steers were slaughtered, the response averaged 8% for groups kept at Swans Lagoon but for steers transferred to Brian Pastures, the response was 22% whilst the steers grazed leucaena.

The majority of carcasses (75%) from non-implanted steers on high-plane treatments receiving supplement or leucaena graded MSA boning group 10 or less, which attracted a small price premium, compared with virtually none (4%) of the HGP implanted steers. Nevertheless, sale values received for implanted steers were generally higher owing to their heavier carcass weights. Most of the low-plane (L-nil) steers in Draft 1 exceeded the abattoir cut-off of 4 permanent teeth and so did not grade MSA.

Table 1. The liveweight (LW), LW gain and LW response relative to the low-input treatment (fed urea/S as weaners and unsupplemented as yearlings), and the intakes and costs of supplement and the supplement conversion rate, for the steers fed the molasses/urea/protein meal mix (MUP) as weaners (drafts 1 and 2) or yearlings.

Group	Average LW	MUP intake		LW gain	LW response	Cost		Supplement conversion
	(kg)	(kg/d)	(%W/d)	(kg/d)	(kg/d)	($/d)	($/kg extra gain)	(kg/kg extra gain)
Weaners 1	246	3.90	1.58	0.63	0.40	0.86	2.15	9.8
Weaners 2	246	3.80	1.54	0.38	0.43	0.84	1.95	8.8
Yearlings	383	6.01	1.59	0.51	0.51	1.32	2.59	11.8

Economic analysis

The main method of analysis used was the 'net value added' method which calculated the final value of each steer and deducted the identifiable costs, both cash and non-cash (*e.g.* opportunity costs), of achieving this value. To account for differences in effective stocking rate, pasture resources accessed and varying age at slaughter, the gross income at sale for each steer was reduced by the opportunity cost of the grazing resource accessed. All other costs and prices were actual values and no allowance was made for variation in sale prices due to different times of sale and abattoirs used. The economic results relate specifically to the consumption of supplements, prices and costs that prevailed during the trial and should be viewed in that context.

The net value added for steers in Draft 1, with HGP implants, was $275, $271, $79 and $15 for the L-nil, L-leuc, L-H and H-H treatments, respectively, where the average response to HGP was $11. The HGP effect was much higher for Draft 2 ($38). Thus, within the constraints applied by the trial and at the market prices achieved, no treatment improved the net value of the steers over that of the conventional low-input system despite reducing turn-off age by at least 12 months. The relatively high cost of supplements mitigated against a profitable outcome from the supplemented groups (L-H and H-H) whilst with the L-leuc treatment it was the high cost of transport to leucaena pasture ($75/steer).

When the trial results were analysed as the outcomes of equivalent herds set up using the Breedcow and Dynama suite of programs (Holmes 2012) based on a representative, Intermediate zone northern Australian beef breeding and fattening herd, the ranking of treatments on whole herd gross margin was similar to that for the value added method except that the gross margins were highest for the leucaena treatments. Within the herd modelling the transport cost incurred to access leucaena pasture was maintained. This analysis reflected how the property and herd, and their profitability, may change using the steer turnoff strategy employed in the trial and indicated a positive economic result from finishing steers on the improved pasture.

Case study 2 (Endowed zone)

Growth paths

The following feeding scenario represents an example of production feeding in the Endowed zone, as sometimes utilised in the high rainfall and fertile Atherton Tablelands region of north Queensland. A common scenario is that producers have heavy steers at about 540 kg in June and experience a dry, frosted winter/spring period ahead which usually requires a reduction in stock numbers. The option is to sell the surplus steers, the majority (say 80%) of which are not well finished, to the abattoirs and accept a lower price (*e.g*. $2.80/kg dressed weight) at a time when fat cattle supply is plentiful. An alternative, and one which is sometimes used commercially, is to feed the steers a MUP-type supplement at high intake for about 100 days and sell the bullocks at about 640 kg LW in September. The supplement intake largely substitutes for the normal pasture consumption expected over the 100 day period and no net effect on the short term carrying capacity of the property is expected. The supplement feeding option targets a sale time when prime cattle availability is in short supply and prices are usually rising. This approach of selling at the end of the feeding period also avoids any erosion of gains through compensatory growth.

Economic analysis

A management choice has been compared using the Breedcow and Dynama (Bullocks) program (Holmes 2012) where steers could be sold in June or later after the feeding of supplements. An average price paid for the non-fed (sold) steers in June of $2.80 at the abattoirs is assumed which, after selling costs, realises $767/steer. The supplemented steers have to net more than this after feeding costs have been deducted from their eventual sale value to provide the producer with a profit from the feeding exercise. With the supplemented steers the assumptions are an intake of MUP of 8.3 kg/day (1.4%W/day; as fed) at an average daily cost of $1.83, for a LW gain of 1 kg/day and a total feeding cost of $183. The values were based on those recorded from cattle feeding trials at Kairi Research Station (BH English and JW Rolfe, Producer Initiated Research and Development project 06.Q04, 2006-2008). Grazing or feeding out costs of $3/head/week have been used. At an assumed premium price of $3.30/kg dressed for steers sold 'out-of-season', the sale price was $1,140 which, after subtracting variable costs plus foregone interest ($271) computed to a profit of $101/steer. The corresponding profit for a sale price of $3.20/kg would be $67/steer. The profitability of this opportunity feeding exercise though does depend on achieving a price premium from selling at a time when finished cattle are in short supply and there is risk involved in this assumption and in any feeding venture dependent on future prices.

Conclusions

There are a number of nutritional interventions or strategies available to northern Australian beef producers to assist them access markets with potentially higher prices. This paper specifically considers strategic improvements in dry season nutrition aimed at meeting specific markets and indicates they need to be assessed cautiously in northern Australia. The assessment should include consideration of immediate returns but be set against a clear view of the risks and returns of the beef business over the longer term. In the present cost/price environment, growth paths dependent on the feeding of dry season supplements to improve weight-for-age of cattle and reduce turnoff time will often result in negative real returns to the producer. This is largely a function of the high cost of supplements and the relatively low conversion of supplement to additional LW gain, exacerbated by current low cattle prices. Improvements in this situation can be made by targeting a specific market and selecting cattle with the greatest likelihood of reaching these market specs with lowest inputs (*e.g*. heavier weaners), by timing feeding to exploit compensatory growth effects and by selecting supplements with the highest LW response relative to cost. There will be cases though where opportunity feeding which exploits a developing shortage in prime cattle and rising slaughter prices, provides a profitable outcome, *e.g*. Case Study 2. It appears that the best current prospects for nutritional intervention to improve weight-for-age lie in the use of improved forages such as leucaena. In regions where soils are less fertile it seems appropriate that the use of stylos and other legumes in this role is revisited.

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Meat quality of grain finished entire male *Bos indicus* cattle

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Abstract. Although the utilisation of young, entire male cattle for premium beef production is common in many parts of the world, it is not widely practiced in Australia. This study examined the carcass characteristics and eating quality of meat from entire *Bos indicus* males sourced from northern breeding herds and grain finished. Entire male calves were weighed and allocated to one of four (4) treatment groups: 1) Early-castrate (n=140); 2) Late-castrate (n=136); 3) Short-scrotum (n=121); 4) Entire (n=129). At ≈200 kg liveweight, all calves were weaned and those in Group 2 were castrated. The weaners were grown out on grass pasture to ≈330 kg liveweight, at which time they were sent to a feedlot and grain fed for 75 days, to ≈420 kg liveweight, prior to slaughter at 25 to 28 months of age. Data collected included carcass (weight, grade, gross value, butt shape, dentition, P8 fat depth, bruise score), MSA grading and meat quality data. Three muscles, eye round (*M. semitendinosus*), rump (*M. gluteus medius*) and striploin (*M. longissimus dorsi lumborum*) from thirty animals in each treatment group were used to generate consumer taste panel sensory test MQ4 scores. Carcasses from non-castrated animals that met the target AusMeat specification for "male" had a ≈$52 higher gross value than did those from castrated animals. Although meat from castrated animals had higher MQ4 scores than did meat from non-castrated animals, there were no differences between the boning groups for any of the sensory test outcomes, and, of the three muscles that were sensory tested, only striploins from early-castrated animals were rated as being of higher eating quality than striploins from late-castrate, short-scrotum or entire animals. Sensory test of meat quality as measured by MQ4 did not differ between carcasses of non-castrated animals that were graded as either "steer" or "bull" (43.862 ± 0.990 *vs* 45.078 ± 1.807, respectively; mean ± SEM), indicating that taste panels did not detect differences in the eating quality of the three muscles from these animals. This suggests that grading of carcasses of young animals on secondary sex characteristics may not accurately reflect the eating quality of meat from those carcasses. There were also significant disparities in the allocation of MSA star grades based on either MSA grading outcomes or taste panel sensory test results. Production of young entire *Bos indicus* males offers the potential for significant returns for northern beef producers with little impact to meat quality. However, there is a need for further data to be generated to allow the MSA grading model to be further refined for *Bos indicus* cattle.

Introduction

Each year some 8 – 10,000 young, entire male cattle are sent to slaughter from breeding properties in northern Australia (McDonald *pers comm.*). Beef from entire males, "bull beef", has traditionally been a by-product of cow/calf breeding operations or the dairy industry, despite evidence suggesting that beef enterprises can benefit from the highly efficient fast growing characteristics of entire male cattle that achieve target weights earlier (Nichols *et al.* 1963; Bailey *et al.* 1966; Seideman *et al.* 1982). Previous MLA funded projects have demonstrated significant productivity gains in entire male cattle (Ridley and Schatz 2006). The results showed that, in comparison to Brahman steers when slaughtered at the same fatness, Brahman bulls had a 15% advantage in carcass weight.

There is an ever growing body of international evidence that supports the concept of producing lean beef from entire males with the animal welfare benefits arising from the elimination of castration from the production system. Some live export markets actually pay a premium for entire males but in the local domestic trade, however, entire male cattle historically receive a heavy discount because of the perception of poorer meat quality. This perception may be attributed to the knowledge that the majority of beef produced from entire males in Australia is a product of cast for age bulls, rather than young animals.

There is significant potential for young, entire male cattle from northern breeding properties to be value-added through grain-finishing, however, consumer perceptions of the eating quality of beef from entire young *Bos indicus* need to be evaluated and addressed. In addition, there are substantial animal welfare benefits to be gained if castration of these animals is avoided.

The objectives of this study were to evaluate carcass yield and quality, and consumer eating quality characteristics of young short-scrotum and entire male cattle finished on grain for the domestic trade compared with early- and late-castrated males.

Methods

This study was conducted under JCU Animal Ethics Committee Approval no. A1342, in collaboration with McDonald Holdings Pty Ltd (MDH) on a number of their properties. The cattle used in the study were bred on *Rutland Plains* (15^o 38.804'S 141^o 50.800'E) and *Dunbar* (16^o 2.852'S 142^o 23.644'E) in the eastern Gulf of Carpentaria/western Cape York region, grown out on pasture at *Devoncourt*, Cloncurry (21^o 12.937'S 140^o 13.958'E), and finished on grain to Domestic Trade Steer specifications at MDH's *Wallumba* feedlot (26^o 50.646'S 150^o 14.173'E) on the Darling Downs.

Experimental design

The study was conducted in an experimental design incorporating four (4) male treatments. In the second mustering round at *Rutland Plains* and *Dunbar*, entire male calves were weighed and allocated at random to one of four (4) treatment groups, as follows: 1) Early-castrate: surgically castrated at 1 to 4 months of age; 2) Late-castrate: castrated at weaning at ≈200 kg liveweight (≈9 to 12 months of age); 3) Short-scrotum: underwent a rubber banding procedure at 1 to 4 months of age to produce short-scrotum entire males (artificial cryptorchid); 4) Entire: remained intact for the duration of the experiment.

At ≈9 to 12 months of age (≈200 kg liveweight), all calves were weaned and relocated to *Devoncourt*, where those calves in Group 2 (Late-castrate) were castrated. All the weaners were grown out on *Devoncourt* to ≈330 kg liveweight, at which time they were sent to *Wallumbah* feedlot and grain fed for 75 days, to ≈420 kg liveweight. On exiting the feedlot (25 to 28 months of age), all animals were sent for slaughter at JBS Australia's Dinmore abattoir (JBS) (see Table 1).

Data collection

Carcass grading data from vendor feedback sheets. The vendor feedback sheets provided data on carcass Sex (M = male, B = bull), Dentition (number of permanent incisors), Hot Carcass Weight (kg) and Gross Value ($); and for each side – P8 Fat Depth (mm), Butt Shape (A to E, with A being most convex and E being most concave.), Hot Weight (kg), Bruise score (1-9 depending on the position of the score-able bruise), Grade, $/kg.

MSA carcass evaluation. The MSA grading model assigns one of four eating quality grades (2-star = unsatisfactory, 3-star = "good every day", 4-star = "better than everyday", or 5-star = "premium") to 40 individual carcass muscles cooked by up to six alternative methods. The grade is assigned by a statistical prediction model which estimates a predicted meat quality (PMQ) score on a 0 – 100 scale for each muscle x cook outcome, based on inputs of % *Bos indicus*, sex, carcass weight, ossification, marbling, rib fat, carcass suspension method, ultimate pH, and meat colour (Watson *et al.* 2008). The current PMQ cut-offs for 3-star, 4-star and 5-star are 46.5-63.9, 64.0-76.9 and 77.0-100.0 points, respectively (Watson *et al. 2008*). For MSA grading purposes, all the project cattle were a high grade Brahman genotype and so were classed as being 100% *Bos indicus*. All were hung by the achilles tendon during the slaughter process and entered in the MSA grading model as steers.

Table 1. Number of cattle either castrated at branding (Early-castrate), castrated at weaning (Late-castrate), banded to create an artificial cryptorchid (Short-scrotum) or left intact (Entire).

	Early-castrate	Late-castrate	Short-scrotum	Entire	Total
Allocated to the project (Sept/Oct 2008)	169	170	161	165	665
Relocated to *Devoncourt* at weaning (July – Oct 2009	≈147	≈151	≈133	≈140	≈571
Inducted into *Wallumba* feedlot (16 July 2010)	142	136	121	129	528
Slaughtered at JBS, Dinmore (23 Sept 2010)	140	136	121	129	526

Assessment of meat quality. Forty animals from each treatment group were initially allocated for evaluation of meat quality, from which 30 animals were selected for further meat quality and sensory testing following MSA carcass evaluation. Three muscles, eye round (*M. semitendinosus* - EYE), rump (*M. gluteus medius* - RMP) and striploin (*M. longissimus dorsi lumborum* - STR), aged either 7 days or 35 days (15 each) were used to evaluate shear force (Geesink *et al.* 2011).

Sensory testing. The sensory testing of three muscles from each of the treatment groups was carried out by Meat Standards Australia using standard protocols and the grilling cook method (Watson *et al.* 2008). In brief, each sample was evaluated by 10 consumers for tenderness, juiciness, flavour and overall liking. Additionally, consumers assessed the star-rating (satisfaction) for each sample. A trimmed mean was used to give a robust and reasonably reliable measure, MQ4. This measure forms the basis of the MSA consumer prediction model, which generates a predicted MQ4 (PMQ4) from available data and is considered to be a good assessment of the consumer assessment of meat eating quality (Watson *et al. 2008*).

Statistical analyses

Predicted meat quality (PMQ) data. All carcass quality and sensory data were analysed using a REML model in GenStat (GenStat 2011) with animal ID as the random effect and treatment Group, Muscle and Aging as categorical variables.

MSA star grade. For muscles animals that were selected for taste panel sensory testing, MSA Star-grades were determined either from the boning group data derived from MSA carcass grading (MSA1-BG), the PMQ data generated by the MSA Model (MSA2-PMQ), or from the MQ4 data derived from sensory testing (MSA3-MQ4). McNemar's test (GenStat 2011), was used to test whether one grading system was more likely to give a grade of 3-star or better, compared to the other.

Results

Carcass grading data from vendor feedback sheets

About 30% of the carcasses from non-castrated animals were graded as "bull" following slaughter, compared with less that 1% of carcasses from castrated animals (Table 2).

Table 2. Numbers of carcasses (proportions in brackets) by treatment group that were classified as either male or bull, based on the presence or absence of secondary sex characteristics.

Treatment group	N	Male	Bull
Early-castrate	140	139 (99.3)^{a}	1 (0.7)
Late-castrate	136	135 (99.3)^{a}	1 (0.7)
Short-scrotum	121	87 (72.1)^{b}	34 (27.9)
Entire	129	87 (72.5)^{b}	43 (27.5)

a, b – Column means with unlike superscripts differ, P<0.001

Castrated animals had lower hot carcass weights than non-castrated animals (P<0.001). For Early-castrate *vs* Late-castrate and Short-scrotum *vs* Entire, hot carcass weights did not differ (Table 3).

There was an association (P<0.05) between sex (Male – castrated or entire animals not showing secondary sex characteristics; and Bull – animals showing secondary sex characteristics) and dentition (Table 4). 87% of animals that graded as "Bull" had two or more permanent incisors compared with 70% of animals graded as "Male", accordingly, 15% of animals that graded as "Bull" had at least four permanent incisors compared with only 9% of animals that graded as "Male" (Table 4). Animals that graded as "Bull" had greater Hot Carcass Weights (P<0.05) than those graded as "Male" (257.7 ± 2.7 kg *vs* 229.0 ± 1.3 kg, respectively). There were no differences among treatment groups for bruising (only two carcasses were trimmed for bruising).

Table 3. Hot carcass weights and gross carcass values by treatment group.

Treatment group	N	Hot carcass weight (kg)	Gross carcass value ($)
Early-castrate	140	226.24 ± 2.49[a]	737.88 ± 12.27
Late-castrate	136	224.09 ± 2.19[a]	725.03 ± 12.68
Short-scrotum	121	242.49 ± 2.66[b]	744.75 ± 12.70
Entire	129	242.09 ± 2.26[b]	737.65 ± 10.40

a, b – Column means with unlike superscripts differ, P<0.001

Table 4. Numbers of animals with permanent incisors (either 0, 2, 4 or 6), either classed as "Male" (no secondary sex characteristics) or "Bull" (secondary sex characteristics).

Sex	Dentition (No. of permanent incisors)				
	0	2	4	6	All
Bull	10	57	11	1	79
Male	133	275	39	0	447
All	143	332	50	1	526

Gross returns. Hot carcass weights, P8 fat depth and gross carcass value stratified by Male or Bull classification and treatment Group are presented in Table 5. Of 526 animals killed, 79 graded "Bull"; these also represented the heaviest carcasses with the lowest fat scores. Carcasses from non-castrated animals that graded "male" had a ≈$52 higher gross value than did those from castrated animals (P<0.05), while carcasses from non-castrated animals that graded "bull" had a ≈$83 lower gross value than those from castrated animals (P<0.05), and a ≈$137 lower gross value than those from non-castrated animals that graded "male" (P<0.05). As such, the average gross value of the carcasses did not differ between the treatment groups (Table 3).

Chiller assessment and MSA grading

There were no differences among treatment groups for meat colour (MC) or fat colour (FC) scores. Carcasses from Entire animals had slower pH declines (P<0.05) than those from non-castrated animals, however, there were no differences among treatment groups for ultimate pH.

Ossification. Castrated animals had lower (P<0.001) ossification scores than non-animals (≈138 *vs* ≈156, respectively), and carcasses graded as "Male" had lower (P<0.001) ossification scores than those animals graded "Bull" (≈144 *vs* ≈165, respectively).

AusMeat and USDA marbling scores. There were no differences between the treatment groups for AusMeat marbling scores, however, castrated animals had higher USDA marbling scores (P<0.05) than non-castrated animals (228.36 ± 3.94 *vs* 204.54 ± 3.94, respectively).

Rib fat score. Castrated animals had greater rib fat (P<0.05) values and smaller (P<0.05) eye muscle area than non-castrated animals (≈4.65 mm *vs* ≈3.50 mm and ≈65.5 cm^2 *vs* ≈68.0 cm^2, respectively).

Hump height. Castrated animals had lower hump heights (P<0.05) than non-castrated animals (≈132 mm *vs* ≈153 mm, respectively).

*Boning groups and non-compliance with MSA standards***.** Carcass parameters by boning group are presented in Table 6. No carcasses qualified for MSA boning groups 1 through 5; and a greater number of carcasses from castrated animals were allocated to boning groups 6 to 10 (P<0.05), compared to those from non-castrated animals. The most common reason for non-compliance or ungraded carcasses was due to insufficient fat cover - 14% of castrated animals versus 31% of non-castrated animals. Carcasses allocated to boning groups 6 through 10 had significantly less hump height, greater rib fat values, greater USDA marbling values, and tended to have lighter muscle colour than animals allocated to boning groups >10. Carcasses allocated boning groups >10 had greater eye muscle area (P<0.05). Fat colour scores did not differ between the boning groups.

Table 5. Hot carcass weights, P8 fat depth and gross values (mean ± SEM) of carcasses from animals graded as "male" or "bull", by treatment group.

Grade	Treatment group	N	Hot carcass weight Kg	P8 fat depth Mm	Gross value $
For carcasses graded "male"	Early-castrate	139	225.61±2.43[a]	11.99±0.35[a]	737.27±12.34[a]
	Late-castrate	135	223.97±2.20[a]	11.77±0.33[a]	726.16±12.73[a]
	Short-scrotum	87	236.61±3.05[b]	9.76±0.32[b]	783.94±14.75[b]
	Entire	87	234.80±2.66[b]	10.31±0.35[b]	780.62±12.09[b]
For carcasses graded "bull"	Early-castrate	1	314.00	6.00	822.68
	Late-castrate	1	240.50	8.00	573.72
	Short-scrotum	34	257.10±4.47[c]	8.63±0.36[c]	647.34±15.56[c]
	Entire	42	257.18±3.16[c]	8.36±0.48[c]	648.65±10.74[c]

a, b, c - column means with unlike superscripts differ, P<0.05

Predicted meat quality (PMQ) scores and meat quality test results. Castrated animals had greater PMQ scores (P<0.001) than did uncastrated animals (≈48.0 *vs* ≈46.0, respectively). Striploins from castrated animals had lower shear force (P<0.001) than those from non-castrated animals (≈4.4 kg vs ≈5.3 kg, respectively). Shear force test for eye rounds and rumps did not differ among the treatment groups. Ageing from 7 days to 35 days reduced (P<0.001) shear force for striploins from Entire animals (≈6.1 kg vs ≈5.0 kg, respectively).

Sensory testing

MQ4 score. In general, additional aging from 7 to 35 days resulted in improved MQ4 scores. For striploins only, Early-castrate animals had higher MQ4 scores than Late-castrate, Short-scrotum or Entire animals, which did not differ (53.11 ± 2.6 *vs* 47.73 ± 2.52, 45.73 ± 2.89 and 41.50 ± 2.53, respectively, P<0.01).

Boning groups. There were no differences between carcasses assigned to boning groups 6 through 10 and those >10 for any of the sensory outcomes. MQ4 scores for muscles from castrated animals were greater (P<0.01) than those from non-castrated animals graded as either "Male" or "Bull", which did not differ from each other (see Table 6).

Table 6. MQ4 from sensory testing of 3 muscles x 2 ages for animals either castrated or entire , and graded as either "male" or "bull".

Treatment group	N	MQ4		
		Mean ± SEM	Median	95% CI
Castrated	179	47.319 ± 0.923[a]	48.483	45.497 – 49.141
Entire – graded as "male"	137	43.862 ± 0.990[b]	44.067	41.905 – 45.819
Entire - graded as "bull"	36	45.078 ± 1.807[b]	44.425	41.410 – 48.747

a, b – Column means with unlike superscripts differ, P<0.01

Table 7. Proportions of two muscles, rump (RMP) and striploin (STR), graded as MSA 3-star by protocol MSA1-BG, MSA2-PMQ or MSA3-MQ4.

Protocol	RMP (% MSA 3-star)	STR (% MSA 3-star)
MSA1-BG	39.2[a]	33.3[a]
MSA2-PMQ	95.0[b]	60.0[b]
MSA3-MQ4	56.3[c]	67.5[b]

a, b - Percentages within a column with unlike superscripts differ, P<0.05

Discussion

Table 5 clearly illustrates the premium that can be achieved by marketing young entire male cattle that achieve a specific target of beef cattle AusMeat grade on a meatworks grid. The cattle in the present study were sold as AusMeat Grain Fed Young Beef (GFYG), for which animals may be female, castrate or entire males that show no secondary sex characteristics. Carcasses from non-castrated animals that met the GFYG specification had a ≈$52 higher gross value than those from castrated animals, while carcasses from non-castrated animals that were graded "bull" because of secondary sex characteristics had a ≈$83 lower gross value than those from castrated animals, and a ≈$137 lower gross value than those from non-castrated animals that graded GFYG.

Gross return

The mean gross return of the carcasses did not differ between the treatment groups. The lower returns from non-castrated animals that were down-graded as "bull" were countered by the greater carcass weights and premiums achieved for the non-castrated animals that graded "steer" (see Table 3)

Chiller assessment and MSA grading

Interestingly, "dark-cutters" are generally mentioned in any discussion of the utilisation of young entire male cattle for beef production. Early-castrates, Late-castrates, Short-scrotum and Entire treatment groups had 4, 1, 0 and 5 carcasses classified as dark-cutters, suggesting that there was no difference in the incidence of dark-cutters between castrates and non-castrates. Although there were differences in the rate of pH decline, there were no differences in ultimate pH, demonstrating that proper nutritional management and minimised sorting or mixing throughout the growing and finishing stages can help to minimise the incidence of dark-cutters.

Ossification and dentition. Ossification was positively correlated with dentition, and while there were no differences in dentition between the treatment groups, castrated animals had lower ossification scores than did non-castrated animals, indicating that although the treatment groups were of similar mean calendar age, non-castrated animals were physiologically older than castrated animals. Although significant, the difference was not great. In the MSA model, for 100% *Bos indicus* cattle, a 10 point increase in ossification score leads to a 1 point decrease in PMQ4 score, for grilled striploin aged for 7 days (Geesink G, *pers comm.*). This supports the conclusion that entire animals should be finished at a younger age than their castrated equivalents, in order to minimise the chance of downgrades.

Hump height and eye muscle area. That castrated animals had lower hump heights than did non-castrated animals suggests that in this case, given that all of the project cattle were high-grade Brahmans, hump height may be more a reflection of testosterone levels than percentage of *Bos indicus* in the cattle. Similarly, eye muscle area was mirrored in the hot carcass weight. Non-castrated animals had greater hot carcass weights and eye muscle areas than did castrated animals, reflecting the anabolic effects of testosterone levels in the non-castrated animals.

Predicted Meat Quality score. Although the current MSA model is not validated for non-castrated animals, inputs into the model other than castration status (ossification, marbling score and rib fat) resulted in castrated animals having higher PMQ scores than non-castrated animals.

Meat quality test results

Shear force. For striploins only, there was a difference in shear force for castrated *vs* non-castrated animals, with the latter having higher shear force test. This result is broadly reflected in the sensory test MQ4 outcomes, with lower shear force scores being indicative of more tender meat, and is consistent with the status of striploin as being of superior quality to the other two muscles tested (Watson *et al.* 2008).

Sensory testing

MQ4. Only striploins from Early-castrate animals had higher MQ4 scores than did striploins from Late-castrate, Short-scrotum or Entire animals. Of the three muscles used for sensory testing, grilled striploins would be expected to be of the highest meat quality score (Watson *et al.* 2008), and therefore are likely to be the most sensitive indicator of treatment effects. The increased eating quality due to ageing from 7 days to 35 days is well documented (Watson *et al.* 2008).

Boning groups. That there were no differences between the boning groups for any of the sensory test outcomes, for rumps and striploins in particular, is surprising and indicates that for high-grade *Bos indicus* cattle at least, taste panels were not able to detect differences in eating quality of some muscles. This finding supports the view that there is a need for further data to be generated to allow the MSA grading model to be further refined for *Bos indicus* cattle.

Sensory testing versus AusMeat carcass grade. Sensory test of meat quality as measured by MQ4 did not differ between carcasses of non-castrated animals that were graded as either “steer” or “bull” (43.862 ± 0.990 *vs* 45.078 ± 1.807, respectively; mean ± SEM), indicating that taste panels did not detect differences in the eating quality of the three muscles from these animals (see Table 7). This suggests that grading of carcasses of young animals on secondary sex characteristics may not accurately reflect the eating quality of meat from those carcasses. Muscles from castrated animals had a higher mean MQ4 score (47.319 ± 0.923; mean ± SEM), indicating that, on average, taste panels judged those muscles to be of slightly higher eating quality.

MSA Star grades

For the three of the muscles that were sensory tested, there were significant disparities in the allocation of MSA star grades based on either boning groups (MSA1-BG), predicted meat quality scores (MSA2-PMQ) or taste panel sensory test results (MSA3-MQ4) (see Table 7). For striploins and rumps, in particular, the disparities in the allocation of MSA star grades based on either boning groups (MSA1-BG), predicted meat quality scores (MSA2-PMQ) or taste panel sensory test results (MSA3-MQ4), appear to be more than one might expect from a grading system designed to ensure that the consumer does not have an unacceptable eating experience from consumption of beef of

MSA 3-star quality or better. This represents a significant potential financial loss for producers targeting the premium available for MSA graded carcasses, as animals that would have provided an MSA 3-star “good every day” eating experience, at least for those muscles, are being incorrectly “ungraded” for MSA.

Production of young entire *Bos indicus* males offers the potential for significant returns for northern beef producers with little impact to meat quality. However, there is a need for further data to be generated to allow the MSA grading model to be further refined for *Bos indicus* cattle.

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Where do we stand with weeds from a research perspective?

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Abstract. State, federal and territory government organisations in collaboration with several universities continue to undertake extensive research aimed at improving management options for the most problematic weeds affecting pasture production in northern Australia. A key focus has been identification of new biocontrol agents, which has resulted in approval to release a new agent on parkinsonia (*Parkinsonia aculeata*), and on-going host testing of a promising rust pathogen on bellyache bush (*Jatropha gossypiifolia*) and a gall fly on Siam weed (*Chromolaena odorata*). Approval will also be sought to release a second agent on parkinsonia following rigorous testing. Prickly acacia (*Acacia nilotica*) has proven more problematic, with several agents failing host specificity testing, but other potential agents will continue to be tested. Investigations into dieback of several exotic weeds have resulted in the identification of endemic fungi capable of causing deleterious impacts on parkinsonia and prickly acacia. Research into the use of low-volume, high-concentration herbicide applications to control Siam weed and bellyache bush has identified an effective option for treating exotic woody weeds in difficult to access areas and should be expanded to include other species. Testing of misting as a lower cost option for treating dense regrowth of prickly acacia in open grasslands is also underway but it is too early to make conclusive findings. Research into the ecology, invasiveness, spread and control of rubber bush (*Calotropis procera*) is progressing with several control techniques showing promise for treatment of isolated plants and dense infestations. Finally, a participatory modelling approach has been developed to guide responses to weed invasions. It has been applied to parthenium, Chilean Needle Grass, lippia, parkinsonia and rabbits across the Murray Darling Basin where it is helping guide management responses and community engagement across the region.

Introduction

Weeds continue to cost the grazing industry millions of dollars through their deleterious impacts and cost of control. They range from those that are recent introductions and in the early stages of invasion to others that are naturalised across large areas and that have been causing significant impacts for many years. In a report by Grice (2002) weeds of significance to the grazing industries of Australia were identified based on eight discrete regions. Weeds identified across all three regions were bellyache bush (*Jatropha gossypiifolia*), calotrope/rubber bush (*Calotropis procera*), mesquites (*Prosopis* spp.) and parkinsonia (*Parkinsonia aculeata*). Five weeds were listed for two of the regions (mimosa – *Mimosa pigra*, perennial mission grass – *Cenchrus polystachios*, prickly acacia – *Acacia nilotica*, sicklepod - *Senna obtusifolia* and sida - *Sida* spp.) and another 11 were considered significant in one region (Grice 2002), which is probably more a reflection of the distribution of the weeds at the time rather than their overall impacts. Another prioritisation process is being commissioned by Meat and Livestock Australia (MLA) to develop a revised priority list to more accurately reflect the current situation.

Prevention and early intervention is by far the most cost effective weed management strategy (Vitelli and Pitt 2006) irrespective of whether it is at a paddock, property, region, catchment, state/territory or national scale. The role of weed research at the early stage of invasion of a weed is primarily to ensure that there are effective control options available to kill plants and to be able to provide information on key aspects of its biology/ecology (*e.g.* age to reproductive maturity, seed bank longevity, dispersal mechanisms) that will help those trying to manage the problem. Being able to provide an indication of potential distributions and habitat suitability are also beneficial as they help direct where to look for the weed and where to focus control efforts. Siam weed (*Chromolaena odorata*) is an example of a relatively new weed (first found in 1994) that has the potential to impact the grazing industry.

For many of the major weeds that are present in the grazing lands of northern Australia, particularly Weeds of National Significance, research has provided a reasonable understanding of their biology/ecology and most can be killed by at least one technique and in many instances a multitude of options are available (Vitelli 2000; Vitelli and Pitt 2006). Rubber vine (*Cryptostegia grandiflora*) is a good example with an effective biocontrol agent reducing seed production in most areas (except some drier habitats) (Julien *et al.* 2012) and plants able to be controlled using a range of mechanical and chemical techniques and the use of fire. The biology/ecology of rubber vine is also well understood and its weaknesses have been identified, such as a short lived seed *bank (*Bebawi *et al.* 2003*).* For other major weeds such as parthenium *(Parthenium hysterophorus)*, prickly acacia, parkinsonia and mesquite there is a good understanding of their ecology/biology and how they respond to traditional control techniques such as the use of herbicides, machinery and fire. Significant advances have also been made in the area of biocontrol with at least one agent currently providing deleterious impacts on giant sensitive plant (*Mimosa diplotricha*), mimosa, some species of sida and mesquite, parthenium, rubber vine and noogoora burr (*Xanthium strumarium*). On the other hand, it has proven difficult to find effective biocontrol agents for prickly acacia, bellyache bush, hyptis (*Hyptis suaveolens*), mother of millions (*Bryophyllum delagoense*), sicklepod and lantana (*Lantana camara*) (Julien *et al.* 2012).

Despite the advances in weed management to date, there are still research gaps and some of the major weeds continue to thicken up (*e.g*. prickly acacia) within existing infestations and/or spread into new areas (e.g. rubber vine and prickly acacia). The reason for this could be due to a range of factors including insufficient resources to deal with the problem for the necessary duration, apathy, legislative restrictions that limit control options and continued reinfestation from neighbouring areas. Industry and stakeholders continue to request more cost effective control techniques and new biocontrol agents to help reduce spread and to obtain control over vast areas that some of these weeds occupy, particularly on relatively low value land.

In this paper we provide an update on the current situation for a number of weeds being investigated by the Queensland government, CSIRO and the University of Queensland (UQ), much of which is funded by MLA. They include prickly acacia, parkinsonia, bellyache bush, rubber bush/calotrope and Siam weed. An overview of dieback projects is also included.

Recent research activities

Prickly acacia

Prickly acacia is most problematic in the Mitchell grass downs of western Queensland where it is estimated to be spread over some seven million hectares (Julien *et al.* 2012). Despite the availability of effective chemical and mechanical control options (Spies and March 2004), it continues to thicken and spread, particularly during a run of wet seasons such as those in recent times. Control of large infestations is difficult and costly, and requires an on-going effort due to the long persistence of the seed bank. There are a number of locations where it can be found in low numbers and is in the early stages of invasion. Movement of livestock containing seed in their digestive system is the most likely cause for many of the outbreaks recorded in new areas and highlights the importance of implementing quarantine strategies. Early intervention should also be a priority.

Prickly acacia has been a target for biocontrol since the early 1980s. Six species of insects, have been released in Queensland. Two insects, a seed-feeding bruchid (*Bruchidius sahlbergi*) from Pakistan and a leaf-feeding geometrid (*Chiasmia assimilis*) from Africa, have established. Thus far, the impact of the seed-feeding bruchid on prickly acacia has been insignificant. The leaf-feeding *C. assimilis* became well established at coastal sites in northern Queensland, but not widely in the arid inland regions (Julien *et al.* 2012). Effective biocontrol therefore continues to be a priority in non-coastal areas of northern Australia. Based on genetic and climate matching studies, explorations for potential biocontrol agents were conducted in India from 2007 to 2011 with funding from MLA. This resulted in the prioritisation of several potential biocontrol agents. Host specificity testing has now been completed on two rusts and a caterpillar. All failed testing. Host testing of the scale insect (*A. indicus*) is currently underway and the leaf-feeding weevil (*D. denticollis*) and a second leaf-webbing species (*Phycita* sp. B) have been imported into a quarantine facility in Brisbane, and will be tested when resources become available. Other priority agents include a leaf beetle (*Pachnephorus* sp.*) from India and a leaf-galling mite (Aceria liopeltus) from Kenya.*

A preliminary study investigating the appearance of naturally occurring dieback in populations of prickly acacia in north Queensland was commenced by the UQ in 2010 with funding from MLA. This research found that a broad suite of fungi were found to be associated with dieback affected and damaged prickly acacia plants in the field. Further analysis and testing of these fungi showed that many of these isolates demonstrated capacity to kill germinating seedlings and an ability to cause dieback symptoms in glasshouse grown juvenile trees. Continued research has resulted in more detailed studies to further understand the infection process, and to more thoroughly screen isolates. Field trials have commenced to evaluate the more aggressive isolates under field conditions. Preliminary data indicate that these fungi are capable of causing dieback symptom.

In addition to the biocontrol work, testing of misters for their potential to treat large scale seedling regrowth at a lower cost than existing options (such as foliar spraying) is being undertaken along with seed longevity studies aimed at quantifying seed bank persistence of prickly acacia.

Bellyache bush

Although this invasive shrub currently occupies only a small proportion of its potential range, it has a foothold throughout the northern rangelands of Queensland, the Northern Territory and Western Australia. Its impacts and current and potential distribution have resulted in its recent declaration as a Weed of National Significance. A concerted research effort over the last 15 years has resulted in an improved understanding of its ecology/biology and how to control it (Randall *et al.* 2009). Nevertheless, control of large infestations is still problematic and biocontrol activities have been underway since 1996 to identify effective agents that might complement traditional control methods. The initial biocontrol program undertaken between 1996 and 2003 resulted in the introduction of a jewel bug (*Agonosoma trilineatum*) but despite releases of large numbers of insects throughout the Northern Territory and Queensland it has failed to establish (Julien *et al.* 2012). A second biocontrol program was initiated in 2007 but to date has not resulted in the release of any further agents, with several promising agents failing host specificity testing. A promising rust fungus *(Phakopsora jatrophicola)* is currently undergoing host testing in the United Kingdom and further explorations are being undertaken in South America.

Parkinsonia

Parkinsonia is a shrub from tropical Americas. It forms dense thorny thickets that negatively affect the pastoral industry in northern Australia by competing with pastures and interfering with stock management. An early biocontrol program resulted in the release of three agents into Australia in the 1990s. One of these, the bruchid *Penthobruchus germaini* is now widespread and common, but it is not causing population-level impacts (Julien *et al.* 2012). Native range surveys recommenced in 1999. These surveys were geographically much broader than the earlier ones as a result of plant genetic studies that showed that the native range was much larger than first thought. Most of the natural enemies recorded in these surveys were rare and few appeared to be both damaging and host-specific. Nonetheless, several potential agents were shortlisted for more detailed study. In particular, two species of looper caterpillers (Lepidoptera: Geometridae) show good potential. The first agent, *Eueupithecia cisplatensis*, is approved for release and initial releases are commencing. The second agent *Eueuthipecia* species 2 has been tested and an application for its release will soon be submitted. It is expected to be released in 2014. These two species have separate geographic native ranges and so will complement each other by maximising the coverage of the wide range of this plant in Australia. The biocontrol program has also provided more general contributions to biocontrol theory and practice, including the use of seed-predators, the role of genetics, and the use of biogeography and new analytical tools to optimise native range survey design (Julien *et al.* 2012; Bell *et al.* 2013).

Research on the naturally occurring and widely observed dieback disease in parkinsonia at the UQ has been ongoing since 2004. Through a range of projects funded through the NT Government, DAFF, MLA and in collaboration with QDAFF, CSIRO and regional bodies, significant improvement in the understanding of this disease has resulted in the development of a successful bioherbicide. A successful program of workshops on parkinsonia dieback provided an opportunity for property and landscape managers to participate in small scale trials to evaluate a developmental form of the dieback agent. The bioherbicide (Di-Bak) is currently undergoing registration through the APVMA. It is anticipated that this product will provide an additional tool to support other control strategies for this weed. A new PhD student (Tracey Nel) supported by MLA has also just commenced at CSIRO to further study dieback in parkinsonia.

Rubber bush

Rubber bush (or calotrope *(Calotropis. procera)* as it is more commonly referred to in Queensland) is an exotic shrub native to Asia and Africa (Grace 2006). It has been present in parts of Queensland, the Northern Territory and Western Australia for many years and is spreading into new areas and forming large thick infestations. This is particularly the situation for the Barkly Tablelands in the Northern Territory and the Gulf of Carpentaria region in Queensland and many landholders are concerned that this reduces pasture production and increases management costs. Due to a paucity of information on rubber bush, MLA has funded a multi-agency project to investigate its rate of spread, invasiveness, biology and control.

Two years into the project, some interesting findings are emerging. In terms of its biology/ecology, pod production by plants varies markedly between areas and appears to be dependent on the availability and abundance of larger-bodied wasps from several families to pollinate the flowers. This directly affects the quantity of seed pods produced and the quantity of seedlings that emerge after suitable rainfall. Seeds of rubber bush do not have any dormancy mechanisms and will readily germinate under favourable environmental conditions. Effective control is therefore achievable, provided new seedlings and regrowth can be treated before reaching reproductive maturity and there is no seed coming from neighbouring infestations. The latter is a risk for rubber bush through wind dispersal of seed (Grace 2006).

In terms of control, the use of mechanical techniques such as grubbing, blade ploughing or cutter barring could be effective in suitable areas provided plants are cut off below ground. In a mechanical trial, medium-sized rubber bush plants were cut off at 0, 10 or 20 cm below ground. All plants cut at ground level (0 cm) survived, whilst all plants cut at 10 and 20 cm below ground died. Large scale seedling recruitment is expected after mechanical control, although the amount will vary depending on how big the soil seed reserves are. Anecdotally, the use of fire appears to be ineffective on adult rubber bush as plants rapidly reshoot from the base afterwards. Whether a regime of repeat fires could provide higher kill rates has not been tested but warrants investigation. Soil-applied herbicides on clay soil country in the Gulf of Carpentaria show promise when applied from the ground or air. They have the advantage of not only controlling the original plants but also seedlings that may emerge afterwards.

Siam weed

Siam weed*,* a perennial shrub native to tropical America, is a relatively new introduction to Australia, having first been discovered in 1994 in northern Queensland. Numerous infestations have been discovered since then. It is considered one of the world's most invasive tropical weeds and has been the target of a National Cost Shared Eradication Program since 1994. Substantial research has been undertaken into the ecology and control of Siam weed over the last 10 years, including soil seed bank persistence and age to maturity trials. Effective foliar herbicides have been identified and registered along with the use of low-volume, high-concentration applications using splatter gun equipment (Brooks *et al.* 2011). Because Siam weed is often found in difficult to access areas, the latter option allows for the use of backpack type equipment and smaller quantities of water. The efficacy of fire has also been tested, with the general conclusion being that a high proportion of small plants can be killed but larger ones will mostly survive (Williams *et al.* 2004).

The eradication program concluded during 2012 and has transitioned to a management program aimed at limiting spread and minimizing impacts. Experiences learnt during the eradication program indicate that early intervention using the available techniques should be a priority in order to achieve cost effective control. It is hoped that approval will be granted to introduce a biocontrol agent to assist with control of Siam weed. Biosecurity Queensland has been actively involved in releasing and monitoring several Siam weed biocontrol agents overseas. Considerable success has been achieved with several agents, particularly the gall fly (*Cecidochares connexa)* in Papua New Guinea, Indonesia and East Timor, leading to the control of Siam weed (Julien *et al.* 2012). Formal approval has been granted to target Siam weed for biocontrol in Australia. Biosecurity Queensland is currently host testing the gall fly.

Dieback studies on additional species

Dieback of a number of exotic weeds in northern Australia has been reported over the years (Haque *et al.* 2011) The UQ and CSIRO have been working together to quantify the causal agents, with a particular focus on pathogens to more broadly understand the science behind this phenomenon. In addition to parkinsonia and prickly acacia, other weeds that have shown dieback symptoms and undergoing preliminary research include gamba grass *(Andropogon gayanus)*, athel pine *(Tamarix aphylla)*, bellyache bush and mimosa. A commercial company (BioHerbicides Australia Pty Ltd) has now been established by the UQ to mass produce capsules containing these fungi and to further develop solutions for a steadily increasing portfolio of problem weeds, some of which, after full development, will become available for land managers to purchase and use to inoculate local infestations.

Risk Modelling

An important aspect of strategic weed management is determining where, when and how to manage weed invasions in a way that makes the most of available resources and minimizes future risks. CSIRO, in partnership with the Queensland Murray Darling Committee and others, have been developing a participatory modeling approach to help guide such decision-making (Murray *et al*. 2012). Expert knowledge is used to build models which identify suitable habitat (where the weed will do best if given the opportunity), susceptible habitat (suitable habitat at risk of invasion from known sources), and how that will be affected by different management actions (such as altered stock management or minimizing dispersal). Examples include a Chilean Needle Grass model to help determine the feasibility of eradication and containment, a parthenium model to help prepare pastoralists in southern Queensland and minimize spread, and a parkinsonia model to help direct on-ground control work to areas at greatest risk within the Desert Channel NRM Region.

Discussion

While the previous sections highlights the significant research being undertaken on invasive weeds of relevance to the grazing lands of Northern Australia, much of it is at a mature stage and consideration needs to be given to future priorities. MLA has commissioned tenders to identify priorities for biological control, develop a new priority list of weeds in the grazing lands and to identify novel ways to manage weeds. The outcomes from these processes will be highly beneficial to research organisations and help direct future research programs. This is particularly pertinent for biocontrol groups who need to start planning new programs now that many of the current ones are in the latter stages. The Queensland government and CSIRO have committed to ongoing biocontrol research through recent joint investment in a quarantine facility in Brisbane. Several pathogens already in Australia are capable of causing dieback in parkinsonia and prickly acacia and this offers an alternative form of biological control. While further testing is required, the results to date are promising. Investigations into dieback on several other species have been initiated but progress could be expedited with additional funding.

There is still research required into the biology/ecology and traditional control methods for some weeds, particularly finding techniques that are cheaper to apply over large areas. This includes overcoming challenges such as removal or placement of restrictions on the use of particular control techniques (mainly chemicals), herbicide resistance, legislation requirements (particularly vegetation management) and an increasing demand for control options in organic production systems. Grazing management also needs to be factored into future weed research to create more resilient grazing systems that are less prone to invasion.

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Measuring and modelling sediment loss and land management change at catchment scales: a synthesis of a decade of research in the Burdekin catchment

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Abstract. Excess sediments (and attached nutrients) from agricultural areas are known to negatively impact on freshwater and marine ecosystems. To prevent further excess sediment reaching coral reefs, we need to better understand the sources and processes generating the excess sediment, and whether the catchment management strategies that are being used to reduce the impact are effective. This paper synthesises a decade of research from the Burdekin catchment that has employed a range of scientific approaches, including modelling and direct and indirect measurement techniques, to improve our understanding of sediment delivery from rangelands to the Great Barrier Reef. Such understanding has the potential to better inform management of grazing productivity.

Introduction

There is increasing evidence demonstrating that excess sediments and associated nutrients from agricultural areas are having a detrimental impact on the Great Barrier Reef (GBR) (De'ath *et al.* 2012). In response to this issue, the Australian Government allocated $200 million in 2008, via the Reef Rescue package, to help land owners and managers implement improved land management practices (Brodie and Waterhouse 2012). This investment is based on the assumption that paddock and end of catchment pollutant loads will decline with improved land management practices. Detecting the effect of land management change on water quality and more critically, ecological condition of the reef, requires a range of scientific approaches. This publication summarises a range of research projects that have been conducted in the Burdekin (and nearby) catchments over the last 10-15 years (Fig. 3). Most of this research was carried out in the Burdekin catchment (Fig. 4) as it is the largest contributor of anthropogenic derived fine sediment to the GBR lagoon (Kroon *et al.* 2012), and the mouth of the river is located near a number of economically and globally significant marine areas (Brodie *et al.* 2009). Only brief details of the results of the projects will be presented herein, and readers are encouraged to consult the cited literature for more details.

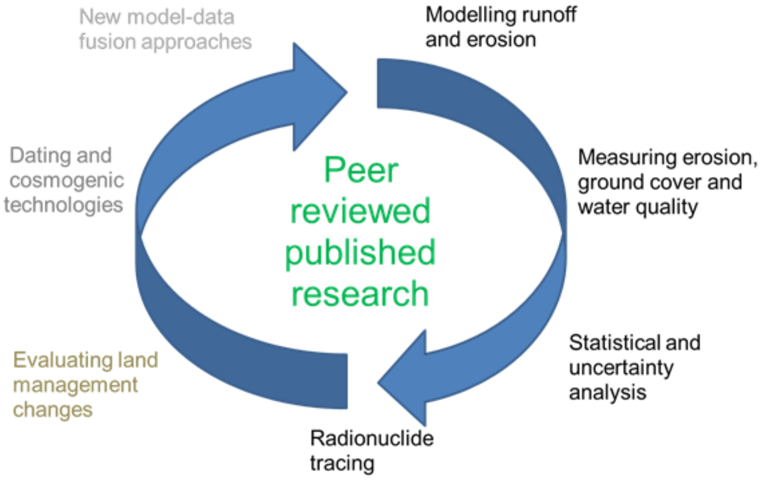


Fig. 3: Conceptual framework linking the various research projects in the Burdekin catchment.

Progress with Catchment (runoff and erosion) Modelling

In 2001, SedNet modelling across the whole of the Burdekin watershed suggested that hillslope erosion was the dominant process delivering ~67% of the sediment load to the end of the catchment (Prosser *et al.* 2001). The remainder came from gully (~27%) and bank (5%) erosion. Although modelled end of sub-watershed sediment yields matched reasonably well with measured sediment loads in some areas of the Burdekin (Wilkinson 2008; Bartley *et al.* In Review-a), we now know that the dominant erosion process is different for different parts of the catchment (Kinsey-Henderson *et al.* 2005), and there are large uncertainties in the modelled estimates for some processes including gully erosion (Kuhnert *et al.* 2010), bank erosion (Hughes and Croke 2011) and dam trapping (Lewis *et al.* 2013).

Using measurements to identify sediment sources and constrain model outputs

To improve the known uncertainties in modelled erosion estimates, a series of field sediment budget and tracing studies were undertaken. These studies determined that although hillslope erosion can dominate fine sediment loads during drought years when ground cover is low (Bartley *et al.* 2007), sub-surface or channel erosion represents 60-80% of fine river sediment in the Burdekin in the long term (Bartley *et al.* 2010b; Hancock *et al.* 2013; Wilkinson *et al.* In Press). There is also considerable evidence from other tropical rangeland areas of Northern Australia demonstrating that sub-surface or channel erosion is the dominant source of sediment contributing to watershed sediment yields (Wasson *et al.* 2002; Brooks *et al.* 2009; Hughes *et al.* 2009; Tims *et al.* 2010; Caitcheon *et al.* 2012).There are a number of reasons for the discrepancy in the ratio of sediment sources between modelled and measured estimates, and improvements to estimates of ground cover and gully location and density are progressing.

Understanding the effect of ground cover on runoff and erosion

A number of studies have been carried out in the Burdekin and adjacent Fitzroy catchments to improve our understanding of the role of ground cover on runoff and water quality. Soil loss from grazed hillslopes increases sharply as cover decreases below 40% (McIvor *et al.* 1995; Scanlan *et al.* 1996; Bartley *et al.* 2010a). When cover is <40%, both fine (<63 µm) and coarse (>63 µm) sediment fractions are eroded, however, when cover is high (>70%), coarse fractions are trapped on the hillslope, and only fine fractions move off the hillslope (Scanlan *et al.* 1996; Silburn *et al.* 2011). The type of cover also influences runoff and soil loss. Despite species such as Indian Couch showing lower erosion rates in some areas (Scanlan *et al.* 1996), hydrological recovery following disturbance can be very slow in areas that are not dominated by resilient tussock communities (Bartley *et al.* In Review-b). Ground cover is also very 'patchy' in these landscapes (Ludwig *et al.* 2007) and this results in large variability in sediment yields even for hillslopes under the same management regime (Bartley *et al.* 2006). Roth (2004) determined that ground cover needs to be >75% to enable infiltration during high intensity events. Even with high cover, localised infiltration varied widely, mainly as a function of macroscopically visible bioturbation by soil macrofauna such as ants, termites and earthworms (Dawes 2010). Patchy vegetation on erodible soils within riparian zones can also lead to the initiation of alluvial gullies and scald features (Shellberg *et al.* 2010). Adequate ground cover, on both hillslopes and riparian zones, needs to be maintained to reduce the potential for gully formation.

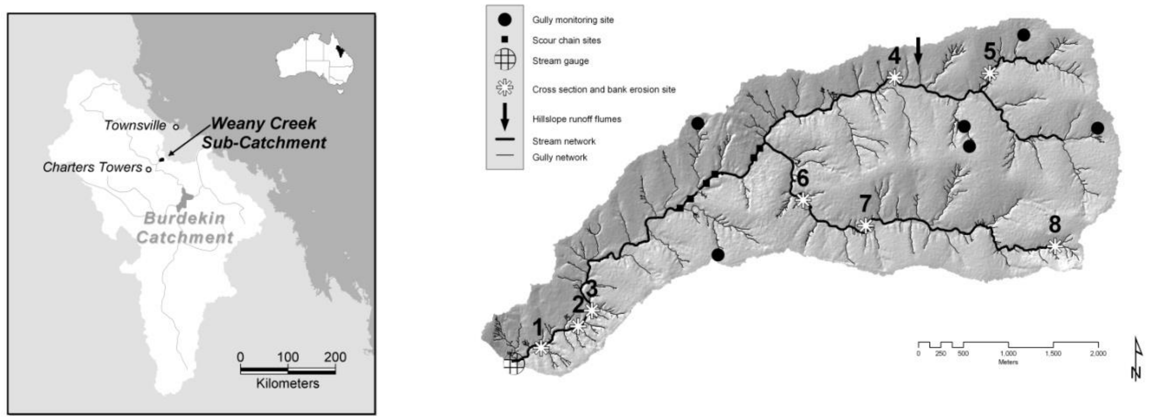
Understanding the drivers and options for controlling gully erosion

Given that gullies are now known to be a major source of sediment in many grazing areas, understanding the options for managing gullies in rangelands will be important for achieving water quality benefits from improved grazing land management. Air photo analysis of gully extension over the past 60 years indicates that most existing gullies in the Charters Towers area are gradually reaching maturity and today erode at approximately half the historical rates. However, the large amount of gully erosion (~80,000 km throughout the GBR catchments; Thorburn and Wilkinson, In Press), means that they collectively remain a major source of sediment. An ongoing field trial at

Virginia Park Station (Fig. 4B) has demonstrated that reductions in gully sediment yield can be achieved by redistributing grazing pressure away from gullied areas, which helps increase vegetation cover on gully walls and in gully channels. Further reductions can be achieved by improving land condition, particularly perennial pasture biomass, and soil health, to increase the soil moisture store and reduce runoff volumes into gullies.

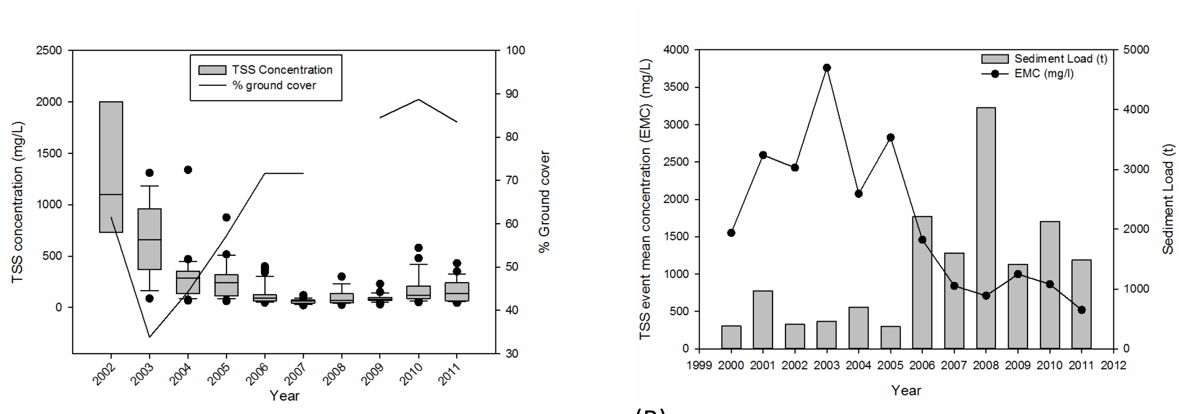
Linking improved management to improved water quality

In the Burdekin catchment, hillslope sediment loss is generally quite low by global standards. As a result, reductions to sediment yields due to changed management regimes are difficult to detect over short time scales (<5 years) (O'Reagain *et al.* 2005). Some studies have shown that it is possible to reduce sediment concentrations and runoff from early wet season events on hillslopes with improved grazing land management within ~5 years (Hawdon *et al.* 2008; Bartley *et al.* 2010a) (see Fig. 5A). Improvements have been more rapid (reducing runoff coefficients by 25% over 3 years) when cattle were excluded completely, and where pastures were dominated by more resilient tussock communities (Connolly *et al.* 1997). However, reducing runoff and sediment yields in highly disturbed catchments (Bartley *et al.* 2010b), or at large catchment scales, will take a lot longer (>10 years) because of the time lags associated with soil and pasture (ecohydrological) recovery (Wilcox *et al.* 2008) and the geomorphic changes required to reduce the rates of channel erosion. For example, in the Weany Creek catchment (Fig. 4), end of catchment sediment concentrations have declined after 10 years of improved grazing management, however, total sediment loads have not changed, and have in fact increased in response to increased runoff (Fig. 5B). Modelling scenarios based on standard erosion relationships indicate that achieving a 20% reduction in fine sediment loss across GBR catchments will require a 20% increase in mean vegetation cover over 50% of the grazing land, and a redistribution of grazing pressure away from gullied and stream frontage areas (Thorburn and Wilkinson In Press).



(A) (B)

Fig. 4. (A) Location of the experimental catchment (B) location of field monitoring sites including the hydrological flume sites and stream gauge.



(A) (B)

Fig. 5. (A) Changes in total suspended sediment (TSS) concentration following 10 years of improved grazing land management, and increasing ground cover, at Virginia Park Station on (A) a hillslope and (B) at the end of the 14 km^2 catchment, noting that the grazing management study started in 2002.

Accurately measuring changes to river water quality downstream

For large catchments with highly variable discharge, it is important to quantify loads accurately to determine the current load and to monitor the effect of changes in catchment management. A new method for estimating the load, and the certainty around that load, has been developed for the Burdekin catchment (Kuhnert *et al.* 2012). The new loads regression estimator (LRE) is a statistical model that incorporates historical flow terms, sediment trapping effects of the Burdekin Falls dam, and vegetation cover. The method accounts for uncertainties in flow rates as well as the uncertainty in concentrations of the measured data to provide a measure of load with estimates of error. Current work is focussed on developing a data assimilation (model-data fusion) approach which uses a Bayesian Hierarchical Modelling (BHM) framework to combine measured data with modelled output arising from more traditional deterministic modelling platforms (Wilkinson *et al.* In Review). Examples of this approach are outlined in Wikle and Berliner (2007). The predictions from this model can be realised as a weighted combination of the measured and modelled data, where the weightings are derived from prior probability distributions that characterise the certainty in both data types. Such models would be able to run scenario's (e.g. Thorburn and Wilkinson In Press) and provide estimates of confidence around the changes in load. Even with the improved methods for estimating constituent load, statistical modelling of flow data in the Burdekin catchment suggest that with current load monitoring programs it will take at least 50 years to detect an average 20% reduction in suspended sediment loads with reasonable (80%) certainty (Darnell *et al.* 2012).

Where to from here?

Our knowledge of the link between land management and water quality has increased considerably over the last decade. There are, however, still a number of areas of further research. These include:

- Understanding how soil moisture (and the closely related issue of soil condition and type) influences runoff in rangeland environments. New non-destructive cosmic ray soil moisture technologies are being trialled in the Burdekin to further develop this area.
- Quantifying pre-European erosion rates to inform and constrain the catchment models that are being used to evaluate water quality targets against pre-European estimates of erosion. A trial project in the Burdekin using terrestrial cosmogenic nuclides (TCN's) will generate independent (non-modelled) estimates of pre-European erosion.
- Expanding the network of sites trialling restoration techniques such as a gully remediation on a range of soil types.

- Integrating the catchment based data assimilation techniques outlined above with similar models in the estuarine and marine environments so that land management changes can be evaluated from the top of the catchment through to the outer GBR (with uncertainty bounds).

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Managing for a variable climate: long term results from the Wambiana grazing trial

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*Abstract***.** Inter-annual rainfall variability is a major challenge for sustainable and profitable grazing management in northern Australia. Results are presented from the 16 year Wambiana grazing trial on the relative performance of five stocking strategies in managing for rainfall variability. The results show that recommended strategies such as moderate stocking, varying stock numbers in response to forage availability and moderate stocking with wet season spelling are both more sustainable and profitable than heavy stocking. It is suggested that managers apply flexible stocking around long term carrying capacity with stocking rates changed in a risk-averse manner as forage availability varies between years. Wet season spelling is also important to maintain pasture condition. These strategies are currently being tested in the second phase of the Wambiana trial.

Introduction

The inherent variability of rainfall in northern Australia is a major challenge to sustainable and profitable beef production. Strategies such as stocking at long-term carrying capacity or varying stock numbers with available forage are recommended to manage for climate variability, but have generally not been tested at a scale relevant to industry. In particular, the relative profitability of different strategies has not been objectively quantified, limiting adoption by managers. To address this issue, a large, long term trial was established to empirically quantify the effects of different grazing strategies on a range of variables including animal production, profitability and land condition. This paper presents a brief summary of results from the first 16 years (1998-2013) of this ongoing trial.

Materials and methods

The trial is located on 'Wambiana' station, ~70 km SW of Charters Towers, north Queensland. The area is classified as *Aristida-Bothriochloa* woodland; mean annual rainfall is 650 mm with a coefficient of variation of 40%. Experimental paddocks are ~100 ha in size and contain similar proportions of three soil-vegetation communities: yellow-brown kandosols dominated by *Eucalyptus melanophloia* (Ironbark), heavy clays dominated by *Acacia harpophylla* (Brigalow) and sodosols dominated by *E. brownii* (Box). This design was chosen to mimic commercial paddocks which are typically comprised of a mixture of soil types.

Five grazing strategies that are either in commercial use and/or are recommended to manage rainfall variability were selected: (i) *moderate stocking* (MSR), stocked at the long term carrying capacity (LTCC) of about 8 ha/animal equivalent (AE= 450 kg steer), (ii) *heavy stocking* (HSR): stocked at twice LTCC (4 ha/AE), (iii) *variable stocking* (VAR) – stocking rates adjusted annually at the end of the wet season (May) based on available pasture, (iv) a *Southern Oscillation Index (SOI) - variable strategy* with stocking rates adjusted annually in November based on available forage and SOI-based climate forecasts for the next wet season, and (v) *Rotational wet season spelling (R/Spell)* applied in a three-paddock system, stocked at about 8 ha/AE. The range of stocking rates selected was based on the advice of the Wambiana Grazier Advisory Committee. All treatments are replicated twice.

Paddocks are grazed by 1.5 and 2.5 year Brahman-X steers, supplemented with wet-season P and dry season urea. Molasses and urea drought feeding was provided to the HSR in 4 of the 16 years of the trial. Animals are weighed at the start and end of each grazing year with older animals sent to the meatworks after 2 years on the trial (O'Reagain *et al.* 2009). Accumulated gross margins (AGM) were calculated from annual gross margins (GM) *i.e.* the value of beef produced minus variable and interest (7.5%) costs. Based on meatworks feed back for trial animals weight gains were valued at $1.30/kg and $1.50/kg for poor and good condition steers respectively (O'Reagain *et al.* 2011). Pasture total standing dry matter (TSDM) and species contribution to yield were assessed annually in May using the BOTANAL procedure. Species data was grouped into 5 functional groups i.e. 3-P and 2-P (palatable, productive and/or perennial) grasses, wiregrasses (*Aristida* and *Eriachne* spp.), annual grasses and 'other' species (forbs, legumes, sedges, other grasses). 3-P tussock densities were measured annually in May.

In Phase 2 of the trial (2011 onwards) the VAR and SOI strategies were modified to incorporate three stocking rate adjustment points with or without wet season spelling. Given the recent nature of these changes, data from the modified treatments is included under the original VAR and SOI treatments.

Results and Discussion

Rainfall and stocking rates

Rainfall varied markedly over the 16 year trial period (Fig. 1). In the VAR and SOI strategies, stocking rates were adjusted accordingly, with very high stocking rates in 2000/2001 leading to overgrazing in the following dry year. However, stocking rates were cut sharply thereafter in both strategies and subsequently managed in a more risk averse fashion (Fig. 1a). In the HSR, dry season drought feeding was required in 4 years to prevent starvation while stocking rates had to be reduced by 1/3 between 2005 and 2009. One replicate of the HSR also had to be destocked for 3 months in 2004 due to the complete absence of forage. In contrast to the HSR, stocking rates in the MSR were easily sustained in all years without drought feeding or destocking being required (Fig. 1b).

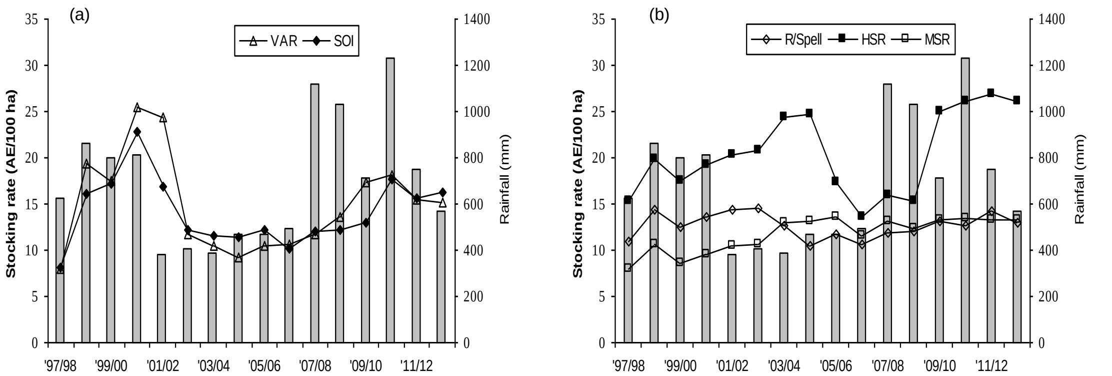

Fig. 1. Stocking rates (expressed as AEs/100 ha) and rainfall over different years at the Wambiana trial for (a) the VAR and SOI and (b) the R/Spell, MSR and HSR strategies.

Pasture production and composition

Pasture TSDM varied from 3000-5000 kg/ha in wetter years to 500 kg/ha or even less in drier years (O'Reagain and Bushell 2011). Grazing treatment interacted with rainfall to have a major impact on pasture condition: after 16 years, the density of 3-P grasses was highest in the MSR and R/Spell, somewhat lower in the VAR and SOI but by far the lowest in the HSR (Fig. 2). Comparison of densities in 2006 following 5 below average rainfall years with those in 2013 following an extended sequence of good years is instructive: although 3-P densities increased markedly in the MSR, R/Spell, VAR and SOI strategies very little recovery occurred in the HSR despite recent above average rainfall years.

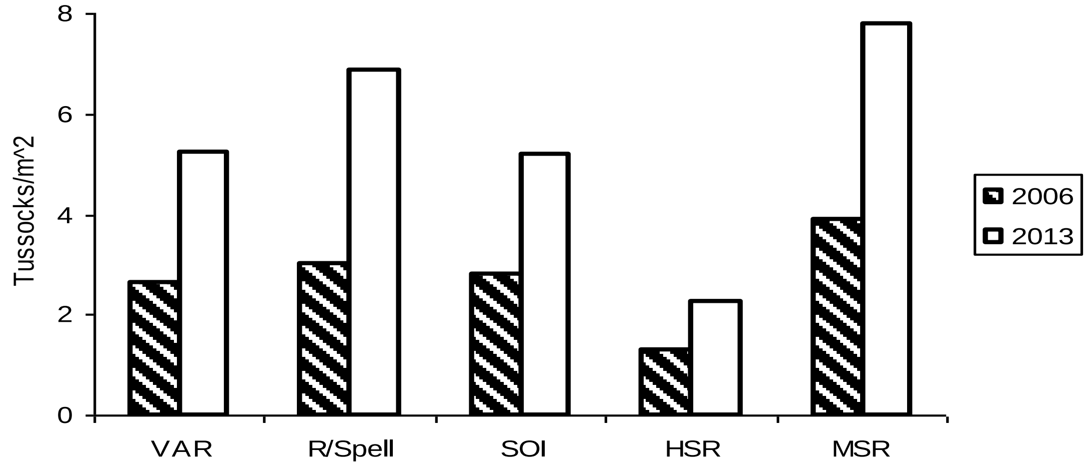

Fig. 2. The density of 3-P (palatable, perennial, productive) species in 2006 and in 2013.

These differences in 3-P density have also had profound impacts on pasture production and composition: after 16 years, pasture TSDM is 3 times greater and 3-P grass yield 4 to 5 times larger, in the R/Spell and MSR than in the HSR (Fig. 3). There has also been a striking increase in the frequency of the exotic *Bothriochloa pertusa* (Indian couch) from 0 % (2005) to 57 % (2013) in HSR paddocks on the dominant sodosol soils. Over the same period, *B. pertusa* frequency only increased to 20 % in MSR paddocks. In the longer term and with an inevitable return to drier conditions, the loss of 3-P tussocks in the HSR will undoubtedly reduce animal production and carrying capacity to a greater extent than that observed in previous dry years.

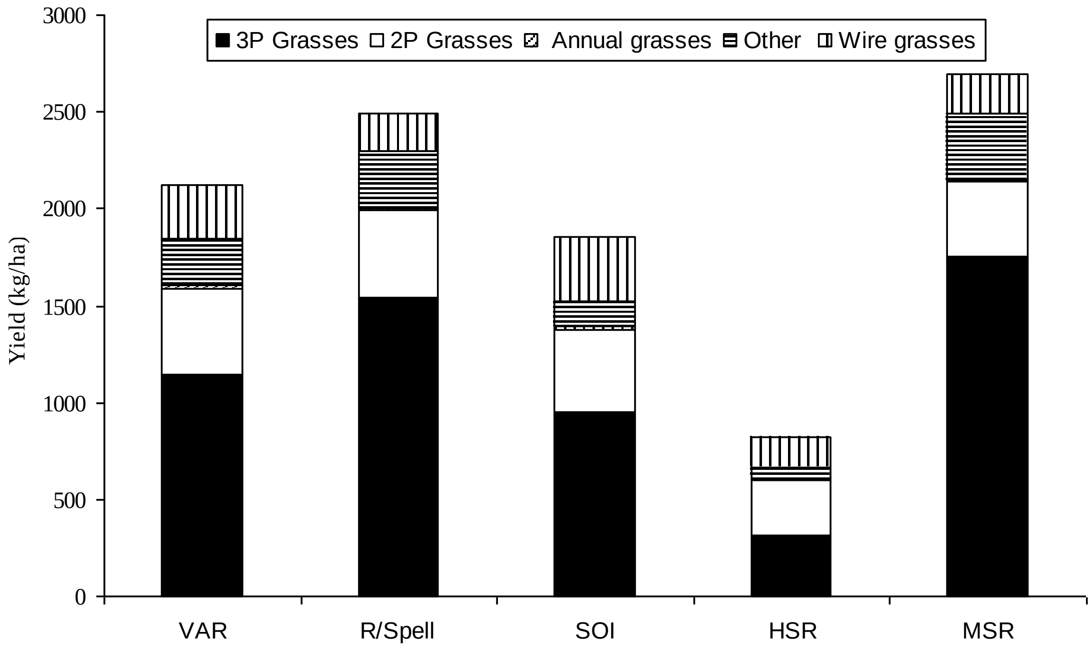

Fig. 3. Pasture yield and species composition after 16 years in different grazing strategies.

Animal production

Individual live weight gain (LWG/hd) varied markedly between years from 5 up to 180 kg/hd/year depending upon rainfall and treatment (O'Reagain *et al.* 2009). Averaged over 16 years, individual

LWG was highest in the MSR (118 kg) and lowest in the HSR (97 kg), with the R/Spell, VAR and SOI averaging 112 kg/hd/yr. After 2 years on the trial, steers in lighter stocked treatments accordingly finished heavier and in better condition than those under heavy stocking. These animals consequently produced heavier carcasses at the meatworks and generally received a price premium of between $0.07 and $0.20/kg, particularly in drier years (O'Reagain and Bushell 2011)

LWG per hectare also varied markedly between years, ranging from 5 to 48 kg/ha/year depending upon rainfall and treatment. In contrast to individual LWG, average LWG/ha was highest in the HSR (23 kg/ha) but lowest in the MSR and R/Spell (15 kg/ha) followed by the 2 variable treatments (18 kg/ha). However, the high average LWG/ha in the HSR came at the not-insignificant cost of drought feeding in drier years.

Economic analysis

In the first 5 good years, accumulated gross margin (AGM) grew fastest in heavier stocked strategies like the HSR, VAR and SOI (Fig. 4). This occurred because the high pasture yields allowed a high LWG/ha without the requirement of drought feeding or a price penalty being incurred for poorer animal condition. With the start of dry years post-2000 however, AGM dropped steadily in the HSR due to consistently negative gross margins arising from the costs of drought feeding, reduced LWG/ha and the price penalty for poorer condition animals.

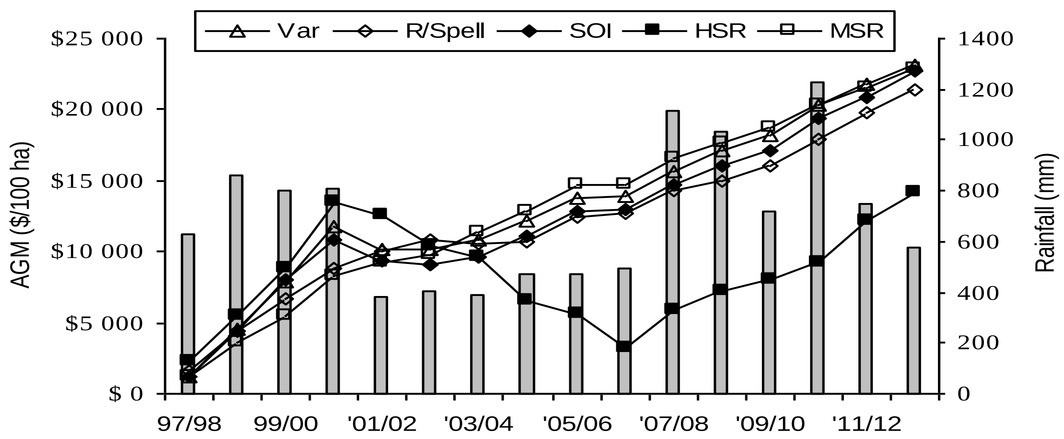

Fig. 4. Accumulated gross margins and rainfall over 16 years for five grazing strategies.

In contrast, while AGMs in the VAR and SOI also dropped in the first dry year, the sharp cut in stocking rate that followed allowed AGMs to recover and continue growing thereafter. Although stocking rates in the HSR were cut by a third in 2005, AGM's only recovered later with a return to wetter years. In contrast to the HSR, in the MSR and R/Spell, AGM's grew relatively steadily and by 2004/05 had equalled and thereafter exceeded those in the HSR. Hence by the end of the 16 year period, AGM in the HSR strategy was some $7200-$8700/100 ha less than in the other strategies. Recent modelling of a breeder herd based on Wambiana trial data (Scanlan *et al.* 2013) also indicates that profitability will be higher at the enterprise level under moderate as opposed to heavy stocking.

Discussion and Conclusions

Although the HSR initially gave good economic and animal performance, in the long term it was the least profitable of all strategies. The strategy was also not sustainable; stocking rates had to be reduced in dry years while perennial grass density and basal area declined (Orr and O'Reagain 2011). Although ground cover and pasture TSDM increased again in later wetter years (O'Reagain and

Bushell 2011) 3-P grass densities did not recover, indicating long term deterioration in pasture condition. Nevertheless, during the last four above-average rainfall years, LWG/ha in the HSR was still the highest of all strategies, indicating the resilience of this system. Further pasture deterioration with an associated decline in animal production is however likely when the inevitable return to drier years occurs.

Moderate stocking, in contrast to the HSR, gave relatively consistent economic returns due to good individual animal production, meatworks price premiums and low costs. Overall the MSR was far more profitable than the HSR and of similar profitability to the VAR, SOI and R/Spell strategies. The MSR also maintained perennial grass density and, with the R/Spell, had the best pasture condition. Experience at the trial nevertheless indicates that the MSR strategy would benefit from wet season spelling as well as some stocking rate flexibility as seasonal conditions changed.

The relatively modest performance of the R/Spell strategy compared to the MSR is unexpected given the accepted benefits of wet season spelling on pasture condition. However, the R/Spell was initially stocked at 6.5 ha/AE i.e. above the MSR; non-spelled sections were thus heavily stocked during the wet season as cattle had access to only 2/3 of the experimental area. This, together with an ill-timed fire in 2001 and the subsequent drought, adversely affected profitability and pasture condition (O'Reagain and Bushell 2011). Following a reduction in stocking rate to 8 ha/AE in 2003, pasture condition improved rapidly in the R/Spell and as of May 2013 is probably superior to that in the MSR. Moreover, over the last three seasons, individual LWG in the R/Spell has been the highest of all strategies. The present results nevertheless show that (i) wet season spelling does not buffer the impact of higher stocking rates on pasture condition and (ii) that some reduction of stocking rates is important in drought years.

Variable stocking as applied in the SOI and VAR was far more profitable than heavy stocking and of similar profitability to the MSR and R/Spell. However, high stocking rates in 2000/01 leading into the dry years adversely affected perennial grasses in both variable strategies, reducing pasture condition. The long term effects of this overgrazing are still evident 12 years later in 2013 (Fig. 2). Variable stocking would thus be improved by setting upper limits to stocking rate and making stocking rate adjustments in a more risk-averse manner. Experience at the trial suggests that the *primary* stocking rate adjustment should be based on forage availability at the end of the wet season with other *secondary* adjustment points in the late dry season (October/November) and possibly, in the early-mid wet season.

In conclusion, the results of this trail indicate that the most profitable and sustainable strategy for managing climate variability will involve flexible stocking around long term carrying capacity with stocking rates changed in a risk averse manner as seasons fluctuate. Wet season spelling is also essential to maintain land condition. These strategies are currently being tested in the second phase of this ongoing trial.

Acknowledgements

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Insights from Cash Cow

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Abstract. The causes of poor reproductive performance in northern Australian beef herds are multi-factorial; however, quantification of the impact of individual factors on performance of breeding mobs is lacking. To address this the reproductive performance of ~78,000 cows managed in 165 breeding mobs located on 72 commercial beef cattle properties was measured over 3 to 4 consecutive years (2008-11) using a crush-side electronic data capture system. Percentage of lactating cows pregnant within 4 months of calving, annual pregnancy rate, percent loss between pregnancy diagnosis and weaning and annual incidence of cow 'missingness' were used to define performance, with the commercially achievable level of performance proposed as the performance of the 75th percentile mob or cow for each measure. Also, methods of estimating beef output from breeding herds were developed, and an achievable level of beef production determined for each country type. The impacts of 83 property, environmental, nutritional, management, and infectious disease factors on performance were investigated. The major factors affecting performance included country type, period of previous calving, wet season phosphorous status, cow body condition, hip-height, cow age, cow reproductive history, severity of environmental conditions and occurrence of mustering events around the time of calving. Presence of wild dogs and evidence of widespread recent pestivirus infection and vibriosis were factors that did not contribute to the final model but, also significantly affected animal performance. A framework for conducting economic analyses of the impact of factors affecting performance was developed.

Introduction

There has been no population-based study of the reproductive performance of commercial breeding herds in northern Australia, or of the major factors affecting performance in these herds. The former would provide producers with a commercial rather than biologically achievable level of performance, and the latter would enable producers to focus management changes and investment on those factors which have been shown to be contributing most to herd reproductive outcomes. Burns *et al.* (2010) have provided a comprehensive review of the factors affecting performance; however, quantification of the contribution of each to the overall performance of commercial breeding females and herds is lacking. Also, there is a lack of published data on beef production from breeding herds and the relationship between reproductive performance and beef production.

A major challenge to studying the reproductive performance of extensively managed breeding herds is the fact that breeding females are often only mustered twice a year and 'mothering-up' of calves is rarely done. The use of foetal aging at the time of annual pregnancy diagnosis enables month of conception and calving to be estimated. This enables assessment of the impacts of environmental, nutritional, management, animal and infectious disease factors on:

1. How efficiently cows become pregnant.
2. The likelihood of pregnant cows rearing a calf.
3. The likelihood of cows going missing (*i.e*. dead, lost ID tag, moved paddocks).

Approximately 78,000 cows managed in 165 breeding mobs located on 72 commercial beef cattle properties distributed across the major beef breeding regions of northern Australia were enrolled in the Cash Cow project and monitored for 3 or 4 consecutive years (2008-11).

Materials and Methods

Data collection

Using a commercially available crush-side electronic data capture system (AgInfoLink's Beeflink™) data on 12 to 20 variables (including body condition score, lactation status) were recorded for each NLIS (National Livestock Identification Scheme) tagged heifer or cow, at processing rates very similar to those normally achieved on each co-operating property (cattle processing rate ranged from 50 to 120/hr). Data capture was conducted twice per year, at the main branding or weaning muster and again at the pregnancy diagnosis (PD) muster. An issue of concern was the 8.3% of NLIS tags that needed to be replaced over the 3.5 year period of the project.

Environmental factors were derived from Bureau of Meteorology databases, property records and digitised paddock maps, and nutritional factors were derived from faecal NIRS (Near Infrared Reflectance Spectroscopy) and wet chemistry faecal phosphorous (FP) analysis (samples collected in January, March, May, August & November) and producer pasture assessments. Management factors were derived from a series of property surveys, and infectious disease factors from cross sectional blood and vaginal mucus sampling performed at each muster in years 1 and 3 of the project. Wherever possible the published threshold values were used for all quantitative variables. However in some cases, where these were not found to be discriminatory, the analysis dataset was used to generate threshold values. For example, the FP to metabolisable energy (ME) ratio, which was used to define the P status of enrolled mobs, was based on an assessment of the preliminary univariable logistic regression models fitting FP:ME as the sole predictor of cow reproductive performance.

Overall, 90% of enrolled properties practised some form of paddock rotation. In the paddocks used by project cows, more than 50% and almost 100% of the area was within 1.5 km and 2.5 km of a permanent water point. Estimates of pasture yield were collected at the same time as samples for NIRS. Overall, the incidence of pasture yields less than 1000kg/ha (a measure of overgrazing) was less than 10%, except during July and September 2009 when incidences of 30 to 70% were recorded across all country types, and in September 2010 in the Northern Forest when the incidence was 10%.

Measures of performance and beef production

Percent pregnant within 4 months of calving - was only generated for those pregnant heifers and cows, where foetal age was determined, and the females were re-mustered the following year and foetal age again determined. The predicted month of calving was calculated using estimated foetal age at the date of the pregnancy test muster and projected forward using a gestation length of 287 days and 30.4 days per month. This measure determines the proportion of lactating cows achieving the biological goal of a 12-13 month intercalving interval.

Annual pregnancy rate - was determined in control mated herds from the findings of the pregnancy test muster conducted after the end of mating. In continuously mated herds it was determined from the foetal aging estimates of conceptions occurring between 1 September the previous year and 31 August of the current year. It provides an estimate of the annual potential calf output from a breeding mob.

Percent foetal/calf loss between pregnancy diagnosis and weaning (includes abortions, still births and calf deaths) - was the proportion of females diagnosed pregnant that failed to be recorded as lactating at a muster after their expected month of calving. Females were recorded as having failed to maintain their pregnancy if they were recorded as not lactating at the first muster after the expected calving month, or, if this muster occurred greater than 1 month after expected month of calving, they were not subsequently recorded as lactating. Also, it should be noted that calculation of foetal/calf loss was restricted to those cows that were mustered and recorded as pregnant in one year then mustered again the following year and recorded as either wet or dry. Cows that missed one of these musters, including those that died in the period, were not included.

Annual incidence of missingness - was defined as the proportion of females which were recorded as 'kept' the previous year and failed to be present at any muster in the current and following year. This measure provides an estimate of cow mortality but does include missingness due to lost NLIS tags and unrecorded movement of breeding females within properties.

Weaner production - was calculated by multiplying the total number of calves weaned in a year by their average weight and dividing this by the total number of cows retained at the pregnancy diagnosis muster the previous year. However, where accurate data on number of calves weaned in unavailable the number of cows lactating after the estimated month of calving can be used. Weaner production is readily derived and provides a useful estimate of annual net live weight production from breeding herds.

Country type

Co-operating properties were classed into four country types on perceived production potential using broad vegetation types that crossed geographic and political boundaries. Properties with forested land types and fertile soils in central and south-east Queensland were differentiated into those outside (southern forest n=19) and within the Brigalow belt (central forest n=12). In northern areas, land types predominated by tree-less black soil downs (northern downs n=14) were separated from forested land types with low-fertility soils (northern forest n=27).

Multivariable modelling

For each measure of performance the impact of each potential factor was assessed by univariable screening. Then using the factors identified as having a significant impact on performance, candidate multivariable models were developed to enable identification of the major factors affecting performance, and to quantify the impact each factor had on the performance of the population of mobs and cows monitored. As the monitoring of infectious diseases was only conducted in the first and third years of the project, risk factors relating to infectious disease monitoring were not considered for inclusion in the final multivariable models. However, their impact on performance was investigated using final models that were restricted to the year/s relevant to the infectious disease monitoring.

Animal ethics

This study was approved by an animal ethics committee at the University of Queensland (AEC Approval Number: SVS/115/11/MLA [NF]).

Results and Discussion

Overall performance

There was marked variation in the reproductive performance of enrolled breeding mobs both within and between country types. The median performance (50th percentile) and interquartile range (25th to 75th percentile) for cows by country type are presented in Table 1. The mean annual incidence of missingness (an estimate of cow mortality rate) for cows (includes both mature and aged cows) in the Southern Forest, Central Forest, Northern Downs and Northern Forest was 10%, 9%, 8%, 17%, respectively.

Table 1. Reproductive performance (median, inter-quartile range)* of cow mobs by country type.

Measure	Southern Forest	Central Forest	Northern Downs	Northern Forest
Pregnant within 4 month of calving (%)	78(65-89)	81(69-88)	76(69-81)	26(14-47)
Annual pregnancy rate (%)	85 (76-92)	85 (79-92)	80 (75-90)	66 (55-73)
Foetal/calf loss (%)	5 (2-9)	6 (5-9)	8 (5-14)	13 (9-18)

*25th to 75th percentile values

Achievable reproductive performance and live weight production

A good indicator of what is a commercially achievable level of performance is the 75th percentile mob or cow performance within country type. Therefore, using the data presented in Table 1 the achievable percent pregnant within 4 months of calving for cow mobs are, respectively southern forest (89%), central forest (88%), northern downs (81%), and northern forest (47%). The achievable percent foetal/calf loss are, respectively: southern forest (2%), central forest (5%), northern downs (5%), and northern forest (9%).

Achievable weaner production was 240 kg/yr (southern forest), 220 kg/yr (central forest), 183 kg/yr (northern downs), and 112kg/yr (northern forest). Average weaner production appeared similar to average estimated annual live-weight gain of steers within property.

Major factors affecting performance of cows and breeding mobs

Please note that in the data presented below all percentage differences are absolute differences. Also as the findings have been derived from a multivariable model it is important to recognise that for each factor listed below the impact described is independent of the impacts of the other identified major factors:

1. The percentage of cows in poor body condition (BCS<2.5 using a 1 to 5 scoring system) at the PD muster the previous year that became pregnant within 4 months of calving was 8%, 14%, 18% and 22% significantly lower than cows in fair (BCS 2.5), moderate (BCS 3.0), good (BCS 3.5), and very good to fat (BCS 4-5) condition, respectively. However, the magnitude of the differences between body condition score categories was consistently much lower (average of 2% difference between BCS categories) for cows in the Northern Forest compared to those in the other country types. Part of the explanation for this difference is that except for cows in poor condition most other cows in this country type lost condition between pregnancy diagnosis and the first annual weaning muster the following year. In addition, cows with adequate dry season pasture availability (>2,000 kg dry matter/ha) and in fair or poor body condition had an annual incidence of missingness 4 and 9% higher than cows in BCS≥3. Where dry season pasture availability was inadequate the annual incidence of missingness was a further 2 and 3% higher.
2. Percentage pregnant within 4 months of calving increased by 8% when body condition was gained in late pregnancy and early lactation, and decreased by 7.5% when average wet season crude protein to dry matter digestibility ratio was <0.125.
3. Cows in poor body condition (BCS<2.5) at the first annual branding or weaning muster had an annual pregnancy rate 10 to 12% lower than cows in good body condition (BCS 3.5).
4. 1st lactation, 2nd lactation, mature and aged (>9 years) cows considered to have an inadequate phosphorus status (average wet season FP:ME <500 mgP/MJ ME) had 24%, 1%, 4% and 10% fewer pregnant within 4 months of calving than those cows which had an average wet season (Nov-Mar) FP:ME ratio ≥500 mgP/MJ ME, respectively. These differences were all significant except for 2nd lactation cows. The large difference in performance of 1st lactation cows is likely because the majority of these cows would still be undergoing skeletal growth at the same time as their foetus is undergoing mineralisation of its skeleton and subsequently they must lactate for periods of 4 to 7 months. The ability of this class of breeding female to meet any deficiency in phosphorous by mobilisation of body reserves is likely to be significantly less than that of older cows.

5. Cows of poor (<2.5) body condition at the previous year's pregnancy diagnosis muster and subsequently were considered to have an inadequate average wet season phosphorous status (<500 FP:ME) had 8% higher foetal/calf loss than cows that had a BCS of ≥4 and adequate average wet season phosphorous status. However, cows in poor or very good to fat condition that had an adequate average wet season phosphorous status (≥500 FP:ME) had very similar percentage foetal/calf loss.
6. Percent pregnant within 4 months of calving was 5% lower and foetal/calf loss was 4% higher in taller cows (hip height >139 cm and >140 cm, respectively) compared to that in shorter cows (hip height <133 cm and <125 cm respectively). This finding is independent of genotype.
7. Foetal/calf loss was 4% higher in cows that did not lactate the previous year and were re-mated, compared to those cows that did lactate the previous year.
8. The percent pregnant within 4 months of calving was significantly lower (20 to 50%) in cows calving in July-September, which was consistent across country types. In the Northern Forest, when all other factors were taken into account, cows calving between December and March had a predicted mean percent pregnant within 4 months of calving at least twice that of cows calving in other periods of the year.
9. There was a progressive decline in the mean annual pregnancy rate as the predicted month of calving for the previous pregnancy moved forward in time from July the previous year to June of the current year. The lowest annual pregnancy rate was observed in those cows that were predicted to calve between April and June in the current year (30% lower than those predicted to calve in December-January).
10. Mustering 1st lactation cows within 2 months of calving was associated with 9% higher foetal/calf loss; poor mustering efficiency (<90%) was associated with a 9% higher calf loss.
11. Prolonged hot conditions (temperature-humidity index >79 for ≥15 days) during the month of calving were associated with 9% higher foetal/calf loss, except in the northern forest.
12. A delay of >1 month in follow-up rainfall after the annual break in the season was associated an average 4% increase in missingness of cows.

Impact of other selected factors

In mobs that had evidence of a high prevalence (>30%) of recent infection with bovine viral diarrhoea virus (BVDV; pestivirus), or where there was widespread evidence (≥30%) of *Campylobacter fetus venerealis (Cfv) infection* (vibriosis), the percentage foetal/calf loss was significantly higher (8% and 7%, respectively) compared to mobs with only a low prevalence (BVDV <10%; *Cfv* <30%) of recent infection.

The presence of wild dogs was associated with 5% higher foetal/calf loss than where dogs were not reported to be present. Also, foetal/calf loss was 4% higher in cows that grazed pastures with a low crude protein to dry matter digestibility ratio (<0.125) during the dry season prior to calving. This finding is consistent with work in the US which demonstrated that cows experiencing marked dietary protein deficiency in the last trimester gave birth to calves with reduced vigour, and produced lower volumes of poorer quality colostrum.

In country types where comparisons between all genotypes could be done there was a trend for cows estimated to be less than 50% *Bos indicus* to have a higher percent pregnant within 4 months of calving than cows with greater than 75% *Bos indicus* content.

Estimating the economic impact of major factors affecting performance

An Excel spreadsheet based method requiring a small amount of readily-measured beef business inputs was developed to generate satisfactory estimates of cattle performance, live weight production and business indicators such as operating margin. This data can then be inputted into Breedcow, and then using the estimates of the effect of specific factors on cow performance derived from the Cash Cow project, estimates of the effects of each factor on gross margin for herds and partial returns per cow determined.

Conclusion

A key feature of the Cash Cow project was its focus on both production and performance. The function of breeding beef cattle herds is net saleable live weight production, the primary income source. Live weight production in breeding herds is achieved through weaned calves and by cows surviving and gaining weight, which are performance traits, and used to indicate where opportunities for improvement exist if production is inadequate.

A second feature of this project is that it has identified achievable levels of production and performance for north Australian environments within the current economic framework. This was defined as the 75th percentile within land type, thus reflecting underlying nutrition and other inherent environmental influences. The selected level takes account of higher levels occurring randomly, due to uncontrollable events, because of very good management, or because of over-investment to achieve the outcome. Average performance and production of well-managed breeding cows in the recently completed Beef CRC study across the same four land types (unpublished data) was similar to the 75th percentile level in this research, thus providing further confidence that this achievable level is appropriately defined.

The project has identified the major factors affecting performance of commercial breeding cows in northern Australia, quantified the impact on performance of each of these factors, and overall has explained as much of the variation in reproductive performance between mobs and cows as a similar study conducted in the Australian dairy industry.

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Genetic keys to progress: improving female reproduction in tropical breed breeds

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Abstract. Genetic improvement using modern breeding techniques such as BLUP estimated breeding values relies on the recording of pedigree and phenotypes. In some cases, traits are difficult to record or unable to be recorded on the selection candidates, for example when they are expressed late in life or in only one sex. Female lifetime weaning rate is such a trait, and the low levels of recording in tropical breeds have resulted in negligible rates of genetic gain. However recent research from the Beef CRC has established that several component traits measured early-in-life in both female and male reproduction in tropical genotypes have moderate to high heritabilities. These traits, as well as some new genomic tests, have been shown to be associated with genetic differences in lifetime reproductive performance and this creates an opportunity for improvement by selection. To achieve this will rely on focusing the breeding sector on a few key factors that drive genetic improvement. Primarily, for the beef breeding sector to make genetic change it needs to increase the accuracy of selection and increase selection intensities. The challenge is to apply these principles in breeding programs in tropical breeds in northern Australia to enable significant genetic improvement in female reproductive performance, thus allowing commercial producers to lift cow weaning rates.

Introduction

Productivity in extensive northern Australian pastoral systems is predominantly driven by turn-off weights and weaning rates. However, reproduction rates are often low, commonly the result of extended post-partum anoestrous intervals, especially in *Bos indicus* cattle (Entwistle 1983; Baker 1969). Traditionally genetics has played little role in improving reproduction in beef breeds due to difficulties in recording and slow selection response. However selection line experiments in Droughtmaster (Davis *et al.* 1993) and Brahman (Schatz *et al.* 2010) have shown significant improvement can be achieved in reproduction rates. This knowledge has been greatly expanded by recent research finding from the Beef CRC northern breeding project. Opportunities now exist to increase rates of genetic improvement for female reproduction through a greater understanding of degree of genetic control on component traits in both females and males. The research has discovered ways to capture this genetic variation through recording of early-in-life traits in females, young bulls and genomics thus providing the basis for a more effective selection strategy to improve reproduction rates in northern Australia (Barwick *et al.* 2013).

The Beef CRC northern breeding project

Project Design

The experiment involved both Brahman (BRAH) and Tropical Composite (TCOMP) that were generated on the cooperator properties, including the Northern Pastoral Group of companies across Queensland and the Northern Territory, seedstock breeders and the CSIRO herds at Rockhampton. The calves produced were the progeny of more than 50 sires per breed and were generated using AI and natural mating over a 4 year period. The two breeds were chosen to represent the range in tropical genotypes used in northern Australia. TCOMP comprised animals from the composite breeding programs of two of the large pastoral companies as well as the Belmont Red breed, and on

*AGBU is a joint venture of NSW Department of Primary Industries and the University of New England average were derived from 50% tropically adapted and 50% non-tropically adapted breeds (see Barwick *et al.* 2009*a* for more detail).

All steers (N=2216) were backgrounded postweaning and entered the feedlot at approximately 400 kg and were fed for 120 days to produce an average carcase weight of 310 kg. Genetic analyses of steer performance have been previously reported for growth and feedlot performance (Barwick *et al.* 2009*a*) and carcase and meat quality (Wolcott *et al.* 2009). The half-sib heifers (N=2174) were allocated to one of four Queensland Research Stations (Swans Lagoon, Ayr; Toorak, Julia Creek; Belmont, Rockhampton and Brian Pastures, Gayndah) that represented a range of northern Australia's breeder cow herd environments. Heifers were grown out and recorded for growth and body composition traits over the first post-weaning wet- and dry seasons (Barwick *et al.* 2009*b*), tropical adaptation traits (Prayaga *et al.* 2009) and age at puberty (Johnston *et al.* 2009). All heifers were naturally mated to first calve at approximately 3 years of age. Subsequently the cows were naturally mated annually and full reproduction data collected, including reproductive tract ultrasound scanning to determine resumption of cycling after calving. Cows remained in the project until the weaning of calves from their 6^{th} mating when they were approximately 8.5 years of age, unless they failed to wean a calf in consecutive years or were culled for other management reasons (*e.g*. poor temperament). Regular ultrasound scanning of the reproductive tract (every 4-8 weeks), coupled with full mating, calving and weaning histories, allowed a comprehensive evaluation of a range of reproductive traits from puberty through to lifetime performance (Johnston *et al.* 2013*a*). Cows also regularly weighed and measured for body composition throughout their lifetime and analyses of these traits in first-calf cows are presented in Wolcott *et al.* (2013). The male progeny generated from the project cows remained entire and 3,500 young bulls were measured for a range of reproduction traits from 4 to 24 months of age. The traits included: physical measures, hormone concentrations, scrotal circumference, crush-side semen traits and sperm morphology (Burns *et al.* 2013).

Full genetic evaluations were untaken for all female and male traits to estimate heritabilities (h^2) and genetic correlation (r_g) among traits. All cows were genotyped using 50K SNP platforms and genome-wide association studies were performed for a range of early female reproduction traits (Hawken *et al.* 2012) and the data were used to construct genomic prediction equations for heifer age at puberty and lactation anoestrous interval (Zhang *et al.* 2013). A subsample of the young Brahman bulls were also genotyped with the 50K chip, and association studies performed for a range of male reproduction traits (Fortes *et al.* 2012).

Key female reproduction traits

Overall lifetime annual weaning rate from the experiment was 65% but reproduction rates were considerably lower in first lactation cows, for example pregnancy rate for BRAH was only 27% in this class of cows. Genetic analyses showed that components traits of early reproductive performance, including age at puberty and first lactation anoestrous interval were moderately to highly heritable (Johnston *et al.* 2013*a*). The heritabilities of lactation anoestrous interval in first lactation cows were 51% and 26% in BRAH and TCOMP, respectively. Heritabilities of binary reproductive output traits (conception rate, pregnancy rate, calving rate and weaning rate) from first and second matings were also moderately heritable. More consistent with expectations for female reproduction traits, heritabilities of lifetime reproduction traits were lower, with estimates of 11% and 7% for lifetime annual weaning rate in BRAH and TCOMP, respectively.

Genetic correlations between early-in-life reproductive measures and lifetime reproduction traits were moderate to high. For example, shorter lactation anoestrous interval was genetically associated with higher lifetime annual weaning rate (BRAH r_g = -0.60; TCOMP r_g = -0.85). These results represent an opportunity to genetically improve weaning rates in tropical breeds by focusing recording and selection on early-in-life female reproduction traits, particularly those traits associated with lactation anoestrus in Brahmans.

Early-in-life indirect measures of female reproduction

Traits associated with heifer age at puberty were moderately to highly heritable in both BRAH and TCOMP (Johnston *et al.* 2009). Age at first observed *corpus luteum* from regular ultrasound scanning was used as measure of heifer age at puberty and had heritabilities of 0.57 and 0.52 in BRAH and TCOMP, respectively. Heritability estimates showed that many of the reproduction traits evaluated in young bulls were also moderate to high in both genotypes (Corbet *et al.* 2013), and were generally higher when measured at 12 months of age for TCOMP bulls, and at 18 months for BRAH. Importantly, genetic correlations existed between young bull traits and female reproduction traits (see Johnston *et al.* 2013*b*). Larger scrotal circumference (SC) was genetically correlated with reduced heifer age at puberty (r_g = -0.40 in BRAH for SC at 12 months; r_g = -0.30 in TCOMP for SC measured at 6 months) however the genetic correlations were lower with later measures of female reproduction. IGF-I concentration (bulls and heifers) was moderately to highly genetically correlated with heifer age at puberty in both genotypes, and blood LH concentration in TCOMP was moderately correlated with lactation anoestrous interval. Semen quality traits, including mass activity, motility and percent normal sperm were consistently genetically correlated with reduced lactation anoestrous interval and increased female lifetime female reproduction rates in both genotypes, although the magnitudes of the relationships differed with bull age at measurement. Several novel measures on heifers (*e.g*. hip height and coat score) and bulls (*e.g.* preputial eversion) were also genetically associated with lifetime calving and weaning rates in both genotypes and offer additional early-in-life indirect selection criterion to improved genetic progress for female lifetime reproductive performance (Barwick *et al.* 2013).

Genomic selection of female reproduction

Genomic data from dense SNP genotyping using 50K chips were imputed up to 800K for use in genome-wide association studies for a range of female reproduction traits. Internal cross-validation analyses yielded accuracies of the genomic predictions of between 0.14 to 0.33 for age at puberty and lactation anoestrous interval in BRAH and TCOMP (Zhang *et al.* 2013). Further independent validation of the genomic predictions using populations recorded outside the training dataset showed accuracies up to 0.4 for pregnancy traits in an independent sample (Zhang *et al.* 2013). Further validation using BREEDPLAN days to calving trait in Brahman yielded genomics accuracies of 0.36 (Boerner and Johnston 2013). These results, while only modest, can contribute significantly to the rate of genetic improvement in female reproduction traits (Barwick *et al.* 2013). Greater numbers of phenotypes and genotypes are required to increase the accuracies from genomics beyond 0.4, thus increasing the utility of genomic information.

Keys to making genetic progress

Through selection it is possible to move the mean phenotypic performance of a population (*e.g.* breed). The rate of progress in a trait (or combination of traits) is a function of the *selection intensity*, the *accuracy* of selection, the *genetic spread* for a population and the *generation interval*. Most of these factors can be directly influenced by animal breeders, and together these factors predict future rates of selection response. The selection intensity, coupled with selection accuracy, simply describes the genetic superiority of the selected animals (*i.e*. those to be parents of the next generation) compared to all animals available for selection. Therefore the greater the selection intensity the greater is the predicted progress. Likewise, higher accuracy of selection results in more genetic progress. Commonly in beef cattle, high selection intensities can only be achieved in males and can be increased further by using AI to decrease the number of bulls required. However in females, given low reproduction rates (especially compared to other species), the selection intensities are very low, if not zero. This is because all replacement heifers are commonly retained. Therefore genetic progress is limited to males (or use of embryo transfer in cows) but achieving high selection intensity has to be weighed up against the possible detrimental effects of inbreeding and loss of genetic diversity.

Accuracy of selection is a function of the heritability of the trait and the level of recording. The heritability of a trait is a biological constant but it can be influenced by the precision of the measure and with the use of repeat records. The main influence on the accuracy of selection is the amount of recording of a trait across a population. Often accuracy is low due to difficulties in measuring the traits (*i.e*. expressed only in one sex, or late in life) or the measure is costly. In some cases progeny testing is required to obtain records (*e.g*. abattoir carcase traits). Emerging genomics technologies are now offering a means of increasing accuracies, especially on difficult to measure traits, and are rapidly changing breeding programs in several species (*e.g*. dairy cattle).

Finally, population genetic spread and generation interval contribute to the rate of genetic progress. Generally nothing can be done about the genetic spread; this is an inherent characteristic of a trait in a given breed. Generation interval describes average age of parents when their selected offspring are born. Increased rates of progress can be achieved by selecting males and females at younger ages. However, there is an inevitable a trade-off in progress through reduced accuracy of these younger animals, although genomics potentially offers a means to counter this in future.

Selection response in beef cattle breeding programs has generally been slow compared to other species. This is due to limitations in almost all of these factors driving progress. However the northern beef industry can improve selection response in reproduction rates by primarily focusing on increasing the accuracy of selection and increasing the selection intensity in bulls. The Beef CRC results suggest by recording and selecting on early-in-life measures and using genomics it is possible to increase accuracies and reduce generation interval. The immediate challenge to achieving this is for the northern beef industry is to increase the levels of recording across the major breeds.

Improving reproduction in commercial herds

Genetic improvement in the commercial herd can initially occur through the choice of breed (as large breed differences can exist) and through the use of crossbreeding. Matching genetics to the environment and production system is important when making these decisions. Then with a breeding system in place, there is an ongoing opportunity to make continuous improvement by using genetic differences within a breed for reproduction, especially when selecting replacement sires each year. Culling of females on reproductive failure is an important management option (and a cash flow) but it is generally not effective way of making large gains in improving the long-term reproductive rate of the herd. The main driver will be through the continual use of genetically superior replacement bulls for female reproduction. In both seedstock and commercial herds it is important that replacements are not kept from cows that missed weaning a calf at their first breeding season or at their first re-breed as a lactating cow.

Future R&D and adoption needs

Future R&D is needed to develop strategies primarily aimed at increasing the accuracy of selection for female reproduction traits across the main tropical breeds. This will require recording of large numbers of additional phenotypes, particularly for the high heritability traits identified though the Beef CRC. Improved gains will also occur through increases in accuracy of genomic selection. To achieve this requires the genotyping of key ancestors in each breed, and this is especially needed for those breeds with low levels of genotyping, but relies on phenotypic records also being available. This is particularly important because current results show genomics selection is likely to be effective only if a breed has its own genotypes and phenotypes (*i.e.* you can't use genomics results from another breed). R&D is required to optimally use this genomic information in beef breeding programs, including applications across different genetic backgrounds (*e.g*. breeds). Other areas of research that have the potential to add to improved levels of female reproduction includes an increased understanding of factors influencing cow longevity (including possible genetics) and strategies to reduce pre- and post-natal losses.

Conclusions

Recent research has transformed our thinking about genetic improvement of reproduction in tropical cattle in northern production systems. Significantly improving reproduction rates in tropical beef breeds through selection is possible using a combination of recording early female reproduction, young bulls and genomic information, and offers the potential to revolutionise northern beef production. Genetic improvement in reproductive performance will be generated in the seedstock and bull breeder herds, and to achieve high rates of progress requires a combination of recording and selection.

Summary steps to improving reproduction rates through selection:

- Record reproductive performance (particularly maiden heifers and first-calf cows)
- Measure correlated traits (young bulls and heifers)
- Pedigree record or DNA parentage assignment
- Genomic test your key sires
- Genomic test young bulls that are selection candidates
- Select replacements (especially young sires) on reproduction EBVs (but also considering other trait EBVs and characteristics e.g. temperament and horn status)

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Recent advances in animal welfare

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Abstract. The paper discusses the development of the MLA 4 year business plan and the research into reducing, refining and replacing aversive practices that has followed. A key strategic change is considering how the average consumer might view a practice as well as objective assessment of the practice and alternatives. Banding of bulls, electro-immobilisation, flank spaying, dehorning and breeder mortality are challenged because superior alternatives are available. Qualitative behavioural assessment and a recent authoritative review of welfare assessment are highlighted.

Introduction

Influential elements of the Australian community are deeply interested in the welfare of Australian farm animals. Their concern reflects a clear desire by the Australian population and consumers of meat to be sure that the farm animals they eat have been raised and handled kindly and well. In the interests of continual improvement the red meat industry, through its service provider MLA, has reviewed many areas that effect animal welfare and developed a plan to guide R&D.

Reviews

A review of cattle and sheep husbandry practices highlighted that 40% of cattle producers have horned or horned and polled cattle and not all are dehorned before 6 months or even before 12 months of age. Similarly some male cattle were castrated over 6 and even 12 months of age. Spaying was practiced mostly using the Willis dropped ovary method. Best practice for surgical husbandry techniques in sheep was widespread but not universal.

Sandra Welsman (2010, confidential report to MLA) was commissioned to report on ‘Animal ownership, rights and welfare – directions in law science and practice’ and articulated some key views. The key measures of animal welfare will be human experience and views on what is stressful, cruel, grotesque, or even painful – not animal perspectives. While some in industry may disagree, this emphasis on human views is no different to the tradition of livestock producers deciding what does or does not amount to pain or distress in their animals. She foresaw that by 2020: Australian industries will be working hard to keep pace with and steer elements of community, consumer and policy thinking in key marketplaces; The Australian Animal Welfare Strategy will be fully developed and lead regular rounds of reviews. In each round the rules will tighten; more human-referenced criteria will enter production systems through consumer demand, retailer buying, policies and laws; Animal law will be coming increasingly popular in law courses and legal practice and advocacy for changes in the right of animals will increase. She made 5 recommendations:

1. Strategy for R&D. Consult widely within industry but this may hinder tactical research.
2. Decide early which practices to defend.
3. Assess human perspectives first. In premium markets, human views (gruesome, unnatural, inappropriate) as they flow to buying decisions, interactions with policymakers, and then to shaping the law, are the main influences on ‘welfare’, not animal feelings or science.
4. Focus R&D on essential procedures that must be retained. In situations where humans would feel pain, evidence will need to show that adjusted techniques alleviate the pain.
5. Look at science frontiers through market eyes. Potential negative buyer reactions in premium food markets may offset technical gains from some science.

Other strategic influences

Standards and guidelines (S&G) for sheep and cattle. This process commenced in 2008 and the public consultation phase will conclude in August 2013. It is likely that the new S&Gs will be endorsed by the Standing Council on Primary Industries in early 2014. The animal welfare lobby declined to join the writing groups at the outset and withdrew from the reference groups late in 2012 preferring to influence the outcome as part of the community engagement phase.

MLA business plan

Following extensive consultation with peak industry councils and in light of the reviews, with the assistance of Scott Williams MLA drafted a 4 year strategic plan to guide research. The vision of this plan is that: By 2015/16, the Australian red meat industries will have solutions that allow them to meet high standards of animal welfare without reducing productivity levels. To meet this vision, four key strategic initiatives are proposed:

1. Develop replacements for aversive procedures;
2. Reduce mortality rates on farms;
3. Increase uptake and demonstration of welfare best practices across the whole supply chain;
4. Develop ways to minimise the pain of aversive procedures.

Completed R&D with some MLA funding

Spaying

Heifers operated on by competent and experience veterinarians had mortality of 1.5% following Willis dropped ovary (WDOT) spaying and 2.5% following flank spaying with reduction in body weights for 6 week after surgery (McCosker *et al*., 2010). Petherick and others (2011) showed flank spaying was worse than WDOT. Petherick and others (2013) also showed that spaying heifers is preferable to cows, that pain relief should be used in all spay operations and that electro immobilisation is very aversive and should not be routinely used.

Castration

The S&Gs will prohibit rings in cattle over 2 weeks of age – from studies based on dairy calves using sheep rings – and banding has increased in popularity in older bulls. To address these practices and provide data Carol Petherick and colleagues from QAAFI and CSIRO (B.AWW.0206 2011; B.AWW.0008 2012) have completed two studies comparing surgical with tension-banding or ring castration in cattle. In 225 and 420 kg bulls the bander caused less pain during the procedure than surgery but immediately afterwards banded bulls were in greater pain. The physiological measures showed greater adverse effects in banded bulls at 2 to 4 weeks after castration principally associated with the prolonged wound healing and presence of necrotic tissue. The difference was more marked in the mature bulls than the weaners and the use of tension banders is not supported. The second study compared rings with surgery in 3 and 6 month old calves. Both methods caused pain but ring castration caused longer lasting discomfort especially at 6 months of age and surgery was worse than the ring during the first 3 days. The study does not support the use of rings in 3 and 6 month old bull calves.

Road transport

For the land transport S&G data was needed around how long sheep and cattle could travel by road and make a full recovery. Mature healthy sheep and cattle were able to make a full recovery from journeys as long as 48 hours if given adequate time, feed and water to recovery afterwards, (Fisher *et al*. 2010; Fisher *et al*. 2009; Ferguson and Fisher B.AWW.055, 2007). These figures are in the S&G and 'Is it fit to load guide?'

Qualitative Behaviour assessment

Stockman and others (2011, 2013) from Murdoch and CSIRO have published several papers addressing a number of welfare issues using QBA. They show edited video footage of cattle, for example in a truck, to observers and allow them to describe how the animal was coping with the situation. The results are repeatable and well correlated to traditional measures such as heart rate, temperature, cortisol level etc. This methodology hold considerable promise as it is contextual and non-invasive.

Poll genetics

Scientists funded via the beef CRC (Mariasegaram *et al*. 2012) and more recently John Henshall from CSIRO (B.AHW.0144; B.AWW.0209) have found a genomic means of identifying carriers of the poll condition with an accuracy of > 99% in all major breeds of cattle. This will allow the phasing out of dehorning in animals where the horn has grown into the skull.

Breeder mortality

Henderson, Perkins and Banney (2012, B.NBP.0664) have characterised high death rates in breeders in some northern regions of Australia and this is clearly an area for further extension and perhaps research.

Predator control

MLA's research contribution in this space is though the Invasive Animals CRC and industry is support research into wild dog, pig and fox control. Through previous investments PAPP and Sodium nitrite baits have been developed.

Current MLA funded R&D

Given the areas of work identified in the business plan MLA has channelled money into research to find alternatives or replacements for aversive procedures and pain relief methods and products. MLA has invested in research to find alternatives to spaying in the past and the PepTech fertility control implant was developed but too expensive for extensive use. Work to find affordable alternatives continue. Two projects have commenced to find practical ways of administering local anaesthetic to sheep and cattle undergoing castration. A number of MLA Donor Company funded projects are looking to deliver practical and hopefully affordable pain relief products for sheep and cattle.

Future R&D and future developments

Sheep CRC rebid

This is before the commonwealth and program 1 would be a program of work directed at finding practical low labour and remote sensing and measuring technologies to assess wellbeing and productivity in the field daily. It may also allow the development of early warning indicators for welfare problems before they arise – such as weight loss, change in flock order through a monitoring point en-route to water or rise in activity levels in the presence of predators.

Welfare assessment

Ferguson and colleagues (2013) have reviewed this space for the livestock industries recently and their authoritative and far reaching review is worth reading and digesting. They crystalise how people assess welfare based on their values and backgrounds in the context of biological functioning (*i.e*. normality), affective states (*i.e.* feelings) and naturalness. Therefore to find an assessment methodology that satisfies everyone is fraught. The lessons they draw principally from Europe are instructive for Australia. We may have the opportunity as an industry to shape such a method in a practical way (Colditz *et al*. 2013) – or it will be imposed from outside.

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Where to with precision livestock management - the chicken and egg conundrum

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Abstract. Precision livestock management (PLM) can be defined as a group of emerging information and communication technologies (ICT) with the aim of providing users with data and information that enables more precise individual animal management. The benefits of PLM technologies include reducing costs, primarily labour costs, improving production, either total output or value of the output, or providing safer working conditions. The value proposition for these technologies is still unclear and there are few examples of PLM technologies being commercialised. This paper aims to provide some examples that might explain why there has not been widespread uptake of PLM and consider the opportunities for the future of PLM. With the introduction of the National Livestock Identification System (NLIS) in Australia, some producers have seen the opportunities of the NLIS system and they have used the electronic ID to implement PLM principles. Remote water point monitoring systems are also available commercially, but despite favourable economics relatively few properties have implemented these systems. Some of the closer to market PLM technologies include pregnancy diagnosis (e-Preg), Walk-over-Weighing (WoW) combined with auto-drafting, animal tracking and monitoring devices and vegetation assessment. A recent review of these closer to market technologies investigated their potential cost savings and production benefits on five properties across northern Australia. When considering the cost saving it was evident that PLM technologies will provide specific benefits that are determined by a specific set of conditions that will be unique to each property. Production benefits were much harder to predict and it will take time for them to be fully understood. To realise the production benefits that PLM technologies can provide may require producers to adopt alternate management systems. The benefits of PLM technologies will be cumulative. As more producers use PLM technologies their confidence will increase and the value proposition will become clearer. However, for producers to start to use PLM technologies they need to have confidence in the value proposition. The confidence and application of PLM is caught in the classic chicken and egg conundrum. Cattle industry partnering with technology developers and livestock scientists will help to identify opportunities for the application of PLM.

Introduction

The term 'precision livestock management' (PLM), in the context of northern beef production systems, has evolved as a term to loosely describe emerging technologies that enable more refined and precise individual cattle management. The focus of PLM research has been largely driven by the global development of a range of information communication technologies (ICT). The extent to which either PLM research or practice has led to significant improvements in the northern beef industry is debatable. A recent overview report of technology products for the beef industry in remote Australia identified eight animal remote monitoring technologies; of the 8 only 1 is commercially available the rest were still under some form of development (Leigo *et al.* 2012). The challenge seems to be that before the beef industry has confidence to adopt PLM technologies it needs data to determine the value proposition. The problem is that whilst a number of desktop studies have attempted to estimate economic benefits and showed that a number of PLM technologies have some promise they are limited in the data that is available to provide enough confidence for industry investment. As more producers use PLM technologies so confidence builds and the value proposition becomes clearer. However, for producers to start to use PLM technologies they need to have confidence in the value proposition. The confidence and application of PLM is caught in the classic chicken and egg conundrum.

Improved profitability is one starting point for the development of PLM technologies. Implicit in increased profitability is either a reduction in costs or increased sales (either total output or value of the output). While economic returns are important, PLM technologies can deliver additional benefits for example safer working conditions. This paper explores the scope and background to PLM. We consider opportunities for cost saving benefits for PLM. The challenges of intensification and increased output using PLM are largely a challenge of determining a robust value proposition. We consider some examples of the value proposition challenge and provide some suggestions that might explain why there has not been widespread uptake of PLM and consider opportunities for the future of PLM.

Overview of precision livestock management technologies

Australian beef producers have been world leaders in the use of electronic tagging through the National Livestock Identification Scheme (NLIS). While the introduction of the NLIS was not universally supported, the mandate that all cattle that left a property had to have an electronic tag created a push towards the adoption of emerging ICT infrastructure, even if this only involved a radio frequency identification (RFID) ear tag. An evaluation[1] of NLIS hardware supplied to the northern beef industry shows that approximately 30% of producers are combining the RFID tag with a reader to collect additional data (mostly animal weights as cattle go through yards). Despite producers using RFID hardware there is less use of software with less than 5% of the northern industry using herd management software. Although cattle producers had to adopt the NLIS system, the limited use for management purposes demonstrates that the enforced introduction of ICT infrastructure does not necessarily result in the adoption of PLM practices. Despite some industry resistance there are producers that have seen the opportunities of the NLIS system and they have used the electronic ID to implement PLM principles. The opportunity to automatically record an animal's ID and simultaneously align it with other management data, which, can be digitally recorded when the cattle move through a set of yards, shifts the focus from mob management to individual animal management. Companies that have promoted the use of the NLIS system have included the development and marketing of hardware and software solutions to enable producers to adopt PLM.

Telemetry system that automatically checks watering points are commercially available and provide cost saving benefits, these systems aim to reduce labour and vehicle costs associated with bore runs. Even though the value proposition appears favourable, uptake of this technology has been modest; with an estimated less than 5% of properties in northern Australia are using technology to monitor watering points. The reasons for this lack of adoption are not clear and reflect the complexity of factors that determine whether a producer will adopt a given technology.

The development of walk-over-weighing and auto-drafting is emerging as a refinement of the NLIS system. Cattle are automatically weighed when they go to water and the auto-drafting system enables individual cattle to be segregated based on either management information e.g. stage of pregnancy or the weight collected using the walk-over-weighing system. Although this system is commercially available there is still work to be done to refine the commercial applications.

A number of research organisations have been involved in the development and testing of a range of PLM technologies. The e-Preg device is a hand held pregnancy testing tool, providing an alternative low skilled method of determining pregnancy status. CSIRO and the University of New England amongst others have developed location-tracking devices; these are mainly based around Global Navigation Satellite System (GNSS, often Global Positioning System - GPS). More recently a number of research projects have been evaluating the potential for using radio-location as an alternative to GPS. The radio-tracking systems rely on low powered radio ear tags to determine the location of cattle and address some of the practical challenges that have in the past limited the

[1] These adoption data were based on estimates provided by PLM technology suppliers and was used to give a rough indication of current PLM technology use in northern beef production systems.

commercial use of GPS technology. However, given the uptake figures of commercially available PLM technologies the extent to which future technologies will be used is still not clear.

Determining precision livestock management benefits

A recent study used a series of case studies to identify potential benefits for a range of PLM technologies (Swain *et al.* 2013). The project team worked with managers of case study properties and used a subjective assessment to identify benefits and estimate the scale of those benefits. The findings from the project demonstrated that within the context of the case studies the managers found it much easier to identify how a PLM technology could be used to save costs rather than identifying a production benefit. Cost saving benefits focus on where a PLM technology can make savings to a specific cost associated with running the business.

Evaluating cost saving benefits

An example of a cost saving benefit is the opportunity to use location information to save costs associated with mustering cattle especially when it involves the cost of using helicopters. Time spent looking for cattle is considered wasted time, location based technologies that enable a more complete and efficient mustering program are considered to provide cost savings. Although location information can save mustering costs these savings require expenditure on cattle tracking infrastructure. Even with the development of the tag based location system that can track cattle using a $20 ear tag it still requires 4 base stations, which, depending on the topography, can cover a geographical average area of 25 km^2, the cost of the 4 towers is approximately $30,000. We would expect that the cost saving benefits will be greatest on large properties with lower stocking rates, these benefits are based on the challenge of locating cattle in more extensive paddocks. If the cattle are stocked at 50 ha per adult equivalent (AE) and the system has a 10 year life the cost for tracking an individual cow on an annual basis is $62. Within high input herds mustering costs (including input from helicopters) have been estimated to be $5 per animal per muster (Fordyce *et al*. 2007). These costs will be higher in more extensive enterprises; however, given the tracking system can only make mustering more efficient the chances of achieving a cost benefit ratio of greater than 1 are unlikely[2].

It is easy to discount a technology based on a desktop cost benefit evaluation. In many cases there has not been widespread evaluation of a given PLM technology. Applying sensitivity analyses to assumptions of the technology applications provides a mechanism to determine the set of conditions that could create a cost benefit greater than 1. For example, evaluating what combination of stocking rate and percentage of the herd that needs to have location tags can help determine the conditions that will determine a cost benefit ratio greater than one for location based PLM technologies. Using the example of the location system, if the stocking rate is 5 ha per AE and only 10% of the herd need to be tagged to ensure efficient mustering then the annual cost per cow goes down to $6.20. If the cattle were mustered 3 times per year then based on reported mustering cost data (Fordyce *et al.* 2007) the cost of mustering would be $15. If the location system reduces mustering time by 50% then the location device makes a net annual saving of $1.30 per AE.

The example of using location based technologies to enable more precise and timely mustering events demonstrates that there are a wide range of scenarios that could lead to either positive or negative economic benefits. The positive economic benefit is based on a large number of 'ifs' and the relatively underdeveloped state of the location based technologies means there is no data to derive confidence around these estimates of benefits. This example of the value of location-based information also demonstrates how PLM technologies will provide specific benefits that are determined by a specific set of conditions that will be unique to each property.

The challenge of determining production benefits

Unlike cost saving benefits where a benefit is mapped directly on to a cost the application of PLM technologies to enhance production (either total output or value of output) results from a set of

[2] A cost benefit ratio greater than one is indicative of a positive return on investment.

much more complex and indirect interactions. Practical measures of production parameters (e.g. pregnancy diagnosis or growth rates) will focus on either reproductive efficiency (conception rate, calving rate and branding rate), or growth rates and price of output (per unit live-weight or dead-weight). While there has been significant research to identify the key drivers of production the interactions are complex and determining a PLM mechanism that can be used to improve performance at best is unclear and sometimes may not have been determined.

The evaluation of e-Preg within a recent assessment that used a series of case studies demonstrated the relative ease of estimating cost saving benefits but the more complex challenge of estimating production benefits (Swain *et al.* 2013). The e-Preg device aims to provide pregnancy testing using unskilled labour and without the need to insert the pregnancy testing device internally. The evaluation of the cost saving benefits identified labour savings as a potential benefit *i.e.* using cheap unskilled labour compared with either a vet or a trained pregnancy tester. The two variables that impacted on the cost saving decision to use e-Preg were identified as the relative time taken to diagnose the pregnancy status and the reliability of the pregnancy tester.

Within the research that used case study properties, the e-Preg system was considered to have potential production benefits by improving calving rates. The logic behind this improvement focussed on two mechanisms; firstly providing a more convenient and potentially cheaper device might lead to more regular pregnancy testing. More regular pregnancy testing can be used to identify the reproductive performance of breeding cows and potentially used as part of identifying poor performers for culling or identifying top performers for replacements. This is an alternative to an annual veterinary pregnancy diagnosis including foetal ageing. The second potential benefit was associated with reducing calf losses by avoiding the need for an internal examination. There was a perceived risk by some producers of direct losses associated with internal pregnancy diagnosis through manipulation of the reproductive canal and disease spread. A number of studies have identified that rectal palpation pregnancy testing methods can lead to small direct pregnancy losses (Romano *et al.* 2007; Romano *et al.* 2011) as well as spread of diseases (Lang-Ree *et al.* 1994; Fray *et al.* 2000; Grooms 2004). However, the extent to which non-invasive pregnancy testing will reduce the risk of diseases spread is unclear. It is difficult to estimate and test the direct benefit of e-Preg for both improved selection aimed at lifting pregnancy rates and reduced losses that can lift overall calving rates. However, there is evidence that more regular monitoring of pregnancy status can provide useful information to select cows that enter oestrus in the first 21 days of the breeding season and conceive at first mating (Wiltbank 1970). There are, however, practical and logistical challenges with using e-Preg to improve overall reproductive performance. Therefore, while e-Preg might have potential benefits compared to existing pregnancy testing methods, the only way to determine these production benefits will be through detailed testing against key production criteria.

Lifestyle benefits

While identifying PLM benefits that improve profitability is the primary goal there are instances where a PLM technology can deliver lifestyle benefits. It is difficult to assign a value to 'ease of mind', 'contentment', 'happiness' or 'a better batting average because you don't have a sore arm from pregnancy testing'. The opportunity to have more complete information on the weights of cattle using walk-over-weighing technology enables a manager to have more confidence in the value of the stock. Using water monitoring and telemetry to instantly know that a trough has water in it or more importantly when it doesn't can reduce worry. Using a crush side e-Preg device for pregnancy testing can avoid health and safety risks associated with rectal palpation pregnancy testing methods. These are some of the potential benefits that may not map easily onto an economic outcome; however, they can provide important incentives for adopting a PLM technology.

Realising benefits using new information and new management strategies

The integration of a range of PLM technologies can help address a number of economic limiting factors and deliver benefits within areas that directly influence profitability. The combination of different technologies will generate a broad range of data. The combination of new data and new technologies provides opportunities for a fresh approach to management strategies. Technologies such as proximity loggers that can automatically identify maternal parentage combined with data on the cows oestrus status linked to post partum anoestrus data provides the opportunity to identify and select either superior bulls or replacement cows based on reproductive performance. Genetic improvement programs require phenotype information that can be linked to a particular animal. Identifying parentage underpins genetic selection programs; using location-based technologies it is possible to automatically identify maternal parentage (Swain and Bishop-Hurley 2007). Measuring progeny traits such as growth rate using walk-over-weighing or age of puberty using location based technologies could be used for both bull and cow selection.

It is unclear the extent to which PLM technologies will lead to a new management paradigm. There are still practical constraints, such a power management and data transfer, which are limiting the widespread use of PLM technologies. Using technology to monitor cattle and infrastructure at set locations such as watering points is providing some useful applications such as walk-over-weighing and monitoring troughs. Identifying and drafting specific groups of cattle based on a combination of an ID and measures of cattle performance avoids the need to muster a whole mob to select a small sub-group. While technologies such as e-Preg are might eventually be able to automatically pregnancy test cattle as they move through a race to a watering point. Alternatively other technologies that measure relative location of individual animals might be used to determine pregnancy status based on bull cow interactions. The automated reproductive performance of individual cows linked to automated mothering-up could identify and self select both replacement heifers and cull cows.

As PLM technologies start to become more integrated so it will open up opportunities for new approaches to manage cattle. Technology developers and livestock scientists are not best placed to identify new practical management approaches for cattle. As producers start to use and understand new PLM technologies they will identify new management opportunities. The challenge is to not only do better than what has always been done, but also to do things better by doing things differently. Cattle industry partnering with technology developers and livestock scientists will help to identify opportunities to do things better.

Conclusions

The principles of PLM provide opportunities to save labour costs and increase production. Precision livestock management technologies are at different stages of development. Those technologies that have been developed to save a direct cost are easiest to implement and evaluate. Increased production relies on many factors and it is difficult to assign benefits directly to a specific technology. Integration and multiple benefits from individual technologies coupled with new approaches to management will be the future of PLM. How the full range of benefits from PLM technologies are realised will depend on finding ways that the northern beef industry can access and refine a broader range of technologies. Cattle industry partnering with technology developers and livestock scientists will help to identify opportunities to do things more sustainably. As more producers gain experience with PLM technologies their confidence will increase and the value proposition will become clearer. However, for producers to start to use PLM technologies they need to have confidence in the value proposition. Confidence in and the application of PLM technologies are caught in the classic chicken and egg conundrum.

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Innovation and investment to boost productivity and profitability for the northern beef industry – what are the opportunities?

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Abstract. Northern beef enterprises are facing significant economic challenges, especially to remain viable. Production costs have escalated rapidly, productivity gains have slowed and cattle prices have declined in real terms over the last five years. While improvements can be made to minimise the production costs, innovations and investments in productivity remain imperative. A recent MLA-supported project has explored potential options for sustainable improvement in the productivity and profitability of the northern beef industry. A range of development scenarios were examined using a new bio-economic modelling approach that captured production, economic and resource condition impacts of their adoption at the enterprise scale. The central innovation of the modelling approach was the capacity to simulate herd dynamics and whole of enterprise productivity of northern Australian beef enterprises based on the fundamental inputs of protein and energy and their role in growth, body condition, reproduction and mortality. The modelled development scenarios were not constrained by limits in currently available technology or practices. Sensitivity analysis of the modelled impacts revealed that even modest improvements consistent with current best practice management in husbandry, land management and financial management can greatly improve enterprise profitability. Low cost legumes suited to a wider range of environments than those presently available, and options for irrigated forages where suitable water resources are locally available both offer opportunities to improve herd nutritional management with opportunities for turning off finished animals to more profitable markets. While the large capital costs of developing land and establishing irrigated forage crops is a major constraint to this opportunity, there may be more opportunities to include field crops into a diversified enterprise mix which warrants further exploration. Genetic improvements offer continuing scope to effect productivity gains within herds, particularly when both animal growth rates and enhanced fertility are targeted. Novel sources of cheap protein such as biodiesel algae residues have considerable scope for supporting further productivity gains in herds. Energy deficits are a primary constraint on her performance and are still a promising target for future R, D & E efforts. While individual technology innovations and improved practices offer genuine scope for productivity gains, the analysis revealed that the largest gains in productivity and profitability lie in their effective integration within grazing and property management systems. This suggests the need for an opportunity to exploit systems based approaches to R, D & E practice and the application of the technologies on-farm.

Introduction

Aided by a substantial investment in R, D & E, the northern beef industry experienced impressive gains in productivity from the 1970s, particularly through the adoption of technological developments, including the wide-scale replacement of *Bos taurus* herds with *Bos indicus* cattle, the use of dietary supplements, pasture development and improved grazing management. However positive trends in key productivity indicators, such as kilograms of beef turned off relative to total herd numbers (Fig. 1), have slowed over the last decade. At the same time, production costs have escalated rapidly, while beef prices have declined in real terms since 2005 and are forecast to continue to decline on the back of rising Australian herd numbers and no increased demand signals

(ABARES 2013). McCosker *et al*. (2010) noted that direct costs per large stock unit (LSU) have increased by 150% over the last decade, and debt levels per LSU have doubled. Consequently many northern beef enterprises are struggling financially, with McCosker *et al*. (2010) reporting that approximately 50 percent of enterprises spent more money than they actually earned in six of the seven years to 2009. The average return on assets (ROA, a key measure of profitability) was less than 2%. Similarly, a more recent analysis in the Kimberley and Pilbara found the average return on assets was barely positive (Stockdale *et al.* 2012). However, the top 20% of enterprises are faring better (4-6% ROA; McCosker *et al*. 2010) due to the combined advantage of larger scale operations, lower costs and generally better management.

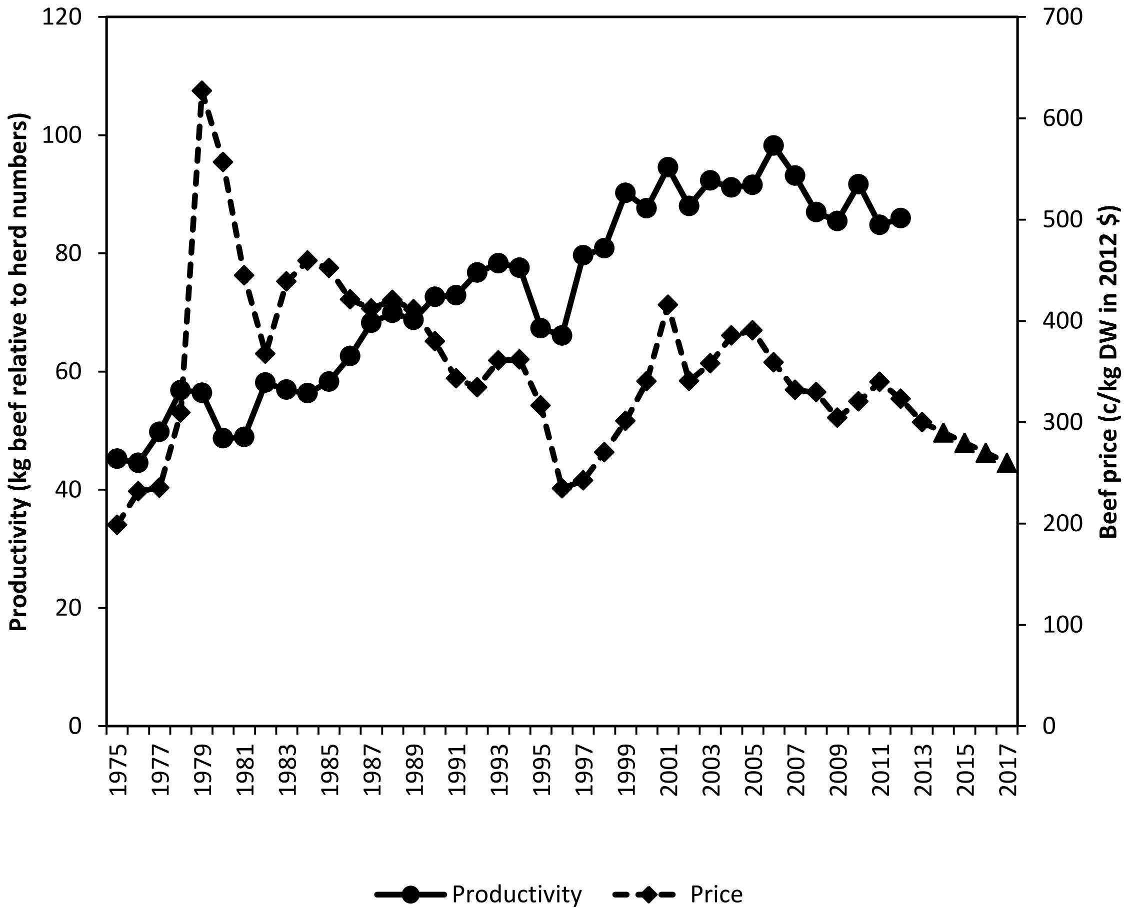

Figure 1. Trends in productivity of beef production (kg beef produced relative to herd numbers) and price received (Qld). Beef produced represents the kg of beef from animals slaughtered in Qld plus live export cattle from Qld (adjusted to represent kg dressed weight) relative to cattle numbers in Qld (based on ABS Statistics). Beef price is the saleyard price of beef (ABARES) adjusted for CPI (ABS) so it represents the price of beef in real terms using 2012 as the baseline. Triangles in the beef price series represents future beef prices based on ABARES Outlook statistics (ABARES 2013).

The broad drivers for profitability of northern beef enterprises include the cattle prices, production costs and herd productivity – the last being dominated by breeder fertility and animal growth rates. However, producers effectively have influence over only two of these three drivers – costs of production and herd productivity. While there is scope for increasing cost efficiency through enhanced financial management, larger scales of production and innovative low cost technologies that reduce labour costs, effecting ongoing productivity improvements remains a key path for lifting enterprise profitability sufficient to ensure that the industry remains viable over the longer term. Productivity on many enterprises can be improved in the shorter term by adopting best management practices to operate closer to current productive potential. However, in the medium to longer-term increasing productive potential will necessarily require further technological developments and innovation. The application of new technology can also help to reduce costs. Puig *et al*. (2011) examined potential futures of the pastoral industry in the Northern Territory and from their modelling work and stakeholder interaction identified some key priorities that included: increased R&D to underpin increased productivity and efficiency of production, diversifying markets, and implementing sustainable management practices. This paper describes a new approach to exploring potential options for sustainable improvement in profitability of the northern beef industry based on technological innovation.

Development options for the industry

Development options with a potential to boost industry performance span many aspects of the beef production system, including livestock reproduction, animal nutrition and growth, improved pastures and management innovations. The options that were considered were not constrained by limits in current technology, as a principal aim was to identify areas where additional research and development would be beneficial. These opportunities were incorporated into development scenarios for evaluation with a newly constructed simulation model of beef production and resource management. For example, a technological breakthrough in rumen ecology was represented in the model as a slight reduction in the decline in forage digestibility during the dry season. The development scenarios focused on productivity gains that could be achieved through the feedbase (introduced pasture, cheap protein source), through changes to rumen ecology to improve digestibility, and through genetic gains in reproductive and growth efficiency. These options were chosen following consultation with producers and through technical expert workshops.

Various development scenarios were evaluated for 10 production regions: Katherine/Victoria River Downs, Kimberley, Pilbara, Central Australia, Barkly-NW Queensland, western Queensland, north Queensland, and central, south and south-east Queensland.

Northern beef enterprise model

The evaluation model integrates livestock, pasture and crop production activities with labour and land requirements, accounts for revenue and costs, and provides estimates of the expected environmental consequences of various management options. Simulated animal growth from birth to turn-off is based on energy and protein supply from forage and supplements, and changes in animal numbers and disposals are tracked. Whereas past approaches employed simple empirical relationships for animal growth and reproduction, the new model uses the nutrient requirements for cattle (PISC 2007) to drive growth of animals and, in the case of breeding animals, body condition.

The model can accommodate both extensive production systems on unimproved native pasture and mixed enterprises with improved pastures and cropping. Data on forage and crop yields are derived from the GRASP and APSIM animal and pasture yield simulation models based on the historical climate record for a given location and the appropriate stocking rate, land/soil type and land condition. The forages and their quality provide the quantity and quality of feed that drives animal production. A range of forage crops (e.g. sorghum, lablab, lucerne, oats) and/or supplements can be simulated for a range of environments, to accommodate scenarios that involve special purpose forage crops or supplementation programs. There is dynamic feedback of grazing pressure on utilisation and land condition and methane production is simulated from animal feed intake.

The model is parameterised for each region using benchmark data on the characteristics and management of enterprises for the region (*e.g*. Stockdale *et al*. 2012 for the Kimberley-Pilbara). Testing of the model for these benchmark conditions suggests the output for key livestock production and economic indicators is consistent with current performance data from other sources (*e.g.* Holmes *et al*. 2011; McCosker *et al*. 2010). Comparison of development options with the baseline assumes the development options are in place i.e. it does not incorporate a transition period for the results shown in this paper.

Results

The study results suggest that further improvements in technologies and practices have the potential to substantially lift productivity and profitability of enterprises across all regions of northern Australia. The scope exists to lift productivity by over 2% p.a. over a 20-year time frame *i.e.* total 40-50% gain in productivity over the next two decades. As would be expected there were regional differences in these gains with the region with highest (South Qld) and lowest (Kimberley) baseline gross margin achieving the least and most gain, respectively, from the combined technologies scenario (Fig. 2).

No single technology or practice will provide these sorts of productivity and profitability gains, but combining technologies in a systematic and systemic fashion offers significant prospects for the industry (Table 1).

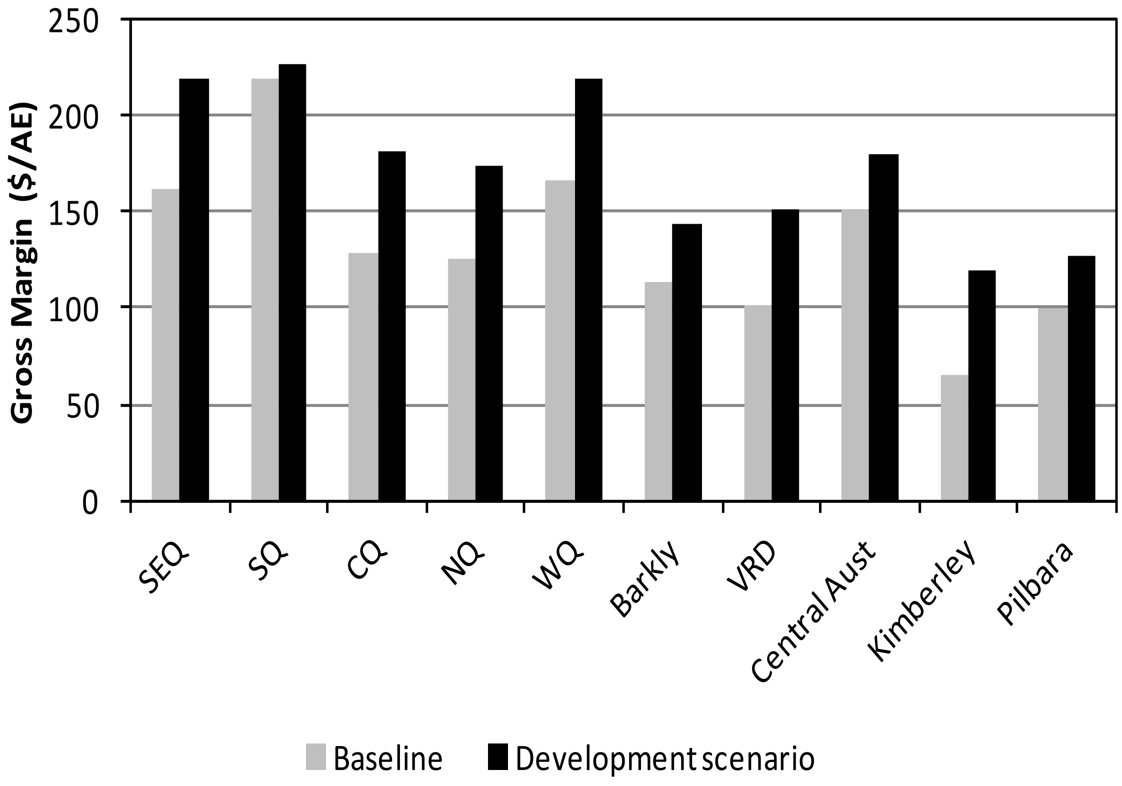

Fig. 2. Gross margin ($) per adult equivalent (AE) from implementing a scenario that combines technological developments (*i.e.* genetic gain in reproduction + growth efficiency + rumen modifier + cheap protein) compared with the baseline scenario for each of the ten regions.

Of the individual scenarios that were reviewed, access to low cost legumes that are adapted to a wider range of environments than those that are currently available provided significant benefits in productivity in nearly all of the case study regions. Although profitability also increased, the significant outlays that are required for pasture establishment on the large, extensive properties in the NT and WA resulted in unfavourable marginal returns on the capital investment. There were generally good returns on capital investment in pasture augmentation in Queensland, assuming successful establishment of the legume. Environmental concerns associated with more widespread use of legumes will need to be considered in further exploring this scenario.

Another scenario with major implications for the property feed base is irrigated forage crops, and this is of particular relevance with a growing interest in the application of mosaic agriculture in northern Australia (Chilcott 2009). The crop simulation modelling suggested that where sufficient water is accessible forages could be reliably grown in sufficient quantities and quality to finish large numbers of growing animals, opening up new market opportunities in lower productivity environments. However, while profitability increased in most regions (with the exception of the Pilbara region where the scenario projected losses because gains in productivity didn't exceed costs), the large capital costs involved meant that marginal returns on investment were generally low to modest. Given both the risks in growing the forage crops and large ongoing variable costs, widespread adoption of this scenario is unlikely in the prevailing economic climate. However, growing irrigated forage crops offers alternative market options for finished steers that may make this option more attractive in the event of further setbacks in live export markets.

Scenarios that involve improving either the nutrition of all the animals in the herd or the growth efficiency of specific classes of animals through genetics typically provided larger productivity benefits than those that only increased weaning rates. This was because improved nutrition or genetic gains in growth efficiency improved not only animal growth rates but also raised cow body condition, which is a major constraint on breeder re-conception rates in many regions of northern Australia.

Table 1. Summary of productivity, profitability, utilisation and methane production for each scenario averaged across all regions.

	Baseline	Improved legume pasture	Cheap protein	Irrigated forage[1]	Improved weaning rates	Improved growth efficiency	Rumen modifier	Combined scenarios[2]
Profit ($/yr)	394,247	628,203	576,472	340,866	470,510	534,520	717,371	983,815
GM/AE ($)	133	162	147	157	141	144	153	174
Adult equivalents (AE)	7,938	9,186	8,797	6,516	8,156	8,304	9,086	9,894
Weaning (%)	59	66	66	61	64	62	66	74
Liveweight gain (kg/hd/yr)	132	158	151	202	132	148	154	184
Beef turned off (kg/per AE/yr)	123	134	135	148	128	129	134	151
Utilisation rate (%)	21	22	21	23	22	21	22	22
Methane (kg/ha/yr)	8	10	9	10	9	8	9	9
Methane intensity (g/kg)	748	677	671	641	723	693	668	578

[1]Irrigated forage scenario was not implemented for Central Australia

[2]Combined scenarios represents the combination of improved weaning rates, improved growth efficiency, rumen modifier and cheap protein i.e. technologies that didn't alter the feedbase.

A significant R&D effort directed at addressing nutritional constraints in northern Australia has been focused on overcoming protein limitations, and both the legume and cheap protein scenarios highlighted the productivity and profitability benefits of addressing this constraint. Some future work on examining novel protein supplements as an alternative to legume-based pastures is warranted.

The study has highlighted the keystone role of available energy as a primary limitation for enhanced animal productivity, and confirms that relatively small changes in the minimum digestibility of available herbage can have very significant impacts on productivity across the whole herd. While the low energy value of tropical pastures has been recognised as a constraint to raising enterprise productivity for many decades, there has been limited practical success in addressing this limitation for extensive animal enterprises. Consequently, more focus has been placed on overcoming protein limitations, and the need to overcome digestible energy constraints has faded as a research priority. However, because large productivity gains can be reaped from relatively small improvements in energy efficiency, increased R&D effort in improving digestive efficiency is warranted, notwithstanding the technical challenges in this area.

When assessing the various development scenarios it is necessary to seriously consider the environmental implications because some provided the opportunity to raise stock numbers carried in response to increased weaning rates and improved animal growth rates. Feedback effects were incorporated within the model to allow for the impact of increased pasture utilisation on land condition. In all modelled scenarios the grazing pressure was set at levels at which land condition would not decline, which meant that pasture utilisation rates stayed fairly constant or only increased slightly over a simulation run. For a number of scenarios canvassed this meant that stock numbers were increased, in some cases not insignificantly, because of the younger age at turnoff. An increase in total stock numbers was most significant for the case of the legume-augmented pastures due to greater forage production and increased carrying capacity, but pasture utilisation rates still remained within safe levels. This analysis assumes sustainable grazing land management practices are put in place in parallel with technology options. History shows that this isn’t always the case (McKeon *et al.* 2004).

Methane production per unit area increased for scenarios where there was higher animal productivity and more animals were turned off. This was especially the case for the legume-augmented pasture scenario where total stock numbers carried were considerably higher than for the baseline scenario and the improvements in digestive efficiency did not offset the increased livestock numbers. However, while there was a small to modest increase in overall methane production per hectare, for many of the development scenarios there were significant improvements in intensity of methane production per kilogram of beef produced. In the case of the combined scenario this improvement in methane efficiency was approximately 20%.

Development scenarios where overall methane production was kept to baseline conditions were not explicitly canvassed. While the profitability of the development scenarios would undoubtedly be reduced under those conditions, further work in this area would be useful in the context of an evolving carbon trading market and likely changes to international agreements and obligations in the future.

Beyond beef

The study has examined improvement in the beef enterprise only and did not explore diversified forms of land use. There is potential to generate additional revenue streams through irrigated cropping and/or via carbon farming. Considerable attention is being devoted to irrigated agriculture in northern Australia either in the form of small scale mosaic agriculture developments which may be well suited to integration with beef enterprises (Chilcott 2009), or to larger scale irrigation development involving regional distribution networks (Webster *et al.* 2009).

Opportunities are emerging to diversify beef enterprise incomes through carbon farming practices. This can take the form of reduced carbon emissions via altered fire management practices, sequestering carbon in soils and vegetation through altered grazing and landscape management practices, or through growing feed-stocks for biofuel production (CSIRO 2012). How realistic and attractive these opportunities will prove to be for northern beef producers will essentially depend on both domestic and international policy and pricing developments.

Conclusions

In summary, the project has developed a novel approach for assessing future development options for the northern beef industry. The present results point to several areas of worthwhile opportunities to lift future productivity and profitability of beef enterprises through research and development investment. Importantly, this needs to be accomplished in an integrated way in order to maximise benefits to the industry while maintaining the integrity of the underlying resource base.

Acknowledgements

This project was supported by Meat and Livestock Australia. We thank the producers who contributed to scenario development and provided feedback on model output. The participants in technical workshops are thanked for their insights, as are members of the project steering committee.

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Meat & Livestock Australia
Creating opportunities for cattle, sheep and goat industries to 2015

MLA invests more than $165 million each year in marketing and R&D programs to help our industry produce more red meat with fewer inputs and generate additional value from the global marketplace. Most of this funding comes from transaction levies placed on the sale of livestock, with the Australian Government providing matching funding for R&D. MLA provides services, tools and information for industry in line with our four strategic imperatives, aligned with the Meat Industry Strategic Plan, and overseen by the industry peak councils on behalf of producers.

Vision

Respected provider of marketing and R&D services to the Australian cattle, sheep and goat industries

Mission

Create opportunities across the cattle, sheep and goat supply chains by optimising the return on collective investment in marketing and R&D

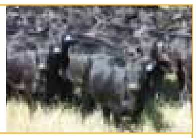
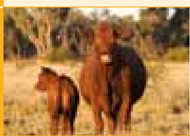
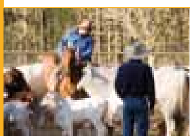
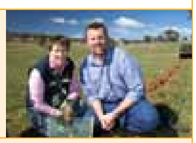
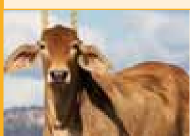
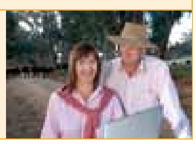
Strategic imperatives

Maintaining and improving market access
Growing demand
Increasing productivity across the supply chain
Supporting industry integrity and sustainability

Focus areas 15 x 15

MLA has developed a series of 15 focus areas that direct the company's marketing and R&D into programs that we expect will deliver a strong return on producers' levy investment to 2015. See over for details.

MLA's 15 x 15

Imperatives		Focus area	
Maintaining and improving market access	1	Assist industry to better integrate and sustainably deliver its on farm risk management systems (Livestock Production Assurance, National Vendor Declarations, National Livestock Identification System)	
	2	Assist government and peak industry councils to secure free trade agreements that eliminate the current tariffs on red meat exports to Korea (currently 40%) and Japan (currently 38.5%)	
	3	Identify high priority technical trade barriers that are impeding red meat export sales, and assist government to alleviate their impact through the provision of science and technology	
	4	Maintain access to livestock export markets by assisting supply chains to implement and comply with Exporter Supply Chain Assurance System regulations through the provision of gap analysis, risk analysis, training and technical advice	
Growing demand	5	Increase Australian consumers' demand for beef through compelling marketing campaigns encompassing eating quality, enjoyment and nutrition	
	6	Create new business for Australian beef in emerging global markets by working with exporters to win at least 20 new major accounts and at least 20 large new product opportunities for branded beef	
	7	Create incremental business for Australian lamb in domestic and global markets by increasing consumer perceptions in key markets and working with exporters to win 20 new major accounts for Australian lamb	
Increasing productivity across the supply chain	8	Create opportunities through research and extension to improve reproduction efficiency in northern beef (by five percentage points) and maternal sheep breeds (by two percentage points)	
	9	Create opportunities through genetic research and management practices to improve pasture and forage crop productivity, quality and persistence	
	10	Create opportunities with new practices or technologies to improve labour efficiency by 5%, encompassing occupational health and safety, labour resource need and yield	
	11	Create opportunities to improve compliance to market specifications by 3% by providing information and tools that encourage practice change on farm, such as Livestock Data Link and BeefSpecs	
	12	Create opportunities through research to minimise the threat and impact of exotic, emerging and endemic diseases on Australian livestock enterprises	
Supporting industry integrity and sustainability	13	Create opportunities through research that will deliver a 10% improvement in production efficiency through new tools and management that will decrease greenhouse gas emissions from livestock systems by up to 30%	
	14	Create cost effective opportunities to replace, relieve and refine animal husbandry practices to continuously improve animal welfare	
	15	Create opportunities through media, social media and events for producers and industry to engage with the community and maintain current high levels of trust (over 80%)	

CARBON AND TECHNOLOGY THEME

The Digital Homestead project - taking grazing into the future

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Introduction

The Digital Homestead project involves collecting real-time property data on livestock, pasture and the environment by remote technologies (such as walk-over weighing scales, satellite images, GPS collars and weather stations), information external to the farm (meat schedules local sale results and weather forecasts) and integrating this information to be viewed at the homestead on the one simple, user friendly computer screen known as the 'Dashboard'. The aim of implementing these technologies and the dashboard is to reduce labour, operating and management costs by providing the grazier with the information to make timely and informed decisions.

Background

The project is a collaborative effort between CSIRO, James Cook University (JCU), Qld Department Agriculture, Fisheries and Forestry (DAFFQ) and Queensland University of Technology. It is partially funded through the QLD Government Smart Futures fund and will run until September 2014. The technology is being developed and tested at CSIRO's Lansdown Research Station and will then be applied at a commercial scale at DAFFQ's Spyglass Beef Research Facility.

Information collected

There is a range of on-farm measures being collected in real-time across Lansdown. These include: Animal live weight from walk over weighing scales; Animal location and grazing behaviour using cutting-edge GPS and animal monitoring collars; Weather, soil moisture and tank level indicators; Pasture availability and condition. In addition, information is being collected from sources external to the property including market information and climate forecasts. Some technologies will also be installed and evaluated at Spyglass, with immediate plans for walk-over-weighing to remotely collect live weight data, weather stations and tank monitors.

The Dashboard

Data is integrated and presented via the Dashboard. It can be customised to an individual grazier needs and present information at a property scale, then by clicking on a particular paddock or herd, you will be able to view all the information for that particular paddock/herd. As an example, live weight data can be presented as either live weight or live weight gain, with the potential to have a display indicating the number of animals meeting a particular user-defined weight range (e.g. >600kg). Animal locations can be seen across the property with alerts appearing if animals move out of designated areas (eg have broken through a fence or have been stolen).

Industry engagement

The Dashboard and the elements it displays are being developed in conjunction with industry. A Grazier Reference group meeting was held in March 2013, which facilitated discussion around the priority requirements for the dashboard, such as the desire to not only have animal liveweight or liveweight gain, but to have the number of animals meeting a market weight specification. Professor Philip Pearce (JCU) will survey graziers further on their requirements.

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Cattle versus carbon. 1. The tug of war begins

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Introduction

In an attempt to reduce greenhouse gas levels in the atmosphere, Governments around the world have implemented schemes designed to engage emitters and reduce emissions. In Australia, beef producers (responsible of 11% of Australia's emissions) can theoretically participate in a voluntary national carbon offsets scheme (Carbon Farming Initiative). The Climate Clever Beef project is assessing the business case for integrating carbon farming practices into beef businesses. Can a beef business sequester carbon and reduce greenhouse gas emissions, is carbon farming an opportunity, a new income stream, or a distraction from productivity with no profitability or efficiency advantages?

Methods

A Case Study site has been established on the 10,570 ha Oaklands property, 80 kms south of Duaringa, in central Queensland. The case study will involve on-ground assessment of the pasture, land condition, woody vegetation, soil carbon and beef herd dynamics. Whole property modelling will be used to assess scenarios over time and space (see Cattle versus carbon. 2. some battle plans). The treatments being measured will utilise the current woody vegetation variation at the site: remnant box woodland, retained 10 year old box regrowth, recently cleared 10 year old box regrowth and completely cleared with Graslan herbicide 10 years ago. For each vegetation type, two grazing treatments have been applied - continuously grazed and wet season spelled. Utilising the existing woody vegetation differences will allow comparisons of soil and vegetation carbon to be made at the start of the project and vegetation carbon change and land condition over the three years of the project.

Results and Discussion

Tree carbon assessments indicate that woody remnant vegetation contained 5-8 times more carbon than 10 year old woody regrowth indicating substantial scope for carbon storage by allowing regrowth vegetation to regrow. Pasture assessments at the end of the dry season in 2012, prior to spelling, indicated generally low pasture yield, low amounts of palatable, productive, perennial grasses and poor (C) land condition. Three herd scenarios have been initially evaluated. The base herd scenario (current situation) has 1005 breeders mated and 68% weaning rate. Heifers are joined at two years of age. Spayed heifers go to a separate fattening property before 24 months. Cull cows are spayed and sold straight to the meatworks after fattening. The weaner steers go to the fattening property. Management sees the current stocking rate as unsustainable due to low pasture biomass and poor land condition in some paddocks, in addition if the decision is made to retain regrowth for carbon trading, stocking rates will need to be lowered. The 2nd scenario mates 896 breeders with weaning rate increasing to 71%. The 3rd scenario involves having the lower stocking rate (896 breeders) and supplementing the cows for three months in the dry season increasing weaning rate to 75%. Herd gross margin declined by 7% with reduced stocking rate even though gross margin per adult equivalent improved by 4%. The cost of supplement offsets productivity gains. Reducing stocking rate by 10% reduced total livestock emissions by 10%, however combined with providing supplement, herd emissions intensity improved by 8% to 12.6 tCO_2e/ t liveweight sold. Ongoing evaluations will assess the balance profitability, emissions and land condition for a range of woody regrowth retention levels, stocking rate adjustments and supplementation.

Acknowledgements: We wish to thank the Dunne family for their support and sharing their business data.

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Managing stocking rates to achieve better outcomes for pastures and profits

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Introduction

In Phase 1 of the Northern Grazing Systems (NGS) Project, it was identified that stocking rates are still considered the single most important factor affecting land condition, animal performance and productivity of grazing lands in the Maranoa Balonne in Southern Queensland. Also discovered were knowledge gaps about stocking rate management, benchmarks and reasons why producers manage their stocking rates the way they do.

Methods

Two key questions evolved from the Phase 1 findings: Are our stocking rate recommendations accurate for the Maranoa Balonne? Are producers adjusting their stocking rates to account for land condition, tree densities and climate variability? Our extension methodology to answer these questions was to form a geographically spread focus group consisting of 4 young families, who are more likely to adopt practice change and try and build up the knowledge of commercial stocking rates. Each business nominated 2 paddocks, with each being predominantly 1 land type, in which they recorded stocking rate, liveweight gain, rainfall, collected faecal samples and had the land condition assessed. The group were also given additional information, decision support tools and training to help determine key motivators for change and stocking rate management. Individual property visits and teleconferences were conducted in order to promote idea sharing and motivation. The group's findings and experiences were showcased to the wider industry, along with a technical guide and a compilation of factsheets and case studies.

Results and Discussion

The land condition in the 8 paddocks was deemed either good or fair, meaning the landholders were matching the stocking rate to the long-term carrying capacity, with the Stocktake software output generally supporting this. It was recognised that the pasture growth models have their limitations, however will be able to be improved over time as more evidence is collected for different land types. The recording period only being 8 months was a limiting factor as those paddocks which received a spell during this time generated underestimated values. The group showed appreciation that research needs to be conducted over several years to gain sufficient data to draw trends. The liveweight gain data followed in a similar trend to the crude protein and dry matter digestibility values of the faecal samples. When asked about the performance of their stock/paddocks over the 8 months, most were satisfied and some thought the paddocks performed better than expected, especially in regards to weight gain and faecal results. The group recognised the value of keeping good livestock, land and economic records to help with decision making planning. Their attitude towards being involved in small, interactive, RD & E groups also improved. Further value to their own business was gained by sharing elements of business information with other like-minded people, seeking advice and using decision support tools available which can assist to improve the profitability and long-term sustainability of their business.

The focus group expanded to 12 businesses in late 2012 under the Climate Clever Beef Project and all have committed to collecting similar stocking rate and paddock information for 3 more years, which will be invaluable in filling research gaps and answering the key questions from Phase 1.

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Can infrared temperature of cattle detect differences due to breed and rangeland environment?

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Introduction

Heat stress can reduce productivity of beef cattle in tropical regions, which might be accentuated with climate change. The objective of this study was to determine body temperature of two cattle breeds grazing two contrasting rangeland environments using infrared thermography (IRT) as a non-invasive methodology.

Methods

Fig. 1. An infrared image of a Brahman

The study was conducted at the Lansdown Research Station using 119 steers from 2 breeds: Brahman and Belmont Red Composite. Animals of each breed were randomly assigned to 1 of 2 mobs with balanced numbers, which grazed both open woodland and a savannah paddock in a crossover design of 4 periods from August until November 2011. Coat score using a scale of 1 (sleekest) to 7 (thickest), and body temperature using IRT were measured at the end of each experimental period when animals were swapped between paddocks. Coat score and IRT data (Fig. 1) of each animal's eye, rump and

Results and Discussion

IRT detected differences in temperatures of the eye, rump and trunk suggesting differences in animal's physiology and the response to ambient conditions. Only for eye temperature did Brahmans have readings lower than Composites (Table 1) despite the sleeker coats of the Brahmans. When moved from woodland to savanna, the animal's response to the higher heat load of the savanna was reflected in greater body temperature and sleeker coat (Table 1) indicative of phenotypic plasticity. In conclusion, IRT showed to be a good candidate to remotely measure body temperature in cattle to assess the interaction between genetics, environment, management, and adaptation to heat stress. Understanding thermoregulation of cattle will help manage hot weather to improve productivity.

Table 1. Body temperature (ºC) and coat score of Brahman and Belmont Red Composite steers grazing open woodland or a savannah paddock.

Variable	Brahman	Composites	Sig.[C]	Savanna	Woodland	Sig.[C]
Eye temp.	38.1 ± 0.05	38.2 ± 0.04	*	38.4 ± 0.04	37.9 ± 0.04	***
Rump temp.	35.2 ± 0.08	35.2 ± 0.06	n.s.	35.6 ± 0.07	34.9 ± 0.07	***
Trunk temp.	35.7 ± 0.11	35.6 ± 0.09	n.s.	36.24 ± 0.10	35.1 ± 0.10	***
Coat score	1.5 ± 0.067	1.9 ± 0.06	***	1.6 ± 0.04	1.8 ± 0.04	***

[C] Significance: *** = P<001, ** = P<0.01, * = P<0.05, n.s. = non significance.

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A method to refine the geographical scale of greenhouse gas emissions for the northern beef industry

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Introduction

National greenhouse gas (GHG) accounts, for livestock, are estimated from a set of formulae that use liveweight (LW), liveweight gain (LWG), proportion of animals lactating (LC) and feed quality to determine emissions. To reflect the differences throughout Australia there is a set of tables describing these parameters for each state (DCCEE 2011)**.** Within each state there are significant regional differences; a possible next step for inventory development would be to move to regional parameters. This paper explores the effect of using regional data (LW, LWG and LC) on estimation of emissions for the northern beef industry.

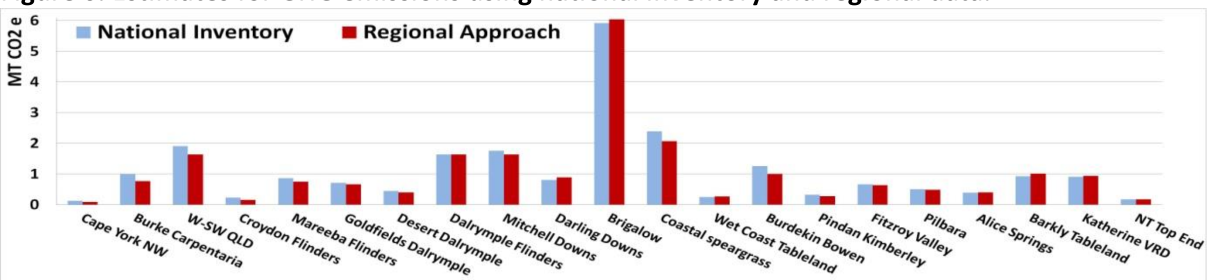
Methods

Regional data were sourced from Breedcow Beef CRC templates (Holmes et al. 2013). The difference between national inventory and regional approach resides in the herd structure (Table 1) and in the assumed LW and LWG. An excel tool interfaced between Breedcow and FarmGas.

Table 2. Correspondence between classes in national inventory and regional approach.

conversion	Cows >2 ➔Heifers 2-3 yrs, Cows 3-4 yrs Cows 4 + yrs, Spayed cows	Reasons	Decrease in fertility at 2nd mating, female still growing to 4 years old and spayed cows give different weight profiles.
	Steers >1 ➔Steers 1-2 yrs, Steers 2-3 yrs Steers 3-4 yrs, Steers 4 + yrs		Range of sale ages gives different weight profiles

Figure 6. Estimates for GHG emissions using national inventory and regional data.



Results

Preliminary results indicate that the effect of using regional inputs (rather than the state level inputs) are a decrease of 5.5% in emissions (range +10% to -34%; see Fig.1) across the northern beef industry, with the average for Qld being -6.7%, WA -6.9% and NT +5.0%. The most likely factors contributing to this would be differences in LW and LC.

Discussion/Conclusion

To refine the geographical scale of estimations requires investigation of both livestock and feed quality inputs at the regional level. It appears that the current methodology may overestimate emissions for Qld and WA, while underestimating for NT. Moving to a regional based approach could represent more accurately the contribution of livestock to the national GHG accounts.

References

DCCEE Australian National Greenhouse Accounts Inventory Report (2011); http://www.climate change.gov.au/publications/greenhouse-acctg/national-inventory-report-2011.aspx

Holmes, W *et al.* (2013) ; http://www.daff.qld.gov.au/16_20534.html

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Harnessing technologies for the beef industry of remote Australia

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Introduction

Embracing innovative ideas and new technology (eg. roadtrains, telecommunications, solar powered bores and calf cradles) has allowed beef producers in remote Australia to overcome the challenges of distance, isolation, the natural environment and labour availability to improve their businesses. The beef industry continues to search for innovation to counter the escalation of costs and the declining availability of labour. This paper summarises a review of sixty existing, new and emerging technologies suitable for the beef industry of remote Australia and proposes the concept of harnessing these for use in the Precision Pastoral Management System (PPMS).

Method

Sixty technology products were selected for review. Products were selected on their ability to meet at least one of the following criteria; commercially available technology products to be used by beef producers; new technology products available to beef producers; emerging technology products either at a development or prototype stage; technology products not available to beef producers but used by researchers; and technology products not currently suitable for Australian beef producers but that may become available or suitable in the future. These technology products were reviewed as a desktop study, based on publically available information, either from the product websites, published reports, journal or newspaper articles. The authors reviewed the products during the period of December 2011 – March 2012 and contacted product owners as needed to determine costs and functionality when information was not readily accessible.

Results

The sixty technology products reviewed were split into three categories, pasture, cattle and unique technology products. Within the pasture category, products included remote monitoring, modelling, mapping programs and management software. The cattle technology products included remote monitoring, herd modelling, remote management and software for management. In the unique technology category were products that guided or undertook management actions on a property. Of all the products, thirty-three are currently available for use by beef producers.

Discussion and Conclusion

The majority of commercially available products were for pasture management, while there is significant research and development being undertaken for cattle technology products. There are no products currently available that harness pasture, cattle and unique technology products into one management decision support system. The Precision Pastoral Management Tools Project aims to fill this gap by developing the PPMS. The PPMS will remotely monitor and analyse the performance of cattle and pasture allowing beef producers to increase precision in their management and production, decrease their costs and improve their profitability.

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Early joining and improved fertility improve profitability and reduce greenhouse gas emissions in the Longreach district

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Introduction

Beef producers are uncertain if carbon farming opportunities can be of benefit or if becoming involved could cost money through reduced productivity. Much of the available information suggests the main way to reduce emissions is to reduce cattle numbers. This could be possible by improving reproductive efficiency and weaning the same number of calves whilst running fewer breeders. Running fewer breeders should reduce input costs and lead to better gross margins across the herd. This paper presents one case study from the Longreach district reviewing the impact of improved breeder efficiency on gross margins and greenhouse gas emissions.

Methods

A 23,000 ha property south of Longreach where early joining and improved breeder fertility is being implemented was chosen. The country is predominantly Mitchell grass with an annual average rainfall of 380 mm. Joining age has been reduced to 16-22 months and weaning rates improved through selection and improved grazing management. Property herd records and regional prices were used to model the herd structure and gross margins (GM) within Breedcowplus (Holmes 2012). This was compared with a regional average herd with heifers joined at 2-3 years and more typical weaning rates. Cattle numbers were held at 1748 AEs across both herds. Greenhouse gas emissions (GHG) were estimated using the Greenhouse Accounting Framework for beef (Browne *et al.* 2011) based on property records and regional averages.

Results and Discussion

Beef turnoff was highest for the property, with 33% higher turnoff compared to the regional herd (Table 1). Total emissions were similar across the herds but the intensity was reduced by 24% in the property herd. The property gross margin was more than double that of the regional herd.

Earlier mating and improved weaning rates increased turnoff which improved herd GM whilst reducing GHG emissions intensity making the strategy viable.

Table 1. Key characteristics and results for the property and regional herd structures.

Herd	No. mated	Breeder wt (kg)	Age at first joining	Weaning %	Beef turn-off (t lwt)	GHG emissions (t CO_2-e)	Emissions intensity (t CO_2-e/t lwt)	GM after interest ($)
Property	1007	435	1 year	79	314.2	3,598	11.5	339,765
Regional	984	481	2 years	62	236.3	3,593	15.2	157,153

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Use of tea seed saponins to reduce ruminant methane emissions: an evaluation of early studies in Northern Australia

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Introduction

In Australia 98 million ruminants contribute 9.7% of the national greenhouse gas (GHG) emissions, while 14 million beef cattle in the North emit approximately 18,890 Gg CO_2-e to the national GHG inventory. Consequently, ***the use of natural feed additives*** such as tea seed saponins (TSSP) might have the potential to meet animal regulations for reducing methanogenesis without deleterious effects on productivity and food security. These studies aim to determine the optimal level of TSSP supplementation that reduces methane emissions associated with research on the rumen physiology and microbial ecology of fed cattle maintaining productivity.

Methods

Two indoor experiments have been conducted over 2012 and 2013 at Lansdown Research Station (LRST) in Townsville. In Experiment 1 (i.e., 59 days) six Brahman steers (240.3 ± 24.71 kg; four rumen fistulated) were fed *ad libitum* using a basal diet (i.e., BD; Rhodes grass (*Chloris gayana*) hay, 15% plus a commercial-mixed high grain feed, MHGF). Animals were accustomed to the BD during 12 days using a portable yard and later were individually fed in pens in two approximately daily equal portions at 08:30 and 16:30 hours. Previous to the AM feeding from day 36 to 59 each fistulated steer received via cannula the TSSP dose (i.e., 6, 10, 15, 20, 25 and 30 g) dissolved in 100 to 200 ml of water for 5, 2, 4, 3, 2, and 3 days, respectively. The non-fistulated animals were given the TSSP solutions mixed with the MHGF. Based on the increasing levels of TSSP supplementation, rumen fluid was collected two hours after the AM feeding for deoxyribonucleic acid, volatile fatty acids (VFA), ammonia, pH and metagenomic analyses on days 42, 48, 55, 57 and 58 as well as during the chamber measurement period feeding the BD on days 22 and 25.

Results

Overall dry matter intake (DMI) in Experiment 1 was not affected by feeding practice while in pens or the open-circuit respiratory system (5.0 ± 0.07 vs 5.2 ± 0.29 kg), while uncorrected methane emissions of 18.0 ± 10.48 g k/DMI (CV, 58.1) were recorded. The ruminal infusion of TSSP resulted in reduction of total VFA concentration, modified pattern of individual VFA concentrations. Nevertheless, body growth was not compromised and animals were growing at 1.5 ± 0.76 kg/day at the highest level of TSSP supplementation.

Discussion/ Conclusions

The results provide valuable information for the design of Experiment 2 (i.e., eight Belmont Red composite fistulated steers) and for the objectives of the project. An important finding of Experiment 1 was that the addition of TSSP did not decrease DMI when the TSSP was introduced initially at lower amounts.

It is suggested that the use of 30 g TSSP supplementation in cattle (264 ± 25.9 kg) fed DM *at libitum* might modify patterns of ruminal fermentation without negatively affecting animal performance.

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Methane emissions from beef cattle and mine dewatering operations in WA

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Introduction

Grazing systems across N Australia are essentially based on native pastures. These operations manage integrated cattle breeding, growing and finishing, but are associated with high methane (CH_4) emission intensity/unit animal product. Under Australia's Carbon Farming Initiative (CFI) farmers will earn carbon credits by reducing greenhouse gas emissions if new or novel practices are demonstrated. Only one of the six CFI methodologies target CH_4 from livestock, but all projects would require detailed monitoring to gain carbon credits. N Australia has much to gain from the CFI, but implementing new and persistent practices will be crucial to qualify for credits. The objective of this study was to measure baseline CH_4 emissions for beef cattle under a current practice and compare with predicted emissions from a "stand and graze" mine dewatering irrigation project.

Methods

This study was conducted on Hamersley Station (22°16.7'S, 117°40.6'E) WA. Methane flux from 60, 2-3 year old Droughtmaster heifers was measured using open-path lasers (GasFinder, Boreal Lasers, Canada). Animals were confined at water, approx 6 h/d for 14 d and instruments aligned to retro-reflectors on two sides of the source area ensuring the CH_4 plume was well sampled. Additional lasers measured ambient CH_4 concentration along predominant upwind paths. A micrometeorological mast with a three-dimensional sonic anemometer (CSAT3, Campbell Scientific Inc, USA) collected daily weather data. Pastures consisted of Curly Mitchell (*A. lappacea*), Kangaroo grass (*T. triandra*) and Roebourne Plains grass (*E. xerophila*). Herd scale CH_4 flux was estimated in WindTrax (V2.0.8.3, Thunder Beach Scientific, Halifax, Canada) using in a backward Lagrangian Stochastic dispersion model and surface-source assumptions (Tomkins *et al.* 2011).

Results and Discussion

Mean (±sem) methane emissions were calculated from 10 min averaged data and ranged from 113.4 ± 35.1 to 146.6 ± 57.9 g CH_4 /hd per day, equivalent to approximately 1.3 g CH_4 /kg $W^{0.75}$. These are the first baseline values to be generated for a grazing scenario typical of NW WA. It is possible that the use of irrigated Rhodes grass based on mine dewatering and concomitant changes in energy utilisation by the animal could reduce emissions to 1.2 g CH_4 /kg $W^{0.75}$ or lifetime emissions by approximately 22%. An alternative stand and graze operation involving 2000 head rotationally grazing Rhodes grass under 5, 50 ha centre pivots would increase diet quality and provide higher ME intakes. Potentially, target reproductive or slaughter weights could be achievable 6 months earlier and reduce emissions by 0.95 t CO_2-e compared to current grazing practices. A management change from grazing native unimproved pastures to an intensive irrigated system on improved pasture could qualify as a CFI methodology given that emissions per unit output (calf or carcass) can be reduced. Further work will quantify these reductions in emissions before any methodology can be verified.

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"Better farming" or "carbon farming"? Show me the money!

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Introduction

Recently, McCosker *et al.* (2010) concluded that the northern beef industry was generally unprofitable and unsustainable in its current state. They nominated several causes for this, including the very poor productivity of extensive breeder herds. Much of the current research and extension effort in northern Australia aims to improve breeder herd performance and live weight gains in a cost-effective way.

Against this backdrop, the Australian Government has introduced the Carbon Farming Initiative as a means of reducing greenhouse gas emissions and encouraging primary producers to generate alternative cash flow via "carbon farming". The Climate Clever Beef 2 project is investigating how management practices perform in terms of their productivity, profitability, land condition and emissions. The project is being conducted by the NT DPIF and Queensland DAFF until June 2015.

Methods

The project team works with producers to benchmark their current herd, financial and emissions performance. During the benchmarking process, practical options for improving productivity and profitability are identified. Using herd, financial and pasture growth models, the longer-term performance of these options is subsequently tested and compared.

Results and Discussion

The following strategies have been identified for improving the productivity, profitability and emissions performance of northern beef businesses:

1. Improving breeder herd efficiency: identifying and culling unproductive breeders, improved heifer management, genetic selection (for fertility) and/or effective phosphorus and other supplementation.

2. Improving diet quality and growth rates: genetic selection, stocking rate management, growing out and finishing animals on better quality country elsewhere and/or incorporating pasture legumes and other improved pastures

3. Improving land condition and associated soil carbon levels via wet season spelling, stocking rate management and/or prescribed burning

4. Increasing carbon sequestration via woody vegetation regrowth management in areas that have been previously cleared.

Case studies conducted by the project to date show that the financial rewards from productivity improvements can be substantial and will be more important than "carbon income" *per se* for the foreseeable future.

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Cattle versus carbon: 2. Some battle plans

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Introduction

It is now theoretically possible for a beef producer to receive income for storing additional carbon or reducing greenhouse gas emissions on their property through the Australian governments Carbon Farming Initiative. How much carbon can be stored in the future, and what is it worth? Will this be at the expense of beef productivity, and if so, will the price of carbon make this worthwhile?

The Australian Government *Carbon Farming Futures Action on the Ground* program was created to help answer questions like these. It is assisting the Climate Clever Beef project assess the business case for integrating carbon farming practices into a beef business, with one case-study property being Oaklands in Central Queensland (see Cattle versus carbon. 1. The tug of war begins).

The battle ground

A trial site at Oaklands property has been established with members of the project team visiting the property to collect information on pastures, woody vegetation, soil carbon, livestock methane emissions, herd productivity, input costs and income. On-ground assessments are being undertaken for four current woody vegetation treatments (remnant box woodland, 10-year old box regrowth, recently cleared 10-year old box regrowth, and regrowth cleared 10 years ago with Graslan herbicide). In these areas two grazing treatments will be applied - continuously grazed or wet-season spelled. Computer models will be used to extend these site measurements across the entire property and explore the impacts of strategies beyond the 3-year project time-frame. Modelling of pasture production, tree growth, herd dynamics, and economics will also enable evaluation of carbon-farming strategies that cannot be practically implemented on Oaklands, and strategies for which results take many years to be realised (e.g. changes in soil and vegetation carbon stocks).

Battle plans

A number of carbon farming strategies will be assessed at Oaklands. These range from improving pasture productivity and cattle turnoff by clearing regrowth, pasture spelling and burning, to running fewer cattle and storing more carbon in soil and trees. The following strategies will be evaluated:

- Allow all regrowth to grow unchecked;
- Clear all regrowth, using two different methods (mechanical, chemical);
- Allow different amounts (25, 50, 75%) of regrowth to grow unchecked, and clear the rest;
- Spell pastures to improve land condition and increase pasture productivity; and
- Targeted supplementation of cattle to increase live-weight gain, and hence earlier turnoff, lower mortality and higher reproduction rates.

What will win the war?

Over the ensuing years a number of strategies will be employed on Oaklands, but it is too early to predict whether carbon or cattle will win the war, or indeed if a treaty will provide a win-win compromise. Cattle hold the ground at the moment, and it may take a lot of carbon and/or a high carbon price before they run up the white flag.

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EXTENSION, SYSTEMS AND SURVEYS THEME

Spyglass Beef Research Facility

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Introduction

The Spyglass Beef Research Facility covers an area of 38,200 ha and is an integral part of the Queensland Government's strategy for providing world class infrastructure for beef research. The research and development program covers animal genetics, reproduction, growth, welfare/husbandry, natural resource management and precision grazing technologies. An extension, education and training program will run in parallel to the research program. The property is located 135km west of Townsville, in north Queensland with a carrying capacity of 4000 adult equivalents.

Facilities & Staff

There is one main set of operational yards with two new yards to be built in 2013/14. These will have five-way automatic hydraulic draft, six-way pound draft and covered work areas in a livestock exclusion zone, man gates, concrete floors, hay feeder, water yards - all for staff safety and livestock welfare. The main office building includes: manager's office, open plan office for 6 additional staff, a small meeting room and kitchen facilities. The accommodation quarters sleeps eight and is fully self contained. Two bedroom quarters accommodation will also be built at outstations: Continong yards and the 'old Spyglass' homestead site. Staff members currently live on-site include: Station Manager, Livestock Supervisor, Station Hand, Farmhand/Boilermaker and Senior Biometrician..

Current Trials

Current research trials on Spyglass include the Recorded Herd (for Genetics) (DAFFQ), Revegetation methods (DAFFQ), Digital Homestead (DAFFQ/ CSIRO/ JCU), Feral Dear Tracking (DAFFQ) and Effects of rainfall on nutrient dynamics (CSIRO).

Animal Husbandry

There are currently 500 head that are BreedPlan registered and it is planned to increase this to 2000. Bulls selected are tested with Estimated Breed Values (EBVs). Animals are culled on temperament, performance traits and dam abnormalities. Weaners are to be trained intensively and low stress handling principles applied. Mustering is done using any combination of helicopters, horses, motor bikes, ATV buggies and quad bikes.

Ongoing Improvements

2000ha of black wattle regrowth is being cleared using dozers and chain and stick raking. Water holding capacity is to be improved by installing four 250,000 litre tanks and new dams. There will be development of improved pasture.

Future Direction and Planning

The property management plan covers weed control, feral animal control, sub-division of larger paddocks, riparian areas, fauna reserves and Workplace Health and Safety policy. There will be a centralised data base of all animal information. Mustering efficiencies will be improved by establishing an integrated sequence of laneways to link all paddocks to yards. Remote weather stations, tank monitors and walk over weighing scales will be established with their information available via satellite back at the main office. The cost efficiencies of these technologies will be calculated. High speed internet is to be available at the office via a fibre optic cable.

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Infrastructure to improve beef business outcomes in the Gulf

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Introduction

There are significant economic and environmental issues impacting on the short and long term viability of family-run cattle breeding enterprises in the Queensland Gulf. Falling prices and increased business costs threaten the social and financial well-being of many beef producers. Set stocking and overgrazing also combine to reduce native 3P (*i.e* productive, palatable and perennial) grass frequency and herd productivity. The Climate Clever Beef and SavannaPlan projects equip beef producers with the skills to evaluate their business and identify key practices to build a productive and resilient beef business in a variable climate.

Infrastructure development to improve grazing outcomes

The Ryan family on Greenhills Station at Georgetown in the Queensland Gulf embarked on a 5 year water and fencing infrastructure development program to improve pasture utilisation, land condition and long term carrying capacity. In 2009, an existing paddock of 11,475 ha was divided into three paddocks of 4307 ha, 4710 ha and 1958 ha through the use of cost effective, single-strand electric fencing. Despite Greenhills being conservatively stocked, the continuous grazing system and lack of water infrastructure resulted in patch grazing and poor pasture utilisation and subsequent decline in desirable pasture species. Through infrastructure development, the Ryan family have been able to introduce a grazing rotation into the newly formed paddocks on the southern half of the property with 60% of this country now receiving a 4 to 6 month spell each year. Stock access to water and grazing distribution was improved through two new bores and reticulation to five water troughs in the newly formed paddocks. In 2009, ten photo monitoring sites (one site per land type) were established in conjunction with the infrastructure upgrades. Early results indicate that 3P species, such as giant speargrass and bluegrass, are returning in the spelled/rotated paddocks. As a result of the rotational grazing system, the Ryan family observed that their carrying capacity has increased in recent years.

BreedCow and Dynama modelling, undertaken as part of the Climate Clever Beef project demonstrated an overall increase of 14% in gross margin over the five years from 2007 to 2011, resulting from increased carrying capacities and overall number of breeders mated. Average prices received for cattle did not significantly differ over the five year period, showing that turnoff numbers and higher liveweight were the main drivers of improved profitability. Greenhouse gas modelling demonstrated an overall increase in carbon emissions from 3836 t CO_2e in 2007 to 4381 t CO_2e in 2011 due to higher numbers of cattle. However, overall emissions efficiency (t CO_2e/t liveweight sold) improved from 17.14 t in 2007 to 14.22 t in 2011, due to greater liveweight gain in young animals and lower age of turnoff.

Acknowledgements: The project team acknowledges the Ryan family for their hospitality, time and willingness to share their business production and financial information.

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Utilising online technologies: the young producers perspective

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Background

The value of working directly with the next generation of producers has been successfully demonstrated across various agricultural commodities. For this reason, an interactive consultation was held by DAFFQ extension officers, involving young beef producers in Charters Towers in March 2013. The intent of the consultation was to gain insight into the different sources and methods the younger generation use to access information for their business. This paper focuses on the preferences surrounding computer usage and the adoption and utilisation of online technologies from a representative of young beef producers in the Charters Towers region.

Methodology

16 producers from 10 beef properties within a 200 kilometre radius of Charters Towers participated in the consultation. Participant age ranged between 18 to 45 years old. A series of questions in relation to online technologies were posed through an interactive PowerPoint presentation. Data was collected electronically using Keepad Interactive responders and Turning Point. Each participant could select their answer using their individual responder. Participant response data was transmitted via radio frequency to the receiver, collated and displayed as a graph instantly within the PowerPoint presentation.

Results and Discussion

E-extension has been identified as the way of the future, particularly with engaging the younger demographic. However when asked to identify their preference regarding computer usage, the group indicated financial / book keeping, herd recording and mapping as the most important activities carried out on their computer. 0% of participants registered interest in using e-extension activities as a source of accessing information for the business. This raises questions regarding the general understanding of the definition of 'e-extension'. When surveyed specifically about using webinar technology, 66% had participated in a webinar; however 33% of these stated that it wasn't a positive experience. This could be attributed to timing or internet connectivity or other undisclosed factors. 63% of the group indicated that early morning was the preferred time for accessing the internet with 13% preferring afternoon or night. Though all participants had access to the internet, 73% of participants said their connection is slow to very slow.

Conclusion

Computers and the internet play an important role for most beef producers, especially young producers. Based on the results, the current form of e-extension may not be the most effective means of providing technical advice to young producers in the Charters Towers region. Time of day and internet connectivity had an impact on utilising webinar technology. There would be significant value in quantifying how large the issues of timing and internet connectivity are and how much they are influencing uptake. With a substantial data set there is a distinct opportunity to address these issues and tailor the service in response to producer preferences.

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Grazing management practice adoption survey: extension sources

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Introduction

The Paddock2Reef Grazing Management Adoption Practice surveys are a joint initiative between DAFFQ and DEHP. The surveys were conducted face-to-face with graziers, from the Cape York catchment down to the Mary catchment. The survey consisted of four major sections – Grazing Land Management, Demographics, Extension and Herd Management. This paper focuses on the extension component, particularly the sources of information that producer's access to make business decisions.

Methods

Grazing properties were stratified by size and location, randomly selected and asked to voluntarily participate in the survey. Property data from was collated and summarised at a catchment level. 211 properties were surveyed in the 2011/12 year, with 196 completing the extension section. Questions elicited a producer preference response on a scale of 1-5, from low to high importance. Information sources such as DAFF newsletters, rural media, radio, TV, internet, resellers, industry bodies, DAFF extension, NRM bodies, private consultants, other producers, banks, accountants and solicitors were included. Computer usage and extension activity including workshop attendance was also recorded.

Results and Discussion

Analysis of the data across all catchments demonstrated that the source of information given highest importance is that of other producers (Table 1).

Table 1. Top five preferred sources of information.

Source	Other producers	Rural media	Resellers	DAFFQ extension	Internet
Average	3.61	3.07	2.92	2.73	2.59

Computer usage results showed that 88.12% of all survey participants are currently using computers. In particular, 86.73% of all participants are using email and 84.69% are accessing the internet. There doesn't appear to be a clear producer preference in regards to activities (Table 2).

Table 2. Preference of extension activities.

Source	Workshops	E-extension	Grazier Group	Field Days	1:1 Extension	DAFFQ	1:1 Industry Support
Average	3.63	1.83	3.37	3.58	3.67		3.10

These results will assist and guide DAFFQ in tailoring extension activities to producer preferences. Additional data will provide further ability to provide concise conclusions.

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Options for northern beef producers: a case study examining the impact of establishing an abattoir in the NT and market alternatives to live export

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Introduction

The Indonesian market represents two-thirds of Australian live cattle export (Evans 2011), with the northern beef industry being the most reliant on this market with 50% of their production sold for live export. A long-term solution would be to extend the market to other importing countries, particularly in South East Asia. Another would be to develop a processing meat industry in the Northern Territory to be able to finish and slaughter cattle within the region. This paper investigates the impact on herd turn-off and income of selling northern cattle into alternate domestic markets in the absence of a live export trade to Indonesia and the establishment of an abattoir in Darwin.

Methods

To identify the scenarios a workshop was held with NT DPI officers to explore alternate markets for NT cattle. The scenarios investigated were: Business As Usual (BAU, see Breedcow Beef CRC templates, Holmes *et al*. 2013; live export market operating with an abattoir in Darwin (S1); live export closed with an abattoir in Darwin (S2); live export closed without abattoir in Darwin (S3). Breedcow was used to model each scenario giving gross margin (GM) returns before interest costs. With the live export market closed, steers were sent at 3 and 4 year-olds for slaughter from Katherine VRD (R713) and Top End (R714), while there was much less impact on turn-off age for the Barkley cattle (R712).

Results and Discussion

Key inputs for GM for each scenario were total weight sold, sale price and costs (largely transport). These did not vary significantly across the different scenarios for R712 (see Fig.1). For R713 and R714, although the weight sold increased, sale prices were lower when the live export market was closed and selling costs increased substantially without an abattoir in Darwin.

For R713 and R714, the addition of an abattoir in Darwin to BAU offers a slight improve in GM. However, in the absence of live export, a Darwin abattoir became extremely significant in terms of beef producers ability to maintain their GM.

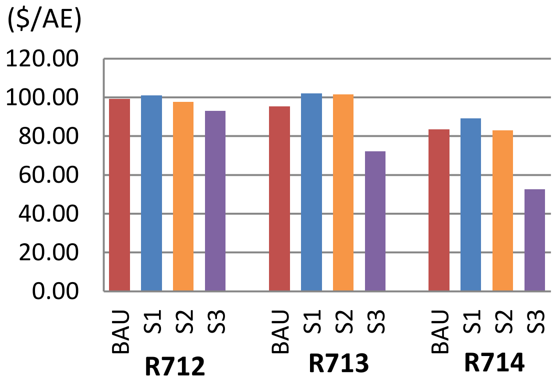

Fig. 7. GM for market and abattoir scenarios.

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Pastoralists identify biggest hurdles in managing pastoral operations in Alice Springs region

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Introduction

The pastoral industry in the Alice Springs region of the NT faces many challenges with the carry over effects of the 2011 live export ban to Indonesia followed by devastating bushfires putting even more pressure on cattle producers. A pastoral industry survey with producers in 2011/12 repeated a similar survey from 2004 (Leigo 2006) documenting land and cattle management practices in the region. Producer perceptions of the biggest hurdles in managing pastoral operations as well as issues affecting the profitability of the pastoral enterprise were compared between the 2004 and 2010 surveys.

Methods

Thirty one enterprises representing 51% of pastoral operations and 50% of pastoral land area in the region were surveyed in mid-2011 and early 2012. Most interviews were conducted face-to-face. A semi structured survey format was followed with open-ended questions included to allow free expression. Businesses were classified as commercial pastoral operations if they ran 300 head or more. Enterprises were sampled from a list until a satisfactory sample size was achieved. This paper reports on the responses to an open attitudinal question “What are the biggest hurdles in managing your pastoral enterprise?” and provides supplementary survey results to provide a better understanding of the magnitude of these obstacles.

Results

The biggest obstacles perceived to affect the management of pastoral operations in 2010 were staff availability (29% of respondents) and seasonal variation (26% of respondents). This was followed by cost of production (16% of respondents), government regulations and roads/access (13% of respondents), while 10% of respondents referred specifically to the high cost of freight. Thirteen precent of producers did not respond to this question. These results were largely echoed in the ranking of issues affecting the profitability of the pastoral enterprise where staff, seasonal variability and cost of production clearly stood out as the most important issues.

Discussion and Conclusions

This survey reported a similar list of issues identified by pastoralists as obstacles in managing their operations as the 2004 survey, but there were some changes of emphasis. The availability of staff has surpassed seasonal variability as the biggest perceived hurdle and dingoes were pointed out as the main feral animal problem. The perceived cost of production on the profitability of the pastoral enterprise has increased considerably since the 2004 survey in which cattle prices were considered to have a greater effect on profitability than cost of production.

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Producers identify market access as key issue affecting profitability in Katherine region

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Introduction

The 2011 live export ban to Indonesia has had significant ramifications for cattle producers in the Katherine region of the NT who predominantly target this market. A producer survey in late 2011 repeated a similar survey from 2004 (Oxley, 2006) documenting land and cattle management practices in the region. Producer perceptions of risks to long term sustainability and issues affecting profitability were compared between the 2004 and 2011 surveys.

Methods

Sixty-three enterprises were surveyed in predominantly face-to-face interviews during late 2011 and early 2012, representing 58% of pastoral operations and 59% of pastoral land area in the region. Businesses were classified as a pastoral operation if they ran 300 head or more. Enterprises were sampled from a list until a satisfactory sample size was achieved. This paper reports on the responses to an open attitudinal question "What are the main issues affecting the profitability of your enterprise?" and a question asking respondents to rank 10 options (seasonal variability, markets, staff, cost of production, cattle prices, natural resource management issues, energy availability, government regulation, climate change and other) in order of "their risk to your long term sustainability".

Results

The major issue perceived to affect profitability in 2011 was market access and stability (35% of respondents). This largely reflected concerns about the security of the Indonesian market following the 2011 live export ban and the lack of profitable alternative markets for cull cows as a result of the 2010 Indonesian 350 kg weight restrictions. Cost of production (33% of respondents), fertility (19%), government regulation/policy (included live export ban, clearing regulation and wild dog baiting regulations)(14%) and wild dogs (13%) were the other most mentioned issues. Fourteen per cent of producers (9) did not respond. These results were largely echoed in the ranking of risks to long term sustainability where markets, cost of production and government regulation clearly stood out as the top 3 risks.

Discussion and Conclusions

This survey captured a change in perceived risks to profitability and longevity of pastoral operations in the Katherine region. In 2004 the major issues affecting profitability were considered to be cost of production, natural resource management issues and production issues, with uncertainty of market mentioned by only 15% of producers, and government regulation not mentioned at all (Oxley, 2006). Perceptions of major issues affecting profitability have changed since 2004 with greater concerns regarding market stability apparent.

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Stocktake Plus – development of FutureBeef's first decision support app

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Introduction

A preliminary investigation into the development, need and potential impact of an electronic forage budgeting and land condition monitoring application (app) for use with mobile devices for the northern grazing industry was conducted in 2011. The Stocktake Plus app was developed based on the industry-recognised Stocktake program developed by Department of Agriculture, Fisheries and Forestry Queensland (DAFFQ) and delivered by the FutureBeef team. The practices of land condition monitoring and forage budgeting are considered grazing best management practices (BMPs), however they are not always easily implemented on-property.

Methods

A multi-skilled project team worked with the app development company (Now Communications Group Pty Ltd, trading as Fresh) using the scoping and design analysis completed as part of the preliminary project. The app was rigorously tested throughout development to ensure it was technically correct, logical and practical for graziers in Northern Australia.

Results

Three interlinked products were developed within this project:

1. Stocktake Plus app for Apple devices
2. Stocktake Plus app for Android devices
3. Stocktake Plus webpage incorporating pages on the use of the app including Frequently Asked Questions (FAQ) and support, along with a 'Dashboard' application for users to securely store and manage their data through their private user account.

Stocktake Plus is a free, grazier decision support tool, which allows the user to monitor land condition, stock numbers and rainfall while in the paddock without the need for mobile phone reception. It has a forage budgeting tool to help calculate the optimal balance of stock to pasture available. Stocktake Plus also produces reports for all records kept, including long-term 'benchmark' carrying capacities for paddocks and properties. These records can be securely backed up.

The app also has a full range of in-built support tools including land type factsheets, pasture yield and ground cover photo standards, and pasture growth output from the grass production model (GRASP) for a range of land types and locations across northern Australia. Using the GPS chip in your device, the user can store the location of monitoring sites and help identify their property land types. **Importantly, each utility within the app can be used autonomously, or all the information and records can be linked through to detailed reports.**

Stocktake Plus has been developed specifically for graziers and agri-advisors in northern Australia (Queensland, Northern Territory and the Kimberley and Pilbara of Western Australia), but has partial functionality elsewhere. The forage budgeting component can be applied to any region provided the user can estimate a starting dry matter yield; whether the forage is predominantly grass, shrubs or crop.

With a rapidly growing percentage of producers now using mobile devices, converting the Stocktake method, software and associated information and tools into an app has meant producers have critical information when and where they need it, to support their stocking rate and pasture management decisions. For more information visit www.stocktakeplus.com.au

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Which beef cattle finishing systems stack up?

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Introduction

A Producer Demonstration Site (PDS) at 'Bannockburn' near Bell, Qld, has for over two years evaluated the economic performance of beef cattle finishing systems encompassing improved pastures, leucaena, oats and grain feeding.

Methods

Two groups of EU (non HGP) steers (350kg entry weight) were assessed, 87 head in 2011 and 100 head in 2012. Approximately ¾ of each group were run on elevated (above the frost line) leucaena-grass pastures for six months up until June, at which point the group was split three ways onto oats, into the feedlot or back onto leucaena. The remainder of the steers were retained on improved pastures (Bambatsi, Green Panic & Rhodes) for the entire period. The steers were weighed every 8-10 weeks, faecal samples collected monthly for faecal NIRS determination of diet quality and stocking rates monitored. Each system has been compared on the partial return on livestock capital invested for 2 periods, with the second commencing in June.

Results and Discussion

All 2011 results are based on a 364 day period and the 2012 results on 320 days. The average daily gain on leucaena was 0.7kg/day for both years whereas improved pastures produced 0.58kg/day and 0.48kg/day, respectively. During winter, steers on improved pastures lost 0.25kg/day however leucaena steers gained 0.1kg/day and 0.56kg/day in respective years. Steers in the feedlot achieved just over 1.5kg/day consistently and oats steers 0.77kg/day and 0.91kg/day. Leucaena generally had a higher crude protein and dry matter digestibility compared to the improved pastures. The stocking rate on leucaena in 2011 was 1ha/hd and 1.68ha/hd on improved pastures, with both 2012 figures slightly lighter. Leucaena produced 252kg liveweight/ha and improved pastures 125kg/ha. Leucaena gave twice as many kg/ha again in 2012. Post the Year 2 period, steers finished using grain gave a positive return. Table 1 summarises the economic findings.

Table 1. Partial return on livestock capital invested in the different finishing systems, 2011-2012.

	First period return			Second period return		Partial Return		Grain bin finished
	2011	2012		2011	2012	2011	2012	2012
Leucaena	21%	9%	Leucaena	8%	6%	32%	17%	33%
			Oats	7%	3%	31%	11%	13%
			Feedlot	12%	13%	36%	18%	
Improved pastures	9%	6%	Improved pastures	9%	-6%	20%	-2%	15% (feedlot)
			Feedlot		15%		25%	

The PDS has shown that at 'Bannockburn', steers grazing elevated leucaena year round can produce higher returns than steers in finishing systems incorporating improved pastures or oats and only slightly lesser returns than systems encompassing feedlotting. This result is dependent on many factors including rainfall, cattle performance, cattle prices and grain prices.

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Breedcow and Dynama rewrite project

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Introduction

Northern beef producers contemplating their management options can put their theories to the test with the new upgraded version of the free herd-budgeting software Breedcow and Dynama. This software package is designed to plan, evaluate and improve the profitability and financial management of extensive beef cattle enterprises.

Discussion

It is now compatible with all MS Windows 32-bit and 64-bit operating systems including 'premium' versions of Windows XP and Windows 7. The old and new versions of Breedcow and Dynama can co-exist quite happily on older computers but the new version will be required if a modern 64 bit computer is purchased.

Breedcow and Dynama programs are based on four budgeting processes:

1. Comparing the likely profitability of the herd under different management or turnoff systems. (Breedcowplus program)
2. Making forward projections of stock numbers, sales, cash flow, net income, debt and net worth. (Dynamaplus program)
3. Deciding what to sell when the plan goes sour or what to buy when there is an opportunity. (Bullocks and Cowtrade programs)
4. Evaluating long term investments in herd or property improvement to determine the rate of return on extra capital. (Investan program)

They are not day-to-day herd management programs that record individual animals.

The programs include a set of regional data files covering Queensland, Northern Territory and the northern part of Western Australia. These provide a starting point when looking at herd performance in the regions modelled, and a baseline to measure the impact of husbandry and other herd management changes.

Changes to the new programs include; file names can now exceed eight characters in length; individual programs now have their own file name extensions to allow easier identification; mouse scrolling is enabled within individual programs; extra breeder age groups have been added to the Breedcow and Dynama worksheets - cows can now be segregated and sold in age groups up to 15 years old. The new programs have all of the functionality of the previous programs.

A comprehensive user manual is automatically downloaded with the programs to guide both inexperienced and experienced users.

The Breedcow and Dynama rewrite project was funded by the Queensland Government, Meat and Livestock Australia and Reef Rescue

To download the programs visit http://www.daff.qld.gov.au/16_6886.htm

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Improving breeder management systems in northern Australia through extension

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Introduction

The Queensland Department of Agriculture, Fisheries and Forestry (DAFFQ) facilitated breeder management workshops throughout Northern Queensland during 2012/2013. The workshops covered a range of topics and hosted guest speakers including Veterinarian Dr Ian Braithwaite, who provided information on breeder management systems for northern beef herds and Principal Scientist Dr Peter O'Reagain, who discussed the rangeland management outcomes of the Wambiana Grazing Trial. We report feedback from producer participants of two workshops.

Method

The two workshops were held at Wambiana Station and Spyglass Beef Research Facility. DAFFQ extension officers surveyed beef producer participants of the workshops to determine which breeder management issues are currently having the greatest impact. The aim of the survey was to gain an insight into the potential for producers to make significant practice changes as a result of attending workshops. Of the producers who attended, 43 individuals from 36 grazing enterprises provided feedback that was collated and condensed. Results are presented as averages and counts as appropriate and are presented according to a rated level of impact on business, which was classified into three categories – no impact, a low impact or a high impact.

Results and Discussion

An analysis of the responses from producer participants highlighted three distinct breeder management issues in relation to fertility (Table 1). The majority of producers rated all three of these breeder management issues as having a high impact on business. It remains unclear whether these results reflect a positive or negative impact on business, although the assumption is that a negative impact on business (hence profitability) was intended by the survey participants.

Table 3. Feedback from surveyed producers who rated the impact of breeder management issues on their business.

What impact are the following issues having on your business?	No Impact (%)	Low Impact (%)	High Impact (%)	Sample Size
Delayed cycling of females post calving:	2.4	19.0	78.6	42
Body condition score impacting on fertility:	9.3	20.9	69.8	43
Low conception in first and second calf females:	0	26.2	73.8	42

Conclusion

The feedback from the survey indicated that the poor performance of females within breeder herds largely impacts on northern Australia beef producing businesses. It also demonstrates that issues relating to fertility have the greatest affects on individual animal and overall business performance. For the results of the survey to be statistically significance further data and case studies are required.

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Powering adoption by using eExtension wisely

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Introduction

eExtension is the use of electronic technologies to enhance traditional approaches (such as face-to-face and paper-based interactions), and enable change in individuals, communities and industries (adapted from SELN, 2006).

Better engagement, innovation and responsiveness

In 2011, over 80% of surveyed DAFF staff who used webinars found they could better engage with their clients as a result. A similar number (78%) indicated that webinars enabled them to be more innovative with their work, and almost 75% reported they could be more responsive to their clients' needs. These factors in combination can power adoption rates and decrease adoption lag times.

Learning journey

Initial engagement with participants at a learning event such as a workshop, is best done face-to-face to allow the group to build trust and rapport. However, before the workshop closes, invite participants to continue the conversation (or learning journey) with you. Since many of the producers often travel several hours to attend workshops, offer to do this electronically. By inviting them to join a one hour webinar every second month extends the interest beyond a 'flash in the pan' activity. While they are at the workshop, demonstrate how easy it is to join a webinar and how to interact online.

Farmers learn best from one another. Hopefully some of the webinar participants will have trialled the innovations suggested at the workshop, and you can encourage them to share their experiences and learning with the other webinar attendees. This in turn may encourage others participating in the event to undertake trials of their own. Revisiting the topic over successive months is more likely to keep the innovation front-of-mind for the participants, and help encourage adoption across the group of participants.

The continued engagement can also lead to changes in the knowledge, skills, and attitudes of workshop presenters. They may become aware of limitations of the innovation being promoted and different ways of applying it in the field. eExtension should be seen as a two-way mode of communication that complements your other extension activities.

Conclusion

Like any tool, the effectiveness of eExtension depends on wise use. To gain maximum benefit, a balanced approach where eTools are integrated with traditional delivery mechanisms is recommended. Change should be viewed not as a one-off event, but as a learning journey.

References

State Extension Leaders Network (SELN) (2006) 'Enabling Change in Rural and Regional Australia: The role of extension in achieving sustainable and productive futures [Online]'. Available at http://www.seln.org.au.

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Investigating market compliance in central Queensland beef businesses

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Introduction

Beef cattle producers involved with the Rolleston CQ BEEF group identified market compliance as an area which could be improved within their beef businesses.

Methods

To identify the rate of compliance and the reasons for failure to meet specifications, animal performance data (live animal and carcase) was collected along with external factors that may have affected compliance. An UltrAmac® fat depth scanner was purchased to measure fat depth at the P8 site before cattle were sent to the abattoir.

Results

Carcase grading data from four properties for 2010-2012 was collated and analysed for compliance to the EU and MSA markets. The overall EU compliance rate was 87%. The main causes of non-compliance with the EU market specifications were P8 fat depth, meat colour and dentition (Fig. 1). For MSA carcases, 60% complied with both MSA and abattoir specifications; 22% met MSA specifications but failed to meet company MSA grading specifications and 18% failed to meet MSA specifications. Failing to meet company specifications was the principle cause of animals not grading MSA with dentition and carcase weight being the principal problems affecting compliance with company specifications. Meat colour, pH, P8 fat depth and fat distribution were the other main causes of MSA non-compliance (Fig. 2).

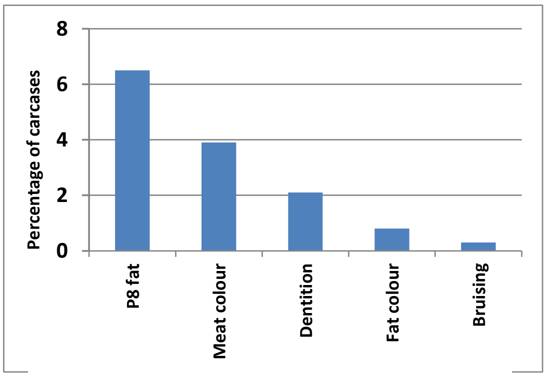

Fig. 1. Reasons for non-compliance with EU market specifications

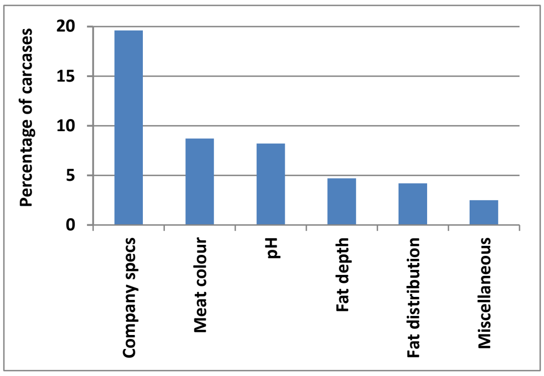

Fig. 2. Reasons for non-compliance with MSA market specifications

Discussion

The inconsistent format of feedback from different abattoirs was a significant obstacle when it came to both collating and analysing compliance data. The fat scanner proved a very useful tool for making the decision of which cattle are ready to sell. It has the potential to help producers improve compliance with market specifications for P8 fat depth. Ensuring cattle meet company specifications was identified as the most important issue for producers attempting to improve compliance with MSA market specifications.

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A woman's capacity – grass roots development of cattlewomen as leaders

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Introduction

Beef producers currently involved in the various leadership roles within the beef industry are predominately male. Additionally there is a shortage of leaders in the Northern Territory (NT) beef industry as a result of the increasing need to represent industry issues and the declining availability of people to represent the industry on various committees, boards and workshops. To meet this challenge the NT Cattlemen's Association (NTCA) and NT Department of Primary Industry and Fisheries (NTDPIF) received funding from the Commonwealth Government's "Recognising Women Farmers" grants, to deliver workshops in 2009 and 2010 aimed at increasing the leadership capacity of NT cattlewomen. This paper reports on the effectiveness of the workshops in achieving this goal.

Methods

Two series of *"A Woman's Capacity"* Workshops were run in 2009 and 2010 for a target audience of NT cattle women. The 2009 workshop series was based on a one-day workshop delivered in seven regional locations across the NT. It focused on personal growth, communication skills, dealing with conflict and negotiation and remaining physically fit for mental strength. The 2010 workshops were delivered in nine locations and covered setting and achieving goals and maintaining physical fitness in isolated locations. Evaluation was undertaken at the end of each workshop and follow-up assessments were conducted.

Results

In the 2009 workshops participants (n=107) on average rated the usefulness of the workshop contents as 4.6 on a scale of 1-5 (1=limited usefulness, 5=Extensive usefulness). In describing the workshop, participants were extremely positive, for example a Top Springs participant said: "*It's about learning to become an effective leader and communicator. Learning about yourself and how you relate and interact with others*". The 2009 workshops were the first of their kind delivered right across the NT and highlighted a real need for this type of training. This was evident from the repeated words found in the feedback of "*desperately needed*", "*long overdue*" and "*badly needed*".

The 2010 workshops were equally well received by participants (n=79), with an average rating of 4.6 (1=not relevant, 5=highly relevant) for the relevance of the content. Attendees from the workshop found the day both challenging and empowering, "*It has given me a structured time frame and steps to achieve my goal. I'm inspired, confident and feel much more driven towards the achievement - Thank you!!*" said one participant at the Daly Waters workshop.

Discussion/Conclusion

The 2009 and 2010 workshops highlighted the existing need in the NT cattle industry for this type of training. The workshops were successful because of their content, but also as they were held in regional locations, provided childcare, were only one day in length, focused on participants needs, provided insights into participants' strengths and weaknesses, provided health and fitness sessions, kept the day fun and importantly provided follow-up activities. Whilst the workshops have contributed to building the skills and confidence of women in the NT beef industry, further work needs to be done by organisations wishing to engage more women as industry leaders.

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Brian Pastures Research Facility

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Introduction

The Brian Pastures Beef Research Facility (fondly known as 'BP') is situated 18 km from the township of Gayndah, located in the subcoastal, subtropical spear grass zone in the Central Burnett region of Queensland. The area receives 700 to 1000mm annual rainfall and the property sits 130 meters above sea level. It is approximately 3.5 hrs drive northwest of Brisbane and 4 hrs southwest of Rockhampton. The property has a variety of landforms from steep, rugged hills to fertile alluvial flats with 10km of significant riparian zones along the Barambah creek. BP was established as a research station in 1952 initially investigating methods of improving beef cattle production, focusing on pasture research which included ecology and management of native pastures, incorporation of legumes in natural pastures, establishment and use of grain and forage crops and improvements to animal health and husbandry. The property is owned by AgForce and managed by Department of Agriculture, Fisheries & Forestry Queensland (DAFFQ).

Facility Infrastructure

The facility is spread over 2145 ha comprising of a mixture of native and improved pastures including 100 ha of Leucaena, which is found over 15 paddocks with some stands established in 1969. Stock water is sourced from the Barambah creek and supplied via troughs throughout the property. The facility has a covered 44 hd individual animal feeding pen complex, which incorporates cemented individual feeding pens adjoining earthen day yards. The feeding complex includes 3 holding yards, a drafting yard and laneway system to facilitate ease of cattle movements. A large fully enclosed feed storage, mixing shed and hay shed adjoin the pen facility. A sealed air conditioned laboratory room, a kitchen area and toilet are also available at the pen facility. The feeding complex has been used extensively for a range of research including: nutrition, methane emissions, phosphorus and fistulated animal studies.

The property also features a large set of stockyards comprised of a covered weigh box and race with wall mounted NLIS reader, and a separate veterinary crush and race with a double loading ramp, surrounded by holding paddocks. Three additional small cattle yards with covered veterinary crushes are located at various points on the property to facilitate cattle handling. Approximately 50 ha of irrigated creek flats with underground mains are used for growing hay for both research and station use. The office complex consists of 11 individual offices with internet and phone connection, a large administration area, large conference room, 2 laboratories and 2 kitchen areas. Outbuildings include: a large workshop, numerous storage sheds, a machinery shed, 2 hay sheds, a greenhouse and nursery area. The complex hosts 6 staff houses and a visitor's quarter with 6 bedrooms, a lounge room, kitchen, and 2 bathrooms.

Past & Current Research Projects

In recent times, BP had an integral part of the Beef CRC operating during the period 2001 to 2011. At the conclusion of the Beef CRC, the genotyped and highly phenotyped breeders were purchased by DAFFQ and continue to have reproductive performance data collected for future research. Currently, BP is hosting a major research project investigating phosphorus deficiency in cattle. Other research conducted on the site includes: genetic, reproduction, Leucaena, improved pasture, legume, ley farming systems, agro-forestry, fistulate, methane and nutritional trials. The facility hosts research for departmental and collaborator organisations as well as industry and private companies.

The current research projects on-site include agro-forestry, phosphorus mobilization, native pasture growth sites (which have been continuously recorded since 1986) and methane emissions. The facility also provides a training ground for school students, domestic and international undergraduate and postgraduate students on an annual basis. Current staff comprises of facility manager, farm supervisor, 2 farmhands, 2 technical officers, senior scientist and a cleaner.

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Economic Trade-offs of HGP and MSA– Lisgar and Trafalgar Results (unpublished)

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Introduction

Hormone growth promotants (HGP's) are vital for the northern beef industry in achieving higher weight for age and meeting market compliance. However, HGP's have a negative impact on eating quality by increasing ossification scores. As a result, HGP treated cattle generally do not score as high Meat Standards Australia (MSA) grades as untreated cattle. This paper focuses on the economic trade-off between using HGPs and obtaining MSA premiums.

Method

Two Producer Demonstration Sites were set up at Lisgar Station, Ayr and Trafalgar Station, Charters Towers. Analysis was done on Lisgar No. 7 Heifers and Trafalgar No. 9 Steers. Trafalgar No. 9 steer compliance was estimated from previous performance. Cattle were individually graded for MSA and detailed feedback given on carcase compliance. Treated cattle at Trafalgar were given two 400 day HGP implants and Lisgar cattle received an 85 day HGP implant 100 days prior to slaughter. Break-even analysis was conducted to determine the relative benefit of each group. Carcasses achieving boning-group 10 or better received a 10c/kg premium.

Results and Discussion

Weight for age and Lisgar's nutrition management system was a driving factor in increasing MSA compliance. Lisgar No 7 Heifers showed a short term (85 day) HGP implant had little effect on compliance into boning group 10 (Table 1). After costs were considered, treated animals returned an extra $21.67/head. Trafalgar No 9 Steers showed that long term HGP programs have a significant effect on MSA compliance. However, extra carcase weight from HGP treatments returned an extra $17.83/head. For Trafalgar, an increase of MSA premiums to $0.34c/kg, or alternatively, 87% compliance, would offset benefits of HGP. No realistic level of premium paid, or compliance rate achieved, could offset the benefits of HGP for Lisgar. Therefore, producers need to determine their achievable compliance rates when assessing potential returns. It is unlikely premiums will rise significantly in the short term future, particularly due to supply and demand of northern beef.

Table 1: Summary of slaughter data.

Lisgar	Non-Treated	Treated
Average HSCW	248.00kg	257.00kg
Compliance (Boning Group 10 or less)	56%	49%
Age (mth) (approx.)	28	28
HGP Cost	$0.00	$1.60/Head
Return (inc HGP cost)	$690.93	$712.60
Trafalgar		
Average HSCW	339.00kg	352.00kg
Compliance (Boning Group 10 or less)	33%	9.67%
Age (mth) (approx.)	39	39
HGP Cost	$0.00	$10.80/Head
Return (inc HGP cost)	$960.39	$978.22

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FutureBeef training packages review

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Introduction

The EDGE*network*® training packages have been successfully delivered across northern Australia for over 10 years. The landscape for delivering workshops has changed dramatically during this time. The evolution of blended learning utilising electronic technology has improved the accessibility, flexibility and appeal of training to potential participants. This is an excellent opportunity to take advantage of innovations, including e-learning technologies and the National Broadband Network, to improve the flexibility and options available to participants and trainers to maximise the learning experiences from these packages. This is the first collaborative project under the FutureBeef Program of Australia.

Objectives

The aims of this two year project, funded by Meat & Livestock Australia, are to: review and update current training packages and associated resources to incorporate the latest research and development (R&D), specifically the EDGE*network* Grazing Land Management (GLM), Breeding EDGE and Nutrition EDGE workshops; develop a business and operational plan to build flexibility into extension products to adapt to participants' needs to enhance learning, including follow-up activities; and to make recommendations on a monitoring, evaluation and reporting system.

Methods

1. Project team and stakeholder planning and preparation: Meetings and e-Surveys to provide a situation analysis of packages and ideas for change.
2. Structure and template development: Review materials and scope alternative delivery models. Review strategic fit between FutureBeef extension effort, key messages, and Monitoring and Evaluation (M&E). Develop a process for regular technical content updates, to ensure the latest R&D is included in the package.
3. Update of training packages: Through a tender process, individuals or groups will be contracted to update the existing workshop materials to fit the new templates. New R&D outcomes will be incorporated.
4. Business and operational planning: Finalise business and operational plans, to implement recommendations and ensure the smooth roll-out of new packages.

Progress to date

Workshops and webinars with private and public EDGE*network* deliverers were successfully facilitated in February 2013. Participants were enthusiastic and contributed invaluable insights and suggestions for enhancing the training packages. The outputs from these workshops have been collated by the project team and further input invited from participants. Most significantly, a SWOT analysis was done at each workshop, and priorities set for what was most critical to the revision and further development of the packages. Attendees committed to tasks such as collecting information relating to each of the packages as well as their level of commitment to be involved in the upgrades to each of the three (Nutrition EDGE, Breeding EDGE and EDGE*network* GLM) packages.

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Mapping extension efforts in the Burdekin Rangelands

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Introduction

Since 2011, the QDAFF Burdekin Rangelands Extension Project team have been using spatial information to plan extension activities and review their impact. The following paper explains how the team and industry benefit from this work.

Mapping examples

Maps are used to document areas where formal extension services (eg seminars, workshops, field days) may not have been delivered and plan work accordingly. For example, the historical participation of grazing properties in QDAFF land management events (Fig. 1a.) was used to highlight unserviced areas to focus the delivery of Stocktake and Grazing Land Management EDGE workshops for the 2013/14 year. Maps are also used to quantify and review industry engagement across the catchment (Fig. 1b.).

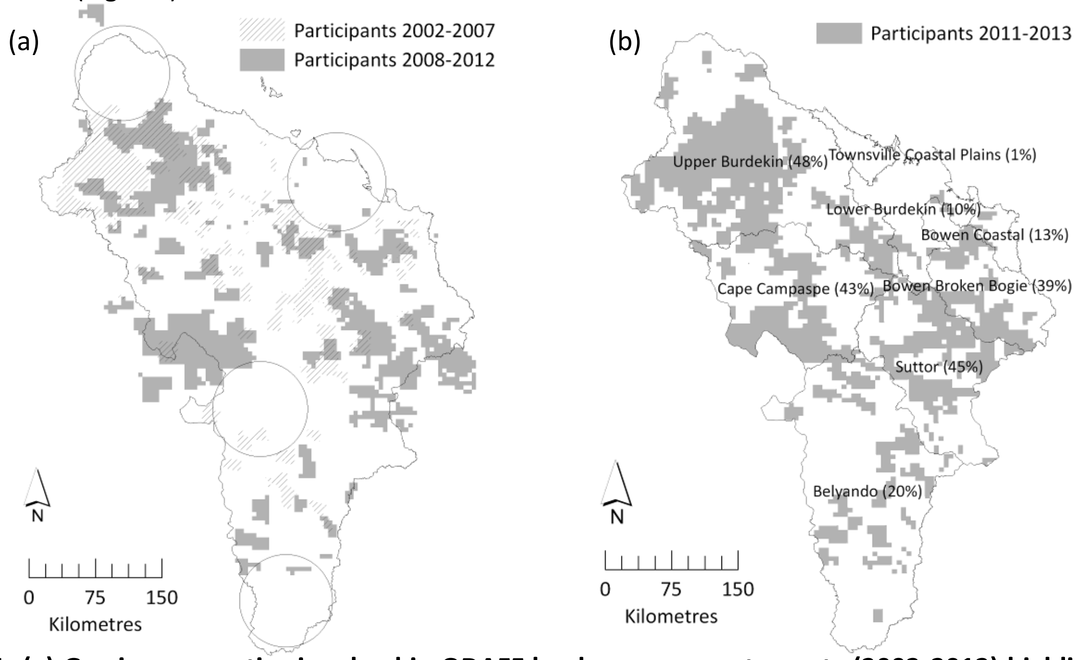

Fig. 1. (a) Grazing properties involved in QDAFF land management events (2002-2012) highlighting unserviced areas targeted for subsequent work (circled) (b) Properties engaged in the Project (2011-2013) and their percentage coverage of the Burdekin subcatchments.

Discussion

Using spatial information in this Project has provided a new way to evaluate the delivery of extension services and better demonstrate the value of this Project. It has highlighted gaps where the Project team works to assist producers with QDAFF services. As data accumulates it will provide insights into the effectiveness of different extension activities in engaging beef producers and the willingness of industry to adopt best management practices. In a period of tight Government resources, and pressure on industry to demonstrate best practice, these are important outcomes.

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FORAGES, GRAZING, SYSTEMS, PASTURES AND RANGELANDS

Economic evaluation of forages grown in the Fitzroy River Catchment: a desk-top study

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Introduction

Intensification through targeted use of high quality forages may improve the profitability of beef enterprises in central Queensland (Bowen *et al.* 2010). Three sites in the Fitzroy River Catchment representing the open downs region, the central Brigalow region and the southern Brigalow region, were modelled. For each region, a steady-state, partial budgeting approach was used to evaluate the long-term (30-year) profitability of utilising 5 sown forage options, compared to the existing tropical grass pasture. Both zero till and cultivation methods of fallow weed control were evaluated. The forages were oats, sorghum, lablab, butterfly pea–grass, leucaena–grass, and established perennial grass pasture (buffel or Queensland bluegrass-dominant native pasture). The profitability of forage options was assessed by calculating the net present value (NPV) which is the sum of discounted values of future income and costs associated with an investment. An initial discount rate of 7% was used.

Results and Discussion

Modelled returns were greatest for the perennial leucaena-grass pasture except for one site under the zero till method of fallow weed control, where it ranked 2nd to forage sorghum. Butterfly pea-grass pasture NPV always ranked 2nd or 3rd. In 11/18 cases the annual forages produced lower NPV than the established tropical grass pasture. While annual forages produced more beef (kg/ha) than the perennial legume-grass forages, the costs over 30 years were also much higher, and long-term returns were negative in 9/18 cases. The marginal profitability of the annual forage crops under many of the scenarios examined, and the lack of association between beef production (kg/ha) and economic performance, indicate the importance of conducting appropriate economic analysis prior to making long-term forage investment decisions in tropical beef production systems. The effects of the various options on whole-farm profitability, as well as environmental and social factors, need to be considered.

Table 1. Comparison of net present value (NPV; $/ha over 30 years) and assumed annual cattle liveweight gain (LWG; kg/ha.year). CQ: Central Queensland, SQ: South Queensland.

		Fallow weed control	Perennial pasture	Oats	Forage sorghum	Lablab	Butterfly pea-grass	Leucaena -grass
CQ Open Downs	NPV	Zero till	285	-468	899	387	1,497	1,581
		Cultivation	285	-683	397	-509	1,282	1,417
	Annual LWG		26	145	203	157	124	138
CQ Brigalow	NPV	Zero till	679	728	2,444	799	1,184	2,131
		Cultivation	679	172	1,478	-167	964	2,017
	Annual LWG		58	147	185	157	104	138
SQ Brigalow	NPV	Zero till	568	388	-61	-802	630	1,415
		Cultivation	568	-168	-1,027	-1,768	410	1,301
	Annual LWG		54	202	153	139	99	110

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Grazing BMP – A Producers Perspective

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Introduction

The Grazing BMP (Best Management Practices) project is modelled upon the successful Grains BMP program, a partnership between Fitzroy Basin Association (FBA), AgForce and DAFF (Department of Agriculture, Fisheries and Forestry, Queensland).

Grazing BMP is a voluntary online self assessment tool to develop and implement a Best Management Practice program for the grazing industry. This program aims to assist landholders improve the economic and environmental performance of their enterprises. The modules are designed to present the best available information and management principles at three levels- above, minimum and below standard for the whole business.

Action plans developed within the program assists landholders to focus and prioritise on the most profitable and sustainable practices and identifies training requirements. Landholders will be able to demonstrate and document good land management and environmental stewardship.

Methods

David and Adele O'Connor "Mountain View" Springsure have completed four of the five modules in the program including; Soil health, Grazing land management (GLM), Animal production and Animal health and welfare. The O'Connors run a 1000 head breeding and fattening enterprise. They use opportunity cropping to fatten bullocks. Their herd is predominantly Poll Hereford based, with some introduction of *Bos indicus* such as Braford bulls to bring up the *Bos indicus* percentage of the breeders. Trade cattle are also bought in to fatten when seasonal conditions are favourable.

Mr and Mrs O'Connor believe the GLM module reinforces the importance of land managers knowing the land types and land condition of their property. Both these factors are considered extremely important in the efficient management of the grazing system. The module promotes good industry practices and assists producers to identify opportunities for improvement and implement them through the creation of individual action plans.

Discussion

The O'Connors stated the module covers a wide range of topics within the key areas. This creates discussion within the group workshop forum. Mr O'Connor believes that people can learn from each others experiences through this discussion and generate new management ideas.

Many of the industry standards addressed within the module are already being practised by the O'Connors. Although they have created action plans to use their pasture monitoring sites more efficiently with the purchase of software to complement their mapping program. They were pleased that the standards were reinforcing that current grazing management on the property is industry standard.

Mrs O'Connor stated that an advantage of the program is the ability of the data to be used by the partners of the program (FBA, AgForce and DAFF) for promotion to consumers and governments that producers are doing the right thing in regards to sustainable beef production.

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Graziers and seed industry are concerned about sown pasture rundown

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Introduction

Sown pasture grasses are very productive when planted after clearing or into fertile cropping soils. However dry matter production and animal performance decline as the available nitrogen reserves decline and become less available to pasture grasses, a phenomenon often described as "pasture rundown". This paper discusses industry (graziers and seed industry) experiences with pasture rundown.

Methods

Graziers and seed companies (including re-sellers) were consulted via focus groups and semi-structured telephone interviews respectively about their experiences with managing productivity decline in sown grass pastures (Table 1).

Table 1. Questions asked to pasture industry stakeholders.

Graziers	Seed companies and Re-sellers
1. What is the extent of productivity decline?	1. What is the extent of productivity decline with your clients?
2. How do you manage productivity decline in your sown pastures?	2. How does it affect the seed industry (your business) and your clients?
3. What are the biggest limitations to overcoming productivity decline?	3. How do you advise clients to manage rundown in sown pastures?
4. What RD&E is needed for the grazing industries to address productivity decline?	4. More information on legumes.
	5. What RD&E would you like to see for sown pasture rundown?

Results and Discussion

Graziers

Decline in pasture productivity was recognised as being a major problem in all areas with the symptoms being widely recognised. Reduced pasture quantity and quality from 'rundown' were blamed for reducing production. A number of mitigation strategies have been tried to reduce the impact of pasture rundown, with the most common being: 1. Live with rundown and accept lower production, 2. Mechanical renovation and 3. legumes to improve feed quality and fix nitrogen.

Seed industry

All but one of the seed industry specialists believed that sown pasture decline was widespread and was most common or worse with buffel grass pastures. The dissenting view was that all pasture rundown and land condition decline could be attributed to grazing management and remediated by rotational grazing. There was a fairly pessimistic view about current trading conditions and the future of the pasture seed industry. Everyone acknowledged the need to plant the right legume in the right situation (soil, climate, short or long term pasture) as grasses still make up the majority of seed sales.
Consultations confirmed that productivity decline in sown grass pastures remains a major problem across southern and central Queensland.

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Comparative performance of pasture legumes in southern and central QLD

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Introduction

A range of forage legumes are suitable for perennial pastures on clay soils, however limited plant production information is available comparing legume options that have been established for a long time, sown side-by-side on the same soil type. This paper reports dry matter production of 4 perennial pasture legumes across 4 old pasture trial sites in southern and central Queensland.

Methods

Four on-farm sites were selected across southern and central Queensland where a range of perennial legumes had been sown approximately 18 years ago. Areas with good legume plant populations were marked and mechanically slashed to 5cm above the ground early February 2013 and spelled from grazing. Plant regrowth was subsequently measured 3 months later, in May 2013. Legumes varied between sites with Caatinga stylo (cv. Prima and Unica) and desmanthus (cv. Marc) at all sites, butterfly pea (cv. Milgarra) at 2 sites and leucaena (cv. Cunningham) at one site.

Results and Discussion

While grass made up the bulk of the dry matter measured at each site, all legumes investigated are productive and persistent in a grass pasture. Two relatively novel legumes desmanthus and Caatinga stylo performed consistently across sites. Drought conditions at Roma/Surat impacted negatively on Caatinga stylo's ability to regrow after slashing. Leucaena was a solid performer at the one site sown and supports it's suitability to the central Queensland environment (Table 1), however site specific characteristics favoured its growth compared to the other legumes.

Table 1. Dry matter yield of a range of perennial legumes after 3 months regrowth.

Site	Soil type	Species	Legume drymatter (kg/ha)	Total drymatter (kg/ha)	Rainfall 1 Feb to 1 May (mm)
Capella	Black heavy clay	Butterfly pea	929	3271	218
		Caatinga stylo	2639	3918	
		Desmanthus	969	3092	
Theodore 1	Black heavy clay	Caatinga stylo	1453	2568	188
		Desmanthus	535	1973	
		Leucaena	3258	7813	
Theodore 2	Brown medium clay	Butterfly pea	670	2605	193
		Caatinga stylo	457	1743	
		Desmanthus	1140	1785	
Roma/ Surat	Grey heavy clay	Caatinga stylo	0	734	73
		Desmanthus	672	1824	

Conclusion

While this study was an opportunistic approach to determining comparative plant performance, it demonstrates that graziers have a range of productive perennial legume options for inclusion into grass-only pastures on clay soils.

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Impacts of land preparation techniques on Leucaena establishment

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Introduction

Leucaena is a highly productive perennial legume, however it can be slow and expensive to establish. Fully removing existing grass and deep ripping the soil prior to sowing are generally recommended, however limited information is available on the establishment and growth benefits to Leucaena.

Methods

Two central Queensland MLA funded Producer Demonstration Site trials: trial 1 on a non-cracking loam soil native bluegrass pasture; trial 2 on a cracking clay soil buffel grass pasture. Approximately 4m wide soil cultivation strips were prepared in existing pasture. At the start of fallow, soil ripping (2 types, 1m apart, 65 cm deep) was randomly applied to some rows along the expected Leucaena sowing lines. Additionally, in trial 2, some inter-row grass strips were sprayed with Glyphosate to simulate full grass removal.

Soil moisture and nutrient were measured directly before deep ripping and again at planting. Leucaena plant population and total biomass were measured prior to the end of the first growing season, and edible biomass measured prior to the first graze and again ~3 years after sowing.

Results and Discussion

Greater soil moisture accumulated at planting after ripping on the loam soil. No soil-moisture difference occurred on the cracking clay soil, regardless of ripping or the full removal of grass.

On the loam soil, establishment and initial Leucaena yield was significantly higher due to deep ripping, however no differences were measured thereafter (Table 1). Even thought ripping on the cracking clay soil produced higher edible yield 1 year after sowing, similar plant establishment, initial yield and yield ~3 years after sowing occurred (Table 1). Completely removing grass had no benefit on Leucaena establishment or yield at the one site investigated.

Table 1. Leucaena establishment and yield.

Trial	Treatment	Establishment (plants/m of row)	Leucaena yield 4 months after sowing (kg/ha)	Leucaena yield ~1 year after sowing (kg/ha)	Leucaena yield ~3 years after sowing (kg/ha)
1 (Loam soil)	Rip	13.5 a	418 a	1,090 a	1,872 a
	Non-rip	10.2 b	240 b	956 a	1,8808 a
2 (Clay soil)	Rip	13.6 a	246 a	1,320 a	113 a
	Non-rip	12.9 a	244 a	1,205 b	128 a
	Sprayed grass	12.1	236	1260	132

While ripping provided plant establishment and initial Leucaena yield benefits on a non-cracking soil, no long term benefits (~3 years) were measured for either land preparation technique applied on either soil.

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Wet season spelling at Alexandria Station, Barkly Tablelands

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Introduction

Wet season spelling is an important tool producers in northern Australian rangelands can use to improve or maintain land condition, accumulate fuel for prescribed burning or increase feed for use later in the year. Ross Peatling, manager of NAPCO's Alexandria Station on the eastern Barkly Tableland, has been implementing wet season spelling since 2005 and is already reaping the rewards. Wet season spelling involves removing all grazing activity from a paddock or bore for some or all of the wet season during the time of active pasture growth.

Pasture growth modelling and increasing anecdotal evidence shows that the regular application of spelling, in conjunction with sustainable stocking rates, can improve and maintain land condition, increase pasture yields and thus potentially optimise cattle production.

Methods

Wet season spelling at Alexandria Station is not used in isolation, but is an important management tool used as part of a more comprehensive animal, land and stocking rate management strategy. The management approach, based on sustainable stocking rates and water point development, allows areas close to bores that have received heavy grazing to be spelled in larger paddocks without the need for more fencing. The water point development has also resulted in more even grazing throughout large paddocks. This is especially important in the extensive grazing systems typical of northern Australia where paddocks are so large that managers cannot usually afford to take them out of production for long periods.

The duration and frequency of a wet season spell on Alexandria is determined by the land condition at the bore and surrounding area, and also on the quality of the wet season. A failed wet season where there is limited pasture growth does little for regeneration and may require a consecutive spell the following wet season if land condition is to be improved.

In order to quantify some of the results Ross Peatling is currently seeing on Alexandria, 3 transects have been established as part of a long term demonstration site in a 700 km^2 paddock investigating the benefits of wet season spelling and sustainable stocking rates. The demonstration is assessing how stocking rate management and wet season spelling can maintain good land condition at new bores and improve land condition at older bores. Annual measurements of pasture yield, species composition and ground cover are collected at the end of the growing season.

Results and Discussion

As the demonstration site was only started at the end of 2010, it is still too early to make recommendations as to the benefits of wet season spelling on a scientific basis, however Ross Peatling's experience with wet season spelling prior to the trial commencing has been nothing but positive. It is envisaged that continued monitoring will quantify the effects of wet season spelling and validate it as a management tool producers will be able to utilise in their overall pasture management plans.

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Forage and animal production in the Fitzroy River Catchment 1. Winter annual forages

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Introduction

Intensification through targeted use of high quality forages may improve the profitability of beef enterprises in central Queensland (Bowen *et al.* 2010). This study reports production results for forage oats grown in central Queensland on commercial beef cattle properties.

Grazed forage oats paddocks were monitored on co-operator properties within the Fitzroy River Catchment in the open downs (CQOD), the central Brigalow (CQB) and the southern Brigalow (SQB) regions. A wide range of management practices made it difficult to make comparisons. Perennial grass pasture was often available in the same paddock as the oats forage, comprising 22–87% of the paddock. Cattle were 18 months - 3 years old on entry.

Results and Discussion

Average liveweight gain of mobs ranged from 0.3-2.2 kg/head.day. Heavier, older cattle had lower weight gains than lighter cattle grazing the same forage paddock. Other factors associated with differences in weight gain included forage quality and biomass (data not shown) as well as likely compensatory gain effects in some cases.

Table 1. Comparison of key production parameters for cattle grazing oats forage on co-operator sites in the Fitzroy River Catchment during 2011 and 2012. Regions defined above.

		CQOD	CQB		SQB	
		2011	2011	2012	2011	2012
N fertiliser (kg N/ha)		0	28	0	0	0
% of total grazing area as perennial grass pasture		87	22	44	32	32
Total grazing period (days)		97	158	110	91	138
Stocking rate (forage area only; AE/ha)		4.9	2.0	1.8	2.0	1.5
Stocking rate (total grazing area; AE/ha)		0.7	1.6	1.0	1.3	1.0
Hormonal growth promotant		none	none	none	100-day	100-day
Mob 1:	Entry liveweight (LW; kg)	622	566	518	523	449
(steers)	Days over which LW measured (days)	34	82	59	63	79
	Daily LW gain (kg/head.day)	0.7	0.5	1.5	0.8	1.5
Mob 2:	Entry liveweight (LW; kg)	462	-	416	520	-
(steers)	Days over which LW measured (days)	42	-	30	28	-
	Daily LW gain (kg/head.day)	1.0	-	1.7	0.3	-
Mob 3:	Entry liveweight (LW; kg)	-	-	361	-	-
(spayed	Days over which LW measured (days)	-	-	30	-	-
heifers)	Daily LW gain (kg/head.day)	-	-	2.2	-	-

This work is providing a better understanding of expected forage, animal and economic performance under management conditions representative of commercial beef producers, and of the key drivers of profitability within these grazing systems.

References

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Perennial *Arachis* and *Stylosanthes* hays have excellent potential as low-input alternatives to lucerne in north Queensland

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Introduction

Pastures based on introduced tropical grasses and legumes are the key feed resource for beef growing in north Queensland. However, poor winter pasture growth rates commonly result in a feed deficit. Perennial herbaceous legumes grown for hay can overcome this by providing affordable, high-quality (digestible protein) dry-season feed. Lucerne (*Medicago sativa*) is commonly used for this purpose in other areas of Queensland, but commercial production in north Queensland is often unsuccessful. The development of anthracnose (*Colletotrichum gloeosporioides*) resistant varieties of *Stylosanthes guianensis* and preliminary experimentation with a range of *Arachis* spp. by DAFF and JCU researchers, presented an opportunity to assess their potential as perennial legume hays.

Comparative performance of *Arachis* and *Stylosanthes* with *Medicago* in north Queensland

A pilot evaluation of 2 commercially recommended lucerne varieties with 2 anthracnose resistant *S. guianensis* varieties and a range of seeding (*5 A. pintoi*, 2 *A. paraguariensis* and 1 *A. kretschmeri*) and vegetatively propagated (3 *A. glabrata*) *Arachis* types was completed at Walkamin between 2009 and 2012. The site has an upland tropical environment (annual mean rainfall 1019 mm, summer-dominant) and a free-draining, acidic (pH_{water} = 6.7) red clay soil. Replicated (2) small-plots (5.4 m2) were established during September 2009 using seedlings or rhizomes transplanted at 11 plants/m^2 into a fertilised (single superphosphate and KCl) site with overhead irrigation.

'Low-input' management strategies were used to grow hay: no additional fertiliser was applied and pests and diseases were not controlled. Irrigation was applied to supplement rainfall in the dry season (~25 mm/wk). Eight-week cutting cycles were completed between 25 March 2010 and 14 September 2011 after which time plots were allowed to grow un-cut until 31 January 2013. All plant material was removed after cutting plots to 5 cm. Leaf and stem above 5 cm was sampled immediately before cutting and dried biomass measured. Subsamples were analysed using NIR (with wet chemistry checks) for indices indicative of value as a feed for ruminants.

The lucerne varieties grew well in the two first dry seasons, but stands quickly succumbed to disease and pests during the wet summers. Biomass production dropped to 20% of some of the other legumes by the 2011-12 wet season. The *Stylosanthes* and *Arachis* lines had summer-dominant growth, better matching seasonal rainfall, were relatively pest and disease-free and continued to grow strongly until the end of the experiment. The *Stylosanthes* and 2 *A. pintoi* lines produced above 25 T DM/ha equivalent over 19 months and the 3 *A. glabrata* lines produced over 15 T DM after establishing slowly from rhizomes. Feed quality of all lines tested was excellent with low lignin (5.7-9.7%) and acid detergent fibre (28-39%) values and high crude protein (18-20%), protein digestibility (67-71%) and metabolisable energy (8.6-10.9) values. The relative feed values of the *Arachis* were significantly higher (50-90%) than for lucerne and *S. guianensis*.

Future development

We hope to progress 1 or 2 of the superior *A. pintoi* (seeding) and *A. glabrata* (vegetative) lines and complete larger-scale testing along with the two commercially available *S. guianensis* lines. We have sourced a rhizome digger and transplanter suitable for *A. glabrata*, and seek co-funding to renovate the equipment and establish source blocks for a rhizome dissemination program.

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Pasture grasses and legumes recently progressed through the (Queensland) DAFF seed production program in north Queensland

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Introduction

Sown tropical grasses and legumes, variously used in combination with native grasslands, are the primary feed for beef enterprises in Queensland. Tropical pasture development in Queensland has historically been conducted by the Queensland and federal governments, often co-funded by research and development corporations. During the 1970s, the Queensland Government established a pasture seed research and development facility in north Queensland to support new cultivar development. The key role of the pasture seed program is to facilitate the development and adoption of grasses and legumes useful for the beef, dairy and grain (through rotation) industries in Queensland. Key activities include seed increase to support plant evaluation and commercial adoption in Queensland, seed crop research and extension to growers once released. Regeneration of high-performing cultivars after private sector failure is also routinely conducted.

Grasses and legumes recently progressed through the program

The seed program has diversified since 2000 following decreased public sector investment in cultivar development. Seed companies and universities have developed their own lines thereby complementing government efforts (Table 1). A large number of grasses and legumes are currently at pre-commercial stages of development and many should become available in the next 3-5 years. This is encouraging given it is unlikely future public sector investment will return to past levels. However, most lines are yet to be extensively assessed under grazing in Queensland and a collaborative effort between the developing agencies would help to clarify cultivar roles for end-users. The resurrection of older, high-performing cultivars remains an important role for the research team and the activity has, overall, been successful at maintaining industry supplies of seed.

Table 1. Tropical grasses and legumes progressed through the DAFF program, 2000-12.

Route of development	Grass species (number of types[1])	Legume species (number of types[1])
Imported elite variety (government or seed company)	*Brachiaria brizantha* (1^{1}), *B.* hybrid (8^{1}), *Bothriochloa insculpta* (2^{2}), *Cenchrus ciliaris* (6^{0})	*Stylosanthes guianensis* (4^{2})
Privately bred/selected in Australia	*Chloris gayana* (3^{1}), *Dichanthium annulatum* (1^{0}), *D. sericeum* (1^{0}), *Digitaria eriantha* (6^{0}), *Panicum coloratum* (1^{0}), *P. maximum* (1^{1}), *Paspalum notatum* (1^{1}), *Urochloa mosambicensis* (2^{0})	*Desmanthus bicornutus + D. virtagus* ($5^{1\ \text{(composite)}}$), *D. virgatus* ($1^{1}$), *Macroptilium bracteatum* (7^{0}), *M. atropurpureum* (1^{0}), *Macroptilium gracile* (1^{0}), *Vigna parkeri* (1^{0})
Publicly bred/selected in Australia (some with private or industry co-funding)	*Chloris gayana* (7^{5}), *Dichanthium sericeum* (2^{0}), *Heteropogon contortus* (2^{0}), *Panicum coloratum* (3^{0}), *P. maximum* (3^{1}), *P. maximum* var. *infestum* (2^{1})	*Clitoria ternatea* (12^{0}), *Desmanthus virgatus* (4^{1}), *Lablab purpureus* (10^{1}), *Macroptilium gracile* (3^{0}), *Stylosanthes* spp. (11^{0})
Regeneration of cultivars released before 2000	*Bothriochloa bladhii* (1^{1}), *B. pertusa* (1^{1}), *Chloris gayana* (4^{4}), *Digitaria eriantha* (1^{1}), *D. milanjiana* (1^{1}), *Paspalum nicorae* (1^{1}), *Urochloa mosambicensis* (1^{1})	*Aeschynomene americana* (1^{1}), *A. villosa* (2^{2}), *Centrosema molle* (1^{1}), *Macroptilium atropurpureum* (1^{1}), *Neonotonia wightii* (1^{1}), *Stylosanthes seabrana* (2^{2})

[1] superscript number – the number of types grown commercially by 2013

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Long-term approach required to mitigate the financial impact of rejected pasture legumes

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Introduction

The incorporation of exotic legumes into tropical grass pastures (sown and natural) is an effective method to improve animal growth rates and reproductive performance in northern Australia. During the 1980s and 1990s broad-scale industry co-funded programs were undertaken by state and federal government agencies to develop new pasture plants, particularly legumes to lift the productivity of sown and natural grasslands used for grazing. These included legume species previously not widely tested in Australia. Some showed promise during early assessment but were later rejected before release because they showed no production benefits over other species or were considered not readily eaten by livestock.

Weed control and containment program

Researcher concerns of some of the legumes becoming widespread contaminants of grazing lands prompted the development of a Queensland Government and Beef Industry funded containment and eradication program in 1999. Three herbaceous legumes, *Aeschynomene brasiliana, Aeschynomene paniculata* and *Indigofera schimperi*, plus one tree legume *Acacia angustissima* syn. *Acaciella angustissima* were targeted for control at 60+ sites throughout Queensland. Since then, the program has been periodically reviewed and is currently in its fourth project cycle.

Staff from the Queensland Government, CSIRO and JCU undertook systematic control of plants to prevent seeding, and thereby erode soil seed banks, using methods developed in the first phase of the program. The aim was to *contain* target plants to their evaluation areas and *eradicate* plants at sites where possible. Plant population and seeding data were compiled and summarised each year to monitor progress. Additional activities were completed to improve understanding and control of the target plants including seed establishment and gut-passage studies, detailed GPS/GIS mapping of sites and the completion of Queensland Government weed risk assessments. Funding from alternative sources was used for surveying and mapping and for on-ground works at large sites.

A longer-term approach

Plants were contained and populations reduced at most sites with some now considered 'clean' and their impact on the grazing industry has effectively been nil. However, seeding has not always been prevented resulting in persistent populations and one site on Cape York contains a large and mobile population of *A. paniculata*. Our understanding of the target plants and weed threat has greatly improved: *Aeschynomene* spp. have proven mobile whereas *I. schimperi* and *A. angustissima* move slowly; *A. brasiliana* has proven to be relatively palatable, being grazed to crowns in the dry seasons at many sites, whereas the others are rarely eaten; and all are highly persistent through long-lived seed in soil (hardseed dormancy) meaning that control needs to be considered in decades rather than years. Only 1 to 2 days effort per year is required to control plants, but timing is critical to prevent seeding. It seems only *A. angustissima* will be declared in Queensland.

In recognition of the above, future activity places a higher priority on *A. paniculata*, followed by *I. schimperi* and *A. angustissima* and there is an increased effort to involve local land managers in controlling the target plants with project support, rather than all control being completed by project staff as mostly done in the past. The revised aim is for *long-term containment* whereby continued small investments in time and materials maintain minimal long-term costs to the industry.

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Improving performance through adaptive grazing – Beetaloo Station

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Introduction

One of the problems typically seen on extensive cattle properties is uneven utilisation of pastures. 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 undergrazed. The subsequent decline in feed levels close to water is detrimental to animal production and land condition. Impacts include poor rates of live weight gain, the loss of body condition in breeders, and reduced branding rates.

Aims of the demonstration

A joint partnership between the BLCA, the Dunnicliff & Armstrong families of Beetaloo Station and the NT DPIF is conducting a Caring For Our Country funded project looking into how a more intensive management system compares to "traditional" extensive, low development, continuous grazing pastoral management typically practiced in the Barkly region. The management approach and on-ground activities conducted have been selected specifically because their primary purpose is to increase agricultural productivity as well as protect and enhance conservation values.

The adaptive grazing demonstration will gather scientific evidence of what the pastures and biodiversity were like in the initial stages of the development and grazing program and how they change over time. The aim is to measure the potential for sustainably and profitability intensifying production through grazing practices that give greater control of livestock distribution, grazing pressure and pasture utilisation.

Methods

The "Peabush" site is predominantly open Mitchell grass plains with some scrubby red soil country encroaching on the western edge. When the family took over, this was an area of about 1,800 km² with only 9 waters and was running about 2,300 head. Significant water and fencing infrastructure intensification in the area was completed in 2009, resulting in 33 tanks, 3 dams and an average paddock size of about 12 km². In 2012 the eastern side of the Peabush rotation area was further subdivided into paddocks of about 4 km². Each rotation paddock has access to two waters. These paddocks have been used for grazing entire bulls in an informal rotation prior to live export. Weaner bulls are grouped up into a rotation mob in about November or December each year. A sample of bulls is weighed upon entry and exit of the rotation. The intention is to run relatively large mob sizes (5,000-7,000 head) in a short duration rotation (e.g. 3-4 day moves).

Outputs

It is hypothesised that greater control of livestock distribution, grazing pressure and pasture utilisation will:

1. Stabilise or improve land condition compared to "traditional" continuous grazing.
2. Achieve more even pasture utilisation and improve the annual management of the pasture supply compared to the traditional grazing approach.
3. Increase the animal production on a per hectare basis on this area of country.

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Pasture monitoring and evaluation – the WA experience

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Introduction

A new method for assessing rangeland condition was introduced in 2010. The Department of Agriculture and Food was tasked with developing a scientifically rigorous alternative method to on ground inspections by the Department of Agriculture and Food of Western Australia (DAFWA) and providing training materials that could be delivered across the whole of the WA rangelands. In using the range condition monitoring method land managers have the opportunity to take ownership and control of the process of assessing and managing land condition on their leases.

Discussion

Range condition monitoring sites are being used to determine the range condition trend on pastoral leases in Western Australia. Leases have been allocated a number of sites determined by the size of the lease and also its ability to carry stock. One third of these sites are to be assessed each year. Managers consider ground cover, pasture composition, soil surface condition, tree-grass balance and photo evidence at each site. Using this objective data, land managers can then make an informed decision on the range condition trend at that site and over the entire lease.

Monitoring sites have specific criteria for location, installation and assessment. They should be located in an area representative of the rest of the paddock, have the ability to improve or decline in condition, not be too close or distant from water and be responsive to grazing management. Grassland sites are assessed by placing a quadrat every two metres and recording the frequency of a maximum of four perennial grass species present over 25 quadrats. The numbers of trees or shrubs over one metre high on the site are counted and an assessment on the soil surface condition is made and a picture is taken. The manager then makes an assessment on whether the trend at this site is improving, stable or declining compared to the previous assessment.

The requirements for these sites are considered the baseline data to make a decision on land condition. Managers have the ability to add value and robustness to the measurements they are taking by increasing the number of grass species that they are monitoring on their sites. This gives land managers a sound basis for the application of more sophisticated feed evaluation models for determining available feed on ground.

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Water ponding on Larrawa station, November 2011: a photo story

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Introduction

On-ground works completed at Larrawa station producer demonstration site in 2011 focussed on building open water ponds to regenerate degraded pastoral land and collecting data on their cost($) to construct. Ninety ponds were built at Larrawa station in 2011. The amount of water ponded at each pond ranged between 10 cm and 15 cm. Two different sized machines (road graders) were compared; 16G and 12G. The model 16G grader is significantly larger and more powerful than the model 12G.

Results and Discussion

Data collected during 2011 indicated that a 16G grader was more economical at water pond construction than a 12G machine. Table 1 displays the median cost per metre and approximate cost to build a 210 m pond for both 16G and 12G machines.

Table 1 Data collected for a 16G and 12G grader.

	16G	12G
Machine cost per hr (with operator & without fuel)	$175.00	$150.00
*Diesel used per hour	22.5 L	22.5 L
Median cost to build pond per metre	$.32	$.49
Approx. cost to build 210 m pond	$67.00	$102.90

*Diesel usage was measured and costed at $1.48 per litre.

The estimated total cost to build two ponds on 1 hectare is $148.52. This includes:

- Surveying (not included).
- x2 ponds at $67 each (includes x2 rips along borrow area and x2 rips inside of pond).
- 2 kg of forage sorghum seed was $14.52.

Two permanent Rangeland Condition Monitoring sites were installed. No annual or perennial plants were recorded at either site during installation. At the time of reassessment in April 2012 all quadrats (25) at both sites recorded some annual ground cover. Pigweed *(Portulaca* sp.*)* provided the majority of ground cover recorded. At the control site where no regeneration activities were undertaken no change in perennial or annual groundcover was recorded, the site remained bare at the time of re-assessment in April 2012. At the time of reassessment, no improvement in land condition was recorded, however an increase in groundcover was observed – attributable to increased soil moisture and a sign of improved ecological function.

Key knowledge gained:

- A 16G was more economical than a 12G to build water ponds – won more dirt per pass.
- Surveying for ponds is best completed by a professional experienced in surveying ponds.
- An experienced machine operator is essential to get full value out of ‘machine hire’.

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Developing a soil information day for the Grazing BMP program

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Introduction

Grazing BMP (Best Management Practices) is a voluntary online self assessment tool designed to assist landholders improve the economic and environmental performance of their business. Modelled upon the successful Grains BMP program, the Grazing BMP program was developed through a partnership between Fitzroy Basin Association (FBA), AgForce and DAFF (Queensland Department of Agriculture, Fisheries and Forestry).

The Grazing BMP program comprises five modules; Soil health, Grazing land management, Animal production, Animal health and welfare and People and business. Through the self-assessment process landholders are able to identify areas where acquiring further knowledge or skills, or implementing a change of practice, would be beneficial to their business. Commitment to seeking new skills or achieving practice change is captured within the program, through participant-developed action plans. The program also provides landholders with a link to technical resources and training opportunities, relevant to their action plans.

Initial delivery of 12 Soil health and 9 Grazing land management modules in the Fitzroy Basin between December 2010 and March 2013 was well received. Participant feedback indicated that many participants were less confident in assessing their soil management practices and were interested in improving both their knowledge and management of soil.

Methods

In response to producer feedback requesting more information on soils and soil management a Soil Information Day was developed, incorporating delivery of the Soil health module with both technical presentations and practical demonstrations of soil properties.

The Soil Information Day provides a comprehensive explanation of soil physical, chemical and biological characteristics and how these determine the productive capacity and resilience of a soil. The presentation provides technical information to assist landholders when making an assessment about the limitations and capabilities of the soils they manage.

An important component of the presentation is the identification of specific management practices that can maintain or improve the capacity of a soil to produce forage. Many of these practices focus on the maintenance of adequate ground cover for a particular soil type.

To compliment the technical presentation, the second half of the Soil Information Day involves an in-paddock, soil surface and a soil profile assessment. The soil surface assessment looks at the condition of the soil within the landscape, examining canopy and basal coverage of vegetation; litter; soil crusts and erosion. The soil profile assessment examines the structure, texture and pH of soil within a soil pit. Group discussion in the paddock explores the linkages between the surface and profile assessment and the quantity and quality of the forage in the landscape.

Results and Discussion

The Soil Information Day has been delivered to a number of groups within both the Fitzroy and Burdekin catchments. Feedback from attendees indicates that landholders are aware of the important role that soil plays within the grazing system and are committed to improving both their knowledge and management of soil.

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Assessment of Land Health in the Northern Gulf and Cape York Rangelands

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Introduction

The Northern Gulf and Cape York NRM Regions cover approximately 30 Million hectares and comprise mainly of extensive rangelands. Over 90% of the Northern Gulf and 50% of Cape York is extensively grazed while, the remainder under conservation or Indigenous Shire management.

These Regional NRM Groups in consultation with graziers have developed a Monitoring and Evaluation (M&E) Program specifically designed to be relevant to graziers providing: a knowledge sharing and management decision support tool; an environmental management benchmarking system; links between grazing practices and productivity; condition and productivity information; forewarning of environmental threats; and a means to evaluate management systems.

Monitoring program

The M&E Program is set up in two phases. Phase 1 has built a framework to monitor and assess Land Health (2011/12) at the regional scale using indicator datasets for the themes of Overall Landscape health, Landscape function (*the capacity to capture and retain rainwater and nutrients)* and Sustainable management (*relates to best practise Grazing Land Management)*. The M&E program framework is in the form of environmental accounts (Wentworth Group 2008), as per economic accounts that monitor a business' performance against benchmarks. The program relies on existing monitoring datasets from external agencies in combination with on-ground monitoring point data (363 End-of-wet sites; 574 Break-of-season sites). This data is interpolated using 4 models to region-wide coverages. Current status of indicators are assessed against their reference condition (varies with IBRA subregion) to determine a Reference Metric % (100% being undisturbed), allowing indicator scores to be amalgamated, weighted or averaged. Confidence level scores for each indicator determine the proportional contribution of each indicator to calculating the health scores for monitoring themes.

Indicators include: *Broad Vegetation Group* 'Extent', 'Patch Metrics', and 'Fire Extent & Frequency'; *End-of-Wet 3P pasture* '% of sward', 'Count/m^2', and 'Dry Matter'; Tree Thickening; Soil Surface; Weeds; *Break-of Season* and *End-of-Wet Ground Cover '*on-ground' and 'remotely sensed'; *End-of-Wet Pasture Dry Matter* on-ground; and *Native pasture* '3P%, '% of sward', and 'Dry Matter'.

Phase 2 monitoring, which will commence now, monitors land health on properties to answer the questions of graziers and will feed into the regional-scale monitoring. Of interest to graziers are: weeds and ferals; woody thickening, sustainable stocking rates on various landtypes; dynamics of pasture grasses and legumes; ground cover and land condition; carbon in the landscape; biodiversity on grazing land versus park land; and soil health on burnt and unburnt country.

Regional scale results

The regional scale 2011/12 review of Land health shows the Northern Gulf NRM area in poorer health than the Cape York NRM area, reflecting an historic heavier grazing pressure. Overall Land Health, Landscape Function and Sustainable Management for the entire NG and CYP region were classified as a "Moderate" (61-80%) 79%, 71% and 72%, respectively. Four IBRA sub Regions were classified as in "Poor" (41-60%) health for both Landscape Function and Sustainable Management.

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Recovering bare eroded grazing land in the Burdekin

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Introduction
Bare areas of D-condition grazing lands, which can be identified by over 20 years of satellite imagery, occur widely across the Burdekin River catchment. These areas are unproductive for grazing and contribute a disproportionate amount of sediment and nutrients into the Great Barrier Reef lagoon. Rehabilitating these patches will have direct benefits to the cattle producer by providing land cover and pasture, and also benefit the wider community by improving water quality and GBR health.

Methods
Four mechanical soil disturbance treatments (chisel ploughing to 20 cm, deep ripping to 50 cm, crocodile seeding with pits to 10 cm, and surface hay mulch after levelling) were compared with an undisturbed control on a bare, eroded, periodically flooded, creek frontage in the mid-Burdekin catchment. The treatments, applied in October 2011, were all surface seeded with a tropical pasture grass and legume mix and grazing was excluded. There were 3 soil types: a crusty deep black vertosol (Ug5.15), a deep grey sodosol (Dy3.13), and a sodic brown dermosol (Uf6.41). Rainfall was 775 mm and 430 mm over the first two wet seasons respectively. Long-term average is 613 mm.

Results and Discussion
There was good pasture germination in cultivated treatments on 100mm of rainfall immediately after sowing, however, these seedlings died in the following 5 dry weeks and temperatures to 40^{0}C. A second 96 mm rainfall germination event occurred in December 2011 and these predominantly grass plants produced to 90% ground cover by the end of the first summer on the vertosol and sodosol soils, and <20% cover on the dermosol soil type. Over the first summer, treatments produced pasture yields to 3900 kg/ha from the hay mulch treatment and average pasture cover of 65% from deep ripping. Cover in the control on the dermosol soil was from annual grasses and pigweed (*Sporobolus* and *Portulaca* spp.) as the sown species failed to establish. In the second year, total cover remained similar, litter cover increased from death of first-year grasses, and DM yields all decreased (Table 1).

Table 1. Mean pasture dry matter yield, cover and basal area after the first two summer seasons.

Pasture parameter	Ripping		Chisel		Crocodile		Hay mulch		Control	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Dry matter yield (kg/ha)	3420	2860	3350	2140	2300	1310	3910	3020	1850	420
Total ground cover (%)	65	66	56	57	47	63	97	90	45	42
Litter cover (%)	6	28	2	24	6	41	93	79	2	25
Basal area (%)	1.8	2.1	1.8	1.6	1.5	0.9	1.5	2.2	1.0	0.3

In the first summer, there was greatest establishment and pasture growth from the deep ripping, chisel ploughing (3400 kg/ha) and the grass hay mulch cover on the disturbed vertosol soil type. There were significant differences in rehabilitation success between the three soil types with most success on the vertosol and failure on the sodic dermosol. Legume yield, >1000 kg/ha, was highest with ripping and chisel ploughing. In the Burdekin catchment, D-condition bare areas on some soil types, such as vertosols, can be rehabilitated by mechanical disturbance, reseeding by adapted pasture species and excluding grazing, in good rainfall years. Subsequent seasonal conditions and management will determine the long-term rehabilitation success after initial establishment.

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Spelling strategies for recovery of pasture condition at Charters Towers, Qld.

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Introduction

Worsening land condition is an issue for many producers across northern Australia. Wet season spelling is a key recommendation to improve pasture composition and land condition; however accurate and reliable data illustrating the effects of spelling in a grazing system is currently limited. Our project seeks to improve the evidence base, and hence modelling capacity, to predictably recover poor condition pastoral land through targeted wet season spelling at two contrasting sites. This paper describes work conducted at one of those sites near Charters Towers in north Queensland (Site 2).

Methods

Site 2, established at the Wambiana Grazing Trial, located 60 km south-west of Charters Towers, examines the combination of different timing, duration, and frequency of spelling on plots of 'C' condition land (poor condition created by continual heavy grazing over 15 years) now subject to a high or moderate stocking rate. Treatments include annual or biennial, early or full wet season grazing spell, and continuous grazing. Treatments are to be applied from Nov 2012 to May 2015.
Spelled and grazed plots are recorded thrice yearly to capture changes in pasture composition and soil surface parameters. The key perennial pasture grasses *Bothriochloa ewartiana*, *Chrysopogon fallax*, *Panicum effusum* and *Aristida* species are mapped from permanent quadrats to measure crown cover, persistence, recruitment and mortality. Pasture yield, composition and ground cover are recorded using the BOTANAL method, while the soil surface characteristics are captured using the Landscape Function Analysis (LFA) technique.

Results and Discussion

Site 2 had good rainfall and growing conditions for the two years leading up to the trial, but below average summer rainfall for the first early wet season treatments of 2012-13. Basal area of the perennial grasses (Table 1), and the main pasture and soil surface condition parameters have not been significantly affected by an early wet season spell under either a moderate or high stocking rate.

Table 1. Spelling effects on perennial grass basal area at Site 2.

		Nov. 2012 Basal area (%)	SE	Feb. 2013 Basal area (%)	SE
Moderate stocking rate	Grazed	1.5	0.3	1.5	0.2
	Early wet season spell	1.8	0.1	1.8	0.2
High stocking rate	Grazed	1.8	0.3	1.6	0.3
	Early wet season spell	1.4	0.3	1.8	0.5

An improvement in land condition via increased perennial grass basal area and a decreased contribution of *Aristida* species is a key desired outcome of this project. The lack of change in pasture parameters with a one-off early wet season spell during below-average rainfall demonstrates the challenge that land managers face when trying to improve land condition. It is too early yet to say whether better seasonal conditions or a longer growing season rest would produce a more favourable outcome.

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Forage and animal production in the Fitzroy River Catchment
2. Summer annual forages

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Introduction

Intensification through targeted use of high quality forages may improve the profitability of beef enterprises in central Queensland (Bowen *et al.* 2010). This study reports production results for 2 summer forages grown in central Queensland on commercial beef cattle properties. Grazed forage sorghum and lablab paddocks were monitored on co-operator properties within the Fitzroy River Catchment in the open downs (CQOD), the central Brigalow (CQB) and the southern Brigalow (SQB) regions. A wide range of management practices made it difficult to make comparisons. Perennial grass pasture was often available in the same paddock as the sown forage, comprising 27–57% of the paddock. Cattle were 14-30 months old on entry. No hormonal growth promotants were used.

Results and Discussion

Average liveweight gain of mobs ranged from 0.2-0.8 kg/head.day. Factors associated with differences in weight gain included age and entry weight of cattle, possible compensatory gain effects, and forage quality and biomass (data not shown).

Table 1. Comparison of key production parameters for cattle grazing lablab or sorghum forage on co-operator sites in the Fitzroy River Catchment during 2011/12. Regions defined above.

		CQOD lablab 2011/12	CQB forage sorghum 2011/12	SQB forage sorghum 2011/12
N fertiliser (kg N/ha)		0	52	0
% of total grazing area as perennial grass pasture		57	39	27
Total grazing period (days)		103	112	108
Stocking rate (forage area only; AE/ha)		1.5	2.2	3.3
Stocking rate (total grazing area; AE/ha)		0.6	1.3	2.4
Mob 1: (steers)	Entry liveweight (LW; kg)	458	477	549
	Interval of LW measurement (days)	54	112	108
	Daily LW gain (kg/head.day)	0.6	0.4	0.2
Mob 2: (steers)	Entry liveweight (LW; kg)	439	383	428
	Interval of LW measurement (days)	62	112	108
	Daily LW gain (kg/head.day)	0.8	0.3	0.6
Mob 3: (spayed heifers)	Entry liveweight (LW; kg)	-	335	-
	Interval of LW measurement (days)	-	112	-
	Daily LW gain (kg/head.day)	-	0.2	-

This work is providing a better understanding of expected forage, animal and economic performance under management conditions representative of commercial beef producers, and of the key drivers of profitability within these grazing systems.

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Spelling strategies for recovery of pasture condition at Clermont, Qld.

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Introduction

Wet season spelling is commonly practiced across northern Australia and is a valid strategy to improve land condition. Key data illustrating the processes underpinning land condition improvements due to spelling strategies, however, is currently limited. Our project seeks to improve the evidence base and modelling capacity to recover poor land condition through wet season spelling at two sites. This paper describes work conducted at one of these sites near Clermont in central Queensland (Site 1).

Methods

Site 1 at Monteagle, located 60 km north-west of Clermont, examines the combination of different timing, duration, and frequency of spelling on plots of 'C' condition land subject to a moderate stocking rate. Treatments include annual or biennial, early or full wet season spell; one-off full wet season spell for each year, and continuous grazing. Treatments are to be applied from October 2010 to May 2015 within a large commercially managed paddock.

Spelled and grazed plots are recorded thrice yearly to capture changes in pasture composition and soil surface parameters. The key perennial pasture grasses *Bothriochloa ewartiana*, *Aristida* species, and *Panicum effusum* are mapped on permanent quadrats to measure crown cover, persistence, recruitment and mortality. Pasture yield, composition and ground cover are recorded using the BOTANAL method and the soil surface characteristics, using the Landscape Function Analysis technique.

Results and Discussion

Site 1 has had good rainfall and growing conditions just prior to and during the first summer, and for the second summer of recordings. Basal area of the perennial grasses (Table 1) appears to have increased with spelling. The other pasture and soil surface condition parameters have not been affected by spelling.

Table 1. Spelling treatments effects on perennial grass basal area at Site 1.

		October 2010 Basal area (%)	SE	October 2012 Basal area (%)	SE
Moderate stocking rate	Grazed	3.0	0.1	3.2	0.4
	Early wet season annual spell	2.6	0.9	4.0	0.7
	Full wet season annual spell	2.2	0.3	4.1	0.5

The project aims to develop spelling strategy recommendations to improve poor condition land and maintain it with better perennial grass basal area and a decreased composition of *Aristida* species. While basal area appears to have improved with spelling through two years of good rainfall and growing conditions, other pasture parameters, including yield have not measurably improved, indicating that a significant change in land condition has not occurred. This work highlights the long term commitment needed to improve land condition through spelling, and the challenges that face land managers.

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Seed production potential of new *Brachiaria* hybrids grown in north Queensland

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Introduction

High-quality, productive sown grasses are an important component of beef production systems in northern Australia, particularly for beef growing enterprises in coastal and sub-coastal areas. Here we describe the development of several promising *Brachiaria* hybrids in Australia.

Tropical grasses of the genus *Brachiaria* have strengths for beef production, including: high nutritional value for ruminants; retention of high-quality green leaf into the dry season; good adaption to acid and neutral soils of moderate to low fertility; and good persistence under grazing. Overseas plant breeders developed *Brachiaria* hybrids to combine various attributes of these grasses. They were developed from crosses between *Brachiaria ruziziensis*, *B. decumbens* and *B. brizantha*. The hybrids are leafy, perennial, true-to-type grasses with mostly erect habits growing to about 1 m in height. They grow well in tropical environments with rainfall between 1000-3500 mm per year and can withstand a dry season of 5-6 months. They can produce higher amounts of biomass than *Brachiaria* currently used in Australia and nutrient value is comparable or slightly better than other tropical grasses. *Brachiaria* hybrids are suited to pasture finishing systems with high stocking rates.

Seed production strategy and methods

Seeds of 6 *Brachiara* hybrids were imported into Australia and plants grown at the Queensland Government quarantine facility at Eagle Farm, Brisbane. Once released from quarantine the seed was supplied to the Queensland Government seed production group at Walkamin, north Queensland. The seed supplied was of variable quality and there were only a few grams of each line.

As there was no previous experience with growing *Brachiaria* hybrids in Australia, we decided to use production cycles and methods successfully used for previously released *Brachiaria* spp. We planted in December/January which allowed for a range of flowering responses. Transplanting seedlings was the chosen method of establishing crops because of low amounts of seed and high levels of seed dormancy. We found *Brachiaria* hybrids were fast-growing and tolerated herbicides normally used for other *Brachiaria* allowing weed free establishment.

Dormancy, caused by tight seed structures around the caryopsis, significantly impeded germination of *Brachiaria* hybrid seed. To overcome this, the outer structures of the seed were removed using a scalpel under a microscope, and naked caryopses (kernals) incubated in the laboratory. Once germinated, seedlings were transferred into tubes and raised in a shade house. After 8 weeks, the plants were transplanted into a well cultivated, fertilised (basal amounts of phosphorus and potassium) and weed-free seedbed. A cleaning cut was performed followed by a nitrogen application to synchronise vigorous reproductive development. Wet season rainfall was supplemented with irrigation as required and most lines were hand harvested in May the first year.

Seed yields from small plots ranged from 160– 250 kg/ha from a single destructive harvest. After the first crop, we tried starting seed crops (with cleaning cuts) at other times of the year and found all lines could be harvested at differing times of the year (*ie* December/January following a September cleaning cut and May/June after a February cleaning cut) with little compromise in yield. *Brachiaria* hybrids appear well suited to seed production in far north Queensland. Seed yields appear to vary between lines and, overall, are lower than other *Brachiaria spp.* grown in north Queensland meaning seed will likely be more expensive.

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The desmanthus revival

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Introduction

There is a limited number of legumes adapted to the dry tropics and sub-coastal areas in northern Australia. Sown pasture legumes can, with the right management, increase the productivity of grass pasture systems. This paper describes the desmanthus legume and its revival as an economically important plant for the northern beef industry.

The opportunity

Desmanthus (*Desmanthus virgatus* and *D. bicornutus*) are perennial shrub legumes with tall and prostate forms. Desmanthus plants are summer growing and well-adapted to environments with annual rainfall of 550-750 millimetres. Desmanthus feed quality is similar to many other tropical legumes and it regrows well from grazing and is a prolific seeder producing hard seed. It also has the ability to compete strongly with many grass species enabling it to persist in dry tropical environments.

Evaluation programs (Legumes for Clay Soils project) conducted in the 1990s included many lines of desmanthus and three cultivars were released. In the last 10-15 years, Dr Chris Gardiner, a researcher from James Cook University, returned to some old evaluation sites to identify plants which had persisted. Several lines of *desmanthus* were selected and grown in controlled conditions to assess various attributes of successful pasture plants. Final selections were made and seed was collected and supplied to the seed production group at DAFFQ Walkamin in 2003 where pre-basic seed multiplication commenced.

Seed production at DAFFQ Walkamin

James Cook University supplied small amounts of high-viability seed of five lines. The seed was scarified to overcome hard-seed dormancy using a scalpel under a microscope and placed on blotting paper in controlled conditions. Once germinated, seedlings were transferred into tubes and raised in a shade house. The plants were inoculated with specific *Rhizobium* just prior to planting in the field. We aimed to improve final yield by spacing plants on weed- mat allowing growth with less competition and fallen seed to be collected on to the mat.

The plants were transplanted during summer (December to January) to allow the plant to develop adequate canopy frame work before entering the reproductive phase under dry conditions suitable for harvesting. Insecticide sprays were applied to control leaf-sucking insects (psyllids). Larger crops were grown in subsequent years. Mechanical scarification was used to overcome dormancy as more seed became available enabling direct sowing either on weed mats or row planting into cultivated ground. The application of fertiliser nitrogen was required to ensure vigorous crop growth in one line only, perhaps indicating poor nodulation in that line. Seed yields of each line ranged from 200 to 800 kg/ha per harvest when harvested from weed mats.

Adoption by industry

Seed was then supplied to Agrimix, a commercial partner, which contracted seed growers to produce sufficient amounts of seed for further evaluation and sales to graziers. 'Progardes' desmanthus has since been commercially released using five of the lines originally developed by James Cook University. Grazier demonstration sites have recently been established by Agrimix to promote the use of desmanthus.

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Pasture rundown – Are your sown pastures nitrogen deficient?

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Introduction

Productivity decline in sown pastures will cost Queensland beef producers ~$17 billion dollars in lost production over the next 30 years (Peck *et al.* 2011). However, many graziers are unaware of the underlying nitrogen deficiency that causes this 'rundown' in sown grass and the extent to which it effects feed production in their own pastures. Raising awareness of rundown, its primary cause and the extent of lost production was a key challenge to our new project funded by Meat and Livestock Australia (MLA) and the Queensland Department of Agriculture, Fisheries and Forestry (DAFFQ). In short, how could we help growers assess the extent of rundown in their own paddocks and demonstrate beyond doubt that nitrogen was the cause?

Methods

The primary aim was for graziers themselves to apply nitrogen to their pastures as a way to assess the extent of any nitrogen deficiency and lost productivity in their own paddocks. Green Urea™ was identified as an accessible form of nitrogen that could be applied easily to existing pastures prior to expected rains with reduced losses from volatilisation for up to 14 days. Graziers that attended an ongoing series of workshops to understand sown pasture rundown, and learn how to recognise and manage it, were provided with 25 kg of Green Urea and a hand held fertiliser spinner commonly used on home gardens to apply 100 kg N/ha to small strips roughly 5 m x 20 m in size, and a recording sheet to document their observations. We volunteered to do some pasture cuts on the subsequent on-farm trials to compare dry matter production if this was possible before the plots were grazed.

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Results

Over 30 replicated and over 40 non-replicated on-farm trials have now been established by graziers across southern and Central Queensland. All trials have included the base rate of 100 kg N/ha, with approximately half the trials assessing 2 or more rates. Most graziers applied the Green Urea to existing pastures without any special treatment and many of the trials in 2012 were grazed by cattle or kangaroos before dry matter assessments could be made. However, nearly all plots responded with dramatic improvements in grass colour, with some equally dramatic increases in dry matter production and protein content. Dry matter increases have been up to 200% and protein levels often increased by 50%. Graziers also observed stock and kangaroos selectively and aggressively grazing these plots. These dramatic results with obvious improvements of feed quantity and quality have encouraged wide interest and a desire to gain more accurate information on these nitrogen responses as an estimate of lost production.

Discussion

Green Urea provided an easy way for graziers to assess the extent of rundown on their own properties, and has clearly demonstrated that 'rundown' sown grass pastures are nitrogen deficient. The dramatic responses in dry matter production, protein content and palatability suggest strategic use of nitrogen fertilisers is worth further investigation with more controlled studies.

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On-Farm Research – exploring options to manage sown pasture rundown

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Introduction

Productivity decline in sown pastures due to a lack of available soil nitrogen as pasture age will cost Queensland beef producers ~$17 billion dollars at the farm gate over the next 30 years (Peck *et al.* 2011). A project funded by Meat and Livestock Australia (MLA) and the Queensland Department of Agriculture, Fisheries and Forestry (DAFFQ) in 2011 is helping graziers to better understand this sown pasture 'rundown' and develop the most practical strategies to manage it on their own properties. A key part of the project is to support graziers to trial and assess any new practices they are considering as part of their chosen strategy.

Methods

An ongoing series of workshops with 19 groups of graziers across southern and central Queensland has helped participants to recognise sown pasture rundown, understand how it works, and take action to mitigate its impacts. Each grazier was asked to nominate what they subsequently considered to be the most appropriate mitigation strategy for their own property and supported to assess any new practices that they would need; for example, with advise on trial designs, small samples of different legumes to compare, and follow up monitoring of their pastures and soils.

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Results

To date there have been approximately 40 replicated trials and 60 non-replicated on farm trials established across a range of mitigation strategies that include:

Strategy 1. Accept rundown and live with it (0 trials)

Strategy 2. Increase nitrogen cycling and availability (5 trials)

- Renovation with mechanical disturbance (1 replicated; 1 non-replicated)
- Renovation with herbicides(1 replicated; 1 non-replicated)

Strategy 3. Increase nitrogen levels (98 trials)

- Increase nitrogen with fertiliser (31 replicated; 44 non-replicated)
- Establishment methods to introduce legumes (3 replicated; 6 non-replicated)
- Legumes species assessments (9 non-replicated)
- Growth responses of legumes to phosphorus fertiliser (3 replicated; 2 non-replicated)

The quality of data from each trial has varied with the research question and level of detail sought by each grazier, the subsequent trial design, and the on-going challenges of on-farm trials (including unexpected grazing events). Trial data has ranged from observations of plant colour, height, flowering and habit, through to dry matter yields, plants per square metres and protein levels.

Discussion

The number of trials undertaken by graziers clearly indicates the importance of sown pasture rundown to them. The approach has been very successful for engagement and farmer learning and the collection of both qualitative and quantitative data on a range of practices to mitigate sown pasture rundown.

References

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Quality Graze Trial: Impact of grazing strategies on consistent supply of quality beef in central Australia

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Introduction

A new long-term grazing trial aimed at investigating the potential to produce quality grass-fed steers for direct slaughter from a remote arid environment has begun on Old Man Plains research station near Alice Springs in the Northern Territory.

Recently the Alice Springs Industry Advisory Committee undertook a Strength Weaknesses Opportunities and Threats analysis. They concluded that the central Australian cattle industry had several advantages, including quality beef production, pasture nutritional quality and the ability to achieve significant weight gain on fully cured pastures from predominantly *Bos taurus* cattle. This subsequently raised the question as to how to take advantage of these strengths? Production of finished steers for slaughter and premium prices through the Meat Standards Australia (MSA) meat quality grading system is one option. Producers in central Australia have begun to investigate this opportunity but have generally believed it is only possible to do so during exceptional seasons. Sentinel herd weight data from the Department of Primary Industry and Fisheries (DPIF) suggests that consistent weight gains in heifers are possible regardless of season. Consistently fattening steers regardless of season in central Australia is thus theoretically possible. However, the industry wants to know how much it will cost, what management changes would be required and the conditions under which such a production strategy is profitable.

Hypotheses

Land condition is a key factor in optimising sustainable cattle production and business resilience in a variable and changing climate. Declining land condition, an extremely variable climate and rising financial pressures to produce more from the existing productive country are making long-term profitable cattle production even more challenging in central Australia.

Hypotheses to be tested during the trial include:

1. Consistent production of 600kg grass-fed steers, turned off within three years direct to slaughter and MSA grading, is possible and a profitable option in central Australia.
2. Long-term matching of stock numbers to land capability using Grazing Land Management (GLM) principles maintains land condition and optimises production.
3. Spelling over the ‘summer’ growing season will improve land condition.
4. Adoption of a successful spelling strategy is possible without compromising production or requiring major infrastructure development.
5. A low-flexible stocking strategy (current industry practise) optimises production, is viable and easily implemented.
6. The practical use of modelled pasture growth data for setting annual stocking rates is possible.

Methods

Weaner steers will be grazed under a variety of grazing strategies on the Old Man Plains research station before direct trucking to slaughter and MSA grading.

Land condition will be monitored using indicators such as pasture growth, species composition, cover and soil stability. Animal performance will be measured via live weight gain, p8 fat, hip height, body condition score and meat quality (MSA kill sheets). Production measures such as price per kilogram of beef produced for both watered and paddock area will subsequently be calculated.

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Grazing Management Practice Adoption Survey: Steer turnoff markets and performance.

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Introduction

Grazing Management Adoption Practice surveys were conducted by DAFFQ extension officers face-to-face with graziers, across the catchments of the Fitzroy, Burdekin, Burnett-Mary (BM), Mackay Whitsunday and broader regions of Cape York and the Wet Tropics. This paper focuses on herd management, markets and market compliance of steers.

Method

Grazing properties were stratified by size and location, then randomly selected, and asked to voluntarily participate in the survey. 211 properties were surveyed in the 2011/12 year, with 134 completing the herd management section. Data was summarised and presented at catchment level. Statistical significance testing was not undertaken. Markets were classified as store, including grass/crop finishers, feedlots and live exports or slaughter, including domestic turnoff, jap-ox, US, EU and the organic market. The percentage of steers turned off into respective markets was found. Weight for Age was considered and represented by average slaughter weights of steers, stratified by sub-catchment. Additionally, average MSA compliance was identified using producers who turned off to MSA, however further analysis using a larger sample size is recommended for this assessment.

Results

The dominant turnoff markets varied by sub-catchment (Table 1). Slaughter weights were similar between catchments, however age of slaughter ranged from 28 months in the Fitzroy to 36 months in the Burdekin. MSA compliance showed a similar trend; catchments with higher weight-for-age produced higher MSA compliance.

Table 1: Steer Turnoff Markets, Weight, Age & MSA Compliance.

Catchment (Sample size)	BM (26)	BOWEN (7)	BURDEKIN (22)	FITZROY (34)	MACKAY (15)	SUTTOR (17)
Steers (Store)	60%	37%	57%	47%	78%	34%
Steers (Slaughter)	40%	63%	43%	53%	22%	66%
Slaughter Steers (age)	28	35	36	28	29	32
Slaughter Steers (kgs)	323	337	322	325	333	317
MSA Compliance (%)	57.2*	N/A**	27.5*	45.2*	15.0*	53.8*

*low sample size, **No responses.

Conclusion

The survey re-enforces that land resources and climatic conditions affect weight for age turnoff at the macro scale. It also demonstrates the trend and capacity of different catchments to service MSA requirements and that weight-for-age turnoff is a strong driver of MSA compliance. However, more data and studies are required to make this statement in a statistically significant context.

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Fire affects structure but not density in semi-arid tropical savanna

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Introduction and methods

Fire is widely recommended to control woodland thickening. However, major gaps exist in the understanding of its effects on woodland structure and density in north Queensland. To investigate this issue, the 1100 ha Wambiana grazing trial near Charters Towers was burnt in October 1999 and again 12 years later in October 2011. Trial paddocks contained three soil types: kandosols dominated by *Eucalyptus melanophloia* (Ironbark), heavy clays dominated by *Acacia harpophylla* (Brigalow) and sodosols dominated by *E. brownii* (Box). Permanent monitoring sites were established on each soil type in each of six paddocks and woody vegetation surveyed pre- and post-fire. Rainfall was above average before and after both fires, but from 2001 to 2007 rainfall was well below average (O'Reagain & Bushell 2011).

Results and discussion

As reported for the 1999 fire by O'Reagain and Bushell (2011), the 2011 fire had a big effect on woodland structure, producing a marked shift from larger to smaller size classes on all three communities (Fig 1A: data shown only for the Brigalow association). This shift to smaller size classes was most marked in the 1 – 6 m size range. Some, very low levels of plant mortality were recorded in both fires but fire had little effect on plant density (O'Reagain & Bushell 2011).

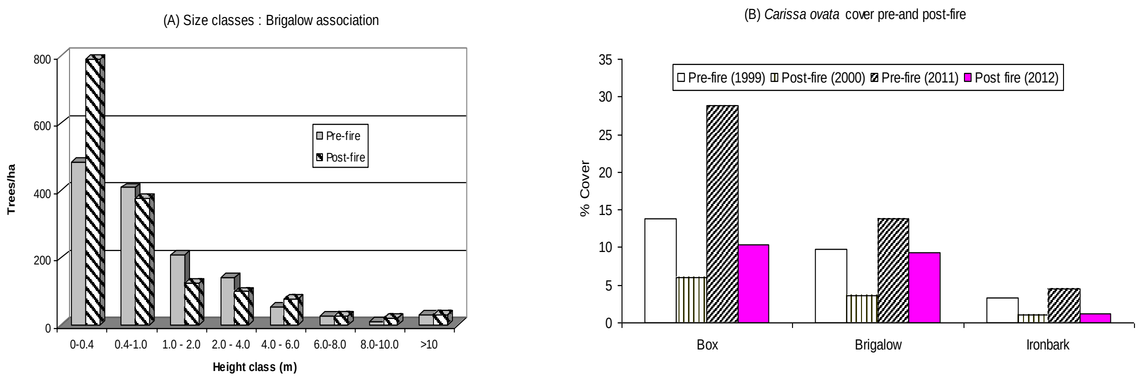

Fig 1. A. Size class distribution of woody species on the brigalow soil association pre-and post- the 2011 fire. B. Canopy cover of *C. ovata* pre- and post- the 1999 and 2011 fires.

Both fires caused a large reduction in canopy cover of the invasive native shrub *Carissa ovata* (Fig. 1B). However, *Carissa* resprouted and grew rapidly post-fire, as shown by the increase in cover between 2000 and 2011. In summary, these results show that while fire has little impact upon woody density it can change woodland structure by shifting plants to smaller size classes. The rapid regrowth of plants in the years post-burn nevertheless indicate that regular fires are required to prevent plants getting above the height at which they can be suppressed by fire.

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Keeping our (seed) heads above water: pasture revival after flooding

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Introduction

The Condamine and Balonne Rivers in southern Queensland experienced major flooding in late December 2010 and January 2011 inundating approximately 100,000 ha (L Hardwick, pers comm.) of pastures and crops upstream of the Barrackdale choke, for periods of 2 to 6 weeks, resulting in the death of pastures along the floodplain. Little or no information existed to inform landholders of appropriate management to expedite pasture recovery. This paper reports on monitoring observations of pasture species emergence and succession up to 15 months post flooding.

Methodology

Monitoring was conducted at 8 sites on 5 properties along the floodplain using the Stocktake (Aisthorpe and Paton 2004) methodology which measures land condition (A to D, A being best) and pasture yield (visually estimated, kg/ha). Additionally, proportions (%) of yield were estimated for living and dead (killed by inundation) components. The living component was then apportioned to: 3P grasses (Perennial, Productive and Palatable to grazing stock); other grasses; forbs; and legumes. Data was collected on 3 occasions: late March 2011; September 2011; and April 2012.

Results

In March 2011, 6 weeks after flooding, average total dry matter was 1,720 kg/ha, of which 44% was living. The living portion of dry matter was dominated by forbs (40%) and sedges (30%). 3P grasses accounted for 22% of living biomass and native legumes were significant at some sites. 3P grasses were predominantly buffel grass seedlings emerged after flooding and Bambatsi tussocks that survived inundation by floodwaters. Land condition across the sites averaged D, very poor.

Dry matter yield in September averaged 1320 kg/ha, 59% of which was living. Forbs dominated living biomass (59%) and 3P grasses remained at 23%. Land Condition was again rated as D, very poor. Dominant 3P grasses, primarily regrowing from old tussocks were Bambatsi, forest bluegrass and curly mitchell. Dominant forbs were lippia, castor oil plant, bladder ketmia and members of Asteraceae family.

In April 2012 total living biomass had increased to 2400 kg/ha. 3P grasses dominated at 55% of yield, forbs were 25% and other monocotyledons 16%. Land condition had recovered to B, good.

Discussion

These observations show a succession of species dominance. Sedges and forbs dominated 6 weeks after flooding, forbs dominated in September 2011, and 3P grasses in April 2012. Grass seedlings, particularly buffel, and surviving flood tolerant grasses like Bambatsi, made significant contributions to pasture yield 6 weeks after flooding. Other 3P grass tussocks that survived the floods, such as curly mitchell and forest bluegrass, contributed to yield and were major components of pasture by April 2012. Resting pastures from grazing after flooding is important for their revival.

References

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Persistence of tropical pasture legumes in southern and central Queensland

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Introduction

Incorporating legumes into grass dominant pastures has been identified as the best long term option for increasing pasture production, animal performance and economic returns on rundown sown grass pastures. Pasture legumes that can persist and be productive with sub-tropically adapted sown grasses in inland areas of Queensland, especially for clay soils, were only released in relatively recent times. Commercial results from legumes have been mixed with many graziers reporting poor persistence of legumes with sown grasses

Methods

Thirty six old trial and demonstration sites were inspected to record the persistence of legumes with a focus on desmanthus (*Desmanthus spp*.) and Caatinga stylo (*Stylosanthes seabrana*). All sites were established more than 10 years ago, most being on clay soils and regularly grazed.

Results and discussion

Desmanthus was still present at 19 of the 26 sites at which it was planted. *D. virgatus* (cv. Marc and other accessions) is persistent where it has established however there are questions about its productivity (dry matter production and leaf retention). Taller types (e.g. *D. leptophyllus* cv Bayamo) deserve further evaluation as they were persistent at some sites and appear more productive with better leaf retention. Desmanthus did not persist on sandy soils and has not persisted well on basalt derived vertosol soils in central Queensland.

Caatinga stylo was still present at 21 of the 23 sites at which it was planted. It appears widely adapted, persistent and productive on clay to loam soils in southern and central Queensland. Caatinga stylo has not done well on un-grazed or infrequently grazed sites, it seems to require some disturbance and reduction in competition from companion grasses to thrive.

Leucaena persisted and seemed productive at most sites where it was planted in central Queensland, but did not persist at two sites. Leucaena did not persist on light soils in southern inland Queensland. Butterfly pea has persisted and appeared highly productive on the better basalt derived vertosol soils in CQ. It has not persisted well in southern Queensland (SQ) or on brigalow clay soils. Grazing management seems important as it was more productive in un-grazed or rotationally grazed sites. Burgundy bean has persisted and appears productive at only 1 un-grazed site. It appears better suited to short-term pastures in rotation with cropping or requires special management.

Conclusions

Although commercial results from incorporating legumes into sown grass pastures in inland Queensland has been considered un-reliable, the old trial sites evaluated during this project demonstrate that there are commercially available, persistent legumes for land types with medium and heavy textured soils in southern and central Queensland. The high level of persistence of several legumes at these trial sites should provide confidence to industry and research, development and extension organisations that it is worthwhile to invest resources to improve the reliability and performance of incorporating legumes into sown grass pastures and for learning how to better manage them for persistence under grazing.

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Increasing seeding rate is not the answer to improving legume establishment in buffel grass pastures in inland areas

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Introduction

A major constraint to the successful use of legumes in sown grass pastures is the lack of establishment reliability. Graziers report successes, but also many failures, especially in inland areas of southern and central Queensland as the likelihood of follow up rain is much lower than in monsoonal or coastal areas. 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 establishment techniques and not graze to allow establishment. Several producers and advisors or sales staffs 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 2 legume seeding rate trials.

Methods

Two seeding rate trials were established near Wandoan; one on an alluvial sandy loam poplar box soil, the other on a brigalow grey clay. Fine-stem stylo was sown on the loam soil. Progardes desmanthus was sown on the brigalow clay. There were 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 after plant.

Results and Discussion

The sites had a very dry spring and early summer leading up to plant with little grass growth. The sites received close to average rainfall in the nine weeks after planting.

All seeding rates failed to produce adequate numbers of plants. At the clay soil site there were 174 plants recorded 5 weeks after sowing across all plots, by 9 weeks this had declined to 4 plants. At the loam trial site there were 28 plants recorded 5 weeks after plant across all plots, which had declined to 8 plants 9 weeks after sowing. The plants that were there recorded 9 weeks after plant were very poorly grown and unlikely to survive until winter, let alone surviving winter to grow next summer.

These results demonstrate that increasing seeding rate and planting directly into existing grass pastures is a risky and un-reliable approach to improving legume establishment in inland areas of Queensland. Controlling competition from the existing grass, fallowing to store moisture and ensuring good soil seed contact are much more likely to improve legume establishment then increasing seeding rates.

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Legumes reduce Indian couch invasion in buffel grass pastures

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Introduction

One of the symptoms of pasture rundown (i.e. reduced availability of nitrogen in the soil) is a change in pasture composition away from fertility demanding grasses to species that are more tolerant of low fertility. Indian couch is tolerant of low fertility, is well adapted to the environment and is an aggressive coloniser spreading by both seed and runners. Many producers are reporting that Indian couch is invading rundown buffel grass pastures which are reducing pasture and animal productivity.

Methods

A trial was established near Moura in 1997 to assess the production benefits of sowing Caatinga stylo sown with buffel grass. The trial consists of two paddocks each 10 ha in size. One paddock was sown to buffel grass (cv Biloela and Gayndah), the other paddock was sown to both buffel grass (cv Biloela and Gayndah) and Caatinga stylo (cv Primar and Unica). The Botanal methodology was used to assess pasture composition and yield early in 2012.

Results and discussion

After establishment both paddocks were dominated by Biloela buffel. After 15 years the grass-legume paddock remains dominated by the sown species (*i.e*. buffel and stylo) while the grass-only paddock has much higher levels of Indian couch and other grasses that are more tolerant of low fertility (*e.g.* native blue grasses, Sabi grass). This is most likely due to greater N availability from the legume allowing buffel to remain competitive, whereas lack of N in the grass paddock means the competitive advantage shifts to grasses with greater tolerance of low fertility.

Table 1. Composition, dry matter yield and frequency in grass only and grass plus Caatinga stylo (G+C) paddocks

Species		Common name	DM Yield Kg/ha		DM Yield %		Frequency %	
			Grass	G+C	Grass	G+C	Grass	G+C
Stylosanthes	*seabrana*	Caatinga stylo	143.5	7429.6	2.7	70.9	22.1	99.2
Cenchrus	*ciliaris*	buffel cv. Biloela	1687.2	2464.6	31.8	23.5	53.6	89.1
Cenchrus	*ciliaris*	Buffel cv. Gayndah	1170.1	405.8	22.1	3.9	51.4	25.6
Dichanthium	*sericeum*	Qld bluegrass	867.8	30.0	16.4	0.3	51.4	2.3
Bothriochloa	*pertusa*	Indian couch	819.3	35.3	15.5	0.3	30.0	3.9
Bothriochloa	*bladhii*	forest bluegrass	240.0	6.4	4.5	0.1	4.3	0.8
Chloris	*spp.*	windmill grass	121.0	8.1	2.3	0.1	21.4	2.3
Urochloa	*mosambicensis*	sabi grass	107.0	31.1	2.0	0.3	12.1	1.6

Pasture composition over the longer term is determined by environmental and management factors, however soil nitrogen supply plays a significant role in the competitiveness of sown grasses.

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Improving reliability of legume establishment in sown grass pastures

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Introduction

Commercially, 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 out of planes after either no or minimal pasture disturbance (e.g. fire) or severe soil disturbance and a rough seed bed behind a blade plough. In the black spear grass zone of central and southern Queensland, surface sowing has been shown to be unreliable with an 80% failure rate; it is likely that sowing into buffel grass pastures in lower rainfall areas have even higher failure rates. This paper reports early results of 2 establishment trials near Wandoan.

Methods

Two trial sites, both with existing buffel grass pastures were established with 2 replicates of 16 treatments. One trial is on a sandy loam alluvial box soil, the other a brigalow grey cracking clay. The trials are designed with 5.5m wide by 20m long plots with 4.5m of grass left between each plot. Fourteen of the treatments have split plots where half of the plot (10m long by 5.5m wide) was drilled with a planter while the other half was broadcast onto the soil surface. The trials were planted on the 13th to 15th February 2013. Seeding rates were: clay soil site – 6kg seed/ha Progardes desmanthus; loam soil site – 6 kg/ha fine-stem stylo and 2 kg/ha Progardes desmanthus.

Treatments are a combination of seedbed preparation or fallow period; seedbed treatment; and post-emergent weed control as follows:

- No disturbance of the grass pasture; with and without slashing at plant (ie 2 treatments).
- Grass pasture disturbed at plant; seedbed treatments were herbicide spray, deep rip or cultivate (tynes) with no post-emergent weed control (ie 3 treatments).
- Short fallow of approximately 2 months. Seedbed treatments were spray with and without post-emergence herbicide; cultivate with and without Spinnaker; and a spray followed by cultivation at plant. That is 5 treatments in total.
- Medium fallow of approximately 4 months. Seedbed treatments were spray fallow with and without post-emergence herbicide; cultivated fallow with and without Spinnaker; sprayed fallow with both grass and legume sown; cultivated fallow with both grass and legume sown. That is 6 treatments.

Results and discussion

The sites had a very dry spring and early summer leading up to plant which reduced the efficacy of the sprayed fallows. The sites received close to average rainfall in the nine weeks after planting. At 5 and 9 weeks after plant legume numbers and size was recorded. At both sites the un-disturbed grass, slashed grass, deep ripped or cultivated at plant (with a tyned implement) treatments all resulted in establishment failure with low numbers of plants that were poorly grown. Sprayed or cultivated fallows resulted in good plant numbers and moderate to good plant size at both sites. Medium length fallows resulted in the best plant size, most likely from better nutrient availability from greater mineralisation of soil organic matter. Drilling seed dramatically improved plant numbers on the sandy loam soil but had no significant effect on the clay soil. Establishment will be measured in the 2013/14 summer to determine plant survival through winter.

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Economic returns of management options used to tackle pasture rundown

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Introduction

The beef industry uses a range of management strategies to improve the productivity of ageing sown grass pastures, often with little analysis of economic returns. This paper compares the likely returns from 12 different mitigation strategies for improving animal production on ageing sown tropical grass pastures.

Methods

A spreadsheet based pasture production and economics model was used to evaluate the benefits and costs associated with management options at the farm level to increase productivity of rundown buffel grass pastures. The twelve mitigation strategies were dry season protein supplements, nitrogen fertiliser at 2 rates (60 and 120 kg N/ha/yr), three different mechanical renovation treatments (chisel plough, blade plough and a 3 month cultivated fallow with 4 cultivations), renovation with herbicides and legumes (leucaena established into cultivated strips, other legumes established into cultivated strips, herbicide strips, behind a blade plough and into a short term cultivated fallow).

Results

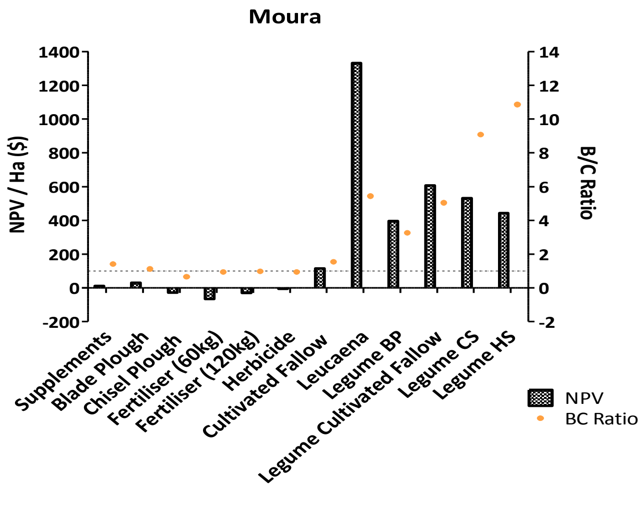

Fig. 1. Net Present Value (NPV) and benefit:cost (B/C) ratios for rundown mitigation strategies at Moura. The dotted line represents a B/C ratio of 1, i.e. the "break even" point. (Codes for legume establishment: BP – blade plough; CS – cultivated strip; HS – herbicide strip)

Discussion and conclusion

Legumes are the most promising option for large areas of rundown buffel grass pastures. Legumes have the potential to reclaim 30-50% of lost production and provide whole farm returns of up to $1300/ha and benefit cost ratios of 4-10. Several management options commonly used by industry provide marginal or negative returns.

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Desmanthus and Caatinga stylo boost productivity of buffel grass pastures

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Introduction

The long term productivity benefits of sowing more recently released summer growing legumes with buffel grass has not been measured. Most trials measure productivity benefits from legumes for 3-5 years after establishment. This paper reports on the productivity benefits of legumes with buffel grass pastures approximately 15 years after establishment.

Methods

Two pasture trial sites (Moura and Wandoan) were established into paddocks that had a history of cropping. Each trial has two 10ha paddocks; one paddock was sown to buffel grass while the other paddock was sown to buffel grass and either desmanthus (variety Jaribu) or Caatinga stylo (cv. Primar and Unica). The Moura site was sown with Caatinga stylo early in 1997. The Wandoan site was sown with desmanthus early in 1995. Pasture and animal production was measured in the 5 years after establishment and again in 2011-13.

Results and Discussion

In the first few years after sowing there was no benefit from sowing a legume with buffel grass. However, after approximately 15 years since establishment there is dramatically higher dry matter production (and animal performance) from the legume (Fig. 1).

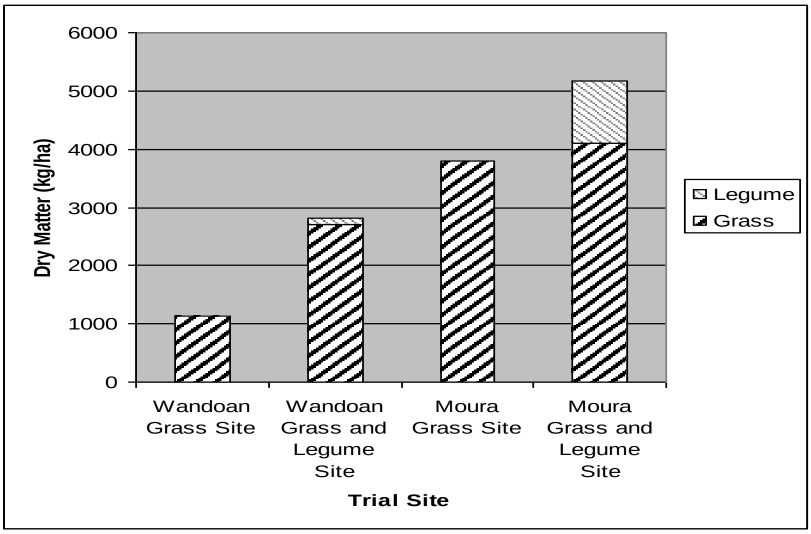

Fig. 1. Pasture dry matter production over a seven month (summer 2011/12) period for grass only compared to grass with legume pastures.

Conclusion

Incorporating legumes into grass pastures is an effective way of improving long-term productivity of sown pastures. However graziers report mixed results from legumes in commercial pastures. These results should provide confidence to graziers and R&D agencies to invest greater resources into improving the reliability and performance of sown legumes.

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Pasture Species Evaluation under Grazing in the Top End of the NT

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Introduction

Pasture grazing trials at the Douglas Daly Research Farm (annual rainfall 1207 mm) were first established in 1972 to assess the productivity of different pasture species and mixtures under continuous grazing and determine their long term potential and sustainability for the Douglas Daly and the wider Top End regions. This paper reports cattle growth rates from 1996-2008.

Method

Brahman steers grazed the pastures in 4 ha paddocks at 1.0-1.5 animals/ha. Animals were allocated to paddocks in June/July (post-weaning) and remained in the grazing trial for 12 months. Live weight gain (LWG), condition score and P8 (rump) fat were measured monthly and pasture composition and yield were assessed twice a year to compare total yield and changes in plant composition.

Results

From the grazing trial during this 12 year period, LWG varied between the pasture mixes and years. It was found that the animals in the grass/Leucaena paddocks performed the best, other grass/ legume paddocks second best and the grass only paddocks the least (Table 1).

Table 1. 1996-2008 -- The average live weight gain per head in each pasture mix.

Species	Average LWG(kg)/hd	Years assessed	Species	Average LWG(kg)/hd	Years assessed
Trial Average (1996-2008)	175	12	Buffel Grass	180	12
Gayndah Buffel / Leucaena	208	12	Buffel / Wynn	179	12
Pangola / Leucaena	196	6	Buffel / Blue Pea	178	12
Sabi / Wynn / Leucaena	189	8	Jarra / Wynn	173	4
Buffel / Mixed Legumes	186	8	Jarra	168	12
Pangola Grass	186	12	Arnhem Grass/ Oolloo	162	12
Silk Sorghum / Cavalcade	185	3	Nunbank Buffel Grass	154	5
Strickland / Wynn	184	10	Sabi Grass	150	12
Buffel / Oolloo	182	4	Wynn Cassia	128	2
Higane / Legume	180	3	Tully Grass	128	5

Discussion

The species evaluation trial has proven to be a successful way for producers across the Top End to assess different pasture mixes and the LWG of cattle grazing them over many years. It has also shown the benefit of incorporating a companion legume to improve the LWG of stock. The most persistent grasses appeared to be the shorter Buffel varieties (Gayndah and American), Pangola, Jarra and Strickland which are long lasting, productive and palatable perennials. Leucaena, Cavalcade, Oolloo, Wynn, Verano and Blue Pea all appear to be persistent companion legumes.

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Pasture utilisation rates from commercial paddocks in central Australia

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Introduction

Pasture utilisation rates are the cornerstone of the grazing industry because they directly determine sustainable carrying capacities. In 2009 we successfully tested a relatively quick, cost-effective method for deriving utilisation rates in the Barkly Tableland of the NT (Walsh and Cowley 2011). The method retrospectively calculates utilisation rates using station cattle records and pasture growth predictions from simulation models. This paper presents the results of similar work conducted in the southern Alice Springs district.

Methods

We calculated average utilisation rates for 3 paddocks on 3 properties. The paddocks were predominantly in good land condition and had accurate recent records of cattle numbers and class for between 6 and 10 years.

Pasture intake was calculated by converting station stock records to adult equivalents (Chilcott *et al*. 2005) and multiplying by a standard daily intake figure (8 kg/AE.day) to determine herd intake for each 12 month period. Pasture growth for the corresponding period was estimated using the GRASP pasture growth model, which has been calibrated for many land types in the region. Pasture growth figures were modelled for the 5km watered area, 3km watered area and total area of each paddock. Utilisation rates were subsequently calculated for each year for these 3 area measurements (Herd Intake/Pasture Growth * 100).

Results and Discussion

Every paddock experienced large annual variability in utilisation rates (ranging from <10% to >70% on a 5 km watered area basis). This is because cattle numbers did not tend to vary much but pasture growth varied widely in response to rainfall conditions. The lowest pasture growth estimate was 69 kg/ha in the very dry year of 2008/09 and the highest was 1,642 kg/ha in 2002-03.

At the current level of water point development recommended for the region (*i.e.* a 5 km radius per water), average utilisation rates ranged from 25-43%. This is higher than currently recommended for the land types studied (<20%) and is inconsistent with the fair to good land condition observed. It is likely that longer periods of records (perhaps >20 years) are required to obtain a reliable estimate of the long-term average utilisation rates being achieved in highly variable climates such as those of central Australia. Furthermore, more research is needed to determine how to account for top-feed availability, which is known to be a significant part of cattle diets in central Australia, even during average seasonal conditions.

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Burning and spelling for pasture rejuvenation on Delamere Station

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Introduction

The northern beef industry relies mainly upon native pastures for production. On the productive and highly valued black soil plains of Willeroo 1 land system in the Victoria River District (NT), the most desirable pasture species is *Dichanthium fecundum.* This 3P grass is sensitive to constant grazing and is therefore often absent or sparsely distributed around favoured grazing areas. A demonstration site has commenced at Delamere Station to determine if burning and wet season spelling can rejuvenate this and other 3P species, thereby maintaining or improving land condition.

Methods

- The Delamere Burn Spell demonstration comprises 2 fenced exclosures, starting 1km from a bore and heading away from it for 1.6km. Each exclosure contains 6 treatment plots ~14ha in size. Previous publications noted that the spelling and burning treatments were to be applied every 2 years and every 3 years. However, prior to treatments being applied, the demonstration has been modified to be more consistent with local recommendations for burning frequency:

1. Wet season spelling only (no burning) – none (control), every 3 years, every 4 years
2. Early wet season burning and wet season spelling – none (control), every 3 years, every 4 years

- Following burning, cattle are excluded from the trial exclosures for the wet season and are allowed to graze them during the subsequent dry season. In years when there is no burning or spelling, the exclosures are open to grazing at all times. Botanal sampling and detailed plant demography assessments are conducted at the start of the dry season every year.

Results

All the "burn" plots were burnt in November 2010 to commence the demonstration. The 2011 and 2012 results show how *D. fecundum* increases with increasing distance from water (Table 1).

Table 1. Average yield of *D. fecundum* at the Delamere Burn Spell demonstration site.

	2011		2012	
	Average yield (kgDM/ha)	Standard error	Average yield (kgDM/ha)	Standard error
No spell no burn 500m-1km from water	13.62	10.84	0	NA
Spelled only – 1-2km from water	91.40	13.99	298.10	34.93
Burnt and spelled – 1-2km from water	153.16	20.55	306.94	40.27
No spell no burn 2-2.5km from water	287.74	53.29	687.31	83.55

Discussion

The "every 3 years" burns and spells will be applied for the first time in the 2013/14 wet season. Future papers will thus present findings once the different burning and spelling frequencies have been applied.

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GENETICS AND REPRODUCTION, NUTRITION AND GROWTH WELFARE AND HEALTH

Practical measures that could assist genetic improvement of Brahman weaning rate

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Introduction

Recent reports from the Beef CRC show there are individual early-in-life female, male and genomic measures that could be valuable genetic indicators for improving Brahman female reproductive performance. Barwick *et al.* (2013) considered the potential to use combinations of the most practical of these. Here we show some of these results for improving Brahman weaning rate.

Methods

Over 30 practical female or male measures were considered. Among these were liveweights, hip heights, coat sleekness score (*Coat*), preputial eversion (PrepEv) and sperm motility (MOT). Weaning rate of Brahman cows was assessed over 6 matings. Genomic EBVs of 30, 40 or 60% accuracy for weaning rate (Gen30, Gen40, Gen60), from genotyping of males, were also included. Combinations of measures were evaluated using step-down analyses of gains from selection (Rendel and Robertson 1950). Measures explaining 5% or more of gains were retained. Selection was assumed to use the top 1% of sires to breed sires, 6.75% of sires to breed dams, 10% of dams to breed sires and 95% of dams to breed dams. Gains for final combinations were also re-estimated assuming only sire selection.

Results and Discussion

Combinations of practical measures yielding most gain are shown in Table 1 and may warrant inclusion in industry recording. Genomic EBVs became more important as their accuracy increased.

Table 1. Combinations of female (F), male (M) and genomic measures (genomic EBVs of 30, 40 or 60% accuracy) yielding most selection gain in Brahman weaning rate (calves weaned /100 cows)[A].

Measures available	Order of importance of individual measures	Expected gain in 10 yrs (%)	
		Selecting sires	Selecting sires & dams
F + M	*Height*, PrepEv, Motility, Livewt, *Coat*	9.4	13.2
F + M + Gen30	*Height*, PrepEv, Motility, Gen30, Livewt	10.1	13.6
F + M + Gen40	*Height*, Gen40, PrepEv, Motility, Livewt	10.9	14.3
F + M + Gen60	Gen60, *Height*, *Coat*	11.7	15.4

[A] See text for definition of measures. Female measures are italicised, male measures are not.

Results require further validating and currently are specific to Brahmans. While the gains shown are only indicative, they suggest that combinations of practical measures could be usefully included in industry genetic improvement and that gains in Brahman weaning rate may be substantial.

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Next Gen Beef Breeding Strategies for the Northern Australian Beef Industry

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Introduction

As many northern producers are achieving less than a 50% weaning rate (McCosker *et al*. 2009), there is an urgent need to optimise beef production efficiency rather than just increasing growth. The main factors influencing reproductive efficiency include age at puberty, age at first conception, duration of post-partum anoestrus and total lifetime productivity as defined by total number and weight of calves produced in a cow's lifetime (Burns *et al*. 2010). The recently completed Co-operative Research Centre for Beef Genetic Technologies (Beef CRC) clearly demonstrated that key component traits of fertility (age of puberty, post-partum reconception interval, scrotal circumference and semen quality) in two tropical breeds (Brahman and Tropical Composite) are at least moderately heritable and that substantial genetic improvements in reproductive performance can be achieved (Corbet *et al*. 2010). In addition, key fertility traits in males (especially sperm morphology traits) were shown to be genetically correlated with key fertility traits in females (Johnston *et al.* in preparation) indicating that genetic selection for fertility in bulls should result in improvements in both male and female fertility and thus overall herd reproductive performance. The challenge now is to apply these research findings into commercial reality. Hence the Next Gen Beef Breeding Strategies Project was developed and subsequently funded by the Queensland Government for 3 years.

This project is participating in on-property collaborative research activities with Droughtmaster, Santa Gertrudis and Brahman BREEDPLAN seedstock bull breeding herds in northern Australia (the three largest tropically adapted genotypes in Australia). This project will evaluate, validate and demonstrate genetic and genomic methods of increasing herd reproductive performance, while being cognisant of growth and carcase trait information, and also increasing the frequency of polledness in these tropically adapted seedstock herds in Queensland. The economic costs and potential returns will be reviewed to assess the commercial viability of various aspects of genetic selection for fertility.

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Monensin reduces consumption of urea supplement blocks

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Introduction

Monensin has been demonstrated to reduce the intake of self fed energy supplements (Muller et *al*. 1986). In contrast to self fed energy supplements, which are often fed to growing cattle, dry season breeder supplements in northern Australia are typically urea based and targeted at maintaining body condition. Desired intakes are 0.1 - 0.2 kg/day and the regulation of supplement intake is an important cost and management consideration for graziers. The objective of this study was to determine the effect of including monensin on the supplement intake of cows consuming a high urea block.

Methods

Sixty one *Bos indicus* cows were allocated on the basis of parity and pregnancy status to either of two supplement treatments and grazed in a common buffel grass (*Cenchrus ciliarus*) paddock at Fletcherview, Charters Towers, between September and December 2009. Cows accessed a single watering point via entry and exit spear gates. A remote automated drafting unit (CAWD Engineering Pty. Ltd.) was located at the exit spear to draft cows into the treatment supplement yards consisting of molten, high urea blocks (Rumevite® 30% Urea + P; R30U) either with, or without monensin. Mean monensin concentration in blocks was 896 ± 4.9 mg/kg (as fed). On 3 occasions, treatment blocks were replaced with lithium spiked blocks and blood samples collected 24 hours after initial access to provide an estimate of daily individual and group block intakes.

Results and Discussion

There were effects of treatment and time, but no interaction, on supplement block intake. Cows with access to monensin blocks had lower supplement intakes compared to control cows at all measurement intervals (Table 1). Supplement intake at first sampling was lower than at the second and third sampling (P<0.001). The lower supplement intake at first sampling was attributed largely to a chance rainfall event 7 days prior to sampling. There was no evidence of correlation between measurements from the same animal. Pregnancy status had no effect on supplement intake. The addition of monensin to dry season supplements may aid in regulating supplement intakes.

Table 1. Mean lithium labelled block intake (g/head.day) for cows supplemented with R30U with or without monensin on 3 occasions during the late dry season.

Treatment	Time 1	Time 2	Time 3
R30U	58.0^{A}	105.8^{A}	78.8^{A}
R30U + monensin	30.7^{B}	86.7^{B}	68.4^{B}

Within columns, means with different superscript letters are significantly different (P<0.05).

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Stability of vitamin A in dry season supplements

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Introduction

High perinatal calf mortality associated with gestational vitamin A deficiency has been reported during extended dry seasons in the Mitchell grass rangelands (Hill *et al*. 2009). Adding vitamin A to supplements may aid prevention however it is inherently sensitive to degradation. Stability depends upon the manufacturing conditions (heat, moisture and pH), oxidising potential of ingredients and storage conditions (Shurson *et al*. 2011). The objective of this study was to determine the stability of Vitamin A when included in dry season supplements manufactured using different methods.

Methods

Three commercially available dry season supplements were manufactured using contrasting manufacturing methodologies; loose lick (LL), molten blocks (MB) and cold pour blocks (CB). All supplements were blended in a horizontal ribbon mixer. The LL supplements were decanted directly into 25 kg bags. The MB mixture was transferred to a heat jacketed mixing vessel, and then poured into cardboard cartons at 90°C prior to hardening. Manufacturing of CB used a patented manufacturing method (IP No. 725349) under ambient temperature. The major ingredients in LL and MB were salt (275 - 300 g/kg as fed) and urea (250 - 300 g/kg). Composition of CB included 200 g/kg molasses, 150 g/kg urea and 100 g/kg salt. Rovimix® A 1000 (DSM) was included in each supplement to deliver 40 000 iu vitamin A/day. Expected concentrations were 240, 335, 270 iu Vitamin A/g for LL, MB and CB respectively. Samples were collected at day 0, 90 and 180 to determine Vitamin A status.

Results and Discussion

Vitamin A degradation was both immediate and extensive for LL and MB relative to target concentrations (see Table 1). The levels decreased between manufacturing and day 90 for LL and MB ($P<0.05$), approaching the limit of detection by 180 days. Vitamin A concentrations of CB remained stable for the duration of the trial. The use of a CB manufacturing process is likely to have greater efficacy than either LL or MB when attempting to deliver vitamin A via dry season supplements.

Table 1. Mean concentration of Vitamin A (iu/g) in dry season supplements stored over 180 days.

Day	LL*	MB*	CB*
0	80^{A} (33)	117^{A} (35)	307 (114)
90	21^{B} (9)	17^{B} (5)	257 (95)
180	10^{C} (4)	10^{B} (3)	267 (98)

Within columns, means with different superscript letters are significantly different ($P<0.05$).
*The percentage recovery of vitamin A relative to target concentrations is shown in brackets.

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Phenotypic associations between udder size and average weight of calf weaned in beef cattle

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Introduction

Research conducted in the dairy industry has found that udder length is correlated to milk yield (Deng *et al.* 2012). In addition to these findings, beef cattle were tested through measuring key phenotypic traits and examining the trends between udder size and average weight of calf weaned, and possible effects on cow condition during the lactation period.

Methods

A total of 2151 calving events of tropical composite cows (born 2001, 2002 and 2003) were monitored from 2003 to 2010 at the Brian Pastures Beef Research Facility, near Gayndah in southeast Queensland. This data was collected as part of the Beef CRC Program. Calving extended from early September to early December with only the events resulting in successful rearing to weaning assessed for the key traits. Cow udder size (US) was recorded at calving on a scale of 1 to 5 (1-small; 3-moderate; 5-large). Cow Body Condition Score (BCS) on a scale of 1 to 5 (1-poor; 3-moderate; 5-fat) was recorded approximately four weeks prior to the calving period, and again at weaning, approximately 18 weeks after the calving period. Calf weaning weights (CWW) were also recorded. Relationships between US, average CWW and average change in BCS during the lactation period (calving to weaning) were analysed.

Results

On comparison of the means, a positive trend was identified between udder size and the average weight of calf weaned (R^2=0.94), and a negative trend between udder size and the average change in BCS during lactation (R^2=0.95).

Discussion

These preliminary findings suggest that on average, cows with larger udders have the potential to raise calves with higher than average weaning weights, though potentially at the cost of a greater loss of body condition during lactation. In saying this, only a small suite of phenotypic factors that may affect the average weight of a calf weaned has been addressed and as a result no direct evidence of cause and effect was found. Research examining additional factors such as weight of calf at birth, age of calf at weaning and genetic associations between traits is required to substantiate these preliminary findings. Application of these observations to a commercial situation would require further analysis of why these correlations exist, in order to avoid selection of undesirable traits.

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Breeder cow losses in central Australia

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Introduction

A livestock inventory approach in a recent study has indicated high annual mortality in the Alice Springs region for all females (11.8%) and breeding females (15.85%) (Henderson *et al.* 2013). To complement use of the property mortality calculator tool from that study, authors of this paper have reviewed estimates of regional cattle mortality. These estimates are based on modelling, averaging and assumptions for adaptation of two methods that were not used by Henderson *et al*. (2013), i.e. 'sex-turnoff difference' and 'turnoff as a proportion of the number of cattle weaned'.

Method

Female cattle losses in the Alice Springs region were estimated over 5-year and 10-year periods (Table 1) using regional data (modelled) from the Northern Territory (NT) WayBill database of the NT Department of Primary Industry and Fisheries (NT-DPI&F 2013), and property data (averaged) from the Australian Agricultural and Grazing Industries Survey (AAGIS) of Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES 2012). Where required, it was assumed that male cattle losses were 3%, weaning percentage was 50 to 80%, calves born were 50% female, cattle imported into the region were 50% female, and cattle lost off an average property were 60% female.

Table 1. Estimates of female cattle losses in the Alice Springs region.

Data: Method:	NT Waybill database sex difference in turnoff	ABARES AAGIS surveys number weaned vs. turnoff
5-year average (2003-07)	8.6%	-0.3%
5-year average (2008-12)	7.7%	7.2%
10-year average (2003-12)	8.2%	3%

Discussion

Although lower than the mortality percentage recently indicated by Henderson *et al*. (2013) for all females in the Alice Springs region, the 10-year average estimates of female cattle losses in this paper were within the 95% confidence interval (2.3–21.3%) of that study. The negative 5-year average estimate (2003-07) that was based on the AAGIS database highlighted the need for caution with these methods when herd build-up or destocking cause large fluctuations (with positive and negative values) in annual estimates. Caution would also be needed if comparing estimates for cattle exposed to different management or different environmental factors.

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"Less is more" for HGP strategies in Northern Territory steers

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Introduction

Hormone growth promotants (HGPs) have been shown to reliably increase the growth of steers in pasture and grain finishing systems in Australia (Hunter 2010). Limited published data exists for the northern NT where growth is minimal during the dry season. This study compared several strategies on a property approximately 300 km south of Katherine, NT.

Methods

Four treatment groups were compared: No HGP (Control); 400 day Compudose® implanted at weaning in the first round of mustering (400); 200 day Compudose® implanted at weaning in round 1 and again at the end of the dry season (2x200); and 200 day Compudose® implanted at the end of the dry season (Wet 200). Male weaners were randomly allocated to treatment groups at weaning in 2010 and again in 2011. Weight and HGP status (missing or present) was recorded at the end of the dry season and the end of the following wet season for both cohorts. Weights were converted into average daily gains (ADG) in kg/d, and the effect of treatment on ADG was modelled using general linear mixed models (Analysis of Covariance) to compare the effect of each implant type on ADG.

Results and Discussion

While all HGP treatment groups had significantly higher growth rates than the control group in both years, there was no significant difference between the HGP groups, suggesting that all HGP strategies were equally effective in increasing growth. HPG loss differed between strategies and between years, with higher loss experienced in the 2 x 200 group and overall in 2011.

Table 1. Summary of the annual average daily gain for each treatment group in 2010 and 2011 with sample size (N) and percent loss of implants.

Treatment group	2010				2011			
	N	ADG (kg/day)	95% CI	HGP loss (%)	N	ADG (kg/day)	95% CI	HGP loss (%)
Control	87	0.191[a]	0.179 – 0.203	-	116	0.255[a]	0.245 – 0.265	-
400	78	0.215[b]	0.202 – 0.228	7	115	0.312[b]	0.301 – 0.323	9
2 x 200	77	0.222[b]	0.208 – 0.235	22	107	0.311[b]	0.300 – 0.321	46
Wet 200	78	0.214[b]	0.201 – 0.227	7	111	0.297[b]	0.286 – 0.309	25

All implant strategies were equally effective; however their costs to implement differed. Mustering costs can have a significant impact on profitability and strategies that require mustering simply for the sake of HGP implantation may not be as cost effective as those timed with other station activities (eg. weaning). Further, repeat implantation of shorter acting oestrogen based implants is unlikely to be a superior strategy in the northern NT due to higher HGP loss rates and little or no growth during the dry season.

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Change in live weight of non-pregnant, mature *Bos indicus* cows of different lactational status over the dry season

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Introduction

In northern Australia large nutritional demands are placed on lactating cows, particularly as pasture quality declines in the dry season. Mobilisation and deposition of adipose tissue and protein may occur in the dry and wet seasons respectively, and this is influenced by the physiological status of the cow and diet quality. Understanding the changes in body composition that occur in cows over the dry and wet seasons may assist in the development of more appropriate supplementation strategies based on their physiological status.

Methods

Mature, non-pregnant lactating *Bos indicus* cows (n=39) were allocated to treatment groups that either lactated (*L*) or didn't lactate (*DL*) throughout the dry season. Calves were then separated dependant on the allocation of their dams in either June (*DL*) or October (*L*). The cows grazed *Heteropogon contortus* dominant pastures as a single mob at the Katherine Research Station, NT. Supplement was distributed weekly, with a urea based supplemented offered at 120 g/head.day in the dry season and a phosphorus based supplement offered at 120 g/head.day during the wet season. Live weight (LW) was recorded in most months over the dry season (June to October 2012; 132 days) and subsequent wet season (October 2012 to April 2013; 175 days) after a 12 hour curfew. Data were analysed using a repeated analysis of covariance.

Results and Discussion

The average LW of cows across time was influenced by lactation status across the dry season ($p<0.001$) (Fig. 1). In October, at the time when calves were weaned from *L* cows, the *DL* cows were 21.1 ± 5.6 kg ($p<0.001$) heavier than the *L* cows. Following the wet season, the difference between treatment groups had reduced with *L* cows 11.8 ± 5.6 kg lighter than *DL* cows ($p<0.04$). The analysis of the wet season data indicated a significant difference between the LW gain of *L* to *DL* cows (Z=-2.63, p=0.008).

This work was funded by the Australian Centre for International Agricultural Research.

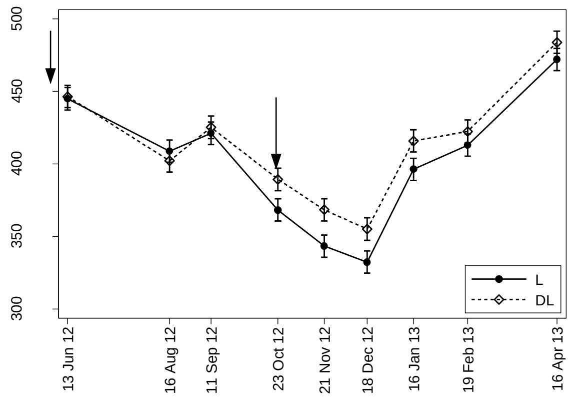

Fig. 4. Change in live weight of mature, non-pregnant *Bos indicus* cows that either lactated (L) or didn't lactate (DL) throughout the dry season. Arrows on figure indicate time of weaning.

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Phosphorus supplementation and adequacy: Distribution of case studies across northern Australia

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Introduction

Phosphorus is reported to be a major limiting nutrient in extensively grazed beef cattle diets across northern Australia. The ratio of metabolisable energy (ME) as determined from Faecal Near Infra-red Reflectance Spectroscopy (FNIRS) to faecal phosphorous (FP) from wet chemistry analysis has been reported to provide a useful indication of the P status of grazing beef cattle (Dixon and Coates 2010). The objective of this study was to examine the relationship between the proportion of mobs considered to have adequate P status and whether the producer practised wet season P supplementation or not.

Methods

Faecal samples were collected during 2009-2011 from 183 Cash Cow project mobs at 2 monthly intervals for FNIRS and wet chemistry analysis. ME was derived from the estimated dry matter digestibility of the pasture using the equation ME = 0.172DMD – 1.707 (CSIRO 2007). The calculated wet season (Nov-Mar) FP:ME ratio was averaged over 3 years. Mobs were categorised as consistently having FP:ME ≥500mgP/MJME or not. This threshold was based on an assessment of preliminary univariable logistic regression model fitting FP:ME as the sole predictor of cow reproductive performance. The mobs were managed on properties located across four different country types (based on perceived production potential using broad vegetation types).

Results and Discussion

Overall, 85 mobs were offered supplemental P and 98 were not (Table 1). The provision of wet season P supplementation had a significant effect on the proportion of mobs with adequate average wet season FP:ME in the Northern forest (Northern Forest – X2M=28.2, df=1, p<0.001) but not in the other country types (Central Forest - X^2=1.39, df=1, p=0.24, Northern Downs – X^2_M=0.07, df=1, p=0.789, Southern Forest – X^2=1.27, df=1, p=0.26).

Table 1. Percentage of breeding mobs for each country type with average wet season FP:ME (Nov-Mar) ≥500mgP/MJME by provision of supplemental P.

Country Type	Percentage of Mobs ≥500 mgP/MJME (%)	
	P supplement provided	No P supplement provided
Southern Forest	47.1 (8/17)	63.6 (21/33)
Central Forest	50.0 (7/14)	70.0 (14/20)
Northern Downs	27.3 (3/11)	28.5 (6/21)
Northern Forest	11.6 (5/43)	12.5 (3/24)

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The cost/benefit of feeding feeder bulls between yarding and loading onto a live export boat

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Introduction

A Producer Demonstration Site (PDS) to examine weight change in the supply chain between yarding feeder bulls (young bulls) and loading onto a live export boat was initiated by the Kimberley Beef Research Committee and funded by Meat and Livestock Australia. Feeder bulls are a common live export article in the Kimberley and Pilbara. This is primarily due to management (once a year mustering) and live export market opportunities (*e.g.* Middle Eastern markets prefer entire males).

Methods

The PDS measured weight change in 180 Brahman X feeder bulls, initial average liveweight 246 kg (range 200–350 kg), over 28 days in September 2012. Stock were weighed on day 1, twice on day 14 (before and after transport) and on day 28. A 12-hour wet curfew was applied to all treatments prior to weighing. Phase 1 (day 1 to 14) was completed at Leopold Downs, Fitzroy Crossing. Stock were randomly drafted into 3 treatment groups of 60 head. Group 1 was fed shipper pellets *ad lib*, Group 2 fed oaten hay *ad lib*, and Group 3 was placed into a well grassed holding paddock. After 14 days on these feeding regimes the feeder bulls were trucked to Roebuck Export Depot (RED) for phase 2; all stock were fed shipper pellets and oaten hay *ad lib* for 14 days.

Results and Discussion

Phase 1 — feeder bulls held in the holding paddock for 14 days at Leopold Downs and delivered to RED (point of sale) returned the greatest net value of $432/head. The net value of feeder bulls fed pellets was $390/head and feeder bulls fed oaten hay was $385/head. It was more profitable to hold stock in a well grassed holding paddock on station than feed pellets or oaten hay while waiting to be transported. There was only a 3 kg liveweight advantage 'at the point of sale' to providing a more nutritious ration; pellets vs. native pasture, for 14 days prior to trucking. The lower net value received was solely due to the cost associated with purchasing and transporting fodder.

Phase 2 — the average net value of feeder bulls after 14 days on feed at RED was $432/head for Group 1 (previously fed pellets), $427/head for Group 2 (previously fed oaten hay) and $422/head for Group 3 (previously fed native pasture). Feeder bulls previously fed pellets at Leopold Downs returned the best net value ($432) after 14 days on feed at RED. This was probably because they were accustomed to the pellet ration, having been on them for 14 days at Leopold Downs.

There were financial benefits from holding stock in a holding paddock that is stock-proof, has adequate water and feed and can be easily mustered prior to transport. Where holding stock in a holding paddock is not an option, the next best option was to deliver stock direct to RED and put them on feed until the point of sale, which negates cartage costs on fodder.

Future producer demonstration sites to further develop this work are being investigated:

- Investigating weight change and feed consumption over 3, 5 and 7 days respectively on-station and at RED. It is hypothesised that sending stock to RED for 4–5 days prior to sale could provide an improved cost/benefit.
- Promote improved management of holding paddocks across the Kimberley.

Acknowledgements: The co-operation of Roebuck Export Depot, Bunuba Cattle Company and the Bunuba Aboriginal people, owners of land and cattle, made this demonstration happen.

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In vitro phosphorus solubility of different sources of phosphorus for cattle

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Introduction

Sixty eight percent of the area of northern Australia is considered deficient in P for cattle with P supplementation recommended. There is a requirement to accurately determine the P requirements of cattle and the availability of P in supplements fed to cattle. Existing methods to determine P solubility were developed for fertilisers, where the pH does not reflect that of the abomsaum of ruminants (pH 2 to 3) after which P absorption occurs. The average retention time of digesta in the abomasum is 20-30 minutes in cattle. The objectives of this study were to evaluate 1) various *in vitro* methods to determine solubility of P supplements for ruminants and 2) the P solubility of various supplements available for use by industry.

Methods

Phosphorus content and solubility of 25 P sources were determined. The sources were classified as monosodium phosphate (MSP, 25.7% P; n=1), monodicalcium phosphate (MDCP, 21.2 $\pm$ 0.2% P; n=9, including Biofos, Kynofos), monocalcium phosphate (MCP, 23.1% P; n=1), dicalcium phosphate (DCP, 19.9 $\pm$ 0.4% P; n=6), tricalcium phosphate (TCP, 19.0 $\pm$ 1.5% P; n=2) and rock phosphate (RP, 10.8 $\pm$ 1.4% P; n=6). Phosphorus solubility of the 25 sources was determined after incubation in water (pH 6.5) (H2O), buffered 0.1M HCl (pH 2.5) (HCl), 2% citric acid (pH 2.8) (CA) or ammonia citrate (pH 9.5) (AC) at 39^{o}C for 30 or 120 minutes. Phosphorus content was determined after incubation using the Molybdovanadophosphate method (AOAC 958.01). P solubility was expressed relative to total P (%). One-Way ANOVA GLM using MINITAB was performed to determine the effects of method, time of incubation and source of P on P solubility.

Results and discussion

Across both times and all P sources, solubility of P was significantly higher ($P<0.05$) for the CA (74.9 $\pm$ 4.8%) and HCl (75.2 $\pm$ 4.3%) methods than the AC (43.5 $\pm$ 5.0%) and H2O (37.6 $\pm$ 5.6%) methods, with no significant difference between the CA and HCl methods. Maximum solubility of MSP, MDCP, MCP and DCP was achieved at 30 minutes using the H2O, CA and HCl methods with no difference between 30 and 120 minutes. P solubility of TCP and RP increased with time for the HCl and CA methods but not with the H2O method. Most sources reached maximal solubility at 120 minutes under the AC method. After incubation in CA for 30 minutes there was no difference in solubility between MSP (99.1%), MDCP (95.7 $\pm$ 1.5%), MCP (96.4%) and DCP (91.5 $\pm$ 5.2%) sources. There was a large difference in P solubility of the two TCP sources (22 and 54%). The RP supplements were lowest in P solubility (1.0 to 27.3%).

Conclusion

At a practical level MSP, MDCP, MCP, DCP are very similar in P availability for ruminants. P content and price should be considered when determining which is the most suitable P supplement to be used for cattle. Untreated rock phosphate sources were very low in P solubility and are unlikely to be useful P supplements. The acidic *in vitro* based tests (HCl and CA) were most appropriate to determine P availability for ruminants but there was no advantage in replacing the established CA method with the new HCl method.

We thank Ridley Agri-Products and A. Brahim (Stocklicks Trading) for providing the P sources.

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Inclusions of grain and cottonseed in molasses-based supplements for cattle

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Introduction

Cattle producers in northern Australia have regularly used molasses-based supplements for production feeding but costs per kilogram gain have increased significantly in recent years. This study investigated the effects of adding barley and whole cottonseed (WCS) to these molasses-based supplements on liveweight gains of cattle.

Methods

Thirty-six Brahman crossbred weaner steers (190.2 ± 7.0 sd) were fed individually in pens over 70 days a basal diet of speargrass (*Heteropogon contortus*) hay *ad libitum* plus 1 of 4 molasses-based supplements. The basic supplement comprised molasses (100 parts, w/w as fed), urea (3), copra meal (10), salt (1), dicalcium phosphate (1) and Rumensin (0.05) and was fed alone (MUP) or with an additional 8.75 parts barley (MUP-B), 17.5 parts WCS (MUP-W) or 8.75 parts barley and 8.75 parts WCS (MUP-BW) to 100 parts MUP mix, w/w as fed. Each supplement was fed at 4 levels: 0.5, 1.0, 1.5 and 2.0% liveweight (W)/day in a response surface approach, with 2 replicates. There were also 4 unsupplemented Control steers.

Results

The Control steers lost 0.16 kg/day. With all supplements there was a linear increase in growth rate with increasing supplement intake (Fig. 1). The addition of barley alone (MUP-B) to the MUP mix did not increase growth rate but inclusion of WCS either alone (MUP-W) or with barley (MUP-BW) resulted in increased gains (P<0.05). Per %W supplement fed, the MUP and MUP-B mixes increased gain by 0.48 kg and MUP-W and MUP-BW by 0.58 kg.

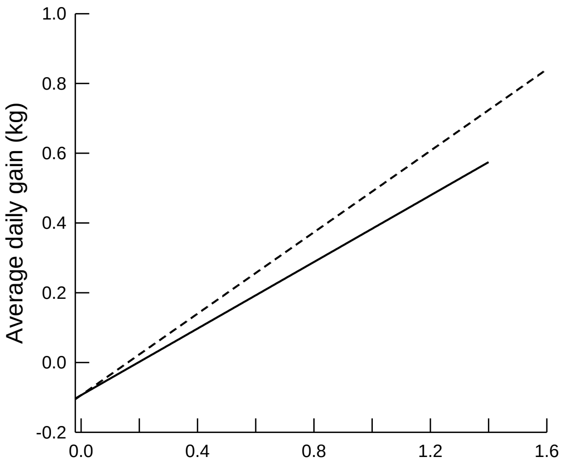

Fig. 1. Effects of MUP and MUP-B (solid line) and MUP-W and MUP-BW (dashed line) on growth rate.

Discussion/Conclusion

The growth response to adding WCS or WCS with barley, but not barley alone, to the MUP mix is probably related to the increased energy density of the diets. Although barley is known to have higher net energy value than molasses, the amount included was probably too small to affect energy intake. By contrast, both other additives including WCS were fed at higher rates and would have increased energy intake especially with the high lipid content of WCS (~20%). WCS is also a source of rumen degradable and undegraded protein but these should not have been limiting in the MUP supplement. Higher inclusion rates of WCS in molasses-based supplements may be feasible but the upper limit of inclusion is currently unknown.

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Vitamin A status of heifers fed a diet deficient in β carotene

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Introduction

Ruminants derive their retinol (vitamin A) requirements from β-carotene and generally have sufficient liver reserves to maintain healthy function through dry periods, but clinical vitamin A deficiency has been reported in cattle during prolonged drought (Hill *et al.* 2009). The level of endogenous reserves at which animals become symptomatic are unclear and manifestation of the disease seems highly variable (Jones *et al.* 1943). We characterised blood and liver retinol levels in growing heifers from a common background, systematically deprived of dietary β-carotene.

Material and Methods

Yearling Braham heifers (n=30) were fed a β-carotene deficient diet consisting of wheaten straw *ad. lib* and a wheat-based pellet, throughout the trial. Blood was collected monthly, liver tissue biopsied every 90d and weight recorded weekly. Retinol concentrations were determined by HPLC.

Results and Discussion

LW increased from 179kg (SEM 2.66 kg) at 0d to 306kg (SEM 4.15kg) at 176d. Initial serum and liver retinol concentrations decreased by 29% and 91% respectively, over the corresponding period (Fig. 1). No animals displayed signs of vitamin A deficiency during the depletion period.

Decline in liver retinol over ~180d agreed with Kohlmeier and Burroughs (1970) for cattle fed dry-forage, but observed poor correlation between blood and liver retinol, except when critically low, suggesting serum retinol levels are not reliable indicators of Vitamin A reserves in young cattle.

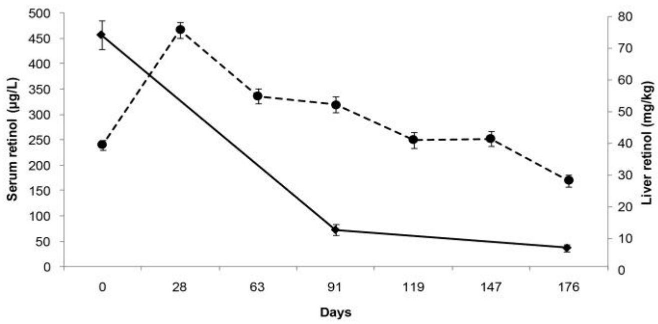

Fig. 1. Serum (--•--) and liver (—♦—) retinol in heifers systematically deprived of β-carotene.

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The association between live-weight gain and rumen microbial diversity in cattle

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Introduction

The use of high throughput 16S rRNA 454 pyrosequencing allows a comprehensive examination of the bacterial diversity in the rumen content of cattle. The objective of this study was to assess the effect of nitrogen (N) supplements on rumen microbial diversity in steers fed a basal diet of tropical pasture and relate these changes to live-weight (LW) gain.

Methods

This experiment was a randomised complete block design involving 42 *Bos indicus* crossbred steers (236 $\pm$ 2 kg) fed black Speargrass (*Heteropogon contortus*) hay (control) or supplemented with increasing amounts of urea + ammonium-sulphate (0.04, 0.08, 0.14 and 0.20 g N/kg LW.day), cottonseed meal or spirulina algae (0.08, 0.16, 0.32 and 0.48 g N/kg LW.day). The experiment consisted of a 7 day equilibration period followed by a 70 day treatment period. Rumen samples were collected on day 50 of the study and genomic DNA extracted, and then amplified using fusion primers 341f-TAG-MID and 787r-TAG. Pyrosequencing was performed on the purified products using a Roche 454 Genome Sequencer FLX (Roche Diagnostics, Mannheim, Germany). Data was analysed using QIIMEs (Quantitative Insights Into Microbial Ecology).

Results and Discussion

To investigate the effect of N intake on the observed number of species, the average operational taxonomic unit (OTU) count for each category, was plotted against the supplementary N intake category. As supplemental N intake increased from 0 (control) to 0.04 g N/kg LW.day, the number of different OTUs found in the rumen contents also increased. However, at the highest supplemental N intake (0.5 g N/kg LW.day), OTU number was reduced. The relationship between OTU number and LW gain was investigated by plotting the average OTU number against high (>30kg), medium (15-30kg), low (0-15kg) and negative LW gain categories. It was found that higher LW gain was associated with higher numbers of OTUs.

This study demonstrated that bacterial diversity increased with increasing N intake to 0.30 g N/kg LW.day but decreased at a higher level of up to 0.5 g N/kg LW.day. Protein supplementation was associated with greater bacterial diversity however the highest diversity was at 0.16 g N/kg LW.day. Higher diversity in the rumen microbe population was associated with greater LW gain. Improved productivity on low quality pastures could be achieved by developing an understanding of the phylogeny of the rumen bacteria involved with these diversity changes together with the source and amount of N supplied.

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The effects of spirulina algae supplementation on the rumen microbial community of beef cattle

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Introduction

A companion study (Panjaitan 2010) demonstrated that supplementation of cattle fed a Mitchell grass (*Astrebla* spp.) basal diet with spirulina algae increased microbial crude protein (MCP) production and the efficiency of MCP production (EMCP) over that of urea supplementation. This increase was associated with increases in intake, digestion and the fractional outflow rate of digesta from the rumen. The effect of supplementation with urea and spirulina algae on the structure and dynamics of rumen bacterial community molecular profiles was examined and associations with intake, digestion EMCP and rumen function determined.

Methods

The experimental designed was an incomplete Latin square, consisting of nine treatments conducted across three experimental runs. Nine cannulated *Bos indicus* steers were fed a basal Mitchell grass hay diet (control) with increasing amounts of urea and ammonium-sulphate (9:1) (90, 130, 170 and 210 g RDP/kg DOM), or spirulina algae (90, 130, 170 and 290 g RDP/kg DOM). Rumen samples were collected at the end of each 30 day experimental period. Genomic DNA was extracted from rumen samples and then amplified using fusion primers 341f-TAG-MID and 787r-TAG. Pyrosequencing was performed on the purified products using a Roche 454 Genome Sequencer FLX (Roche Diagnostics, Mannheim, Germany). Data was analysed using QIIMEs (Quantitative Insights Into Microbial Ecology).

Results and Discussion

The addition of both N supplements increased the diversity of bacteria in the rumen. This was particularly the case for spirulina algae supplementation. The Shannon Index was greatest in the rumen microbe population of steers supplemented with spirulina algae (170 g RDP/kg DOM). The rumen bacterial community structure of steers at both the phyla and genera level were largely stable in spite of large changes in rumen function associated with increases in MCP production and EMCP.

Spirulina algae supplementation removed a limitation to the growth of rumen microbes and supported a more diverse bacterial community due to its greater complexity of nutrients. However, regardless of N supplementation, a large core of bacterial species was represented in all animals. Minor species which made up the extra diversity may still possess important and yet unrecognized ecological functions. No particular species or group of bacteria appeared to be associated with high EMCP values. The similarity of bacterial community structure between treatments indicated that improvements in MCP were related to better growth conditions for all bacteria.

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Advancing research on buffalo fly control: development of a laboratory culturing method

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Introduction

Buffalo flies, *Haematobia (irritans) exigua* cause irritation to cattle, reducing weight gains and milk production. They also vector a filarial nematode *Stephanofilaria sp*. that causes a high prevalence of skin lesions in northern cattle, downgrading skin quality and raising welfare concerns. In recent years buffalo flies have dispersed southwards and westwards and their range is projected to extend significantly with climate change. Research into new methods of buffalo fly control has been limited by the need to maintain live cattle hosts. This is expensive, severely restricts the type of research that can be conducted and is problematic from an animal ethics standpoint.

Methods

Flies are held in 30 x 30 x 40 cm cages at 28.5°C and 70% RH under artificial lighting, with a simulated dawn-dusk light regime and provision of a 'cow back' shaped mating rostrum. They are fed citrated cattle blood from water jacketed membrane feeders warmed to 37°C. Blood is collected from cattle fortnightly and stored at 5°C until needed. Blood pads are provided as a backup blood source and a vitamin supplement given. Larvae are reared in dung collected from pasture fed cattle and pupae collected by sieving and flotation techniques.

Results and Discussion

Of the initial 19 attempts at establishment, on 6 occasions the flies did not breed past the collected generation, on 9 occasions 2nd generation flies emerged, on 3 occasions 3rd generation flies established and on one occasion one 4th generation fly emerged. A total of 54 different collections and attempts to establish a colony, with ongoing technique modifications, were made before establishment of the current persisting colony. This colony has now been reared through 16 generations without further field introductions with the life table parameters shown in (Table 1).

Table 1 Egg, pupal and fly parameters from early collections and the current colony.

Colony	Eggs/fly/day	% Pupae from eggs	% Fly emergence from pupae	% Flies from eggs
Early collections	1.5	1.7	65.6	1.1
Current colony	2.9	27.0	57.2	15.4

Early observations indicated failure of flies to mate as the main barrier to establishment of a persisting colony. Field observations of fly behaviour and laboratory studies identified conditions that favoured mating and enabled the establishment of the first ever totally *in vitro* colony of buffalo flies in Queensland. Availability of this colony will aid investigation of new biological controls and other novel approaches, facilitate the screening of new chemical actives and enable improved monitoring for insecticide resistance through the provision of a reference strain. It will also avoid the animal welfare issues and expense associated with maintaining live animal hosts for buffalo fly research.

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Inclusion of feed efficiency, tenderness and temperament traits to the BREEDPLAN evaluation of tropically adapted beef breeds

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Introduction

Version 6.0 of the BREEDPLAN analytical software was developed at AGBU and is being implemented for the genetic evaluation of beef breeds. Several new features have been added in version 6.0 including new genetic grouping strategies based on country of origin, breed type and year of birth, updated breed specific genetic parameters, improved accuracy of computation for days to calving, blending of genomic breeding values and new traits. These new traits include feed efficiency, temperament and tenderness. Adding these three traits to the routine evaluation of BREEDPLAN (Graser *et al.* 2005) for Brahman (BRAH) and Santa Gertrudis (SANTA) will benefit beef producers in Northern Australia.

Materials and methods

Feed efficiency was measured as residual feed intake (RFI), temperament as flight time (FT) and tenderness as Warner-Bratzler shear force of the *longissimus dorsi* muscle (SF). The RFI, FT and SF records were generated by BRAH and SANTA breeders and the Beef CRC. To include these traits in the evaluation, it was necessary to estimate their heritabilities and their genetic correlations with other traits in the multi trait model. Only the heritabilities and the genetic correlations of RFI, FT and SF in BRAH and SANTA are presented here.

Results and discussion

Genetic parameters included in the routine BREEDPLAN analysis (Table 1) indicate that RFI, FT and SF were heritable in both breeds. Therefore, EBVs from the BREEDPLAN evaluation can be effectively used to improve RFI, FT and SF in both breeds. Negative genetic correlation of FT with SF indicates that selecting animals with higher EBVs for FT will improve their meat tenderness. Furthermore, BREEDPLAN version 6.0 has made provision for the inclusion of genomic information in the evaluation of RFI, FT and SF as it becomes available, which will increase the accuracy of EBVs for these traits in the future.

Table 1. Heritabilities (diagonal) and genetic correlations (above diagonal) of feed efficiency (RFI), flight time (FT) and tenderness (SF) in Brahman and Santa Gertrudis breeds.

Trait	Brahman			Santa Gertrudis		
	RFI	FT	SF	RFI	FT	SF
RFI (kg per day)	0.24	0.19	0.18	0.24	0.04	-0.01
FT (sec)		0.25	-0.48		0.31	-0.36
SF (kg)			0.26			0.29

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The effect of crude protein content or level of metabolisable energy intake on skeletal growth in *Bos indicus* crossbred and Holstein genotype steers.

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Introduction

Improving growth rates of cattle in northern Australia is a major driver of profitability. The question being addressed in this project is "Can targeted nutritional supplementation selectively drive continued bone elongation in the face of nutrient restriction as seen in the dry season in northern Australia?" The primary practical objective is to increase skeletal elongation during the dry season which will prepare the animal for high compensatory growth in the wet season. This experiment examined the effects of crude protein (CP) and metabolisable energy (ME) intake on skeletal growth and subsequent compensatory growth in 2 different phenotypes of cattle.

Materials and methods

The experiment consisted of a 103 day treatment period (Phase 1) and a 94 day re-alimentation period (Phase 2). Weaner *Bos indicus* (B) steers and Holstein/Friesian (HF) steers were allocated to one of three treatment diets during Phase 1 (n=5/genotype/treatment) and to a single treatment diet during Phase 2. In Phase 1 the steers were fed either lucerne chaff *ad libitum* (LAL), Mitchell grass hay *ad libitum* (MAL) or lucerne chaff restricted to an equivalent ME intake as MAL on a LW basis (LR). In Phase 2 all steers were offered LAL. The MAL treatment included 50 g of cottonseed meal/kg Mitchell grass hay from day 49 of the experiment. The LR treatment included 84 mg mono-sodium phosphate (MSP)/kg W/day. Liveweight and hip height (HH) were measured every 7 and 14 days respectively.

Results and Discussion

Changes in liveweight and HH are summarised in Table 1. In Phase 1, steers that were fed LAL had higher rates of HH change than steers that were fed MAL or LR. This was consistent between genotypes. HF steers fed LAL had higher rates of HH change than B steers fed LAL. There was little difference in rate of HH change during Phase 2 regardless of genotype or treatment during Phase 1.

Table 1. Change in HH; mm/day ± SD) and average daily gain in liveweight (ADG; kg/day ± SD) of Holstein (HF) and *Bos indicus* crossbred (B) steers offered lucerne *ad libitum* (LAL), Mitchell grass *ad libitum* (MAL) or lucerne restricted to an equivalent ME intake of MAL (LR) during Phase 1 and LAL during Phase 2.

		HF-LAL	HF-LR	HF-MAL	B-LAL	B-LR	B-MAL
Change in HH	Phase 1	1.14± 0.10	0.38± 0.07	0.25± 0.09	0.87± 0.18	0.42± 0.10	0.29 ± 0.09
(mm/day)	Phase 2	0.79± 0.19	0.92± 0.19	0.98± 0.19	0.76± 0.14	0.82± 0.08	0.76 ± 0.14
ADG	Phase 1	1.38 ± 0.06	0.14 ± 0.04	0.24 ± 0.05	1.18 ± 0.02	0.2 ± 0.05	0.05 ± 0.02
(kg/day)	Phase 2	0.87 ± 0.02	1.29 ± 0.10	1.52 ± 0.04	0.92 ± 0.04	1.32 ± 0.05	1.32 ± 0.04

Changes in HH during Phase 2 were not higher than steers fed LAL during Phase 1 suggesting that increases in skeletal elongation cannot exceed a maximal rate during compensatory growth.

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Fungal biopesticide for Buffalo fly control

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Introduction

The cost of buffalo flies (*Haemotobia irritans exigua*) to the Australian cattle and dairy industries has been estimated at $78.2 million. With the increased temperatures predicted by climate change modelling, the range of parasites such as buffalo flies is likely to extend. Insecticides, particularly ear tags, are currently relied on to control buffalo flies. However there has been increasing commercial, environmental and biological imperatives to find alternative control agents. Fungal biopesticides offer a sustainable and promising alternative method of buffalo fly control. The aim of this study was to appraise the effect of aqueous formulations of the fungus *Metarhizium anisopliae* on buffalo fly populations on cattle under field conditions.

Methods

Eighteen Hereford heifers held under field conditions were allowed to develop natural infestations of Buffalo flies over summer. Two fungal biopesticide formulations (spray and "pour-on") were prepared with dried *M. anisopliae* spores suspended in emulsified oil. One formulation was diluted with water then sprayed onto each of six heifers once. The other formulation was painted onto delimited areas of each of six heifers three times per week for 3 weeks. Six heifers were left untreated. The three groups were kept in separate paddocks with the untreated group more than 250 m from the treated groups. Visual assessment of the buffalo fly burdens were made on yarded animals over 4 weeks, with different yards used for the treated and untreated cattle. Flies were netted from animals for laboratory incubation to confirm *Metarhzium* infection.

Results

Natural infestations of buffalo flies built up to extremely high levels on all heifers so that at treatment all groups had approximately 500+ flies per side-of-animal. This very high number of flies continued to increase on untreated cattle. By day 21 it was estimated that untreated cattle were carrying 500-1000 flies per side. The buffalo fly burden on heifers sprayed with the biopesticide dropped rapidly after spraying so that these animals averaged barely 5 flies per side by 2 days post spraying. However a linear decline in treatment effect meant that fly numbers built to an economic threshold after 19 days post spraying (Average 300 flies per side). Nonetheless this level was still well below that seen on untreated cattle. Cattle treated with the "pour on" formulation showed a steady decline in buffalo fly numbers to approximately 1- 50 flies per side 7 days after the first application. This low number was maintained for much of the trial until day 26 (12 days after the last application) when fly numbers had recovered to approximately 150-300 flies per side.

During the last days of the trial some untreated heifers began to develop lesions associated with extremely heavy buffalo fly infestations. The treated cattle developed no such lesions and overall showed much better condition than the untreated cattle.

Discussion and Conclusion

This study suggested that both spray and "pour-on" formulations of a *Metarhizium*-based fungal biopesticide have potential for buffalo fly control. The fungal spores were noted to remain viable in the animal coat for up to two weeks after application during peak summer heat. Further investigations to develop a fungal biopesticide control for Buffalo flies are warranted.

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Establishing a Performance Recorded Beef Herd In Northern Queensland

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Introduction

Herd management is a complex process. Keeping accurate records is a vital part of making informed and skilled business decisions in any beef business. In 2012, staff from the Department of Agriculture Fisheries and Forestry of Queensland (DAFFQ) established a recorded herd (where key animal performance traits are intensively recorded) at the new Spyglass Beef Research Facility. The purchase of the commercial Spyglass and Lucky Break properties to form the Spyglass Beef Research Facility was part of the Queensland Government's reinvestment for the future profitability and sustainability of Australia's northern beef industry. Spyglass is situated 110 kilometres north of Charters Towers and 130 kilometres west of Townsville. It covers 38,221 hectares (94,446 acres) and can comfortably run up to 4000 adult cattle. It is currently running both recorded and commercial cattle. The concept of having a highly recorded herd based upon observed characteristics and genetic information will enhance interpretation of subsequent animal performance traits. The recorded herd will address two areas firstly, to ensure accurate records for research purposes are collected within controlled conditions, and secondly to raise industry awareness of the value of using measured traits for accelerating genetic improvement in beef cattle.

Method

425 cows (240 Brahman and 185 Droughtmaster) were brought to Spyglass from the original herd recording program at Swans Lagoon in Ayr. Their calf when born is captured within 24 hours and allocated an identity number. Specific information including birth date, breed, sex, colour and markings are all recorded and a DNA sample taken. There is also reference to the mothers' identification number along with her teat and udder score. This data is then entered in a digital recording system and available for later uploading to BREEDPLAN.

Results and Discussion

The Spyglass Agri-Science Queensland (ASQ) research herd have the measured traits for increasing reproduction efficiency through genetic improvement. A primary aim is continuing the development of DNA tests to guide accuracy in predicting an animal's genetic potential for economically important traits such as reproduction, meat quality, adaptation and welfare. Through the measuring and recording of its performance herd on Spyglass and Brian Pastures Research Facilities near Gayndah, and through collaboration with research collaborators in QAAFI, CSIRO, MLA and the University of New England, ASQ will achieve this aim.

For an individual grazier, a recorded herd with up-to-date accurate records provides a basis for informed selection on individual traits, improving the genetics of the herd, with overall productivity gains. 2013 will be the second year of the program at Spyglass with 286 Brahman cattle and 150 Droughtmasters currently mated. The program aims to move towards herd segregation into calving groups and the recording of individual birth weights.

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Cattle producers have a key role to play in strategies to reduce bovine respiratory disease in feedlots

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Introduction

Bovine respiratory disease (BRD) is the number one health issue of feedlot cattle in Australia. The development of BRD is a result of a complex interaction of animal factors, environmental factors and exposure to infectious. In order to understand how these factors contribute to BRD development an epidemiological study was undertaken to confirm and identify risk factors. Knowledge of factors that put cattle at increased risk of developing BRD will allow feedlot operators to identify appropriate management strategies to minimise the economic impact of BRD.

Methods

From April 2009 to December 2011 170 groups of cattle entering feedlots were enrolled into the National BRD Initiative (NBRDI). A blood sample and a nasal swab were collected at the time of induction from each animal. Management data were also collected for all study animals from the feedlots for the time on feed. In addition, where possible the owners of directly sourced animals were surveyed regarding the prior management of study cattle. The National Livestock Identification Scheme (NLIS) was also utilised to track the movement of study animals from property of birth to feedlot arrival. A subset of blood samples were tested.

Results

At the completion of the study 35,160 animals in 170 pens of cattle from 14 feedlots were enrolled in the NBRDI. The feedlots were located in New South Wales (7), Queensland (5), South Australia (1) and Western Australia (1). During the course of the study 18.2% of cattle were diagnosed with BRD. The BRD death rate among study animals was 0.66%. Completed surveys from cattle vendors were obtained for 10,693 animals (31%). Testing of blood samples confirmed that the key viruses are circulating in feedlots.

Animal factors linked to BRD development, included breed and induction weight. The testing of blood samples demonstrated that pathogen exposure is a component in BRD development. Weaning methods were identified as important, with yard weaning reducing the likelihood of cattle getting BRD. The NLIS data on animal movement enabled the assessment of the impact of animal movement and mixing on BRD development for the first time. Risk of BRD is higher when cattle are mixed when they go on feed, particularly if at least 4 groups of cattle are mixed, or they have never been mixed before. Risk is reduced for cattle that have been in larger stable groups (>100head for at least 2 weeks).

Discussion

The importance of weaning method and cattle mixing/moving in BRD development indicates how producer/vendors can impact on BRD in feedlots. The results support the concept that effective BRD management requires greater cooperation between all sectors of the Australian beef industry.

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Measuring milk yield in beef cattle

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Introduction

To enhance reproduction research, this study investigated the efficacy of the weigh-suckle weigh method of estimating milk yield in Brahman cows during a dry season.

Method

Thirteen Brahman cow-calf pairs were used to estimate daily milk yields. Cow body condition scores were between 2 and 4 on a 1-5 scale, and calf weights ranged from 79-201 kg. A standard weigh-suckle-weigh method was used on two separate occasions (Weeks 1 and 3). Calves were weighed before and after suckling cows (15-20 min) that were un-suckled for two consecutive half-day intervals. This was compared to a detailed measure (Week 2) when calves suckled and were weighed regularly over 24 hours and calf weights were adjusted for urination, defecation and calculated insensible water loss.

Results

Average insensible water loss by calves was 5.5% of live weight per day. Estimated urine output was 1 mL per kg live weight. Faeces averaged 0.51 kg per 100 kg live weight per day. The repeatability of the standard measure, which under-estimated milk yield, was 0.46. Correlations of standard measures in week 1 (av: 1.5 kg/d) and week 3 (av: 3.0 kg/d) with detailed measure week 2 (av: 3.3) were 0.39 and 0.48 respectively. Trends were for lactation yields to increase by an average of 1 kg daily for each unit increase in cow body condition score and to decrease by an average of 2 kg daily for each 100 kg increase in calf weight.

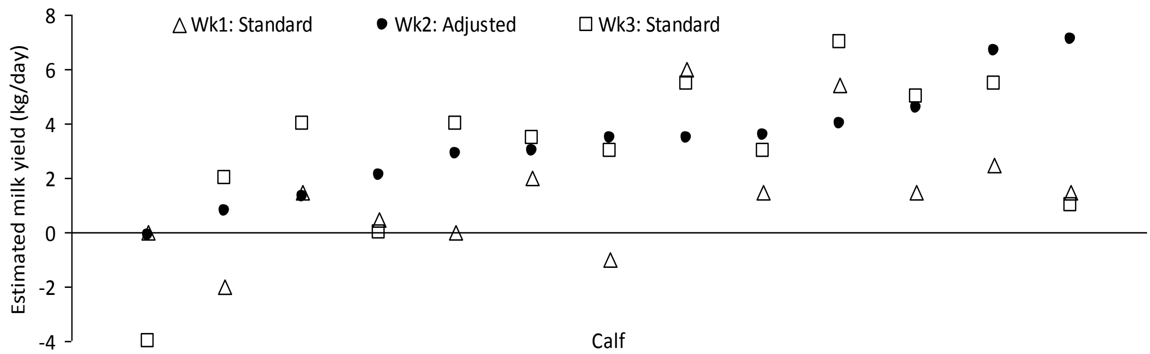

Fig. 1. Estimates of 24-hour milk yield (kg) using standard or detailed weigh-suckle weigh.

Conclusions

The weigh-suckle-weigh method for estimating daily milk yields should account for urination, defecation and insensible water loss to improve accuracy and repeatability. The effects of low cow body condition and of suckling older calves in depressing milk yield emphasises the importance of weaning calves at a young age to reduce the incidence of dry season lactation.

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Breed, environment and management factors affecting diet selection and growth of steers

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Introduction

In both an Australian and world context, diet selection associated with genotype (G) interactions between environment (E) and management (M) in tropical rangelands have not been extensively investigated. This study aimed to identify the presence of G, E, and M factors affecting diet selection of grazing steers using faecal near infrared reflectance spectroscopy (F.NIRS).

Materials and methods

Eighty yearling steers from 2 breeds were used: Brahman (BB) and Belmont Red Composite (BRC: interbred Africander, Brahman and Hereford-Shorthorn). Animals were pastured at Lansdown Research Station and randomly assigned to 1 of 2 mobs which alternatively grazed open woodland, dominated by *Stylosanthes* spp., and savanna dominated by *Chloris* spp. A crossover design of 8 periods was used from November 2010 to February 2011 (wet season: 1014 mm rainfall) and August to November 2011 (dry season: 8 mm rainfall). Animals were treated for cattle tick and helminths. Data were analysed using mixed-effects linear regression in SAS.

Results and Discussion

Overall, the BRC grew faster (P<0.001) compared to BB and tended (P<0.10) to select higher proportion of non-grass species resulting in greater nitrogen in the diet (Table 1). These results could be a consequence of greater protein demands in BRC due to their greater genetic potential for growth (Frisch and Vercoe 1984). Diet selection was highly predictable with increasing proportion of non-grass species towards the end of the dry season for the savanna paddock (Fig. 1). However, plant selectivity was far less predictable in the woodland paddock. Such variation could be related to different phenological states of *Stylosanthes* and the prevailing environmental conditions. The tropically-adapted *Bos taurus*-based composite showed greater potential for growth; however including legumes in pastures will facilitate the expression of such growth potential in the dry tropics.

Table 1. Initial and final liveweight and diet selection of BB and BRC.

Initial liveweight (kg)	249 ± 5.2	258 ± 3.0$^{n.s.}$
Final liveweight(kg)	395 ± 7.7	421 ± 5.6***
Non-grass (% diet DM)	25.6 ± 0.51	26.7 ± 0.30$^{\#}$
Nitrogen (g/kg DM)	13.5 ± 0.12	13.7 ± 0.07$^{\#}$

*** P<0.001, $^{\#}$ P<0.10, $^{n.s}$ P>0.10

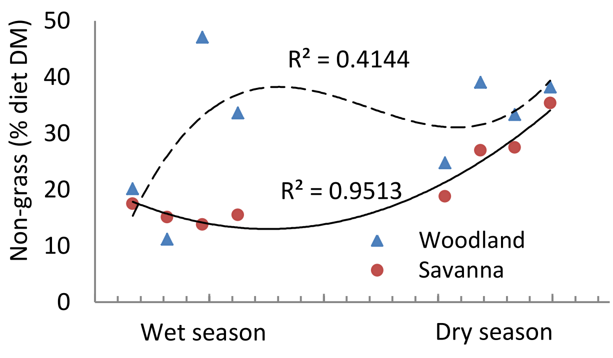

Fig. 1. Diet selection of steers grazing woodland or

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Growth of Brahman, Ongole and crossbred bulls kept by smallholder farmers in Indonesia

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Introduction

Increasing beef production in Indonesia requires an increase in the productivity and profitability of smallholder cattle fattening enterprises. In East Java, smallholder farmers keep many different breeds of cattle for growing and fattening prior to slaughter, but there is no published information available about how the different breeds of cattle perform under village conditions. The aim of this research was to compare the growth performance of three breeds of beef cattle during the dry and wet seasons at the smallholder farmer level.

Methods

The three breeds of cattle monitored were: Peranakan Ongole (15 in dry season and 26 in wet season), Brahman (19 in both seasons), and Brahman cross (21 in dry season and in 28 wet season). Different animals were monitored in each season. Cattle were uncastrated bulls aged 1 to 2.5 years and were kept by smallholder farmers in East Java, Indonesia. Cattle were monitored for 12 weeks in the wet season (March to June 2012) and 10 weeks in the dry season (July to October 2012). Liveweight was recorded at the start and end of each monitoring period. Average daily gain of different breeds was compared using General Linear Models in SPSS.

Results

Average (±SE) weights of Ongole, Brahman, and Brahman cross bulls at the start of the dry season were 186 ± 22, 219 ± 13 and 271 ± 17 kg, respectively. Weights at the start of the wet season were 207 ± 17, 192 ± 12, and 243 ± 13 kg. The average daily gain of Brahman and Brahman cross bulls was higher than Ongole bulls during the dry season (Table 1). There was no difference in growth rates between seasons in any of the three cattle breeds.

Table 1. Average daily gain of cattle kept by smallholder farmers (kg/day).

Season	Ongole	Brahman	Brahman cross	SEM
Dry	0.19[a]	0.41[b]	0.47[b]	0.05
Wet	0.26[ab]	0.26[ab]	0.39[b]	0.03

Averages within columns and rows followed by different letters are significantly different (*P* < 0.05)

Conclusions

Liveweight gain was below the genetic potential of all breeds of cattle and demonstrates the huge potential to increase beef production within villages. The low growth rates recorded were directly related to the quantity and quality of feed offered (data not presented). The amount of feed offered was below *ad lib* intake, and contained large amounts of poor quality crop residues such as rice straw.

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Welfare outcomes from ring and surgical castration of 3- and 6-month-old calves

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Introduction

The Cattle Welfare Code of Practice is undergoing review. It currently stipulates that rings should only be used for castration of calves less than 2 weeks of age, but the basis for this is unclear. It is not practicable to castrate very young calves in northern Australia, but castration at 3 months of age, instead of 6 or more months, may be realistic. This experiment was performed to examine the welfare outcomes for 3- and 6-month-old calves castrated by surgery or rings.

Methods

Unweaned, 3- (range 2.5-4 months, average liveweight 93.7 kg) and 6-month-old (range 5-7 months, average liveweight 163.3 kg) Belmont Red calves were sham (control), ring or surgically castrated according to best practice (n = 10 for each of Sham3, Surg3, Ring3, Sham6, Surg6 and Ring6). Blood samples were taken on restraint (time 0) and at 30 min, 2 h and 7 h post-castration and assayed for cortisol and samples taken on days 1, 2, 3, 7, 14, 21 and 28 were assayed for cortisol and haptoglobin. The extent of activity was recorded for 2 weeks post-castration by data-loggers strapped to the calves' hind leg. Wound healing was scored weekly for 5 weeks post-castration.

Continuous data were analysed using restricted maximum likelihood with a model including the effects of castration method and age group. Activity data were averaged for 13, 24-h periods post-castration. Wound scores were summarised into two categories: (1) normal healing and (2) delayed healing/infection and analysed by logistic regression using a Generalised Linear Model.

Results and Discussion

On the day of castration, cortisol concentrations decreased ($P<0.05$) most rapidly in the Sham calves with no difference in cortisol profiles between Ring and Surg calves of either age group, indicating that ring and surgical castration were equally stressful and painful. There was a significant ($P<0.001$) castration method x time interaction for activity; Surg calves were less active than the other treatments in first 24 h, activity of the Ring calves then declined to levels similar to those of the Surg calves until period ('day') 7. Thereafter, the activity of the Surg calves increased to be similar to the Sham, but levels were lower in the Ring calves to 'day' 12. These findings indicate most pain from surgical castration for the first day, then similar levels of pain from ring and surgical castration for about 7 days, but with pain in the ring castrates persisting for about 12 days. This was supported by the haptoglobin concentrations which increased significantly at week 2 in the Ring calves of both age groups, indicating greater inflammation at this time compared with other treatments. There was also evidence ($P<0.05$) of delayed healing of wounds in the 6-month-old calves at week 1 and in the Ring6 calves at week 2.

Conclusions

Both ring and surgical castration cause pain, but the pain from ring castration is longer-lasting, peaking at about 2 weeks post-castration. Welfare outcomes are similar for 3- and 6-month-old calves, although wound healing is slower in 6- than 3-month old calves. Thus, best practice surgical castration provides better welfare outcomes than ring castration for both 3- and 6-month-old calves.

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A comparison of F1 Senepol x Brahman and Brahman steer growth in the NT.

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Introduction

The Senepol is a tropically adapted *Bos taurus* breed known for having good meat quality (O'Connor *et al.* 1997). A research program was undertaken to determine if crossbreeding Brahman cows with Senepol bulls is a viable way of producing animals that perform well in northern Australian conditions and are readily accepted in both the Indonesian live export and Australian domestic markets (where high grade Brahman animals are often discriminated against on the basis of perceived poor meat quality). If this is the case then it would increase marketing options for producers in northern Australia with high grade Brahman herds. The first stage of this program was to study the growth of Senepol cross animals under north Australian conditions.

Materials and methods

Senepol and Brahman bulls were mated to Brahman cows at the Victoria River and Katherine research stations to produce F1 Senepol x Brahman (F1 Sen) and Brahman progeny. Shortly after weaning the male progeny were relocated to the Douglas Daly Research Farm (DDRF) where they grazed improved pasture together for about a year. The steers were weighed at DDRF at the start and end of the post weaning year and several times in between. Each year in March all the steers were weighed so that those approaching the 350 kg live export limit could be turned off. The liveweight gain (LWG) of the two genotypes was compared from the start of the experiment at DDRF (usually June or July) until March. This was repeated with 3 year groups of animals.

Results and discussion

The average LWG from June/July until March for 3 year groups of steers of each genotype is shown in Table 1. Within each year, mean LWG for the genotypes were compared using Analysis of Covariance (ANCOVA) with starting weight as the covariate. LWG was significantly higher in the F1 Sen than Brahmans in each year group of steers (2010 $p=0.012$, 2011 $p=0.042$, 2012 $p<0.0001$).

Table 1. The average liveweight gain (kg), from June/July to March, of three year groups of steers.

Genotype	2010 weaned	2011 weaned	2012 weaned
Brahman	118.4 $^{(N=74)}$	102.1 $^{(N=60)}$	90.9 $^{(N=118)}$
F1 Senepol x Brahman	129.2 $^{(N=31)}$	107.4 $^{(N=58)}$	100.7 $^{(N=98)}$

These results showing higher growth rates from F1 Sen steers than Brahmans during the post weaning year in the Top End, coupled with the improved meat quality of Senepols (O'Connor *et al.* 1997), should be of interest to northern cattle producers looking for more marketing options for tropically adapted cattle. They indicate that such crossbreeding programs should produce animals with more marketing options and no reduction in post weaning performance.

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The effect of birth weight and month of birth on pre-weaning growth of calves on the Barkly Tableland, NT.

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Introduction

The live weight of calves at weaning is largely determined by age at weaning, sex and growth rate prior to weaning. This study reports on the effect of birth weight, month of birth and age of dam on the pre-weaning growth of calves on an extensive Barkly Tableland property.

Materials and methods

A herd of 510 Brahman and Brahman/Charbray cross cows mated to calve during September 2012 to January 2013 were observed during calving at Brunchilly Station on the Barkly Tableland (Northern Territory). Calves were caught and tagged shortly after birth and their birth weight, birth date, gender, dam ID and age of dam were recorded. Calves were weighed at the time of weaning (average 170 days after birth) and their birth date and weight were used to calculate their pre-weaning growth rate.

Data were square transformed and analysed using an ANCOVA which consisted of the main effects: calf sex, dam age category, month of birth and birth weight as a covariate. All potential interactions were explored. However, no significant interactions were retained in the final model. Marginal means, standard errors and pairwise comparisons of means were calculated. All analyses were completed using Stata, version 12.1.

Results and discussion

An average pre-weaning growth rate (PWGR) of 888 ± 6.9 S.E. g/d was recorded for the 281 calves that contributed data in the analysis. PWGR increased as birth weight increased ($p=0.004$), which is consistent with the findings of Winks *et al.* (1978) who reported that, in calves born from Shorthorn cows in north Queensland, heavier calves at birth grew faster to weaning. This is further supported by the established genetic correlation between birth and 200 day weights (Bennett and Gregory 1996).

Calves of dams between 11-12 years of age recorded 53.9 ± 17.5 S.E. g/d lower average PWGR than calves of dams between 5-7 years of age ($p=0.008$). Sex of calf was significantly associated with PWGR ($p<0.001$) with male calves recording a 56.3 ± 14.5 S.E. g/d higher PWGR than female calves.

PWGR was not found to be associated with month of birth in this study ($p=0.61$) and this is thought to be because only cows that calved at a favourable time of year were observed. Previous studies have shown that calves which are born during unfavourable times of the year (during the dry season) display reduced PWGR (Schatz, 2001).

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Predicting the effect of rainfall on nutrient cycling for the management of stocking rates

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Introduction

One of the key gaps for modeling pasture and animal production in northern Australia is the understanding of nitrogen dynamics. After water availability, nitrogen is the key limiting factor for pasture and animal production. Nitrogen flows in the system are driven strongly by climate variability with low animal production often following big wet seasons that induce nutrient dilution, and, conversely, large production spikes following years of drought in response to a buildup in available soil nitrogen. Our biological understanding of the climate-nitrogen dynamics is poor and our current approaches to modeling animal production in northern Australia don't yet adequately incorporate nitrogen dynamics and its effect on pasture availability and quality.

Methods

In 2012, a 10 ha experimental site was selected on the Spyglass Research Station (19°28', 145°43'). The site is characterized by a deep clay soil that is mostly dominated by Black Speargrass (*Heteropogon contortus*) embedded in bare soil matrix. Five rain treatments were erected: 50% and 25% reduction of precipitation, actual precipitation and addition of 50% and 100% of precipitation.

Reduction of precipitation was achieved by rainout shelters that reduce the amount of rain falling on the ground. The rainout shelters were constructed by building 9 square meter frames in the paddock. Clear polycarbonate strips were attached to the frame to allow light through. Water landing on the polycarbonate strips is guttered out from the plot into trenches in the ground that remove the water from the plots. The trenches also prevent runon from entering the plots and remove any excess runoff from the plots. Addition of water is achieved by irrigating the 9 square meter plots with rainwater within 36 hours following the rainfall event. The amount of water irrigated is based on the actual rainfall amount measured on site. Soil moisture is monitored by soil moisture probes connected to a data logger.

During the beginning, peak and end of the 2012/13 wet season, soil and plant samples were collected for chemical analysis. The soil properties that are being analysed are: ammonium, nitrate, total nitrogen, organic carbon, phosphorus, potassium, and sulphur. The plant properties that are being analysed are aboveground biomass, belowground biomass and foliage quality.

Applications

These results will be used to quantify the relationship between climate and nitrogen dynamics and consequently pasture productivity. Furthermore, we will add nitrogen dynamics to pasture and animal production models of northern Australia.

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Reproductive performance of Brahman cows kept by smallholder farmers in Indonesia

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Introduction

Indonesian feedlots have increasing demands for Brahman cattle, and many smallholder farmers now keep Brahman cows instead of local breeds. Increasing beef cattle production by smallholder farmers in Indonesia requires an increase in the reproductive performance of cows. However, there is very little information available about the reproductive performance of Brahman cows kept by smallholder farmers in Indonesia. The aim of this project was to develop and implement a productive Brahman cow-calf system at village sites in Indonesia. This paper presents some preliminary results from the project.

Methods

A research site was established at Tulang Bawang Barat, Lampung, Indonesia, in May 2011. We monitored 117 cows belonging to 66 farmers. Dates of mating, calving and weaning were recorded as well as monthly body condition score (BCS). Results were compared using two-sample t-tests in Genstat (15th edition, VSN International). Farmers were encouraged to adopt the 'Integrated Village Management System' developed in previous ACIAR projects. The principles of this system are improved mating management, weaning of calves at 6 months or younger, and strategic allocation of feed resources to target a body condition score of 3 (1-5 scale) of cows at calving.

Results and Discussion

Although the results were not significant between years, reproduction rate of cows has tended to improve over the duration of the project (Table 1). The proportion of cows in BCS less than 3 at calving decreased from 67 to 17% of the herd, and 100-day in calf rate increased from 10 to 35%.

Table 1. Reproductive performance of Brahman cows (average values).

Description	2011	2012	P
Body condition score of cows at calving (1-5 scale)	2.7	3.2	0.06
Post-Partum anoestrous interval (days)	101	89	0.57
Length of lactation (days)	123	146	0.09

Reproduction rate of cows has tended to improve over the duration of the project. This is largely due to better nutrition of the cows, resulting in higher BCS and 100-day in calf rates. One of the problems still faced by farmers is mating management. Many farmers grow crops as well as keeping cattle, and sometimes miss oestrous detection or do not have time to arrange mating because they are busy with other activities. Mating opportunities are also missed when the farmer cannot afford to pay for artificial insemination or natural mating, or when the bull or AI technician is not available.

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Trials and tribulations of diagnosing Vibriosis (BGC) in cattle

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Introduction

Bovine genital campylobacteriosis (Vibriosis) causes venereal disease of cattle characterised by infertility and sporadic abortion, caused by *Campylobacter fetus* subspecies *venerealis*. "Gold standard" diagnosis relies upon culture isolation and differentiation, which is complicated further by the inability to isolate Campylobacter from rapid overgrowth of contaminants during transport to diagnostic laboratories. This has led to the development of several molecular identification tools (McMillen *et al*. 2006). However, recent reports indicate that reliance on PCR alone can lead to false positive or negative results. Further work is necessary to develop reliable unique assays for identification and for improved media to facilitate culture.

Methods

Smegma samples were collected from the preprepuce of bulls post exsanguination using the Tricamper™ Sampling device into PBS and culture medium. Samples were cultured and identified using 8 biochemical tests (OIE). Samples were tested using real time PCR (McMillen *et al.* 2006) and 2 conventional published PCR protocols (Abril *et al*. 2007; Hum *et al*. 1997).

Results and Discussion

The results confirm inconsistencies between current "gold standard" OIE testing methods and published molecular assays for the identification of *C. fetus venerealis*. The gene target used in the McMillen assay can produce false negatives and positives (Spence *et al.* 2011). Our laboratory has been researching alternative molecular assays and culture methods.

Table 1. Isolate identifications using "gold standard" culture techniques and PCR.

Culture Identification (OIE standard methods)	n	ParA positive (Hum *et al.*)	ISC*fe*1 positive (Abril *et al.*)	ParA positive (McMillen *et al.*)
Campylobacter fetus subsp. *venerealis*	25	18	25	25
Campylobacter fetus subsp. *fetus*	4	2	4	4
Arcobacter sp	11	3	10	3
Campylobacter-like organisms	11	1	5	7

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Update on the Brahman BIN (Beef Information Nucleus) project

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Introduction

Australian Brahman Breeders' Association with funding assistance from MLA Donor Company, under their Beef Information Nucleus (BIN) program, are currently conducting a large scale sire progeny testing project for Brahman cattle. The project will collect accurate phenotypic measurements on important economic traits which will be analysed by BREEDPLAN genetic evaluation system to produce EBV's. Brahman breeder will benefit by higher accuracy on sires for hard-to-measure traits and, very importantly, we'll have phenotypic measurements that will be used in the development of Genomic predictions that will be implemented into BREEDPLAN EBV's

Materials and Methods

The project aims to produce approximately 30 progeny from 20-25 bull annually over 3 years on 3 co-operator properties in Central Queensland. On two co-operator properties at Banana and Bauhinia high grade commercial Brahman heifers were artificially inseminated (AI) to registered Brahman bulls to produce progeny. At the 3rd property, Belmont Research Station registered Brahman cows and heifers were AI and then went to natural service sires to produce the progeny. Steers are to be grown out on grass and carcase and meat quality data to be collected at slaughter. Heifer progeny are to be retained in the project until pregnancy test after their 2nd joining.

Information collected to date:

- Hair and blood samples to be collected for DNA
- BREEDPLAN growth, fertility, temperament and carcase data collected and analysed.
- Additional measurements: structure scores, ovarian scanning

Results and Discussion

At present rounds 1 and 2 calves have been born and weaned while the round 3 are in utero to calf in the spring. In total 72 Brahman sires have been used to produce 1150 calves in the first 2 years and 814 pregnancies in the final year (Table 1). Some bulls were used more than one year increase the number of progeny to 30 animals. Data collected and analysed on Year 1 progeny to date is weights at 200, 400, 600 day (birth weight), rump fat, rib fat and Eye Muscle area (EMA).
When comparing average 600 day weight EBV's(kgs) of the top and bottom 5 bulls for before (March 2012) and after weights (April 2013) were analysed there was no change in average EBV's of both the top and bottom 5 sires. Also the accuracy of the EBV's rose from 70% to 90% (Fig. 1).

Table 1. Number of sires used and progeny

Animals	Year 1	Year 2	Year 3
New Sires	26	23	23
Steers	243	322	
Heifers	248	329	
Pregnancies			814

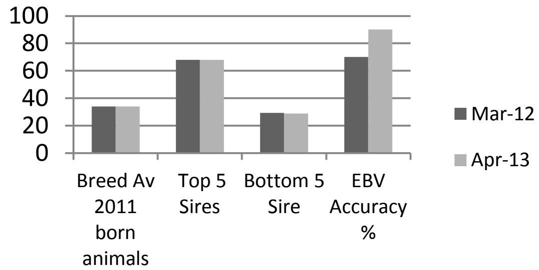

Fig. 1. Change in 600 day EBV's for top and bottom 5 sires before and after BIN data.

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Genetic association of maternal weaning weight with growth and body composition in lactating cows of two tropical beef genotypes

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Introduction

Weaning weight can be partitioned into direct and maternal (maternal WWT) genetic components (Meyer *et al*. 1994). This study examined whether selection for maternal WWT (published as the milk EBV in BREEDPLAN) may have consequences for growth and body composition traits in lactating first calf cows, of two tropically adapted genotypes, at the start of their second annual mating.

Materials and methods

The genetics of growth and body composition traits in first lactation cows at the start of their second annual mating (into mating), when females averaged 39 months of age, were evaluated in 636 Brahman (BRAH) and 868 Tropical Composite (TCOMP). Measurements analysed were liveweight (LWT), ultrasound scanned eye muscle area (EMA) and P8 fat depth (P8) and body condition score (BCS). Traits describing the change in these over the 109 day period from prior to first calving (pre-calving) to into mating were also analysed. Maternal WWT was estimated from weaning weight records on these cows, their steer half-sibs and their progeny generated from up to 6 annual matings (N = 12528). Genetic correlations were estimated between maternal WWT and cow traits in bivariate analyses. On average, lactating females lost LWT, EMA, P8 and BCS over the pre-calving to mating period, thus negative correlations with change in these traits describe relationships with greater loss.

Results and discussion

Into mating LWT, P8, EMA and BCS, and the change in these from pre-calving to mating were heritable in BRAH and TCOMP (h^2 = 0.17 to 0.73). The results in Table 1 show that lactating BRAH cows with higher maternal WWT had lower into mating EMA and BCS (r_{gM} = -0.44 and -0.50). For both genotypes, higher maternal WWT was associated with greater loss of LWT, EMA and BCS from pre-calving to mating (r_g = -0.40 to -0.85). These results demonstrate that selection to increase maternal WWT in tropically adapted genotypes can increase mobilisation of EMA, LWT and BCS, in lactating first calf cows. As these relationships were not one, animals could be identified which, at a constant maternal WWT, mobilise less LWT, EMA and BCS during their first lactation.

Table 1. Genetic correlations (r_g), and standard errors (s.e.), of Brahman (BRAH) and Tropical Composite (TCOMP) maternal WWT with into mating liveweight (LWT), eye muscle area (EMA), P8 fat depth (P8), body condition score (BCS), and change in these from pre-calving to into mating.

Trait	Units	Into mating				Change from pre-calving to into mating			
		BRAH		TCOMP		BRAH		TCOMP	
		r_g	s.e.	r_g	s.e.	r_g	s.e.	r_g	s.e.
LWT	kg	0.15	0.13	0.23	0.13	-0.47	0.17	-0.40	0.16
EMA	cm^2	-0.44	0.19	-0.31	0.16	-0.85	0.30	-0.66	0.22
P8	mm	-0.09	0.19	-0.22	0.22	-0.03	0.17	-0.41	0.20
BCS	1-5 score	-0.50	0.19	-0.14	0.20	-0.70	0.29	-0.56	0.20

References

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Notes :