CSIRO PUBLISHING
The Rangeland Journal, 2016, **38**, 261–272
http://dx.doi.org/10.1071/RJ15093

Rangeland profitability in the northern Gulf region of Queensland: understanding beef business complexity and the subsequent impact on land resource management and environmental outcomes

Joe W. Rolfe[A,H], *Alison E. Larard*[B], *Bernard H. English*[A], *Emma S. Hegarty*[C], *Tim B. McGrath*[D], *Niilo R. Gobius*[E], *Joanne De Faveri*[A], *Joanna R. Srhoj*[F], *Michael J. Digby*[G] *and Richard J. Musgrove*[E]

[A]Queensland Department of Agriculture and Fisheries, Mareeba, Qld 4880, Australia.
[B]Agribusiness Consultant, Tolga, Qld 4882, Australia.
[C]Queensland Department of Agriculture and Fisheries, Cloncurry, Qld 4824, Australia.
[D]Queensland Department of Agriculture and Fisheries, Cairns, Qld 4870, Australia.
[E]Northern Gulf Resource Management Group, Mareeba, Qld 4880, Australia.
[F]Agribusiness Consultant, Mareeba, Qld 4880, Australia.
[G]NRM Spatial Hub, Yorkeys Knob, Qld 4878, Australia.
[H]Corresponding author. Email: joe.rolfe@daf.qld.gov.au

Abstract. The farm-gate value of extensive beef production from the northern Gulf region of Queensland, Australia, is ~$150 million annually. Poor profitability and declining equity are common issues for most beef businesses in the region. The beef industry relies primarily on native pasture systems and studies continue to report a decline in the condition and productivity of important land types in the region. Governments and Natural Resource Management groups are investing significant resources to restore landscape health and productivity. Fundamental community expectations also include broader environmental outcomes such as reducing beef industry greenhouse gas emissions. Whole-of-business analysis results are presented from 18 extensive beef businesses (producers) to highlight the complex social and economic drivers of management decisions that impact on the natural resource and environment. Business analysis activities also focussed on improving enterprise performance. Profitability, herd performance and greenhouse emission benchmarks are documented and discussed.

Additional keywords: business management records, business performance, equity and expansion, greenhouse gas emissions, herd performance, seasonal variability, stocking rate management, succession.

Received 15 September 2015, accepted 22 March 2016, published online 14 June 2016

Introduction

Beef production is the primary land use in the northern Gulf region of Queensland, Australia, with a total herd size of ~930 000 head (MLA 2011). There are ~180 commercial grazing businesses, covering an area of ~19.7 million hectares, turning off ~250 000 cattle annually with an estimated farm-gate value in excess of $150 million (based on a 27% turnoff ratio and mid-2015 average cattle prices of $600 head^{-1}). Producers in the region target the live export, slaughter and United States grinding beef markets. Many owners transport weaners to southern growing and fattening properties endeavouring to lift animal and enterprise performance. Seasonal variability, extreme weather events, depressed markets and government policy impact on business viability and reinforce the importance of adaptive business and property management.

Sustainable and profitable grazing strategies have clearly been demonstrated (Smith 2000; O'Reagain *et al*. 2014) and there is an abundance of grazing guides, packages and fact sheets available to assist extensive beef producers manage the grazing resource (Chilcott *et al*. 2003; McIvor 2010; O'Reagain and Bushell 2011; McIvor 2012). However, managing native pasture systems and stocking rates in a variable climate across large areas remains problematic for many producers. A regional study (consisting of 260 sites) recorded land condition and productivity decline on the majority of recognised grazing land types (Shaw *et al*. 2007). Loss of perennial pasture species and weed invasion were key land condition discounts for the high grazing value land types whereas native woodland thickening discounts were common on the low grazing value land types. Subsequent site evaluations continue to flag degradation of the resource and loss of landscape productivity (Gobius 2013).

Significant regional investment (~\$4 million) over the last decade in grazing management extension and infrastructure programs in the northern Gulf indicates rangeland condition is a major concern for natural resource management (NRM) groups and Government agencies. The wider community environmental expectations also include the reduction in beef enterprise greenhouse gas (GHG) emissions over the long-term (McAlpine *et al*. 2009). However, the immediate challenges at the enterprise level relate to business returns, low equity and seasonal pressures. According to McLean *et al*. (2014) the average beef enterprise in the region carries 5023 adult equivalents (AE = 450-kg steer at maintenance) on 70 875 ha. From 2001 to 2012 average profit (earnings before interest and tax) was \$24 AE^{-1} (gross income \$122 AE^{-1}, enterprise and overhead costs \$98 AE^{-1}). High female mortalities, poor reproductive performance and low annual liveweight gains are commonly recorded in the northern Gulf region (Henderson *et al*. 2013; McGowan *et al*. 2014). The decoupling of land values and enterprise productivity is at the core of the cost-price squeeze and industry profitability challenges (McCosker *et al*. 2010). Herd production efficiency in the region clearly impact significantly on total GHG emissions and GHG emissions intensity (emissions per tonne of liveweight sold) (Broad *et al*. 2011; Bray *et al*. 2014).

Ash and McIvor (2005) discuss the climatic, productivity, marketing and scale constraints to rangeland pastoral systems at an international level and detail the complex socioeconomic drivers behind decision making. A detailed analysis of beef business performance in the northern Gulf region was undertaken to better understand the complexities behind stocking rate and land management decisions. This paper reports on a whole-of-business approach used to analyse and benchmark profitability, herd performance and typical GHG emissions on 18 extensive beef businesses (producers) in the region. The project team used these analyses to assist producers to understand and resolve immediate enterprise issues surrounding budgeting, refinancing, succession, lender relationships, herd nutrition, infrastructure mapping, marketing, age of turnoff, grazing management, carrying capacity, destocking and potential production system changes. Finally, this paper will detail the socioeconomic and production extension framework that is necessary for NRM programs to positively influence rangeland condition and environmental outcomes.

Methods

Site description

The northern Gulf region of Queensland, Australia, lies between 15° and 19°S and 141° and 145°E and includes the Norman, Gilbert, Staaten and Mitchell River systems, all of which terminate in the Gulf of Carpentaria (Fig. 1). December–March rainfall, ranging from 500 to 1200 mm, is highly variable (CV = 34–45%). Although the region includes some large corporate enterprises, the project team primarily targeted family owned and operated beef businesses. This program was conducted from 2013 to 2015 and included business performance data from the previous five financial years (2008/2009–2012/2013).

Producer engagement

Initially beef industry, extension, farm management economic, business mentoring and spatial expertise was sourced and assembled through collaborative projects (Tropical Savanna Grazing, \$avannaPlan-Beef\$ense and Climate Clever Beef), which involved the Department of Agriculture and Fisheries, Northern Gulf Resource Management Group and NRM Spatial Hub. The consultant-mentor approach outlined by Coutts and Roberts (2003) was used with 29 families who each manage on average ~38 000 ha and ~2680 AE, with average business value approaching \$10 million. Initial on-property engagement focussed on identifying the immediate needs of the enterprise and a business analysis. The collation and analysis of property, grazing, herd, marketing, financial and business structure data were completed during subsequent property visits or through ongoing email and phone contact.

Property infrastructure mapping and grazing management

Project team members with Geographic Information Systems (GIS) and grazing systems expertise developed property maps for each business. The property maps included property infrastructure, water distribution, land types and development plans. Very high resolution (0.3–2.5 m) satellite imagery allowed each producer to identify and map fencing and stock water infrastructure. Grazing circles were customised for each property map based on proximity of water supplies, land types, topography and landholder development aspirations. Regional ecosystem mapping, agency land systems data and producer knowledge were combined to identify significant land types (soil, slope and vegetation associations) on each property. Customised GIS symbology was used to label property, paddock and infrastructure features unique to extensive beef operations. Property development options (pasture improvement, fencing, stock water, yards and access tracks) were identified and included as a spatial layer.

The property mapping process and paddock inspections supported debate in relation to land type productivity, land condition and grazing management. Landholder and delivery team experience was pooled to assign grazing capability values to each land type based on relative pasture biomass production, soil fertility and overall productivity. Photo-standards were used to assist each property management team in assessing pasture yields and land condition. The ABCD land condition framework (Chilcott *et al*. 2003) was presented including the impact of pasture composition, woodland thickening, weed invasion and declining soil surface condition on land type and paddock carrying capacities. Standard producer stocking rates for each land type, paddock and property were nominated and recorded. The estimated safe carrying capacities for each property were based on seasonal variability, water infrastructure, land type mix, land condition, demonstration and research trial data (Smith 2000; O'Reagain and Bushell 2011; O'Reagain *et al*. 2014) and Department of Agriculture and Fisheries grazing management expertise spanning five decades.

Herd performance and GHG emissions

Herd dynamics, productivity and annual turnoff information over 5 years was documented and analysed for each business.

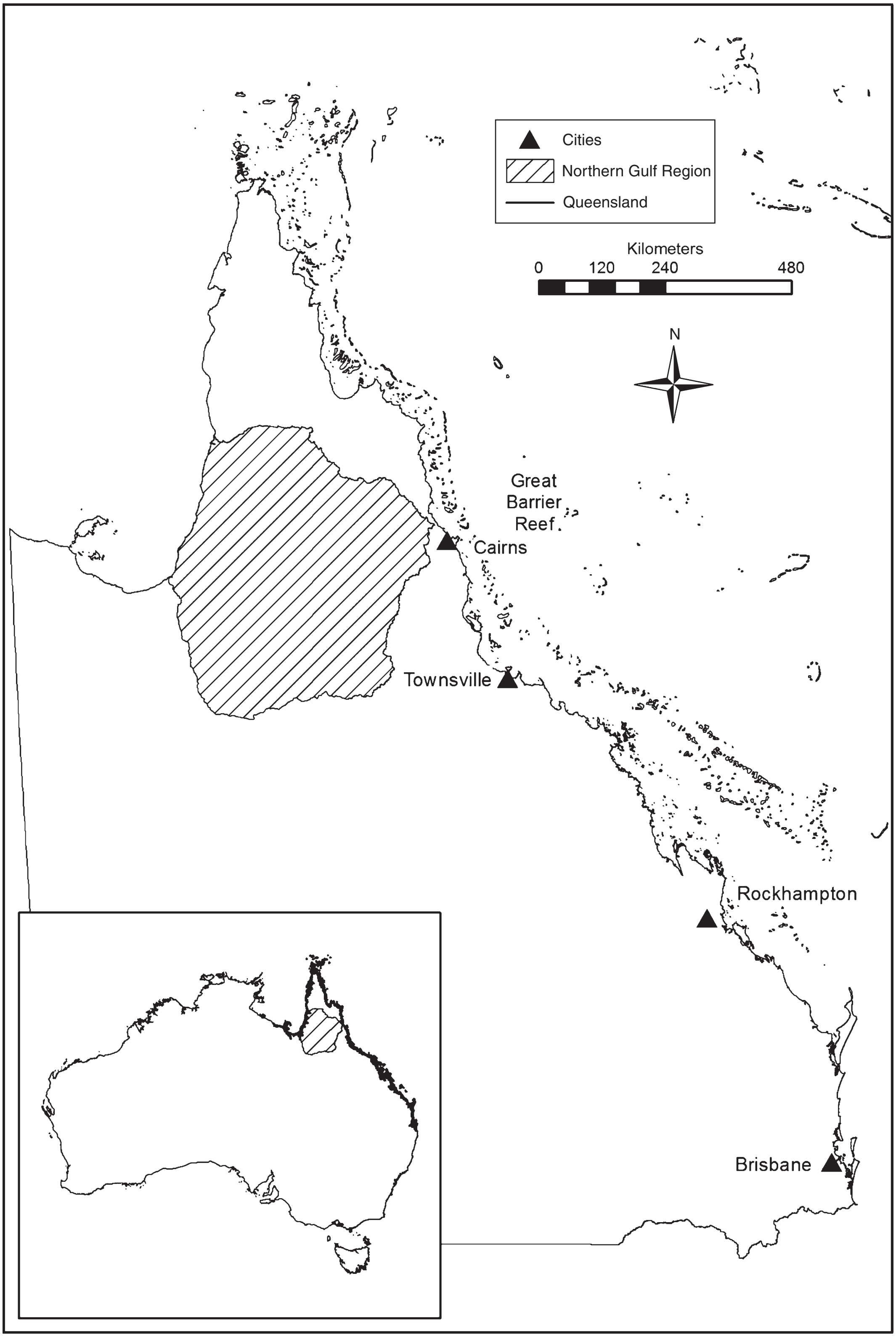

Fig. 1. Map showing the location of the northern Gulf region, Queensland, Australia.

Herd data were collated on-property where production records were readily accessible and close collaboration with the business owner was possible. Comprehensive herd recording systems are rare, but most beef producers document branding, weaner and sale numbers. However, branding and weaning records required close examination as double counting often occurred when larger weaners are branded and weaned simultaneously. Some businesses measure and understand average annual liveweight gains (kilograms per head per year) yet, the majority of producers rely on point of sale (live export, meatworks and saleyards) information to estimate weight gain performance. The delivery team closely examined property records, property locality, research results and land type productivity to estimate average annual liveweight gains (of growing cattle) for each business. The Breedcow and Dynama herd model (Holmes 2013) was used to build a likely herd structure where producer records were lacking. Herd analysis confined to individual years is often distorted by unplanned sales in response to cash flow or seasonal pressures. Therefore, 5 years of data were analysed to develop a steady-state overview of herd performance and turnoff.

Cattle classes analysed included weaners, heifers, steers, cows, spayed cows and bulls. Current and historical cattle numbers (actual and AE), productivity and age details for each class were collated for each business. This included mature breeder and heifer reproduction rates, annual liveweight gain of growing cattle and mortalities across all classes of cattle. The number of heifers retained to replenish the breeder herd and female sales as a percentage of total sales helped estimate female deaths across each beef operation. Bull joining percentages, annual bull costs and herd culling practices on age and temperament were established and documented. Veterinary, ear tags, hay and supplement direct costs were extracted from the on-property records or profit and loss statements and allocated against the relevant cattle classes. Herd management practices were recorded for each business including supplementation, weaning, breeder segregation, heifer management, stocking rates and frequency of musters.

The liveweight and market value of females at 6, 18, 30, 42 months as well as mature breeders (>48 months of age) was compiled. Male liveweight and market value data, based on this age stratification up to the maximum age of turnoff for a particular business, were also collected. The project team analysed producer records, transport permits and sales dockets to describe annual turnoff by sex, age, weight and gross price received. Cattle data were used to formulate herd performance indicators including: (i) weaning rates (%), (ii) growth rates, (iii) female sales as a percentage of total sales, (iv) gross margin per AE, and (v) AE carried per full time equivalent (FTE) employed in the business.

A subset of four breeding businesses within the study group was selected as case studies to benchmark enterprise GHG emissions. The case study properties represented a range of regional production efficiencies (weaning, growth and death rates) and turnoff ages. Cattle and enterprise data for each businesses were then processed using an excel version of the FarmGAS GHG emissions calculator (Australian Farm Institute 2015). FarmGAS outputs were tonnes of carbon dioxide equivalents (t CO_2e) per year, per AE and per tonne of liveweight sold from each business.

Business performance

On-property sessions with each business were conducted to discuss and analyse sensitive personal and financial information. Service agreements, signed by all parties, outlined the $avanna Plan-Beef$ense program's commitment to confidentiality. Signed permission forms also granted the project team direct access to financial and taxation records through the relevant accountant.

Initial 'kitchen table' discussions focussed on the overall operation, structure and financial position of each beef business. The operation was described in detail with most businesses relying on managers or family members to operate two or more properties, often located large distances apart. The business entities (trust, company, partnership or sole trader) within each operation were discussed and recorded. The financial records for each entity within the operation were amalgamated to gauge whole-of-business performance. The management roles of each family member and business assets were discussed to understand succession and asset transfer issues and pathways. Delivery team, rural lender and landholder expertise was pooled to itemise and value land, livestock, plant, equipment and off-farm assets. Total liabilities (overdrafts, term loans, chattel mortgages and personal borrowings), interest rates, interest payments and principal payments were recorded. The business equity ratio was established and financial position understood by the delivery and business management teams, and then used as a major determinant of follow-up activities.

Where business management records were absent the project team relied on financial statements (for annual taxation reporting) to standardise enterprise performance data. An Excel system was developed to analyse 5 years of financial data (2008–2013). The property and business identifiers, along with the herd and financial performance indicators total 25 variables (Table 1). To understand the complex business inter-relationships, these variables have been analysed by using a principal components analysis (PCA) and displayed in a biplot (Gabriel 1971). Table 1 lists and explains each variable.

Principal components analyses and associated biplot

To better understand the relationships between variables uncovered in the project, a PCA was undertaken. PCA defines new variables (principal components), which are linear combinations of the data variates, which are uncorrelated with each other and successively describe as much of the total variability in the data as possible. The aim is to reduce the dimension of a multivariate dataset into a smaller number of principal components in order to visualise and investigate the relationships between units.

The PCA took the 25 variables for the 18 extensive beef businesses (producers) and explained the variation between these measurements in a smaller number of dimensions. The values for each variable were standardised to allow an evaluation of the inter-relationships between variables. To display the property results and variables simultaneously, the first two

Table 1. A summary of the 25 variables analysed from the study group data (18 businesses), an explanation of each variable and the associated biplot abbreviations

Variable	Explanation	Abbreviations used in biplot (Fig. 2)
Number of properties per business	Number of properties owned and operated by each beef business (does not include agistment)	Properties
Full time equivalents (FTE) per business	Number of 40 h week^{-1} labour units working in the business, paid and unpaid	FTE
Family units per business	Often several generations or siblings involved	Families
Area of properties (ha)	Total area owned by each beef business	Area
Total business assets ($)	All land, cattle, equipment, vehicles, cash accounts used to operate the beef business	Assets
Total business liabilities ($)	All liabilities/debts owed by the business including overdraft, term loans, chattel mortgages and family loans	Debt
Annual interest rate (%)	Annual average interest rate charged on debt	Int_rate
Breeders per business (head)	Number of breeding aged females in the herd	Breeders
Total adult equivalents (AE) per business	An AE is a 450-kg steer at maintenance. Adult equivalents are used to standardise cattle numbers from varying herd structures	Herd_AE
Stocking rate to safe carrying capacity	Total adult equivalents per business divided by safe carrying capacity estimate based on seasonal variability, water infrastructure, land type mix, land condition, demonstration and research trial data and grazing management expertise	SR_to_CC
Cattle sales per year (head)	Total annual cattle sales	Sales
Average age of turnoff (months)	Average sale age of growing cattle	Av_age_T
AE per FTE	Number of standardised AE in herd per full-time labour unit	AE_FTE
Weaning rates (%)	Calves weaned from breeding age females in herd	Weaning
Estimated annual liveweight gain (kg head^{-1} year^{-1})	Weight gained per head annually	Ann_LWG
Female sales as portion of total sales (%)	The portion of the females that are not sold are an indicator of mortalities in the herd	F_Sales
Average sale price	Sale price head^{-1} achieved on average annually	Av_Sale
Average gross margin per AE	The margin that remains after herd costs are taken from income, compared with the number of cattle being run	GM_AE
Equity (%)	Net worth (total assets – total debt) compared with total assets	Equity
Return on assets (%)	Earnings before income and tax divided by total assets	ROA
Return on equity (%)	Earning before tax divided by owner's equity	ROE
Operating costs to income (%)	All operating expenses (herd/variable and overheads/fixed) divided by income	Op_to_Inc.
Finance cost to income (%)	Interest expense divided by income	Fin_to_Inc.
Debt to income ratio	Total debt divided by annual income	D_to_Inc.
Net worth per family	Total assets less total debt (net worth) per family in the business.	N_W_Family

principal components were used to construct the biplot in Fig. 2 (Gabriel 1971). A vector is drawn from the biplot origin (0.0) to each variable marker (arrowhead). The biplot gives an indication of how the variables are correlated with vectors (arrows) pointing in the same direction being highly positively correlated and those in the opposite direction being highly negatively correlated. Those perpendicular to each other have a zero correlation. Vectors extending furthest from the centre of the biplot identify variables that explain most of the variation in the data. The producers (labelled 1–18) are arranged on the biplot and this shows which producers have high values and the most influence on certain variables. The biplot presented in this paper was generated using the statistical package R (R Core Team 2015).

Results

Generally, all businesses appreciated the targeted on-property approach and embraced the whole-of-business analysis. The diverse skill base (extension, spatial, beef industry and business analysis) and collective expertise (87 years) of the delivery team was critical in building the trust and rapport necessary to collect and analyse sensitive family and financial information. As detailed in Table 2 the study group properties (39) from 18 beef enterprises, covered an area of 1.104 million ha and represented 29 families and 56 FTE. Most businesses operate a breeding enterprise in the Gulf and one or more finishing properties located outside the region. The combined assets and liabilities of the study group were in excess of $170 million and $54 million respectively. On average, each family had assets of $9.4 million and liabilities of $3 million. Low profitability and significant liabilities led to most businesses negotiating interest-only repayment terms with their respective lenders. At the time of analysis only two businesses were making regular principal and interest payments. The mean annual interest rate (fixed and variable) across the study group was 6.1%.

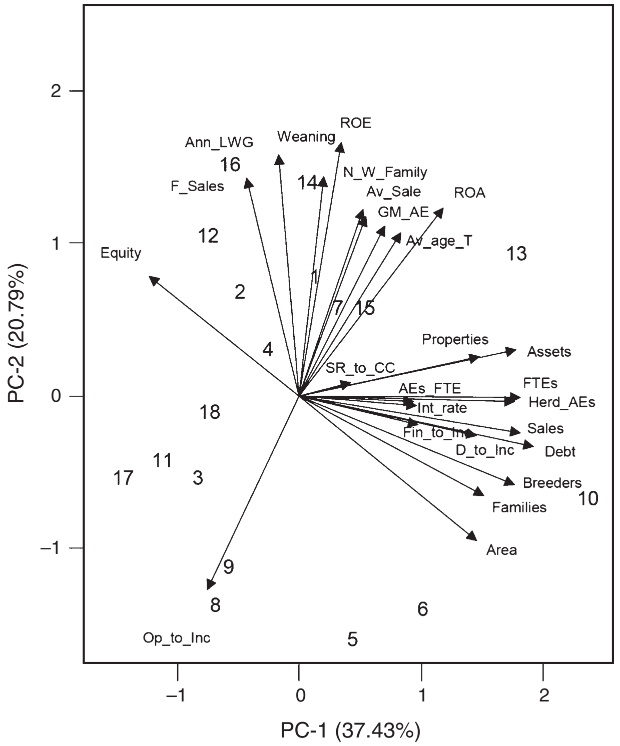

Fig. 2. Biplot analysis showing the inter-relationship between 25 productivity, financial and social variables analysed for the study group of 18 beef businesses in the northern Gulf region, Queensland, Australia. Axes are the first two principal components (PC). Variable abbreviations are explained in Table 1. Each grazing business (numbered 1–18) is also plotted to indicate association with the various variables.

Property infrastructure mapping and grazing management

The acquisition of very high resolution satellite imagery greatly improved the accuracy of property layout and infrastructure maps for each beef business. Producer knowledge and project team experience was combined to assign long-term carrying capacity values (ha AE^{-1}) to each land type. Water infrastructure attributes, permanency and grazing circles highlighted opportunities to improve grazing distribution through investment in stock water facilities. These spatial data were also used to assess the feasibility and affordability of property and pasture development options.

Property infrastructure and land type mapping underpinned the discussion and examination of wet season spelling and stocking rate strategies. In response to sustained seasonal pressures, and overstocking in many cases, the delivery team helped producers optimise sell-down strategies and better match cattle numbers with available feed and water. This included investigating the feasibility of agistment options (i.e. renting of pastures) to manage overgrazing, feed costs and breeder mortalities. Only six businesses had a systematic wet season spelling program in place over the previous 5 years. Average cattle numbers, as calculated across the previous 5 years, exceeded long-term carrying capacities on at least 12 of the 18 businesses analysed (Table 3). The cattle carried (AE) to safe carrying capacity ratio ranged from 1.2 to 1.9 on six businesses. One business had a very low stocking rate to safe carrying capacity ratio (0.6) due to the purchase of an additional understocked property. Total cattle numbers across the study group included 77 976 AE consisting of 45 000 breeders and growing cattle of mixed sex and age. The age and class of sale cattle was determined by the enterprise mix, property locality,

Table 2. Summary of enterprise, family and financial data for 18 extensive beef businesses located in the northern Gulf region, Queensland, Australia

Statistic	Number of properties per business	Full time equivalents per business	Family units per business	Total area (ha)	Total business assets ($)	Total business liabilities ($)	Annual interest rate (%)
Minimum	1	1.5	1	11 331	2 800 000	0	0
Maximum	6	7.8	4	213 422	31 911 630	12 000 000	6.77
Average	2.2	3.1	1.6	61 313	9 478 682	3 018 457	6.1
Total for all businesses	39	56	29	1 103 627	170 616 270	54 332 218	NA

Table 3. Summary of cattle number, cattle sales, turnoff age and stocking rate to safe carrying capacity ratio for 18 extensive beef businesses

Individual business data were the average of 5 years

Statistic	Breeders per business	Total adult equivalents (AE) per business	Stocking rate to safe carrying capacity ratio[A]	Cattle sales per year (head)	Average age of turnoff (months)
Minimum	368	690	0.6	132	8
Maximum	6500	14 309	1.9	4190	48
Average	2500	4332	1.1	1336	22
Total for all businesses	45 000	77 976	–	24 056	–

[A]Safe carrying capacity estimates were based on seasonal variability, water infrastructure, land type mix, land condition, demonstration and research trial data and grazing management experience.

land type productivity and marketing decisions. Although the average turnoff age for the study group was 22 months, the turnoff ages of growing cattle ranged from weaners (~8 months) to bullocks at 48 months.

Herd performance

A range of herd performance indicators, based on analysis over 5 years, were compiled. Enterprise scale and efficiency was highly variable with each FTE in the business managing between 460 and 2166 AE (Table 4). Weaning rates were $\leq$50% for eight businesses and ranged from 50% to 60% on three businesses. The remaining seven businesses had weaning rates >60%. Low annual liveweight gain (70–90 kg $head^{-1}$) was a major constraint for those production systems located solely in the northern Gulf savannas. Growing cattle on breeding businesses located on the more fertile soils (alluvial, basalt, red duplex and black soils) achieved average liveweight gains of 110 kg $head^{-1}$. Four businesses use pasture improvement on their Gulf breeding operations and/or finishing properties located outside the region to increase annual liveweight performance (120–150 kg $head^{-1}$).

Female sales, expressed as a percentage of total annual sales, were used as an indicator of death rates due to the inherent difficulty in measuring mortalities on extensive breeding enterprises. Missing females and/or high mortalities constrain sales income and female replacement on these businesses. The female sales were weak (<40%) for six of the businesses studied. Marginal female sales (40–44%) were recorded for eight businesses whereas female sales were strong ($\geq$45%) for four businesses. The lowest female sales (34%) and the highest (48%) indicate female losses (mortalities and missing) range from 3% to 9%. The 5-year average sale price of turnoff cattle was highly variable ($409–$1008) and was strongly influenced by seasonal conditions, weight for age and fluctuating cattle markets. Gross margin (GM) per AE, or cattle sales less direct costs, were wide ranging. Six businesses had GM <$100 AE^{-1} whereas GM per AE on nine businesses ranged from $105 to $137 AE^{-1}. The GM per AE on the remaining three businesses exceeded $159 AE^{-1}.

When particular herd productivity issues were identified, the delivery team helped producers examine: (i) cost-effective supplementation and production feeding programs, (ii) breeder and heifer segregation and management programs, (iii) the feasibility and affordability of on-property infrastructure projects and off-farm investments, (iv) the feasibility and profitability of establishing improved pastures, (v) suitable herd and financial record keeping systems appropriate to their production system, and (vi) cash flow budgets to identify income deficits when considering older age of turnoff.

Enterprise GHG emissions

Four case study properties were selected to feature the range of herd production systems and likely GHG emission scenarios in the northern Gulf including the Georgetown, Kidston and Mareeba districts (Table 5). Case study breeder herds varied in size (494–2870) and the range of weaning rates (46–67%) was similar to that of the larger study group. Breeder mortalities were similar in the Georgetown and Kidston areas, however high breeder losses recorded at Mareeba include both mortalities and 'missing cattle' due to wet season damage to boundary fencing. Annual liveweight gains in growing cattle ranged from 85 to 160 kg $head^{-1}$. Total GHG emissions ranged from 1764 to 5442 t CO_2e $enterprise^{-1}$. Herd and FarmGAS modelling GHG emission intensity estimates ranged from 11.7 to 23 t CO_2e t^{-1} liveweight sold or turned off (transferred from the property) annually.

Table 4. Summary of labour efficiency and herd productivity data for 18 extensive beef businesses
Individual business data were the average of 5 years

Statistic	Adult equivalents per FTE (AE FTE^{-1})	Weaning rates (%)	Estimated annual liveweight gain (kg $head^{-1}$ $year^{-1}$)[A]	Female sales as portion of total sales (%)	Average sale price ($)	Average gross margin per AE ($ AE^{-1})
Minimum	460	42	70	34	347	20
Maximum	2166	70	150	48	1008	207
Average	1397	56	101	41	629	116

[A]Estimate based on land type productivity, regional research/demonstration trials and sale data.

Table 5. Herd performance, turnoff (liveweight sold), total greenhouse gas (GHG) emissions and GHG emissions intensity for four breeding businesses in the northern Gulf region, Queensland, Australia (2011–2012)

Case studies	Total breeder number	Weaning rate (%)	Breeder losses (%)	Annual growth rate estimate (kg $year^{-1}$)	Liveweight sold (t)	Total GHG emissions (t CO_2e)	GHG emissions intensity (t CO_2e t^{-1} liveweight sold)
(1) Georgetown	1533	67	2–3	160[A]	406	4747	11.7
(2) Kidston	2870	57	3	110	411	5442	13.2
(3) Georgetown	1800	52	3–4	110	308	4380	14.2
(4) Mareeba	494	46	8	85	76	1764	23.2

[A]All male cattle and excess female fed basic silage ration for up to 60 days before feedlot consignment.

In the Mareeba case study, herd analysis and steady-state modelling compared bullock turnoff with a range of younger steer and weaner turnoff strategies (Table 6). Gross margins per AE steadily declined as turnoff age decreased, with weaner gross margin estimated to be nearly \$15 AE^{-1} behind the current bullock operation. Annual GHG emissions steadily decreased from 1764 t CO_2e $year^{-1}$ with the current bullock turnoff to 1525 tonnes if the production system moved to selling weaners However, emission intensity improved from 28.7 t CO_2e t^{-1} liveweight sold for weaner production to 23.2 t CO_2e t^{-1} liveweight sold for bullock turnoff.

Business performance

Key business performance and debt exposure benchmarks were established through a detailed analysis of profit and loss records (2008–2013) and close examination of business assets and borrowings (Table 7). The range of equity ratios (39–100%) of the study group reflect a complex assortment of family, property purchase, seasonal and decision making circumstances. Eleven businesses had equity levels below 75% while lender pressure was evident on three businesses with equity below 50%. Two business performance indicators, not including for the cost of borrowing, were calculated for each business. First, the average return on assets (ROA) was weak at less than 1%, with six businesses recording negative ROA (Table 7). Second, the mean operating cost to income ratio (income spent producing annual turnoff), was very weak at 80%.

In light of the recent increase in regional agricultural lendings (86% increase from 2003 to 2011: ABARES 2014) business ratios were developed to quantify how interest costs impacted on net profit. Mean return on equity (ROE) was approaching negative 1% and only eight businesses have positive ROE. The average finance costs to income, or how much income is spent on servicing interest payments, was very weak at 19%. Debt to income ratios, comparing borrowings to annual income, were weak (>2) on 12 businesses.

Calculating net worth per family (~\$4.0 million) was particularly useful for families undertaking succession, business restructuring or exit planning. The delivery team helped convene family meetings to improve communication, clarify roles and responsibilities and discuss pathways for asset transfer. In preparation for these meetings we also helped individual families examine the viability of business exit strategies including asset sales.

What drives business performance?

The biplot (Fig. 2) displays the results of the PCA plotting the first two principal components for 25 variables associated with 18 extensive beef businesses (producers). Table 1 explains the abbreviations used in the biplot. The first two principal components explain 58% of the total variation in the data. This relatively low proportion of variance reflects the complexity of the relationships among the measured variables.

The biplot reveals the inter-relationships between the variables. The most prominent inter-relationships were:

(i) A cluster (group) of related variables in the direction of PC1 (bottom right hand corner) in the biplot, include Properties, Families, Area, Breeders, Herd_AE, Sales, FTE, Debt, Assets, AE_FTE, Int_rate, Fin_to_Inc. and D_to_Inc. Many of these traits reflect the scale of an operation. The more properties in the business, the greater the asset base, the larger number of Herd_AE and breeders, and the more FTE and Families to run the business. The fact that debt-related variables (i.e. Debt, Int_rate, D_to_Inc., Fin_to_Inc.) are closely associated with the 'scale-related' variables, indicating that debt was the vehicle used to acquire assets and expand these businesses. SR_to_CC was shown as being correlated with this cluster, indicating that the bigger operators (those with scale) tend not to be running conservative stocking rates.

(ii) A second cluster of correlated variables can be observed in the direction of PC2 positioned either side of 0 (zero)

Table 6. Impact of five turnoff age options on gross margin, total greenhouse gas (GHG) emissions and GHG emissions intensity, as modelled for a breeding business at Mareeba

	4.5 years	3.5 years	2.5 years	1.5 years	Weaners
Total breeders mated	494	515	539	584	615
Gross margin for herd	\$65 393	\$58 900	\$54 514	\$43 767	\$40 979
Gross margin per AE ($\$AE^{-1}$)	\$65.39	\$58.90	\$54.51	\$43.77	\$40.98
Total GHG emissions (t CO_2e $year^{-1}$)	1764	1652	1587	1560	1525
GHG emissions/AE (t CO_2e AE^{-1})	1.76	1.65	1.59	1.56	1.53
GHG emissions intensity (t CO_2e t^{-1} liveweight sold)	23.2	23.2	24.6	26.6	28.7

Table 7. Summary of business financial performance indicators and net worth per family for 18 extensive beef businesses in the northern Gulf region, Queensland, Australia

Individual business data were the average of 5 years

	Equity (%)	Return on assets (%)	Return on equity (%)	Operating costs to income (%)	Finance cost to income (%)	Debt to income ratio[A]	Net worth per family (\$)[A]
Minimum Value	39	–1.25	–5.8	38	0	0	2 045 796
Maximum Value	100	3.7	2.76	106	50	6.3	13 047 322
Average	68	0.98	–0.69	74	19	2.8	4 037 641

[A]At the time of the on-property analysis.

on the PC1 axis. It includes F_Sales, Ann_LWG, Weaning and return on equity. The three 'industry-recognised' herd performance drivers of profitability include: weaning rates, mortalities (measured here as F_Sales) and annual average liveweight gain (Ann_LWG). The biplot results show some correlation between these three variables and return on equity.

(iii) A third correlated cluster in the direction of PC2 and in the positive quadrant for both PC1 and PC2 (top right hand corner) includes N_W_Family, Av_Sale, GM_AE, Av_age_T, and ROA. Higher average sale prices, higher gross margin per adult equivalent and higher average age of turnoff are all indicative of better returns.

(iv) The longer the vector (arrow) the more variation is explained by that variable. Hence, ROE, ROA, Assets, Debt, Breeders, Op_to_Inc., Equity and Ann_LWG explain a similar degree of variation. Conversely, SR_to_CC (marker close to origin of biplot) explains less of the variation between producers.

(v) Equity appears negatively correlated with the traits of the first cluster (i), particularly Area, Families and Breeders (located at opposing positions on the biplot), again related to the bigger operations having lower equity in their business as their scale is financed by debt.

(vi) Op_to_Inc. appears negatively correlated with variables of the third cluster (iii). This suggests that operations with higher operating costs may have lower GM_AE and some effect on return on assets and return on equity.

(vii) Numerous zero or close to zero correlations (perpendicular lines) are indicated on the biplot. One interesting result is between AE_FTE and return on equity, suggesting minimal relationship between profitability and labour efficiency among the group analysed.

(viii) The biplot shows which producers have high values of certain variables. Producer 10 has high Assets, high Properties, high FTE, high Herd_AE, high Sales, high Debt and low Equity. Producer 16 has high F_Sales and high Ann_LWG whereas producers 8 and 9 have high operating costs that negatively impacts on their GM_AE.

Discussion

Approach

The purpose of this study was to explore how business complexity, performance and profitability influence environmental management decisions. The consultant-mentor approach, used by an experienced multi-disciplinary team, proved effective in engaging producers and understanding the business, production and personal intricacies of each enterprise. This study comprised 10% of the commercial beef businesses in the region with a further 27 beef businesses to be analysed by June 2016. Preliminary data provide a clear insight into the diversity and complexity surrounding extensive beef businesses in the northern Gulf of Queensland. The study group data included 25 variables and the analysis suggests multiple factors drive these production systems.

Managing the complex bio-physical components of extensive beef businesses is challenging for most beef producers. Paddock and property stocking rates are a key strategy for producers to manage variability in rainfall and annual forage production. The collaborative on-property mapping process focussed on helping producers understand and manage variability. Very large paddocks are commonplace, with attendant difficulties in controlling and managing fire and grazing distribution. Managing preferential grazing is also problematic with diverse land types in each paddock. Paddock topography, wet season access and flooding can greatly constrain management options. Proposed on-line GIS systems (e.g. NRM Spatial Hub) will enable producers to efficiently update map layers and use associated GIS tools to better manage seasonal variability and/or infrastructure failures.

Spatial innovations to assist in managing this complexity are developing rapidly and include: (i) digital elevation models to identify impact of topography/slope on effective grazing distances of livestock, (ii) sub-metric resolution imagery (~3 m) to remove guesswork and improve positional accuracy of infrastructure and landscape features, (iii) paddock carrying capacity models based on stock water (permanency and distance), land types and land condition, (iv) strategically locating proposed water points in under-utilised areas and using a GIS model to measure the effect on paddock carrying capacities, (v) a dataset of 893 native fauna species from which species expected to be found within a particular property boundary can be determined, (vi) a model determining 30-year trends in paddock woody thickening based on a 'Persistent Green' GIS dataset and, (vii) 30-year trends in paddock fractional ground cover to help producers identify areas of concern and improve stocking rate management.

Profitability, equity and expansion

Low profitability resulted in a decline in routine repairs and maintenance of fencing and water infrastructure for most study group businesses. Detailed property infrastructure and land type maps helped producers identify land condition decline, water distribution issues, development plans and grazing management options. However, new infrastructure investment has been negligible with cash deficits accumulating across all study group businesses.

Only one-third (6) of the businesses studied actively manage stocking rates, and routinely spell significant areas each wet season. The high (92%) average equity observed in this subgroup suggests healthy equity levels are a key driver of conservative grazing strategies; however, it would be naïve to suggest that every producer with high equity levels would automatically have better grazing management practices.

Study group operational efficiency (AE managed per FTE) does not appear closely linked with profitability. Herd production efficiency was generally low across the study group, which aligns with the regional herd performance data presented by Henderson *et al.* (2013) and McGowan *et al.* (2014). Generally the three industry-recognised drivers of profitability include weaning, mortality and growth rates. Our data indicate ROA and ROE are closely correlated with these herd performance indicators i.e. female sales (mortalities), weaning rates and annual liveweight gain. There was also a negative relationship between operating costs to income and gross margin per AE. Higher operating costs can reduce ROA where producers invest heavily in lifting herd performance without achieving a financial gain.

Low profitability and poor business equity pressures on producers also appear to drive overstocking for many properties. In some cases the project team found it difficult to engage producers in destocking and land management decisions when financial and lender pressures were 'front of mind'. Where low equity was a concern the delivery team spent considerable time helping producers understand their current business position and develop debt-servicing strategies. Financial and herd performance ratios were also presented to assist producers in understanding the link between their decision making and overall business performance. In addition, given the complicated set of trading entities established for succession and taxation purposes, most families also found profit and loss data difficult to interpret. Consequently, Profit and Loss (PandL) data were seldom used by producers as a business analysis tool. As a step in the resolution of this issue customised business analysis spreadsheets were provided to assist management teams track business position and performance more closely.

Businesses purchasing additional property 5–10 years ago, without the financial reserve to adequately fund the strategy, are now marking time and are in a poor financial position. Successful expansion plans have included: (i) properties with grass biomass reserves and good land condition, (ii) financial reserves to accommodate unplanned delays in turning off sale cattle, (iii) business exit plans built in as flexibility, (iv) a detailed analysis of the cost per beast area related to average district productivity levels, and (v) careful planning based on conservative estimates of seasonal variability, liveweight gain, stocking rates, prices, costs, long-term interest rates, replacement of equipment and living costs.

The study group data suggest that scale does not always equate to profitability. The 18 businesses analysed include operations varying in size from \$2.8 million to \$31 million, with widely varying business returns. In many cases, scale was funded by debt, with inadequate research and questionable logic pervading this decision making. Over the past 15 years the decoupling of land values and enterprise productivity and profitability has resulted in numerous examples of failed beef business expansions. Scale does not appear to relate to safe equity thresholds. Based on the study group, cattle price, return on assets (<1%) and interest rates (~6%) data, safe equity thresholds were developed for beef businesses in the region. Medium-scale businesses with a ~\$10 million breeding and finishing asset require at least 75% equity to comfortably service principal and interest payments. Data from the smaller beef breeding operations (\$4–5 million) within the study group suggest the safe equity level at this scale is 85–90%.

Generally the findings of this study concur with many of the conclusions drawn by McLean *et al*. (2014). Losses are common for northern Australian beef producers and the average ROA is very poor at less than 1%. Negative ROE is also common where debt levels are high and businesses incur significant interest costs. Breeder productivity (weaning and death rates) and heavier sale weights are recognised profit drivers for the northern beef industry. However, significant points of difference between this study and the McLean *et al*. (2014) study relate to the impact of business scale and labour efficiency on business performance. In contrast to McLean *et al*. (2014) our study group data suggest scale (often funded through debt) and operational efficiency (AE managed per FTE) does not closely link with profitability measures including ROA and ROE.

Greenhouse gas emissions

Identifying current GHG emissions and validating change in herd GHG emissions is difficult due to the scale of northern breeding enterprises and poor herd performance records. Branding, growth and death rates are not only the key production drivers of any breeding business, but directly influence total GHG emissions as well as GHG emissions intensity. Case study modelling suggests that total GHG emissions reduction would only be possible if stocking rates and sales were reduced, which is likely to significantly impact business profitability unless loss of income is adequately offset by GHG emissions reduction payments, which is unlikely (Cullen *et al*. 2016; Walsh and Cowley 2016). Based on herd and FarmGAS modelling, the GHG emissions intensity from Australian Gulf breeding enterprises ranged from 11.7 to 23 t CO_2e t^{-1} liveweight sold or transferred off the property. Improving emissions intensity provides opportunities to increase production efficiency, increase profitability and improve the GHG emissions impact. The Australian Government's methodology determination made on 9 September 2015 (Carbon Farming Initiative – Beef Cattle Herd Management; Hunt 2015) provides an opportunity for extensive beef producers to participate in the Emissions Reduction Fund carbon market initiative. However, property scale and compliance costs will be an issue for many businesses (Cullen *et al*. 2016; Walsh and Cowley 2016).

Working and living together

Working and living together in remote locations adds another degree of complexity and tension within many grazing operations. The 29 families in the study group face a variety of succession, asset transfer and rural family communication issues. These succession issues were further exacerbated by poor business returns and low equity. Many family operations survive by sourcing poorly remunerated family labour. These people often take a view that rather than receiving wages they will eventually receive equity in the business. The more successful operations have a member of the management team who is the 'business manager'. They focus as much on the management accounting issues as taxation compliance. These business managers exhibit financial control and endorse 'business management' as a key proviso of succession.

Summary

This project has improved our understanding of the complex relationships between profitability, productivity, decision making and sustainable resource management. Producers running extensive beef businesses face a complex mix of biophysical, productivity, family and financial challenges. It is inherently difficult for each family to successfully manage such large scale (~38 000 ha) and diverse grazing landscapes in a variable climate. Inadequate fencing and water infrastructure constrains rotational wet season spelling to improve land condition. Low profitability and debt servicing pressures make pasture improvement and the installation of additional infrastructure unaffordable for most businesses. Breeder management and weaning options are also limited by poor paddock infrastructure and lack of improved pastures.

Regional land condition surveys clearly indicate that grazing and stocking rate management continue to impact on rangeland condition and productivity. Financial pressures appear to drive high stocking rates and land condition decline. The decision to hold over cattle sales while prices are low further degrades natural resources. There appears to be limited acceptance that matching stock numbers to long-term carrying capacities is good business. Generally, every producer experiences the same seasonal pressures. However, producers in this study who manage low rainfall years by selling-down or accumulating grass reserves appear to be in control and under less stress. Most beef businesses studied were run by two families. Families who are living, working and are in business together face a unique set of challenges. Succession issues can place an enormous financial strain on a beef business, which often translates to overstocking.

Regional NRM group and government (state and federal) investment demonstrates the community unease with the environmental impacts of the grazing industry such as rangeland condition decline and GHG emissions. Yet poor business returns, low equity and seasonal pressures dominate producer decision making at the enterprise level. Grazing and stocking rate management appear to be low priorities in this business environment; nevertheless, improving herd management practices and production efficiency seem synonymous with improved livestock emissions intensity and profitability.

The decline in rangeland condition is highly visible to extension and scientific agencies as well as the broader community. However, land degradation is largely ‘unseen’ by many producers operating within a market structure that offers no incentives for good land stewardship. Perhaps the emphasis on pasture composition, woodland thickening, soil surface condition and weeds dilutes the message that conservative stocking rates help producers manage seasonal variability. A practical ‘grass = options’ philosophy may enable regional NRM programs to better connect with beef producers operating complex production systems within a volatile market and climate setting. Overgrazing, although rational for those maximising current earnings to ensure short-term survival, often occurs at the expense of maintaining the long-term productivity and capital value of the resource.

Using the $avannaPlan-Beef$ense approach to service northern Gulf beef producers, could be perceived to be an expensive process when compared with other extension models. The reality, however, is much different given that (i) with each client we are influencing a significant land and asset base (a typical beef producing family in the region owns and manages over 38 000 ha and operates a $9.5 million business), and (ii) the benefits are tangible and take into account the complexity of these businesses. The $avannaPlan-Beef$ense approach provides the skills and knowledge that are necessary to run complex beef cattle businesses, profitably. Producers need to recognise the need for better business management practices and actively improve their skills to be successful in the modern business environment.

Successful extension programs in the future will include a mix of delivery methodologies. The on-property consultant-mentor approach is effective in engaging beef-producing families and improving financial, production and NRM outcomes. Programmed and group-based learning (Coutts and Roberts 2003) will also continue to be a key component of regional beef extension programs. However, group-based methodologies alone are not suitable to analyse the biophysical, financial and social complexities of a particular business.

Beef extension programs must identify and explore the key issues impacting on the short-term survival of each business. Individual business constraints, once understood, ensure NRM discussions are both well timed and within the context of the production system, financial position and family situation. Beef extension officers must examine and understand enterprise complexity and personalise forward plans to positively influence business prosperity and subsequent land condition. Self-help online property infrastructure mapping platforms need to evolve to further assist producers manage complex and challenging bio-physical systems. Understanding the business position often clarifies the reasons behind grazing management and stocking rate decisions and dictates the direction and feasibility of extension services provided.

This study highlighted the inherent difficulty in designing and funding whole-of-business beef research programs that mimic the real world scale, landscape, productivity and financial components of an extensive beef enterprise. Although research can focus on understanding and improving components of the business, it is inherently difficult to analyse wealth creation based on long-term overgrazing and regular acquisition and sale of properties. On-property research demonstrating practical herd recording systems are needed to compliment future extension programs. Weaning, death and growth rates are the recognised profit drivers for northern beef producers but these herd productivity parameters are poorly recorded and understood. Without accurate herd performance indicators beef producers will continue to find it difficult to lift productivity and profitability. The cost effectiveness of electronic tagging of cattle and maintaining detailed herd records needs to be evaluated in extensive northern breeder herds. Accounting for changes in annual cattle numbers and performance will enable producers to better target decision making and improve business performance.

Acknowledgements

We thank the Northern Gulf Resource Management Group, the Queensland Department of Agriculture and Fisheries and the Australian Department of Agriculture for funding these projects. We would also like to thank the northern Gulf families for their hospitality and willingness to share their personal business and financial information.

References

ABARES (2014). ‘Regional Farm Debt: northern Queensland gulf, south west Queensland and north western New South Wales.’ (Australian Bureau of Agricultural and Resource Economics and Sciences, the Australian Bankers’ Association and the National Farmers’ Federation: Canberra.) Available at: www.agriculture.gov.au/abares (accessed 9 July 2015).

Ash, A. J., and McIvor, J. G. (2005). Constraints to pastoral systems in marginal environments. *In*: 'Pastoral Systems in Marginal Environments. Proceedings of a Satellite Workshop of the XXth International Grassland Congress'. 3–6 July 2005, Glasgow, Scotland. (Ed. JA Milne.) pp. 17–20. (Wageningen Academic Publishers: The Netherlands.)

Australian Farm Institute (2015). FarmGAS Calculator ST and Financial Tool. Available at: www.farminstitute.org.au/calculators/farm-gas-calculator (accessed 19 June 2015).

Bray, S., Walsh, D., Rolfe, J., Daniels, B., Phelps, D., Stokes, C., Broad, K., English, B., Ffoulkes, D., Gowen, R., Gunther, R., and Rohan, P. (2014). 'Climate Clever Beef: On-farm Demonstration of Adaptation and Mitigation Options for Climate Change in Northern Australia.' Final report B.NBP.0564. (Meat and Livestock Australia: North Sydney, NSW.)

Broad, K. C., Bray, S. G., English, B. H., Matthews, R. A., and Rolfe, J. W. (2011). Adapting to beef business pressures in the Gulf. *In*: 'Proceedings of the Northern Beef Research Update Conference'. 2–5 August 2011, Darwin, NT. (Eds R. Dyer, R. Holroyd, J. King, J. Kyte and T. Schatz.) p. 176. (North Australia Beef Research Council: Park Ridge, Qld.)

Chilcott, C. R., McCallum, B. S., Quirk, M. F., and Paton, C. J. (2003). 'Grazing Land Management Education Package: Workshop Notes – Burdekin.' (Meat and Livestock Australia: North Sydney, NSW.)

Coutts, J., and Roberts, K. (2003). Extension Models and Best Practice in Extension. In: 'Invited paper, APEN Extension Conference'. 26–28 November 2003, Hobart, Tas. Available at: http://dev.couttsjr.com.au/wp-content/uploads/2013/03/apen2003couttsja.pdf (accessed 11 August 2015).

Cullen, B. R., Eckard, R. J., Timms, M., and Phelps, D. G. (2016). The effect of earlier mating and improving fertility on greenhouse gas emissions intensity of beef production in northern Australian herds. *The Rangeland Journal* **38**, in press.

Gabriel, K. R. (1971). The biplot graphic display of matrices with application to principal component analysis. *Biometrika* **58**, 453–467. doi:10.1093/biomet/58.3.453

Gobius, N. R. (2013). 'Developing the Northern Gulf and Cape York Peninsula Land Condition EcoAccounts – Initial Findings: Land Heath Check 2011–2012.' (Northern Gulf Resource Management Group: Georgetown, Qld.)

Henderson, A., Perkins, N., and Banney, S. (2013). 'Determining property-level rates of breeder cow mortality in Northern Australia.' Final Report B.NBP.0664. (Meat and Livestock Australia: North Sydney, NSW.)

Holmes, W. E. (2013). Breedcow and Dynama Herd Budgeting Software: A Manual of Budgeting Procedures for Extensive Beef Herds. Version 6.' (Department of Agriculture, Fisheries and Forestry: Brisbane, Qld.)

Hunt, G. (2015). 'Carbon Credits (Carbon Farming Initiative – Beef Cattle Herd Management) Methodology Determination.' (Australian Government, Department of Environment: Canberra, ACT.)

McAlpine, C. A., Etter, A., Fearnside, P. M., Seabrook, L., and Laurance, W. F. (2009). Increasing world consumption of beef as a driver of regional and global change: A call for policy action based on evidence from Queensland (Australia), Colombia and Brazil. *Global Environmental Change* **19**, 21–33. doi:10.1016/j.gloenvcha.2008.10.008

McCosker, T., McLean, D., and Holmes, P. (2010). 'Northern Beef Situation Analysis 2009.' Final Report B.NBP.0518. (Meat and Livestock Australia: North Sydney, NSW.)

McGowan, M., McCosker, K., Fordyce, G., Smith, D., O'Rourke, P., Perkins, N., Barnes, T., Marquart, L., Morton, J., Newsome, T., Menzies, D., Burns, B., and Jephcott, S. (2014). 'Northern Australian Beef Fertility Project: CashCow.' Final Report B.NBP.0382. (Meat and Livestock Australia: North Sydney, NSW.)

McIvor, J. (2010). 'Enhancing adoption of improved fire and grazing management practices in Northern Australia: Synthesis of research and identification of best bet management guidelines.' Final Report MLA B.NBP.0579. (Meat and Livestock Australia: North Sydney, NSW.)

McIvor, J. (2012). 'Sustainable Management of the Burdekin Grazing Lands – a Technical Guide of Options for Stocking Rate Management, Pasture Spelling, Infrastructure Development and Prescribed Burning to Optimise Animal Production, Profitability, Land Condition and Water Quality Outcomes.' (Queensland Government, Department of Agriculture, Fisheries and Forestry: Brisbane, Qld.)

McLean, I., Holmes, P., and Counsell, D. and Bush Agribusiness and Holmes & Co. (2014). 'The Northern Beef Report (2013 Northern Beef Situation Analysis).' Final Report B.COM.0348. (Meat and Livestock Australia: North Sydney, NSW.)

MLA (2011). 'Cattle numbers – as at June 2011. Natural resource management region.' (Meat and Livestock Australia: North Sydney, NSW.) Available at: www.mla.com.au (accessed 2 March 2016)

O'Reagain, P. J., and Bushell, J. J. (2011). 'The Wambiana Grazing Trial – Key Learnings for Sustainable and Profitable Management in a Variable Environment.' (Queensland Government, Department of Employment, Economic Development and Innovation: Brisbane, Qld.)

O'Reagain, P. J., Scanlan, J. C., Hunt, L. P., Cowley, R. A., and Walsh, D. (2014). Sustainable grazing management for temporal and spatial variability in north Australian rangelands – a synthesis of the latest evidence and recommendations. *The Rangeland Journal* **36**, 223–232. doi:10.1071/RJ13110

R Core Team (2015). 'R: A Language and Environment for Statistical Computing.' (R Foundation for Statistical Computing: Vienna, Austria) Available at: www.R-project.org/ (accessed 24 August 2015)

Shaw, K. A., Rolfe, J. W., English, B. H., and Kernot, J. C. (2007). A contemporary assessment of land condition in the Northern Gulf region of Queensland. *Tropical Grasslands* **41**, 245–252.

Smith, D. R. (Compiler) (2000). 'Northern Stocking Rate Demonstration.' Final Report on NHT 962011. (Department of Primary Industries and Fisheries: Brisbane, Qld.)

Walsh, D., and Cowley, R. (2016). Optimising beef business performance in northern Australia: what can 30 years of commercial innovation teach us? *The Rangeland Journal* **38**, in press.