SPECIAL ISSUE: AAAS CONFERENCE 2022 | RESEARCH PAPER
https://doi.org/10.1071/AN21422

ANIMAL PRODUCTION SCIENCE

Can a return to small ruminants increase profitability and drought resilience in the semiarid rangelands of northern Australia?

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Handling Editor:
David Innes

Received: 20 August 2021
Accepted: 8 November 2021
Published: 14 December 2021

Cite this:
Bowen MK and Chudleigh F (2022) *Animal Production Science*, **62**(10–11), 975–982.
doi:10.1071/AN21422

ABSTRACT

Context. The semiarid rangelands of northern Australia have high climate variability and a history of suffering periodic severe droughts. To remain viable, livestock businesses in the rangelands need to build resilience to climatic and market variability by regularly producing a profit and increasing wealth. **Aims.** Our aim was to use the farm-management economics framework to conduct a contemporary assessment of the profitability and resilience of alternative livestock enterprises in the semiarid rangelands of northern Australia. **Methods.** Livestock options were examined for a constructed, hypothetical property representative of the central-western Queensland rangelands (16 200 ha; long-term carrying capacity 1071 adult equivalents). First, the profitability of beef cattle, wool sheep, meat sheep and meat goat enterprises was assessed in a steady-state analysis using herd or flock budgeting models. Second, farm-level, partial discounted cash-flow budgets were applied to consider the value of integrating or fully adopting over time several of the alternative enterprises from the starting base enterprise of either a self-replacing (1) beef cattle herd or (2) wool sheep flock. **Key results.** In the steady-state analysis of existing enterprises, meat sheep and rangeland meat goat enterprises produced the greatest rate of return on total capital (3.9 and 3.7% per annum respectively). The operating profit, of all self-replacing herds or flocks, was most sensitive to meat prices. Where full investment in a wild dog exclusion fence around the boundary of the property, and some refurbishment of existing infrastructure, was required to convert from beef to small ruminant production, the investment increased the riskiness and indebtedness of the overall enterprise. This was the case even when the long-term operating profit of the property could be substantially improved, e.g. by a change to rangeland meat goats (extra A$45 700 profit/annum). **Conclusions.** Existing small ruminant enterprises in the semiarid rangelands of Queensland are profitable and resilient alternatives, based on contemporary prices. However, when changing from the predominant beef cattle enterprise, and incurring significant capital costs to do so, financial risk is substantially increased, which has implications for property managers. **Implications.** The farm-management economics framework should be used by individual grazing businesses for their specific circumstances, to support decision-making.

Keywords: beef cattle, extensive grazing systems, farm-management economics, goats, meat, modelling, rangeland management, sheep, wool.

Introduction

In the semiarid rangelands of northern Australia, large intra- and inter-annual rainfall variability, including periods of severe drought, creates challenges for the viability of grazing businesses (O'Reagain and Scanlan 2013; LongPaddock 2020; Bowen and Chudleigh 2021*d*). Clearly, grazing businesses in the rangelands need to regularly produce a profit and build capital so as to maintain resilience through environmental challenges, variable commodity prices, and the long-term declining trend in terms of

trade (ABARES 2019). The semiarid rangelands of Australia, including western Queensland, were historically dominated by Merino wool sheep enterprises that were recognised as well-suited to, and resilient in, this environment (Johnston *et al.* 1990). However, a long-term decline in sheep numbers has occurred across Australia, and most dramatically in Queensland, during the past six decades due to a decline in the economic competitiveness of the wool industry (ABS 2021; Chudleigh 2021). Current sheep numbers in Queensland are the lowest since records began in 1885 (1.2 million head; ABS 2021), with wool sheep being largely replaced by beef cattle. Nevertheless, there is currently renewed interest in small ruminant production in the semiarid rangelands of western Queensland due to recent improvement in the profitability of sheep and goat meat production, relative to beef production, and also industry and government initiatives to support the construction of wild dog exclusion fencing.

We have previously demonstrated the value of the farm-management economics framework to assess alternative management strategies for impact on profit and financial risk, and thus to support decision-making (Bowen and Chudleigh 2021*c*). The objective of the present study was to use the farm-management economics framework to conduct a contemporary assessment of the profitability and resilience of alternative livestock enterprises for a hypothetical grazing property in central-western Queensland, as an example of the semiarid rangelands of northern Australia.

Materials and methods

Approach to economic evaluation

The farm-management economics framework was applied at the property level to assess alternative livestock enterprises for profitability and resilience. This framework is described by Bowen and Chudleigh (2021*c*) and follows the principles outlined by Makeham (1971), Makeham and Malcolm (1993) and Malcolm *et al.* (2005). The Breedcow and Dynama (BCD) herd budgeting software (Holmes *et al.* 2017) was used to conduct analyses for beef cattle enterprises. We developed models similar to those in the BCD software to assess small ruminant enterprises. Using these tools, beef, sheep and goat enterprises were modelled individually or as components of a mixed rangelands enterprise. All dollar values were in Australian currency as at the year 2020. All returns were calculated in real terms rather nominal, that is, inflation was not accounted for in the analysis.

Steady-state analysis of established enterprises

Regionally representative models were developed for the following enterprises: (1) a self-replacing (SR) beef cattle herd, (2) steer finishing, (3) a SR Merino wool flock, (3) Merino wether sheep, (4) a SR meat sheep flock, and (5) a SR rangeland meat goat herd. Biological and economic values derived from available published data, and from surveys and discussions with producers, were applied within the herd or flock budgeting models to identify the relative profitability of established beef cattle, wool sheep, meat sheep, and meat goat enterprises in steady-state analyses.

The economic criteria were the operating profit and the rate of return on total capital. The operating profit was calculated as follows: operating profit = (total receipts − variable costs = total gross margin) − overheads. The rate of return on total capital was calculated as the operating profit expressed as a percentage of the average capital employed for the annual period. The calculation of livestock gross margin was simplified in the steady-state modelling approach as a change in inventory value does not occur.

Implementing alternative enterprises

Partial discounted cash-flow budgets constructed with an annual timestep were applied to assess the value of integrating or fully adopting several of the alternative enterprises, over a transition period of 24 months, from the starting base situation of either a SR beef cattle herd or a SR Merino wool flock. The scenarios examined were (1) full conversion from a SR beef cattle herd to (1a) a SR Merino wool sheep flock, or (1b) a SR rangeland meat goat herd, or (2) partial conversion from a SR Merino wool sheep flock to 50% SR Merino wool sheep flock and 50% SR rangeland meat goat herd. These change scenarios were considered as examples most relevant to property managers in the region. The economic and financial effect of implementing alternative enterprises was assessed by a marginal comparison to the starting base enterprise over an investment period of 30 years. Changes in herd or flock structure, labour, capital and the implementation phase were included in the investment analysis.

The economic criteria were the net present value (NPV) at the required rate of return (5%; as the real opportunity cost of funds to the producer) and the internal rate of return (IRR). The NPV represents the addition to the investors' current wealth above or below that which they would gain if they invested the capital involved in an alternative that earned at the real discount rate applied and the IRR indicates the return on extra capital invested. The NPV was calculated over the 30-year life of the investment, expressed in present-day terms at the level of operating profit. An amortised (hereafter, annualised) NPV was calculated at the discount rate over the investment period to assist in communicating the difference in returns between the baseline property and the property after the alternative livestock enterprise was implemented. The financial criteria were peak deficit in cash flow, the number of years to the peak deficit, and the payback period in years. Peak deficit was calculated assuming interest was paid on the deficit and compounded for each additional year in the investment period. The

payback period was calculated as the number of years taken for the cumulative present value to become positive.

Representative (base) property

A hypothetical, constructed property, as described by Bowen *et al.* (2021), was established to be representative of the central-western rangelands near Longreach, as an example of a semiarid rangelands environment. The representative property, herd and flock characteristics were informed by recent industry surveys and research relevant to the region (McIvor 2010; Bray *et al.* 2014; McGowan *et al.* 2014) as well as the expert opinion of scientists, extension officers and local producers gathered during discussions held in 2020. The property closely followed that described by Scanlan and McIvor (2010) and Scanlan *et al.* (2011) and was 16 200 ha of primarily native pastures growing on land types characteristic of the region. The property was assumed to start in land condition B (Scale A–D; Quirk and McIvor 2003), in accord with regional survey data (Beutel and Silcock 2008), with 69% perennial grasses in the pasture. The long-term stocking rate, informed by pasture growth modelling (GRASP; McKeon *et al.* 2000; Rickert *et al.* 2000) and experienced local livestock producers, was 1071 adult equivalents (AE), or 9000 dry sheep equivalents (DSE). Grazing pressure equivalence between livestock species was determined according to the recommendations of McLennan *et al.* (2020) where an AE or DSE rank is assigned to a grazing animal as the ratio of its metabolisable energy (ME) requirements for a particular level of production to that of a 'standard animal'. The standard animal for all species was defined as having zero weight change, walking 7 km/day on level ground and consuming pasture of 55% dry matter digestibility (7.75 MJ ME/kg DM). A standard bovine animal, representing one AE, was defined as a 450-kg, 2.25-year-old *Bos taurus* steer requiring 73 MJ ME/day. A standard ovine or caprine animal, representing one DSE, was defined as a 45-kg wether sheep or goat, with no fibre growth above that included in maintenance, requiring 8.7 MJ ME/day. This corresponded to a 1:8.4 ratio of AE:DSE.

For the steady-state analysis of established small ruminant enterprises, the assumption was made that exclusion fencing and ongoing wild dog control was already in place. To convert from one enterprise to another, investment in additional infrastructure was required to make the change. To convert from a SR beef cattle herd to a SR Merino wool sheep flock or a SR rangeland meat goat herd, investment in a wild dog exclusion fence around the boundary of the property was A$435 000 (A$8000/km). In addition, it was assumed that investment required to refurbish internal property infrastructure was A$250 000 for conversion to sheep and A$135 000 for conversion to goats. Partial conversion of a SR Merino wool sheep flock, with existing wild dog exclusion fencing, to a mixed sheep flock and rangeland meat goat herd was assumed to require investment of A$135 000 to remediate internal fences and facilities.

Representative livestock enterprises

Key performance and price assumptions are given in Table 1. All SR herd and flock enterprises were breeding and growing activities that relied on the production of weaners by breeding females. For each SR herd or flock, the optimal (most profitable) age of female culling (sale), and the optimal male sale age and weight, were determined. Optimising algorithms embedded in BCD accounted for flock/herd structure and price interactions and maintained equivalent grazing pressure. The SR beef cattle enterprise was based on *B. indicus* crossbred cattle. The steer finishing enterprise involved annual purchase of weaner *B. indicus* crossbred steers (6 months of age, 180 kg liveweight) for growing out and sale as slaughter steers at finishing weights (the optimum sale target). The SR Merino wool sheep activity had an average greasy wool production of 3.61 kg/head.annum. Two types of Merino wether enterprise were assessed, with shearing frequency of either every 8-months (i.e. six times in 4 years) or every 12 months. Wethers were purchased as 2-tooth sheep, kept for 4 years, and sold off-shears. Average wool production for wethers was 6.98 and 5.59 kg/head.annum for 8-month shearing and 12-month shearing respectively. The SR meat sheep enterprise was representative of a breed such as the Australian White composite, with no shearing or crutching required. The SR rangeland meat goat herd was assumed to receive basic levels of management input that included the following: (1) weaner bucks were not castrated but were separated until sale, and (2) weaner does were separated from bucks until yearling mating. The expected future sale price for meat for all enterprises (Table 1) was estimated from long-term, published price data (MLA 2019), with modification to match expectations of experienced, local property managers. Wool quality and price for all Merino enterprises were based on data for the Northern Market AWEX Wool Indicator (AWEX 2019). However, expected future wool prices (Table 1) were adjusted down to reflect the recent price fluctuations of 2020, in accord with the expectations of the collaborating producers.

Results

Steady-state analysis of established enterprises

The property-level, steady-state analysis of discrete livestock enterprises run on the representative property indicated substantial differences among enterprises in profitability, at the same level of grazing pressure and management, with a range in rate of return on total capital of 0.58–3.9%, and a range in annual operating profit of A$39 801–A$285 487

Table 1. Underlying assumptions and modelled property-level returns, expressed as the annual operating profit and the rate of return on total capital, for alternative enterprises on a representative property in the rangelands of central-western Queensland.

Key parameters required for calculation of property-level returns	Enterprise scenario						
	Beef cattle		Merino wool sheep			Self-replacing meat sheep	Self-replacing rangeland meat goats
	Self-replacing herd	Steer finishing	Self-replacing flock	Wethers (8-month shearing)	Wethers (12-month shearing)		
Weaning rate (%)	72	–	67	–	–	114	122
Breeder mortality rate (%)	4.3	–	4.0	–	–	2.0	5.0
Average herd mortality rate (%)	2.5	4 (first 2 years), then 2	3.2	3.5	3.5	1.6	3.1
Male liveweight gain, post weaning (kg/head.annum)	139	139	27	11	11	41	28
Male sale age (months) and, in parentheses, liveweight (kg)	44 (620)	44 (620)	20 (43)	48 (61)	48 (61)	9 (53)	13 (39)
Target market for males	Slaughter	Slaughter	Yearlings	Mutton	Mutton	Slaughter	Slaughter
Expected average meat price for male and female sales (A$/kg carcass weight)	$5.15	$5.28	$5.98[A]	$3.80	$3.80	$6.46	$6.00
Assumed greasy wool price (A$/kg)	–	–	$7.99	$7.94	$7.94	–	–
Net livestock sales (A$)	$373 431	$635 977	$347 340	$206 831	$206 831	$552 471	$480 741
Net wool sales (A$)	–	–	$294 892	$445 698	$356 558	–	–
Husbandry costs (A$)	$12 615	$1645	$174 678	$115 459	$89 040	$9535	$6651
Average husbandry costs (A$/head)	$8.90	$0.96	$15.44	$12.97	$10.00	$1.07	$0.56
Net bull, steer, ram or buck replacement (A$)	$10 000	$251 807	$26 000	$265 098	$265 098	$58 000	$4000
Gross margin (A$)	350 816	382 525	441 554	271 972	209 251	484 937	470 090
Fixed costs and labour (A$)	$87 500	$87 500	$97 500	$92 500	$87 500	$97 500	$102 500
Plant replacement allowance (A$)	$21 950	$21 950	$21 950	$21 950	$21 950	$21 950	$21 950
Allowance for operator's labour and management (A$)	$60 000	$60 000	$80 000	$65 000	$60 000	$80 000	$70 000
Operating profit (A$)	**181 366**	**213 075**	**242 104**	**92 522**	**39 801**	**285 487**	**275 640**
Rate of return on total capital	**2.4%**	**2.8%**	**3.3%**	**1.3%**	**0.58%**	**3.9%**	**3.7%**

[A]The value of young ewes sold as replacement stock is included in this average price.

(Table 1). The SR meat sheep and rangeland meat goat enterprises produced the greatest rate of return on total capital (3.9% and 3.7% respectively), followed closely by SR wool sheep (3.3%). Steer finishing, or a SR beef cattle herd, produced intermediate returns (2.8% and 2.4% respectively), while wether wool production enterprises produced the lowest returns (1.3% and 0.58% for 8- or 12-month shearing intervals respectively).

Sensitivity analysis for a range of key production and cost parameters indicated that operating profit was most sensitive to meat price for the SR beef cattle herd, Merino wool flock, meat sheep flock, and rangeland meat goat herd. A ±20% change in meat price resulted in ±43%, 31%, 41% and 36% changes in operating profit for the beef, wool, meat sheep and rangeland meat goat enterprises respectively. Similarly, a ±20% change in meat price for the Merino wether enterprise (with 8-month shearing) resulted in a change in operating profit of ±48%. However, for this latter enterprise, the operating profit was most sensitive to wool price and annual wool production, with ±20% change in these parameters resulting in ±98% and ±96% change in operating profit respectively. The SR Merino wool flock enterprise had a lesser sensitivity than did the wether enterprise to these changes of ±20% wool price and annual wool production, i.e. ±25% and ±24% change in operating profit respectively.

Production and cost parameters, other than sale prices of meat and wool, had much smaller effects on property operating profit. A change in growth rate or weaning rate of ±5% resulted in a change of operating profit in the range of ±1–6%. Similarly, a change in mortality rate of ± 50% resulted in a change within the range ±2% (meat sheep) to ±8% (beef cattle and Merino wool sheep). A change in husbandry costs of ±20% caused changes in operating

profit within the range of ±0% for rangeland meat goats to ±14% for Merino wool sheep. A change in fixed costs for the property of ±20% resulted in changes in operating profit within the range of ±7% for meat sheep and rangeland meat goats, to ±10% for beef cattle.

Implementing alternative enterprises

Table 2 shows the modelled change in marginal returns (NPV and IRR) and the financial risk (peak deficit, years to peak deficit and payback period) due to implementing alternative enterprises for the starting base property operated as either a (1) SR beef cattle herd or (2) SR Merino wool sheep flock. Where full investment in a wild dog exclusion fence around the boundary of the property, and refurbishment of existing infrastructure, were required to facilitate a shift from beef cattle production to small ruminant production, the investment substantially increased the riskiness and indebtedness of the overall enterprise, as indicated by the substantial peak deficits and payback periods. This occurred even when the long-term profitability and resilience of the property could be substantially improved by the change to rangeland meat goat production, i.e. additional A$45 700 profit/annum, but a 12-year payback period (Table 2). Converting from a SR Merino wool sheep flock to 50% rangeland meat goats with investment in goat infrastructure decreased profitability of the property by A$6500/annum.

Discussion

The present study has provided insights into the contemporary relative profitability and resilience of livestock enterprise alternatives suited to semiarid rangelands of northern Australia. Clearly, the prices and costs applied in this analysis were highly dependent on current and past market circumstances and the necessary assumptions about initial property resources and infrastructure. Furthermore, the lack of published data on the biology of meat sheep and meat goat production in these environments necessitates caution in extrapolating the results. It is advisable that the framework demonstrated in this analysis be applied to individual properties, wherever possible, to assess the most appropriate investment strategies and enterprise mix for each set of circumstances and resources and to consider the goals of individual producers. Despite these limitations, the present study provides important insights to inform decision-making, as well as demonstrating the value of using the farm-management economics framework.

A broad conclusion from the property-level, steady-state analysis was that the profitability of discrete livestock enterprise, with comparable grazing pressure and standards of management, could differ considerably. The small ruminant enterprises, when run as SR flocks or herds of meat sheep, rangeland meat goats, or wool sheep, produced the greatest returns on total capital, ranging from 3.3% to 3.9%. These returns are up to 1.6 times those for SR beef cattle herds that currently predominate in these rangelands of Queensland (ABS 2021; Chudleigh 2021). The greater profitability of small ruminant enterprises under contemporary cost-price structures indicates that partial or full restocking with small ruminants may be an attractive option for existing beef producers in these rangelands, during recovery from drought. However, an important constraint for existing beef enterprises, when changing to

Table 2. Profitability and financial risk of implementing alternative livestock enterprises for a representative property in the rangelands of central-western Queensland.

Strategy	NPV of change (A$)	Annualised NPV (A$)	Peak deficit (with interest) (A$)	Years to peak deficit	Payback period (years)	IRR (%)
Convert from self-replacing beef herd to self-replacing Merino wool sheep flock, including investment in exclusion fencing and some internal infrastructure	−$311 400	−$20 300	−$1 637 500	20	n/c	3.0
Convert from self-replacing beef herd to self-replacing rangeland meat goats, including investment in exclusion fencing and some internal infrastructure	$702 300	$45 700	−$681 900	3	12	13
Convert from self-replacing Merino wool sheep to 50% wool sheep and 50% rangeland meat goats, including investment in goat infrastructure	−$99 500	−$6500	−$419 500	20	n/c	1.8

Note: NPV is the net present value of an investment, referring to the net returns (income minus costs) over the 30-year life of the investment and represents the extra return added by the management strategy, i.e. it is the difference between the base property and the same property after implementation of the strategy. The annualised NPV represents the average annual change in NPV over 30 years resulting from the strategy and can be considered as an approximation of the change in profit per year. Peak deficit is the maximum difference in cash flow between the strategy and the base scenario over the 30-year period of the analysis. It is a measure of riskiness. Payback period is the number of years it takes for the cumulative present value to become positive. Other things being equal, the shorter the payback period, the more appealing the investment. IRR is the internal rate of return, i.e. the rate of return on the additional capital invested. It is a discounted measure of project worth.
n/c, not able to be calculated.

small ruminant production, is the requirement for wild dog exclusion fencing and suitable internal infrastructure to allow management of small ruminants. In the steady-state analysis, the assumption was made that suitable infrastructure was already in place for all enterprises, including for small ruminants.

The analysis of implementing alternative enterprises indicated that where the property was initially a beef enterprise, but required investment to construct an exclusion fence and refurbish internal infrastructure to implement sheep or goat enterprises, the relative profitability of the property could be improved over the long term through conversion to a meat goat enterprise, but not to wool sheep. Although profitable over the long term, an important constraint, on the change from beef to goat production, was the level of debt required (–A$681 900 peak deficit) and the long interval (12 years) before the property was expected to be back to the same financial position as that without change. This financial risk makes a change from beef production a challenging proposition for property managers where the high costs of wild dog exclusion fencing must be funded in the absence of government subsidies. Similar results have been observed for conversion of a SR beef herd to rangeland meat goats in the mulga lands of south-western Queensland (A$48 300 extra profit/annum, 14-year payback period; Bowen and Chudleigh 2021*b*).

Our analysis of rangeland goat production systems was designed to estimate the performance and profitability possible when goats were managed to prevent overutilisation of the pasture resource. Such overutilisation can occur in commercial property situations due to high reproductive rates (122% weaning rate in this analysis), and also possibly greater drought resilience and survival than for other livestock species due to the more flexible diet and better ability to select for diet quality (Hacker and Alemseged 2014). The present analysis applied a sufficient rate of sale of surplus goats so as to maintain (and avoid increasing) equivalent grazing pressure on the pasture compared with other livestock enterprises. Our estimate of the number of goats able to run on the constructed property was conservative, due to the greater use of browse by goats than by other species (Hacker and Alemseged 2014; Pahl 2019). Thus, the relative profitability of the rangeland meat goat enterprise may be underestimated in our analysis, given the likelihood that a greater stocking rate (than that assumed in our analysis) may be sustainably applied.

The profitable outcome when the beef enterprise was converted to rangeland meat goat production, but not to Merino wool sheep, is heavily dependent on the following two assumptions: (1) the lower capital adjustment to convert to goats than to wool sheep, and (2) the relative and absolute price of goat meat being maintained over the longer term. We did not examine a change from a beef enterprise to a meat sheep enterprise. However, since the profitability of the meat sheep was similar to that of meat goats (3.9% cf. 3.7% rate of return on total capital), and similar infrastructure would be required, it could be anticipated that results for a change from beef to meat sheep would be similar to that for goats. This would be the case, providing the capital value of meat sheep, relative to goats, remained similar to that assumed in this analysis. The poor investment performance of the conversion from a SR Merino wool sheep flock, to a mixture of meat goats and wool sheep, is due mainly to the small difference in the expected returns of goat and wool sheep enterprises. The opportunity cost of the extra capital required for goat infrastructure was greater than the extra return generated by the combined enterprises.

In the present study, the greater returns from the steer finishing enterprise than from the SR beef cattle herd (2.8% cf. 2.4% rate of return on total capital) is in agreement with scenario analysis for the northern downs region of Queensland where conversion from a breeding to a steer turnover enterprise generated an additional A$62 500/annum (Bowen and Chudleigh 2021*c*). Furthermore, the steer turnover enterprise may have additional benefits in increasing drought resilience due to increased flexibility to sell steers in response to poor seasons and to restock in drought recovery. Wether wool production produced the lowest returns (1.3% and 0.58% for 8-month or 12-month shearing intervals respectively) that were substantially less than for the SR Merino wool flock (3.3%). This was largely due to lower meat prices for mutton than for sale of cull surplus ewes for the SR flock, the wool price, and the trading costs associated with the wether enterprises.

An important insight from the sensitivity analysis was the low importance, for operating profit, of increasing weaning and growth rates for each of the livestock species. The low sensitivity of operating profit to these production parameters is further exacerbated by the ‘costless’ nature of change in a sensitivity analysis, i.e. the cost involved in achieving any change in production is not included in the analysis. As an investment of labour and/or capital is generally required to improve production parameters, this would reduce the economic impact of the level of response estimated in the sensitivity analysis. Therefore, implementing strategies to improve weaning and growth rates are not likely to have a large, positive effect on profitability. From an economic perspective it would be better to focus on low-cost strategies that maintain these two factors, and mortality rates, at their present levels. This finding is in contrast to the commonly held paradigm that addressing these production limitations and improving outputs will lead to increased economic performance (e.g. McLean and Holmes 2015). For example, there has been considerable recent interest in improving reproductive performance of livestock in the rangelands, particularly by reducing fetal and calf/lamb/kid loss (McGowan *et al.* 2014; Allworth *et al.* 2017; Robertson *et al.* 2020). Clearly,

an increase in production does not always result in a profitable outcome at the property level. This is in accord with the established principle that the most profitable level of output occurs when marginal costs almost equal marginal revenue, but never when production is maximised (Malcolm *et al*. 2005).

An additional outcome of the sensitivity analysis was to demonstrate the capacity of a SR wool sheep flock to moderate the year-to-year variation in returns due to fluctuations in meat price. In general, there is a trend for the increases and decreases in the prices for sheep, beef and goat meat, to occur together. A component of the operating profit derived from wool sales will reduce the variation in operating profit compared with enterprises where all income from the business was derived from meat sales. Such benefits to business resilience from diversifying the enterprise mix have been discussed by Buxton and Smith (1996) and Freebairn (2019). However, the benefits clearly have to be balanced against the requirement for additional capital investment to achieve diversification.

In the present study, the biological parameters required as inputs for the analysis were derived from empirical data and expert opinion of experienced local producers, scientists and extension officers. The production parameters assumed for each livestock enterprise were intended to represent the long-term, average expectation for this region. However, there is an obvious challenge in adequately accounting for the high annual rainfall variability that occurs in this region, given limited published data. Regardless, the parameters adopted in this analysis are considered adequate to provide a broad understanding of the opportunities and outcomes of implementing alternative livestock enterprises. Our experience was that the conversation with industry participants to describe what the 'best-bet' parameters might be, that adequately capture the variability likely to be experienced by the representative property and livestock enterprise, is a key component of model development. We concluded that the learning and shared understanding of industry participants, that resulted from the discussion to set appropriate values for the key parameters, was much more valuable than was focusing on a modelling process to describe and capture the expected full range of variability of outcomes that can be difficult to communicate to industry.

In conclusion, the present study has indicated that, at contemporary costs and prices, small ruminant enterprises are profitable and resilient alternatives to the predominant beef cattle enterprise in the semiarid rangelands of central-western Queensland. However, implementing a complete or partial change from an existing beef enterprise may involve substantial financial risk where considerable capital investment is required to make the change. This finding emphasises the importance of applying an appropriate and thorough farm-management economics framework for individual producers that incorporates consideration of their unique combination of circumstances, skills and goals to support decision-making.

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Data availability. The majority of the data that support this study are available from the final project report (Bowen and Chudleigh 2021*a*), which is available online at https://futurebeef.com.au/projects/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/. Additionally, the herd and flock models used in the analysis can be obtained from the authors upon request.

Conflicts of interest. Maree Bowen is an Associate Editor of *Animal Production Science*, and Publications Committee Chair for the Australian Association of Animals Sciences 2022 Conference and the special journal issue, but was blinded from the peer review process for this paper. The authors have no further conflicts of interest to declare.

Declaration of funding. This study was co-funded by the Department of Agriculture and Fisheries, Queensland, and the Queensland Government Drought and Climate Adaptation Program (DCAP 2) as part of project DAF 6.

Acknowledgements. We particularly thank the following producers who made a significant contribution to the development of this analysis: Mike Pratt, David Counsell, Scott Counsell, Colin Forrest, and Cam and Jenny Lindsay. The authors have also benefited from discussions and input provided by many research, development and extension specialists within the Queensland Government.

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