Intensification of extensive livestock systems using irrigated forages or hay – a bioeconomic modelling approach

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Abstract
Despite its intuitive appeal, there is very little irrigated hay or forage production in the extensive rangelands of northern Australia used for beef cattle production. There are many reasons for this, including: constraints related to lease tenure conditions; difficulty and expense of obtaining regulatory approval for irrigation development; differing skills and capacity amongst the pastoral workforce; and the economic viability of growing irrigated hay or forage.

Theoretically, the use of irrigated hay or forage production would allow pastoralists (ranchers) more options for marketing cattle: meeting market liveweight specifications for cattle at a younger age; meeting the specifications required for different markets than those typically targeted by cattle enterprises; and providing cattle which meet market specification at a different time of the year. Forages and hay may also allow graziers to implement management strategies, such as early weaning or weaner feeding, which should lead to flow-on benefits throughout the herd, including increased reproductive rates.

We used a bio-economic model (CLEM, Crop Livestock Enterprise Model) to investigate the financial and production implications of growing forages for both hay production and for ‘stand and graze’ systems in the Victoria River catchment of the Northern Territory (NT). Predicated on the average annual utilisation rate of native pasture being kept constant, the use of irrigated hay or forages allowed a higher number of breeder cattle to be maintained. Total income, liveweight gain per animal, and total beef production increased with the use of irrigation. However gross margins were typically higher for the base enterprise, i.e. without irrigation. An analysis of NPV (Net Present Value) which considers the capital cost of development as well as the annual costs, suggested that irrigated forages and hay were only viable when the capital cost of development was low and the price of beef was high.

Introduction
The majority of catchments in northern Australia contain little intensive agricultural development, such as for cropping. Extensive beef cattle grazing (pastoralism) is the dominant agricultural land use and there is very little

development of surface water or groundwater resources, except for domestic use or to supply drinking water for livestock. However, there is recent interest, and research and development, aimed at investigating options to use these water resources more intensively (Moore et al., 2021).

The Victoria River catchment of the NT covers approximately 82,400 km^2 and about 62% is used for pastoralism (Petheram et al., 2024). The majority of property sizes are between 2,000 and 4,000 km^2 (Cowley 2014). Carrying capacity estimates range (depending on range condition) from a maximum of 12.5 to 23.0 AE/km2 (AE = Adult Equivalent, a 450 kg dry cow) on basalt-derived cracking clay soils to a low of 0.5 AE/km^2 on sandy and gravelly soils in poorer condition (Pettit, undated).

The predominant beef production system is a cow-calf operation with sale animals turned off at weights to suit the live export market. About 78% of all cattle across the broader region were Brahman, with about another 17% being Brahman derived (Cowley 2014). The majority of properties surveyed ran between 15,000 and 20,000 head of cattle. The majority of cattle (68%) were bred for live export with 22% bred to be transferred and grown-out elsewhere, often on properties which are part of the same aggregated agricultural business.

Feed quality of native pasture declines in the dry season, and cattle struggle to maintain weight during this period. To counter this, a commonly held view within the northern cattle industry is that the development of water resources would allow irrigated forages and hay to be integrated into existing beef cattle enterprises, thereby improving their production and potentially, their profitability. Ideally, production would increase by allowing cattle to reach minimum selling weight at a younger age and allowing for greater weight gain during the dry season when animals on native pasture alone either lose weight, or gain very little weight. There are also potential benefits to the reproductive capacity of the herd by providing better nutrition to young females. Finally, the addition of forages and hay should allow more cattle to be carried, while still maintaining a constant average utilisation rate of native pastures. However, despite this, there are very few examples across northern Australia of beef enterprises integrating irrigation into the business.

Methods

A bio-economic modelling approach was taken using CLEM (Liedloff et al., 2024). The model is a more sophisticated improvement of an earlier model but retains the core principles of a whole-property dynamic simulation which links feed availability, animal performance, management operations and business performance (Ash et al., 2015).

Simulations included: a base enterprise with no supplemented feed; a base enterprise in which weaners were supplemented with hay bought on the open market (common practice within the industry); stand and graze options for both forage sorghum and lablab and; hay produced on-farm from both forage sorghum and Rhodes grass. Forages or hay were fed to all cattle which were weaned and less than 24 months old during the period from June to October (or June to September for the shorter growing season lablab). Excess hay was sold into the open market. Selling months were May and September/October. All male cattle (not including bulls) were sold once they had reached a minimum liveweight of 280 kg. The bottom 30% of females (as a proportion of normalised weight) were sold at a minimum liveweight of 280 kg while the model dynamically balanced breeder numbers at each sale date with further sales where required. The maximum breeder numbers were set for the period of the model run so as to maintain an average annual utilisation rate of 20% (cattle offtake of native pasture equal to 20% of native pasture growth, averaged across years), as recommended by Walsh and Cowley (2014) and in the Land Condition Guide of Pettit (undated) for clay soils. A limited sensitivity analysis was performed by considering LOW, MED (Medium) and HIGH beef prices. Gross margins, profit (as EBITDA earnings before interest, taxes, depreciation and amortisation) and NPV (net present value, which captures the capital costs required for irrigation development) were considered. The number of breeders on properties in the Victoria catchment is typically higher than the number modelled here, due to large output file sizes from CLEM's individual animal modelling. The herd size (and subsequent results) could be scaled by a factor of around 10 to reflect this (notwithstanding economies of scale in such scaling) but the raw modelled results are presented here. Further detail of the enterprise set-up and modelling assumptions are provided in Webster et al., (2024).

Results

Irrigated forages and hay increased the total liveweight of cattle sold and weaning percentages (Table 1). Gross margins were higher under the two baseline enterprises, reflecting the high variable costs associated with growing irrigated forage and hay, although the decision to irrigate becomes more attractive at HIGH beef prices. At MED beef prices, EBITDA was highest for the Rhodes grass option – profitability is highly sensitive to the cost of the irrigation options and the area of irrigation required to provide sufficient feed for each cohort. The NPV analyses showed that none of the irrigated options had a positive NPV. A significant proportion of the animal production increases at the property scale were due to increased number of breeders which could be carried when irrigated forages or hay were included in the feedbase. The estimated capital cost of development was between AUD $1.3 million and $8 million, depending on scenario and cost per ha of development.

Cattle fed irrigated forages or hay increased their rates of growth compared to the two baseline options. This meant that sale weight was reached at a younger age (Table 1). At the extreme, nearly 79% of the cohort of male cattle between 8 and 12 months old were sold in October under both hay options while none of the same cohort were sold then under the two baseline options. The majority of these cattle were sold in the following May, contributing to the stocking rate over the wet season.

Discussion

Despite the intuitive attractiveness of introducing irrigation to extensive beef cattle enterprises, very little is practiced in northern Australia. While animal production benefits can be obtained, both the initial capital outlay and ongoing costs of intensified development preclude it being a viable option – unless graziers are able to operate under a lower cost structure than modelled here, or have patient capital. In addition the enterprise would need to develop, or buy in, the additional expertise and knowledge required to run a successful irrigation enterprise of that scale. This is a constraint recognised by graziers elsewhere in northern Australia (McKellar et al 2015) and almost certainly contributes to the lack of uptake of irrigation in northern Australia. Specialist hay production is another option, but largely occurs now outside of the extensively grazed rangelands.

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Table 1 Production and financial outcomes from the different irrigated forage and beef production options for a representative property in the Victoria River catchment. Cattle were sold twice per year in all options. Cattle were sold in May for all options. Cattle were sold in September for the two base-enterprises and for lablab stand and graze. Cattle were sold in October for forage sorghum stand and graze and the two hay options.

	BASE-ENTERPRISE	BASE-ENTERPRISE PLUS HAY	FORAGE SORGHUM – STAND AND GRAZE	FORAGE SORGHUM – HAY	LABLAB – STAND AND GRAZE	RHODES GRASS – HAY
Forage/hay	None	Bought hay	Forage sorghum	Forage sorghum	Lablab	Rhodes grass
Maximum number of breeders	2050	2100	2230	2380	2290	2788
Mean of herd size (AE) across calendar year	2525	2553	2943	3084	2999	3094
Average annual pasture utilisation (%)	20.1	20.1	20.1	20.1	20.0	20.1
Weaning rate (%)	59.2	60.4	62.6	64.6	63.8	64.6
Mortality rate (%)	6.8	6.8	6.6	6.3	6.2	6.2
Percentage of 'one year old castrate males' (i.e. 8 to 11 months or 8 to 12 months old) sold in September or October	0.0	0.0	8.8	78.4	62.8	78.9
Percentage of 'one and a half year old castrate males' (i.e. 15 to 19 months old) sold in May	77.5	86.8	79.4	20.3	27.6	19.9
Percentage of 'two year old castrate males' (i.e. 20 to 23 months or 20 to 24 months old) sold in September or October	9.1	6.7	11.8	1.3	9.7	1.2
Percentage of 'two and a half year old castrate males' (i.e. 27 to 31 months old) sold in May	13.4	6.6	0.0	0.0	0.0	0.0
Liveweight sold per year (kg)	343,106	351,446	415,624	468,346	443,607	471,258
Gross margin ($/AE) (LOW BEEF PRICE)	133	120	-6	103	30	115
Profit (EBITDA) ($) (LOW BEEF PRICE)	72,596	40,766	-282,084	52,172	-173,157	91,099
Gross margin ($/AE) (MED BEEF PRICE)	219	206	79	171	119	183
Profit (EBITDA) ($) (MED BEEF PRICE)	288,753	262,178	-32,710	262,928	93,007	303,166
Gross margin ($/AE) (HIGH BEEF PRICE)	305	294	164	239	208	252
Profit (EBITDA) ($) (HIGH BEEF PRICE)	504,910	487,103	216,664	473,683	359,172	515,232

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