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Testing virtual fencing for the sustainable management of north Australian rangelands: Impacts on beef cattle grazing behaviour, pasture resource, and cattle production.

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Key words: Adaptive grazing; grazing distributions; perennial pastures

Abstract
The selective grazing behaviours of cattle frequently lead to degradation of selected areas. Virtual fencing (VF) will be tested to control cattle spatial grazing distributions in extensively managed herds in northern Australia. If VF can successfully be used to change spatial grazing pressure, this would allow for increased rest for preferred areas and improved utilisation of less preferred areas that would otherwise have limited productive value. This will likely improve land condition, carrying capacity, and drought resilience. If successful, VF could be an important tool for management of grazing impacts to increase production and achieve a variety of environmental goals in the extensive systems of northern Australia.

Introduction
Cattle are highly selective grazers at the patch and landscape scale (e.g., Mott 1987; Senft et al. 1987), preferring specific areas, especially those close to water and on flatlands, while under-utilising other, less preferred areas within a paddock (Andrew 1988). This uneven spatial use is particularly problematic in the large heterogenous paddocks of northern Australia, even when stocking rates are appropriate (Hunt et al. 2007). Overutilisation of selected areas leads to negative changes in pasture and land condition such as loss of palatable perennial grasses, increased bare ground and risk of soil erosion, and weed invasion. Increased utilisation and thus productive use of previously underutilised areas may provide opportunity to incorporate rest in preferred areas.

While physical fencing may be implemented to increase the evenness of spatial grazing pressure (Bailey 2004), it is often cost prohibitive in the extensive rangelands of northern Australia. Virtual fencing (VF) has been demonstrated to be highly successful in managing cattle grazing distributions across pastures in intensively managed systems (e.g., Lomax et al. 2019). However, the use of VF in extensively managed north Australian herds, and the associated impacts on pasture and cattle production, are yet to be studied in detail.

In this four-year experiment, a virtual fencing system will be tested to investigate the following in extensively managed beef herds: 1) Can VF technology successfully be used to overcome preferential grazing and increase evenness of cattle grazing distribution across large, spatially variable paddocks? 2) Do VF-enabled changes in spatial grazing pressure result in improvements in pasture species composition and dry matter production? and 3) Do VF-enabled changes in spatial grazing distribution influence cattle production? In preparation for the experiment, initial work has been completed investigating cattle learning of the VF system and grazing preferences. This paper covers the experimental methods and preliminary results on cattle learning and grazing preferences.

Methods

The four-year grazing experiment will be conducted at the Spyglass Beef Research Facility (110 km north of Charters Towers, Queensland; 19°29'24.6"S 145°41'30.3"E), with an average rainfall of ~610 mm. Two treatments are to be compared: VF and Control. In the VF groups, VF collars will be used to control utilisation of different land types, allowing resting of areas as needed while excluding cattle from any scalded areas. The control herds will be managed conventionally, with free access to the whole of their paddocks. The VF and control herds will be managed in separate paddocks matched for similar watering circles, soil types, and topography. The VF and control paddocks will be replicated twice, with replicate 1 paddocks being approximately 790 ha each and replicate 2 paddocks being approximately 390 ha each. Paddocks will be stocked primarily with young cows (approx. 60 and 16 per paddock for replicates 1 and 2 respectively), with a small number of growing non-reproductive cattle (10 per paddock) for the monitoring of weight change without the confounding effects of lactation. Stocking rates will be adjusted mid-year annually based on forage availability (Department of Primary Industries 2018). Cattle movement planning will be done in consultation with the project's producer advisory group. All groups of cattle will be managed to meet their nutritional and welfare needs.

Pre-experimental work, including training cattle to use VF, investigation of grazing distributions and baseline pasture monitoring was conducted as follows.

Heifers (n=50) were trained to use VF in small paddocks. Several changes in the location of the VFs were made to investigate cattle behavioural responses, as seen in Figure 1B. Training began in a 24 ha paddock, with the VF first activated on the morning 17 November 2023. The VF was then shifted out approximately 50 m to allow an additional grazing area on the morning of the 20 November 2023. A week later, the gate into an adjacent 57 ha paddock was opened and the VF was moved to allow cattle into the adjacent paddock. On 30 November 2023, the VF shape in the new paddock was shifted to confine grazing to the north/northwestern side of the paddock. To investigate baseline grazing distributions, freely grazing heifers (n=227), including those in the initial training program, were allowed to graze across all replicate 2 paddocks during the month of August 2024. GPS co-ordinates were recorded at 10-minute intervals using the virtual fencing collars.

Animal behaviour data analysis was conducted as follows. The success of VF group cattle responding to the VF within the groups during and after training was quantified by a success ratio, i.e., the ratio of audio cues to electric pulses (Hamidi et al. 2024). GPS data for baseline grazing distributions were used to quantify cattle preference for topography types using Ivlev's index, where a value of -1, 0, and 1, respectively, indicate that a land class is never used, is used in proportion to its availability, or is exclusively used (Ivlev 1961). Topographical position class was mapped and analysed using Ivlev's index. Topographical position class is an index based on differences in elevation between different points at different scales and local slopes (Weiss et al. 2001).

Baseline measurements of land condition were taken at evenly spaced grid points at intervals of 325 m across the paddocks and will be resurveyed at the end of the grazing trial. A detailed soil survey conducted previously for Spyglass (Bryant and Harms 2016) was utilised to map the soil types in each paddock. Land condition was assessed using the ABCD framework (see Quirk and McIvor 2003; Karfs et al. 2009; State of Queensland 2015) which includes rating both pasture and soil condition. Other measures taken included the top three species contributing to yield, total standing dry matter, level of defoliation and tree basal area. Indian couch grass (*Bothriochloa pertusa*) occurrence is also being monitored as a proxy for disturbance (Spiegel 2023). Baseline mapping of degraded areas (scalds and gullies) will be conducted. Cover metrics (organic cover, green cover, biomass) will be collected annually. Preliminary findings reported herein are focussed on one replicate only, with a closer to complete data set.

Measurements

Live weight production of cattle will be calculated based on yarding weights collected at annual weaning musters (Fordyce 2023) with weekly weight change monitored using Optiweigh portable weighing platforms.

Seasonal pasture monitoring will use the BOTANAL methodology (Tothill et al. 1992) at the end of the wet and dry seasons. Average yields and defoliation scores will be used to develop pasture species selection indices (Andrew 1986; Hunt et al. 2013). Paddock site data will be pooled for soil type and related to animal distribution data. Pasture biomass and green cover will also be assessed at a paddock level using a combination of remote sensing methods, including CiboLabs remote sensing (Guerschman et al. 2023) and LongPaddock MyFORAGE (https://www.longpaddock.qld.gov.au/forage/myforage/).

Preliminary results

During the initial training of cattle to use the VF system, there were high incidences of both audio cues and electric pulses delivered on day one, which rapidly decreased by day two (Figure 1A). There was a rapid increase in success ratio from day one to day three (Figure 1A). The activation of a virtual fence in the second paddock (30 November, Figure 1B) was associated with a rapid increase in incidence of audio cues delivered with minimal electric pulses delivered.

Cattle preference, land condition and proportion of 3Ps (perennial, palatable, productive pasture species) are shown by topographical position class in Table 1. The only topography class with a positive Ivlev index value was the flat plains . The lowest proportion of 3P species also occurred on the flat plains (46% c.f. 62% for highlands). Overall mean land condition ratings ranged from B class (fair) for the open slopes and highlands, to C class (poor) for the flat plains and lowlands. The overall mean land condition across all topographies was a high C (C^+). The naturalised stoloniferous grass *Bothriochloa pertusa* was found across all topography classes with the exception of lowlands, with the highest occurrences on the flat plains and open slopes, and to a lesser extent on the highlands (data not shown).

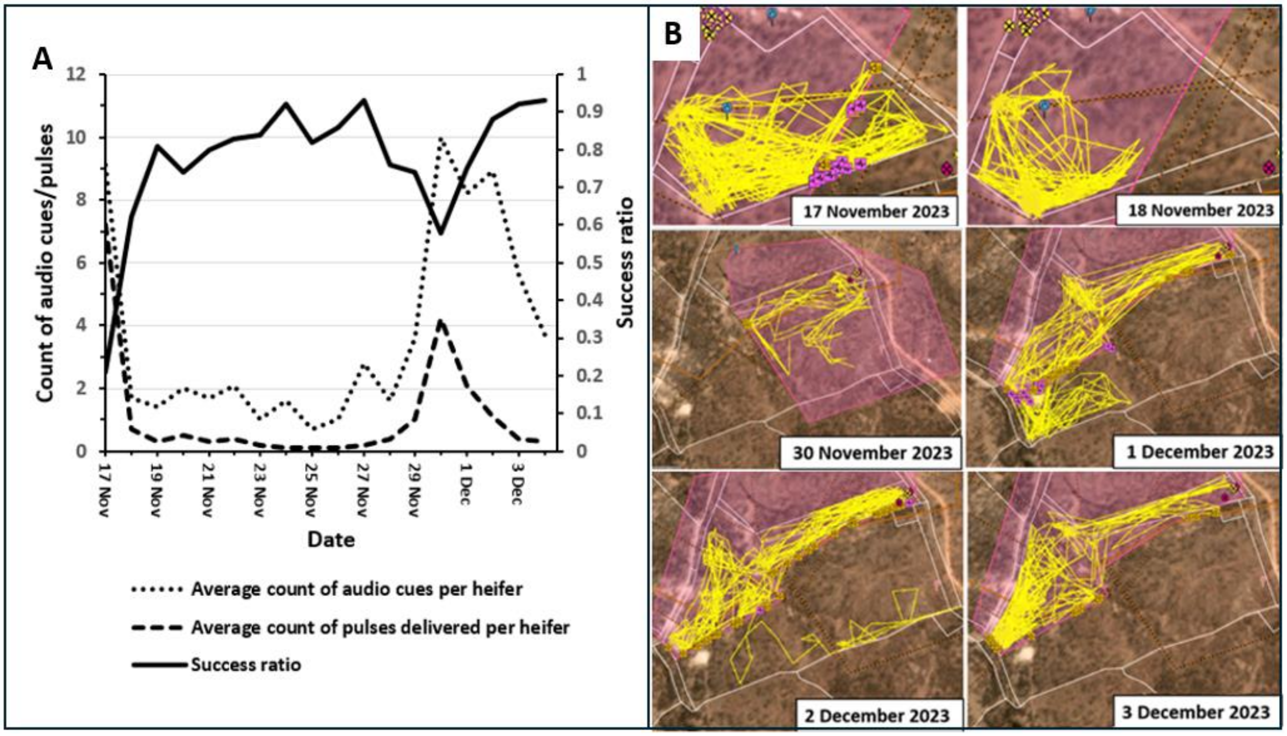

Figure 1. Audio and pulse cues delivered to heifers and success ratio throughout the training program from 17 November to 3 December 2023 (A), and cattle movement 'tracks' for 10 randomly selected heifers during the first 16 days of the training program. White line=physical fence, pink shaded area=virtual fencing inclusion zone, yellow= 'tracks' walked by cattle (B).

Table 1. Preliminary results for cattle preference, the contribution of 3P species to yield and average land condition by topography type for paddocks within replicate 2.

Topographical position class[A]	Ivlev's index value[B]	Proportion 3P species[C] (±SEM)	Average land condition[D]
Flat plains	0.13	46% (±5%)	C^+
Lowlands	-0.29	52% (±10%)	C
Open Slopes	-0.33	60% (±7%)	B^-
Highlands	-0.44	62% (±12%)	B^-
Other	-0.85	no data	no data

[A]The topographical position class is an index based on differences in elevation between different points at different scales and local slopes (Weiss et al. 2001).
[B]Ivlev's index is a common measure of food selection based on both the extent of selection and the relative abundances of the food types in the environment, in this case the relative abundance of land areas by topographical position class.
[C]3P stands for preferred grass species that are Perennial, Palatable and Productive. The proportion of 3P species was calculated from the top three pasture species contributing to yield.
[D]Land condition classes include A (good), B (fair), C (poor), D (very poor), with the possible range within each class including variants from high (plus), neutral, to low (negative).

Discussion

This study demonstrates that naive cattle can learn to respond to the VF audio cues within a day, as indicated by a rapid increase in success ratio after day one of training. When the animals were shifted to a second paddock and restricted to a portion of the paddock, they were able to be contained to the VF inclusion zone largely by responding to the audio cue with a minimal incidence of electric pulses. The success of cattle learning to respond to VF cues in this study is consistent with other studies investigating the learning of a VF system by dairy cattle (Lomax et al. 2019) and moving small herds of beef cattle (<13 cattle) short distances of <400 m (Campbell et al. 2021). While the functionality of VF does show promise on a small scale, no published studies to date have evaluated its capacity to hold and shift cattle in the extensive, variable landscapes of northern Australia.

The large paddocks and variable terrain in north Australian production systems present additional challenges for VF systems. These include obstacles (e.g., hills, gullies, and trees) for radio transmission between VF base stations and collars, the large proportion of herds that are predominately breeding females and the challenges associated with cow-calf movement patterns, predators, and multiple widely spaced watering points. Potential challenges to achieving full use of VF technology, yet to be investigated in this study, are likely to be associated with shifting cattle from one watering point to another and shifting cows during the calving period.

Preliminary results indicate that the topography type with the highest preference and therefore highest risk of overgrazing is the flat plains, with all other topography types being avoided by cattle. However, this result is based on cattle GPS data for the month of August 2024 only, and grazing distributions will likely change at other times and with varying seasonal conditions. The preference of cattle for flat plains (e.g. Raynor et al 2021) is consistent with the lower 3P abundance in the flat plains compared to other topography types.

Conclusion

This experiment aims to test the VF system for high level control over grazing distributions in extensively managed herds, while also monitoring impacts on land condition and cattle production. Our preliminary results show that it can be used at least on a small scale and provide data on cattle grazing behaviour and land type selection. Whether VF can be used to implement increased rest of pastures within large heterogenous paddocks and ultimately produce positive biological and economic outcomes in a northern production systems context is yet to be established.

Acknowledgements

This research forms a part of the Virtually Fence Free project, a collaborative effort between NQ Dry Tropics and the Queensland Department of Primary Industries. The project is funded by a 'Long-term Trial of Drought Resilient Farming Practices Grant' from the Australian Federal Government Future Drought Fund. Angela Anderson and Katherine Delaney are gratefully acknowledged for support with statistical calculations and mapping, respectively. Animal ethics approval for the ongoing work was granted by the DPI Animal Ethics Committee (approvals SA 2023/10/901, SA 2024/01/908, and SA 2024/06/939).

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