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Foundations of Virtual Fencing: Economics of Virtual Fence (VF) Systems

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Introduction

This analysis explores the economic considerations of investing in virtual fence (VF) systems, examining their application for representative cow-calf operations under different operating conditions. Virtual fencing (VF) is a tool for livestock management that uses collars and a radio or cellular systems to influence the movement of livestock using auditory and electrical cues (Antaya et al. 2024). Users program the system to establish invisible barriers on a landscape. The system detects the location of animals and if animals approach or cross a "virtual" fence, they receive an auditory or electrical cue encouraging them to move away from the barrier. VF systems have the potential to offset physical fencing costs, enable adoption of adaptive management practices (Boyd et al. 2022; Boyd et al. 2023; Golinski et al. 2023; Verdon et al. 2021), and save ranchers time in locating animals, among other benefits (Campbell et al. 2018; Boyd et al. 2022; Schillings et al. 2024). Commercial VF systems have varying fee structures and require labor to operate which is an additional cost of adoption. Cost and economies of scale are factors that affect livestock producers' willingness to adopt technologies (Pruitt et al. 2012; Lima et al. 2018).

Currently, there is limited research quantifying the benefits of using VF for cattle ranching operations. This analysis relies on a series of hypothetical scenarios to account for differences across producers and how they might implement the technology in their operations. First, we estimate the conditions necessary for VF systems to break even each year, whether by avoiding physical fencing costs, time savings, or productivity gains. Then, under conservative assumptions about the benefits achieved using VF systems, we present a series of benefit-cost analyses of the technology for a representative ranch in Arizona. Finally, we contextualize these findings within a model of representative ranch costs and returns for different ranching regions within Arizona to consider the influence of market conditions on the feasibility of adopting VF.

Costs of Adoption

Up-front (year 1) costs of VF systems include the cost of system hardware such as collars, base stations (if applicable), batteries, and time spent learning to operate the system. Additionally, vendors typically charge a per-collar annual fee. Finally, there are labor costs borne by the ranch associated with operating the system, placing or replacing collars, locating dropped collars, and other related tasks. Total first-year costs of adopting VF technology are estimated to range from around $175 per cow to roughly $400 per cow depending on the vendor and herd size (Figure 1). In terms of total cost for the representative ranches modeled, this equates to a range of $35,000 for a herd size of 200 cows to $180,000 for a herd size of 500 cows. Beyond the first year, costs include annual fees and ongoing labor costs of operating the system. Costs for year 2 and beyond range from around $80 per cow to $130 per cow depending on the vendor and herd size. In terms of total annual costs, this ranges from around $17,000 for a herd size of 200 cows to $45,000 for a herd size of 500 cows. These estimates assume that the system is purchased outright without financing.

Generally speaking, holding all else constant, the cost per cow of VF systems decreases with herd size. Total cost per operation increases with herd size because of per-collar annual fees and the up-front cost of purchasing collars, however fixed costs of operation and the cost of base stations (when applicable) are spread over a large number of cows as herd size increases.

It is important to mention that in this analysis, all results are inclusive of estimated labor costs associated with operating VF systems. Some producers may be interested

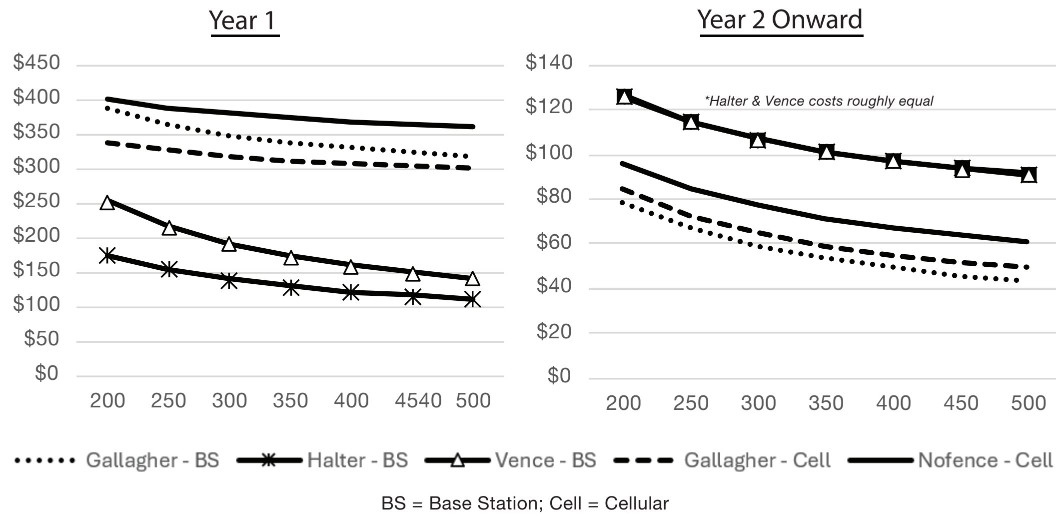

Figure 1. Year 1 & Year 2 Onward Costs per Cow of VF Adoption by Herd Size & Vendor

to know the cost of VF systems excluding labor costs. As a rough estimate, for a 300 head herd, labor costs represent an average of 20% of total costs in year 1 across all vendors. In year 2 labor costs represent an average of 50% of total costs in year 2 and beyond, across vendors. The relative importance of labor as a share of total costs is less in year 1 because of the up-front costs of VF system adoption. Labor costs remain relatively steady across years and therefore represent a higher share of costs in year 2 and beyond because annual costs are lower in year 2 and beyond.

Benefits of VF

As a baseline for this analysis, we make a conservative assumption of 40 hours of labor saved searching for cows for a rancher and 40 hours saved for one ranch hand per year. Additionally, we consider $10,000 in interior physical fence (5-strand barbed wire cattle fencing) maintenance costs and $10,000 in new interior physical fence installation costs (1/2 mile at a cost of $20,000 per mile) avoided per year. Combined, VF systems were estimated to result in labor savings and avoided physical fence costs between $40 and $120 per cow. For representative ranches, this would be a combined total of roughly $22,000 in labor savings and avoided physical fence costs per year. These labor savings are relative to a baseline scenario of no VF use (considered as a benefit of VF use) and do not reflect any labor costs of using VF technology.

Combining these baseline benefits with costs per cow, we arrive at estimates of net costs per cow for VF systems for the first year and for the second year and beyond. Again, based on these conservative baseline assumptions including time savings and avoided physical fence costs, none of the virtual fence systems examined in this analysis would pay for themselves over the expected lifecycle of their hardware. While estimated annual benefits (including any labor savings) outweigh costs from year two onward in some cases (negative net costs), the difference between benefits and costs in those cases is relatively small and would require long periods to achieve payback.

Benefits Required to Break Even

To provide a sense of how VF systems can "pay for themselves", we present Year 1 upfront cost and Year 2 and beyond cost-equivalents in terms of savings or benefits that would need to be achieved for the systems to fully pay for themselves. While we might not expect an investment to immediately pay for itself, these equivalencies provide a rough sense of how the systems most quickly pay for themselves, or how they might do so through a combination of savings and benefits.

A principal benefit of a VF system is its ability to offset interior fence (cross fencing) repair costs and avoid expenditures on new interior fencing (Antaya et al. 2024). We assume that fencing costs $20,000 per mile (B. Blum, personal communication, Sept. 1, 2024; Hoag et al. 2024). Figure 2 presents this equivalence by vendor and herd size for first year costs as well as year two and onward. Mileage of fence avoided to immediately offset year 1 and year 2 costs increases with herd size, as each additional animal requires a collar and an annual fee per collar. For year 1 costs, this ranges from an equivalent of nearly 2 miles of fence to 9 miles of fence, depending on vendor and herd size. For year 2 costs, this ranges from an equivalent of less than 1 mile of physical fence avoided to over 2 miles of fence avoided to immediately offset system costs.

Another potential benefit of VF systems is their ability to reduce labor associated with locating animals. The time

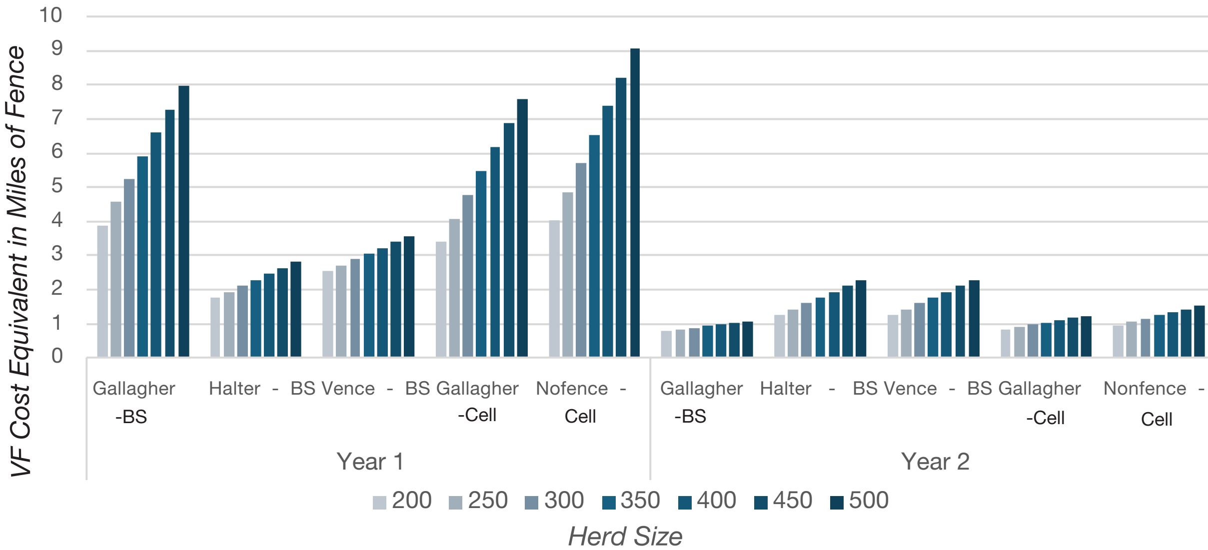

Figure 2. First Year and Second Year Avoided Fence Length to Immediately Offset VF System Costs by Vendor & Herd Size

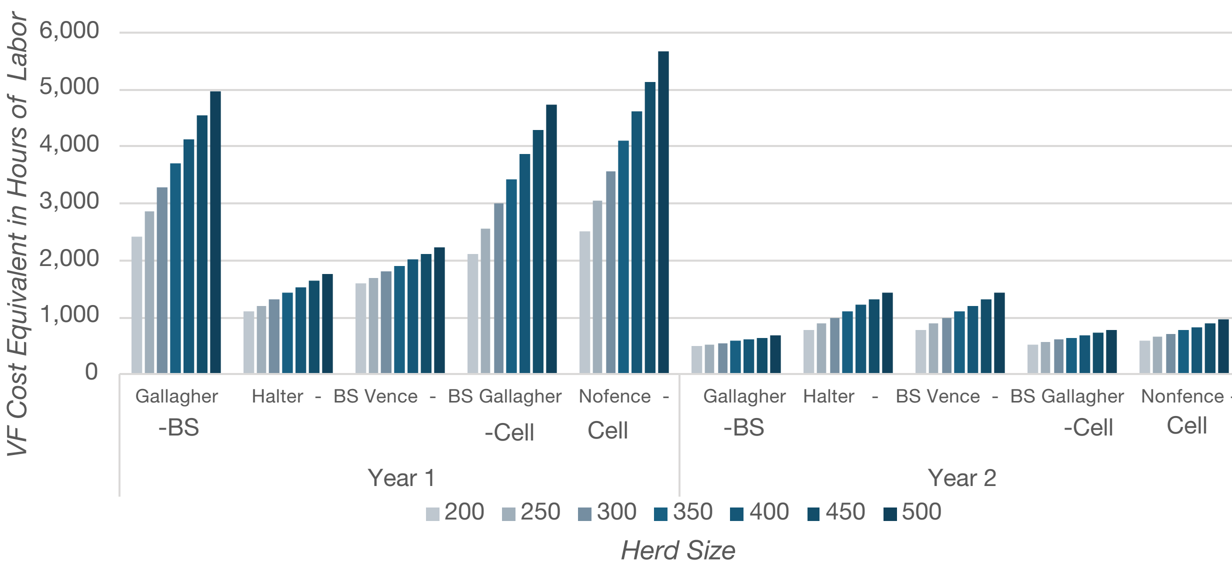

Figure 3. First Year and Second Year Time Savings to Immediately Offset VF System Costs by Vendor & Herd Size

savings required to fully offset the cost of VF systems in year 1 or subsequent years are significant, however. Applying an average hourly rate for agricultural supervisors in Arizona as a proxy for the opportunity cost of rancher time ($31.97 per hour, Bureau of Labor Statistics 2024), the time savings required to completely offset Year 1 costs are often in excess of a year of full-time work (2,080 hours). Required time savings for year 2 and beyond range from roughly 500 hours to well over 1,000 hours (Figure 3). Time savings alone may not be sufficient to justify the cost of VF systems. Nonetheless, in combination with other benefits, individual operations may achieve considerable time savings using VF systems.

While the effects of rotational grazing on animal performance has been an ongoing debate (Augustine, et al. 2020), assuming that use of VF systems contributes to calf weight gain through improved pasture utilization or forage productivity, VF systems could bolster ranch profitability. We model the weight gain that would be required across all calves (compared to a baseline of not using VF systems) for VF systems to immediately pay for themselves in year 1 or year 2 and beyond (Figure 4). Alone, the weight gains required to fully offset the cost of VF systems are implausibly large, particularly in year 1. Modest weight gains, in combination with other benefits such as time savings, could significantly offset VF system costs in some

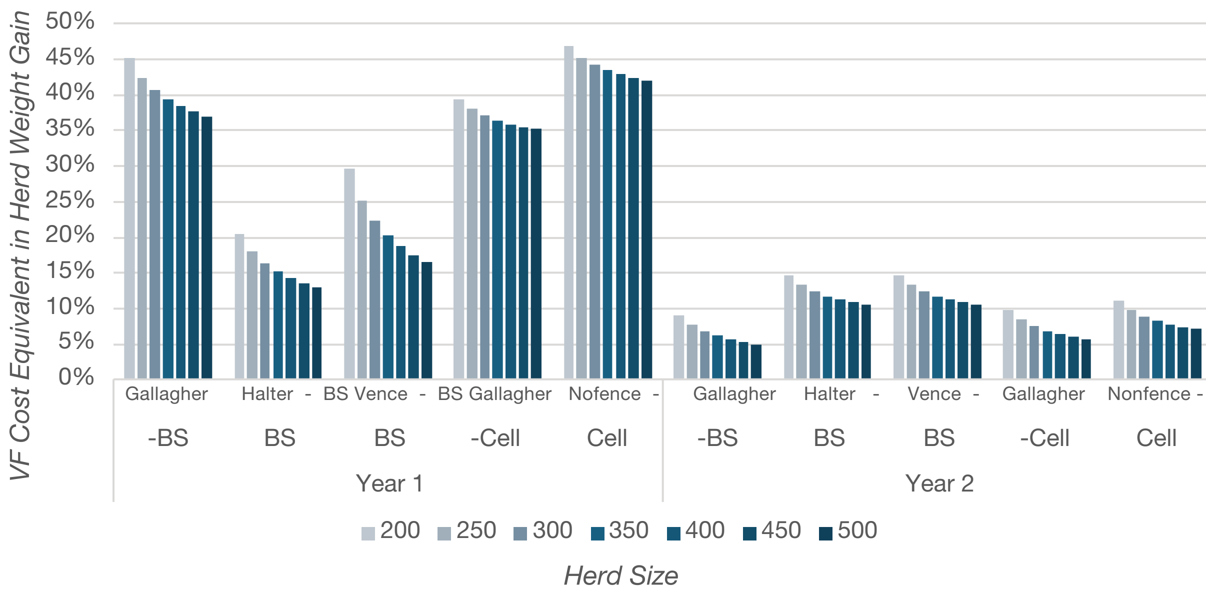

Figure 4. First Year and Second Year Weight Gain Across Herd to Immediately Offset VF System Costs by Vendor & Herd Size

cases. Other possible benefits not examined in this analysis include benefits to soil health, protection of riparian areas, and maintenance of grazing permits.

Benefit-Cost Ratios

Benefit cost ratios compare the value of a stream of benefits over time to the value of a stream of costs over time. Future costs and benefits are discounted to account for the opportunity costs of foregone investment opportunities (in other words, the next-best investment opportunity). A benefit cost ratio of 1 means that the present value of benefits is equal to the present value of costs. A value greater than 1 means that benefits are greater than costs, and a value less than 1 means that benefits are less than costs. The expected lifecycle of most VF hardware is estimated between 5 to 10 years; hence, we conducted benefit cost analyses over a 7-year time period for a representative ranch in Arizona using a discount rate of 3.9% based on estimated returns to ranch production assets in Arizona. All analyses assume two base stations are used for base station systems, $20,000 in annual fencing costs are avoided, and the systems lead to 80 hours of labor savings annually.

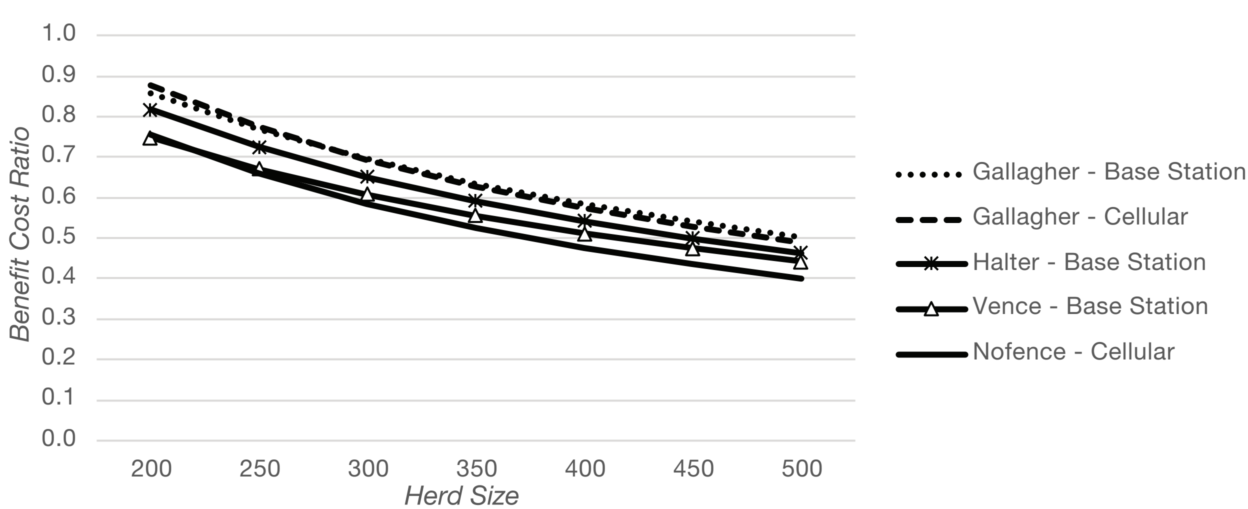

Figure 5. 7-Year Benefit Cost Ratios Under Baseline Assumptions

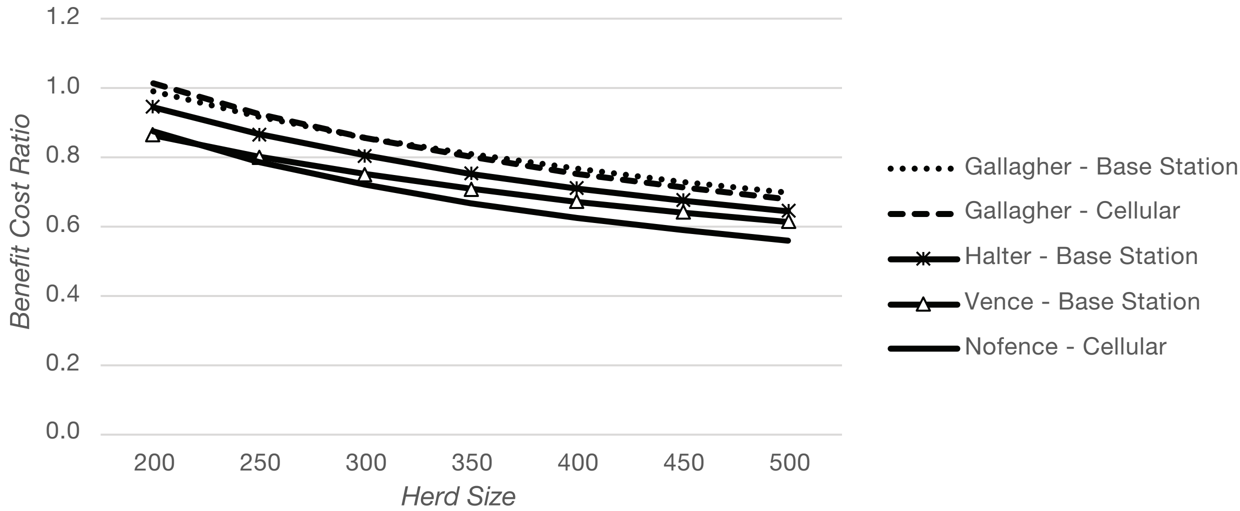

Figure 6. 7-Year Benefit Cost Ratios 2% Weight Gain Across Herd

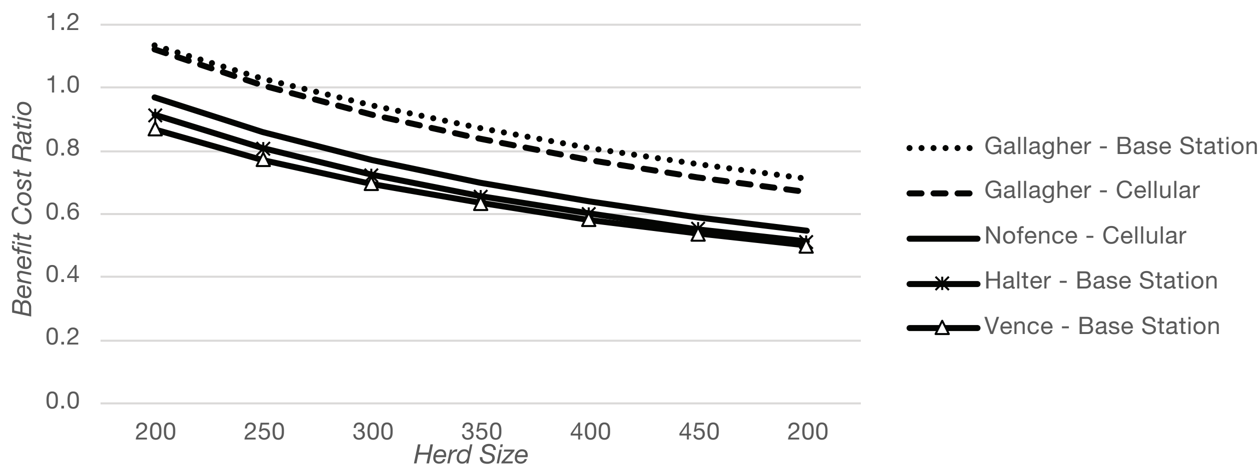

Figure 7. 7-Year Benefit Cost Ratios with 50% Year 1 Cost Share

Under baseline assumptions about VF system adoption (2 base stations for base station technologies, time investment, time savings, etc.), none of the VF technologies achieve a benefit-cost ratio greater than 1, e.g., benefits exceeding costs, over a 7-year period (Figure 5). This is consistent with findings from the baseline breakeven analysis, which predicts payback periods of 9 years and beyond in all cases under baseline assumptions. To account for the possibility of other benefits, we consider a modest calf weight gain due to improved pasture utilization or forage productivity. Assuming a 2% calf weight gain, one VF systems narrowly surpasses a benefit-cost ratio of 1 for some herd sizes, however most are still less than 1 (Figure 6). Finally, we consider a potential cost-share for up-front costs in year 1. Assuming a 50% cost share of all year 1 costs, two VF systems achieve benefit-cost ratios greater than 1 for some herd sizes (Figure 7). Most vendors and herd sizes, however, have benefit-cost ratios less than 1, e.g., costs exceeding benefits, over a 7-year period.

VF Costs & Ranch Returns

Examined in isolation, VF systems may potentially pay for themselves within their useful lifecycle through a combination of different benefits and avoided costs, particularly if they can be used to avoid investment in interior physical fencing. The decision to invest in a technology, thereby incurring additional costs, is made in the context of prevailing prices and returns. Under calf prices ranging from $175 to $275 per cwt, year 1 costs of VF systems generally exceed ranch returns over total costs, excluding VF-related costs. Year 2 costs are significantly lower, however, therefore at lower cattle prices VF costs would likely still exceed ranch returns on a per-cow basis. Though current cattle prices are high, uncertainty around future cattle prices may lead risk-averse producers to avoid incurring additional costs, thereby limiting adoption of VF systems under current cost structures.

Conclusion

Our findings suggest that under current conditions in Arizona, VF systems may be a cost-effective alternative to investment in physical fencing when significant amounts of fencing are required. It may also be an economically viable tool to enable adaptive management practices such as pasture rotation or exclusion from sensitive areas when necessary. However, this is predicated on producers' willingness to fully adopt the technology. Additionally, cellular coverage may not be adequate for VF systems in many areas of the state, making certain systems unviable for certain producers. Satellite internet service may address this issue but would further increase costs. Under existing cost structures for VF systems examined in our analysis, prevailing cattle prices are sufficient to maintain positive returns while covering out-of-pocket up-front investment and ongoing yearly costs for VF technology in some cases. However, cattle prices are expected to decline over the next 10 years (FAPRI 2024). The prospect of lower returns in future years may dissuade producers from incurring additional ongoing costs. Under such conditions, adoption of the technology may be limited to "early adopters" and those wishing to offset the high cost of new physical fencing. Partnerships, cost-share opportunities with land management agencies, or conservation programs may be necessary to make VF adoption economically feasible and achieve a breakeven for producers within the expected lifecycle of the products.

Disclaimer

There are several companies that manufacture hardware and software including eShepherd™ from Gallagher™, Halter™, Nofence™, and Vence™. Virtual fence components from different manufacturers are generally not interoperable or interchangeable. Specific components, GIS data needs, software protocol, software training, frequency and duration of the cues, GPS error, livestock collaring, and livestock training protocols may vary depending on the manufacturer. Follow the manufacturer's recommendations and guidelines. The University of Arizona does not endorse a specific product.

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For additional information about virtual fencing, visit: https://rangelandsgateway.org/virtual-fence

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