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Digital virtual fence user guide for rangeland management

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Abstract

Virtual fence (VF) is an expanding technology used on rangelands around the world. The system uses invisible barriers established by Global Navigation Satellite System (GNSS) coordinates to influence livestock movement without a physical fence. VF systems use a combination of auditory and electrical cues (i.e., beeping noises, benign electrical shocks) that originate from a wearable, GNSS-enabled VF collar. This emerging precision livestock management technology has the potential to change grazing systems by improving livestock control and distribution. Collars also generate livestock location data, which can provide information about grazing behaviour and support decision-making. Despite these opportunities, VF systems can be complicated and expensive to adopt. To address these challenges, researchers at the University of Arizona and the Southern Arizona Experiment Station have developed a digital Virtual Fence User Guide based on ongoing field trials at the University of Arizona's Santa Rita Experimental Range (Green Valley, Arizona, USA) in collaboration with the Rangelands Partnership (RP) and members of the Virtual Fence Working Group. Available on the RP's Rangelands Gateway (https://rangelandsgateway.org/virtual-fence), the guide includes practical information about VF adoption, learning modules, early adopter videos, recordings and handouts from past webinars, and answers to frequently asked questions. Tools for comparing costs between the various vendors and instructions on how to mobilize a base station to optimize coverage are also available. This comprehensive guide of digital support tools empowers land managers to effectively evaluate and use VF to improve rangeland management.

Introduction

Precision livestock management is becoming an increasingly appealing opportunity for land managers as climate change, severe drought, and unpredictable extreme weather events pose growing challenges for land managers on rangelands around the world. Virtual fence (VF) systems are precision management tools that use invisible barriers to manage livestock distribution on a ranch. When used with a grazing management plan, VF has the potential to change grazing systems by allowing novel influence over livestock movement with a combination of auditory and electrical cues (i.e., beeping noises, benign electrical shocks) that originate from a wearable GNSS-enabled collar (Antaya et al. 2024a). These systems rely on three interconnected components (1) software to draw VF boundaries on a digital map, (2) GNSS-enabled collars worn by livestock that deliver an auditory and/or electrical cue when an animal approaches the invisible VF barrier, and (3) base stations or cellular service to relay information about the invisible VF boundaries to the collars (Antaya et al. 2024a; Ehlert et al. 2024). While VF systems were first described decades ago, improvements in technology have brought VF to the forefront of ranching with the launch of several commercial VF systems by different vendors (Anderson 2007). However, as an emerging technology, there has been limited information available from unbiased sources to help land managers effectively evaluate and implement VF for sustainable rangeland management. As more VF vendors enter the market, interest and excitement over VF technology is likely to increase. Because of this, we developed an impartial VF outreach and educational resource so prospective users can make informed decisions before investing time and money in novel VF technology.

The challenge of finding accurate science-based rangeland information is the foundation of the Rangelands Partnership (RP), a group of rangeland professionals, agricultural librarians, and technology experts from across the United States (Hutchinson and Ruyle 2002; Hall et al. 2022). Since 2002, the RP has worked to bridge the gap between peer-reviewed content and on-the-ground land managers by maintaining an online portal called Rangelands Gateway (https://rangelandsgateway.org/). Rangelands Gateway provides access to a database of quality and peer-reviewed information related to rangeland ecology and management. The portal also provides access to new cutting-edge educational resources through diverse platforms including decision support tools and videos (Hall et al. 2022). The RP and Rangelands Gateway provide a unique opportunity to create and distribute information about VF.

Within Rangelands Gateway, the Virtual Fence User Guide (https://rangelandsgateway.org/virtual-fence) is designed to empower land managers to effectively evaluate and use VF for improved rangeland management by providing access to comprehensive information and resources. This article introduces the VF User Guide and describes the digital resources that it provides through diverse platforms including factsheets, videos, webinars, and support tools.

Methods

The VF User Guide is a digital resource created within the RP's Rangelands Gateway. The platform was designed to synthesize rangeland information and provide an opportunity to learn about emerging technologies through articles, factsheets, videos, webinars, and additional resources (Hall et al. 2022).

The primary resource in the VF User Guide is a collection of VF articles, called the *Foundations of Virtual Fencing*, based on real-world field trials at the University of Arizona's Santa Rita Experimental Range (Green Valley, Arizona, USA). Through a collaboration between the Marley Endowment for Sustainable Rangeland Stewardship, Arizona Cooperative Extension, and the Santa Rita Ranch LLC, researchers deployed a ranch-scale VF system (Vence™ CattleRider™ ver. 2 rev. c-g, Vence Corporation, San Diego, CA, USA) on the Santa Rita Experimental Range, a working research ranch, in 2021. From these early

experiences, a variety of opportunities and challenges associated with VF adoption were documented. Additional early adopter experiences were gathered from the VF Working Group (VFWG), a community of practice primarily made up of researchers from USA land-grant Universities and non-governmental organizations formed to address knowledge gaps (Ehlert et al. 2024). Implementation and ongoing issues were documented and organized into overarching themes. With a diverse set of experiences and recurring problems, factsheets were developed to explain, offer solutions, and acknowledge the challenges of implementing VF so future users would be more prepared than the initial group of early adopters.

A multimedia approach was taken to develop the VF User Guide, incorporating learning modules, videos, webinars, and interactive decision support tools. Learning modules were collaboratively developed with VFWG members and created using Google Earth, an open access software. The intent was to provide prospective users with an instructional reference without needing access to the proprietary, vendor-specific VF software. This allows prospective users to understand what is required to set up and manage a VF system without having to first purchase a system. To share the experiences and insights of early adopters, the guide includes a four-part video series designed to help prospective users understand how others have integrated VF into real-world operations. Additional videos created by other VFWG members provide additional information on other relevant topics. Three webinars were held in fall 2024 and winter 2025 focused on adoption and implementation of VF. Webinar topics were developed based on feedback from prospective users. Recordings and handouts were posted online for open access. Finally, several interactive decision support tools were either created by University of Arizona researchers or identified and compiled from VFWG members. These include answers to frequently asked questions, resources about the financial impact of VF adoption, instructions on modifying a base station to make it mobile, and access to geospatial databases.

Results

The VF User Guide contains four primary sections to help prospective users make informed decisions about VF and improve the chances of initial success if they adopt the technology. These sections are factsheets, videos, webinars, and support tools.

Factsheets

The main function of the guide is to provide users with written information about VF that can be accessed at any time. The collection of science-based, peer-reviewed open-source factsheets are focused on the foundational information needed from start to finish, and include:

1. Basics of a VF system (Antaya et al. 2024a),
2. Economic viability of VF adoption,
3. Vital role of high-quality geospatial data (Antaya et al. 2024b),
4. Collar deployment recommendations,
5. Principles of livestock training and animal welfare considerations (Mayer et al. 2024a),
6. Strategies for collar management (Antaya et al. 2024c), and
7. Complexities and challenges (Mayer et al. 2024b).

Videos

The guide includes a variety of learning modules, early adopter videos, and other videos. Learning modules include (1) how to create a VF boundary on a digital map using VF terminology and (2) what factors to consider when placing a VF (i.e., quality of the digital map, buffer zones, fence design, water sources, and locations where VF is not appropriate). There is also a four-part video series that showcases the experiences and insights of early adopters across the USA. Additionally, videos created by VFWG members filled in

knowledge gaps related to collaborations, land manager experiences, applications, animal reactions to collars, and tutorials.

Webinars

Recognizing the need for an interactive component, one-hour webinars were developed to focus on high-impact VF topics. The first webinar highlighted the basic components and compared the VF vendors available at that time. Building on this introduction, an application webinar focused on three real-world examples of how VF has been used to improve rangeland and livestock management. An economics webinar outlined the benefits, costs, returns over time, and tools to make informed decisions. Recordings and handouts are available in the VF user guide for future reference and continued distribution.

Support Tools

A variety of support tools were either created or compiled to help prospective users obtain the necessary information in one place. These items include:

1. Calculators to compare the cost of VF systems and physical fences under different scenarios,
2. Concise answers to frequently asked questions,
3. Instructions on how to mobilize a base station to optimize coverage, and
4. Direct links to USA-based geospatial databases.

Discussion, Conclusions, Implications

The VF User Guide aims to assemble comprehensive, unbiased educational and outreach materials to help land managers understand the complexities and challenges of applying an expensive, unfamiliar tool on real-world ranches. Collectively, the resources should help prospective users determine whether VF is a good fit for their unique operation and what to expect and prepare for during implementation. Without this information, land managers may miss opportunities to use VF to adapt to challenges or may misapply the technology, ultimately leading to frustrations when learning and using the technology.

As of 2024, there are four companies that manufacture and sell VF hardware and software in the United States. Whenever possible, resources in the guide describe VF components in a vendor neutral fashion to avoid bias toward a particular vendor. Most resources also include a disclaimer indicating the University of Arizona and RP do not endorse a specific product. Thus, recommendations are general and may lack the specificity required for a particular vendor. Additionally, as the technology evolves over time, suggestions may slightly misalign with the VF vendor recommendations. The guide is not a replacement for manufacturer instructions. Instead, the VF User Guide is intended to provide non-vendor specific practical guidance based on our experience and the experiences of those in the VFWG.

VF is rapidly evolving as interest in precision livestock management technology increases and wearable technology improves. There is a critical need for more independent, University-led research to understand the capabilities of these systems to support rangeland stewardship and research findings must be shared so prospective users can make informed decisions. The VF User Guide is a platform to share research findings with diverse audiences. However, the guide is only useful if the resources available cover the spectrum of questions and concerns of real-world land managers. To stay up to date, we will continue to add relevant information to the guide. This will require continuing collaborations with the VFWG as well as creating new collaborations to amass open-source and public domain content. We hope the Virtual Fence User Guide on Rangelands Gateway will be the place to access unbiased, science-based information to make informed decisions about VF.

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