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Big landscapes meet big data in StockSmart--grazing decision support with temporally and spatially explicit annual net primary production data

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Abstract

Grasslands, shrublands, and savanna ecosystems worldwide are often grazed by domestic livestock. These vegetation types are critical for human flourishing and are vulnerable to overuse and degradation when local socio-economic conditions or misunderstanding of plant ecology leads to overuse. On large grazing areas, whether used as private property or as common pool resources, the ability of plant communities to retain rangeland health attributes of soil stability, hydrologic function, and biotic integrity depend on both stocking rate and careful application of patterns of grazing timing, duration, severity, and frequency. Sustainable stocking rates depend on judicious allocation of available forage. Historical stocking rate tools have assumed that land managers have accurate information on forage quantity and that a static sustainable stocking rate can be developed. But in non-static arid and semi-arid ecosystems already defined by resource scarcity and prone to threshold events driven by abiotic variables, the inherent interannual variability of precipitation and unpredictable net primary herbaceous production pose particular challenges for pastoralists. Washington State University Extension, in partnership with the University of Arizona and the United States Forest Service, developed a free grazing decision support tool that incorporates historical forage production and variability with user-defined animal behavior parameters and spatial distribution to estimate livestock terrain use. We show how StockSmart allows stocking calculations and grazing planning based on spatially-explicit estimates of available forage rather than total forage. It also allows testing infrastructure investments against resulting increases in forage availability. These considerations are critical for avoiding ecological state changes through overgrazing into degraded but stable conditions.

Introduction

Ranchers and public land managers collectively make land use decisions on over 700 million acres of rangelands in North America (Havstad et al., 2007). These lands provide a broad array of ecosystem services critical to human flourishing. In addition to food, fiber, and habitat (SRM 2022), humans have connection to land that is hugely influential on physical health, mental health, and social cohesion (Dean et al., 2021). Maintaining the ecological integrity of the nation's rangelands is extremely important and the management actions influencing ecosystem processes and attributes are made predominantly by ranchers and public land managers. Grazing is a significant and visible management factor influencing plant community trajectories, wildfire mitigation, wildlife habitat, water relations at the plant-soil interface, pollinators, and more. The most basic grazing decision is "how many animals can be grazed for how long?" Although numerous factors contribute to the effects of grazing over time, the decision of stocking rate is unavoidable; literature syntheses indicate it is critical to rangeland health, independent of intensity of animal distribution (Bestelmeyer & Briske, 2012; Briske et al., 2008; Provenza et al., 2013).

More broadly, rural communities depend on the financial viability and resiliency of pastoralists and related businesses. Agricultural businesses, especially rangeland-based livestock production, depend on protecting the productive capacity of the land and sustaining ecosystem functions. Profitable businesses enable family stability and farmer mental wellness at the individual scale and social resiliency at the community scale, contributing to quality of life. The nearly inevitable result of ranch failure is fragmentation and environmental degradation of various kinds. The less common trajectory of land purchase and passive management can be ecologically dysfunctional as well. There is tremendous need to enable economically sustainable grazing use of private and public lands, and StockSmart can contribute to ensuring that good data underlie key sustainable stocking decisions. Federal, state, and tribal land managers make decisions about grazing on extensive, heterogenous rangelands, and these decisions are sometimes controversial. Ranchers make decisions on private lands and contribute to decisions and plan execution on private and public lands. All of these decisions directly impact rangeland resources. Stocking rate is a primary management variable in grazed rangelands. Poor grazing management, which includes excessive stocking rates, can have cascading negative environmental effects. Climate smart grazing management, which begins with an adaptive stocking rate, can maintain and improve various ecosystem services and values through promoting biodiversity, heterogeneity of plant community types and seral stages, limiting wildfire risk, and enhancing wildlife habitat attributes. Improved management may depend on investment in grazing infrastructure, practices that must be effective in order to justify the cost. StockSmart allows users to quantify the increases in accessible forage production due to proposed infrastructure development, including watering sites, virtual fencing boundaries, or physical cross-fence to better control timing of grazing.

Methods

StockSmart, a web application developed by the authors and University of Arizona Communications & Cybertechnologies, allows users to access accurate, spatially-explicit forage production data and combine it with spatially-explicit predictive terrain use by livestock to develop reasonable starting stocking rates that are responsive to interannual variation in herbaceous above-ground biomass and are based on calculations of forage in the areas actually accessed by grazing animals (Hudson et al., 2021). StockSmart addresses key challenges in landowners' and managers' abilities to accurately estimate grazing capacity on rangelands under their control, to track and monitor changes in the vegetation under a particular set of management decisions, and to prepare for and adjust their management as forage availability changes with climate change. Development of StockSmart had three sequential elements: 1) Develop a spatially-explicit, web-based decision support tool (DST) that accesses Normalized Difference Vegetation Index (NDVI)-based rangeland forage production data for an area of interest, allows the user to define key factors that determine rangeland accessibility, and produces maps of stocking rate and other synthetic metrics showing variation through the growing season and from year to year. 2) Convene an advisory group of rangeland owners and managers to provide actionable input and real-life pilot cases to test the tool on, ensuring that the DST provides relevant and actionable information needed for improved grazing management decisions. 3) Engage with Extension agents and specialists, public land managers, and other rangeland advisors through existing communication networks to build awareness, collect valuable feedback, and encourage early adopters to use the DST. The access to data characterizing variations in forage availability and other key factors will improve private landowners' and public land managers' ability to enhance the sustainability of the nation's forests and rangelands, provide ecosystem services and market goods, improve ecological and operational resilience to climate change, and support rural livelihoods.

Results

Forage production data

Advances in remotely-sensed data and enhanced access to these data by ranchers and public land managers offer opportunities for improved calculations of stocking rates across vast rangeland environments. The primary data that StockSmart uses emanate from the Rangeland Production Monitoring Service (RPMS) (Reeves et al., 2021) and the Rangeland Analysis Platform (Allred et al., 2021). Based on the RPMS data, StockSmart computes the historical mean and standard deviation of total annual production from 1984 to 2024, giving one value for each 30x30m square (less than a quarter of an acre, approximately one tenth of a hectare). It then uses the most recent Vegetation Cover data from the Rangeland Analysis Platform (RAP) to apportion total production into shrubs, herbs (annual and perennial), and tree growth.

Users identify an area of interest, including multiple pastures, enter on the map where water sources are (point, polyline, or polygon), select a harvest coefficient (how much of ANPP one wishes to allocate to grazing consumption), and calculate available forage based on the historical mean 1984-2024 and one standard deviation above and below the mean.

Accessibility of forage

To determine what forage is actually accessible to the animals grazing these rangelands, StockSmart corrects the forage production values based on tree canopy cover, terrain, and distance to water. Where remotely sensed estimates of understory forage are unreliable because of the interference of tree canopies, some basic linear models are used to estimate forage growing beneath the trees. All the edible forage is then corrected, accounting for how steep a slope your livestock will traverse, and how far from water they will disperse. After also adjusting the accessible forage using a harvest coefficient—the fraction of total forage produced that is assigned to grazing animals for consumption—and a shrub utilization fraction (some animals browse shrubs, some don't), StockSmart provides the user with a final number. This can be either the number of days your herd of cattle could graze, or the number of head of cattle that could graze there for a predefined length of time.

Decisions StockSmart can inform

With access to accurate, spatially explicit historical forage production data, ranchers and other rangeland managers can fine tune grazing management decisions and compare scenarios (and save them, if one creates an account). One can visualize what areas are too far away from water to be accessed by livestock and explore how stocking rate changes by adding a source of water in that part of a pasture. One can explore whether dividing pastures as well as developing water would make a big enough difference in terms of available forage to be worth the investment in fencing. The historical variations in forage production—and therefore stocking rate—are particularly valuable as the climate continues to change. StockSmart will not indicate when, how, and how much to graze, but it will provide robust estimates of how much forage is available with realistic parameters on where animals will graze and will provide clarity on how variable that forage is likely to be from year to year. When paired with careful grazing planning and monitoring of rangeland health, it provides a very useful additional tool in the rangeland manager's toolbox, to help understand and deal with the complexities of maintaining healthy herds and healthy rangelands, now and under a changing climate.

Discussion

StockSmart is available now at Stock-Smart.com; the geographic range is currently limited to the 11 Western U.S. states, but efforts are underway to expand StockSmart to the rest of the U.S. and a few other countries, including Australia. It is currently being used by federal, state, and tribal entities to plan grazing on large landscapes. It has been used in throughout the Western US in public land management scenarios. Uses have included quantifying appropriate stocking rates from Arizona to Canada and for evaluating the value of grazing lands for the purposes of land purchases. The main uses thus far have been for evaluating federal allotment management plans as well as providing a “second opinion” to evaluate field observations obtained by consultants and managers alike. In addition, it offers a unique platform for teaching range management concepts to various age and user groups.

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