Collaborative Adaptive Rangeland Management: Lessons learned and opportunities awaiting from the first decade

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Abstract

In the semiarid, shortgrass steppe of North America, the Collaborative Adaptive Rangeland Management (CARM) project engaged an 11-member stakeholder group composed of ranchers, non-governmental conservation organization representatives, and state/federal agency personnel since 2012. The stakeholder and research team collaboratively implemented adaptive, multi-paddock (AMP) rotational grazing management, and compared multiple outcomes to those from traditional management of season-long grazing at the same stocking rate during the growing season (mid-May to October). The transdisciplinary scientific team collected and provided to the stakeholders monitoring data about vegetation, livestock, and wildlife habitat, including cattle foraging behaviour and movement dynamics, diet quality, distribution of grazing animals, remotely sensed standing biomass, grassland bird populations, animal weight gains, financial returns, soil health and carbon, and vegetation production, composition, structure, and diversity. A collaborative learning objective was added for co-production of new knowledge and its application to new areas, and increasing trust, respect, and understanding among participants. Iterative decision-making and learning within and across years have been documented through revised objectives, key triggers for drought planning and flexible stocking, and enhanced dashboards for tracking precipitation, soil moisture, forage conditions, and livestock diet quality. A key lesson learned is the importance of open and transparent communications through sustained engagement of stakeholders, leading to increased trust. Research results highlight that higher stocking density with AMP grazing consistently reduces animal weight gains and consequently financial returns in non-drought years through altering foraging behaviour and reducing diet quality. At the same time, vegetation heterogeneity across paddocks is enhanced with AMP grazing, providing a wider range of grassland bird habitat. Future directions include application of new technologies for precision livestock management (e.g., on-animal sensors, near-real-time remote sensing) for flexibility in within-season stocking density to address improvement of livestock performance and profitability, low- and high-vegetation structure for numerous ecosystem services, and greater drought resilience.

Introduction

Born out of the key recommendation to have ranch-scale management-partnerships to address the production-conservation interfaces in rangeland management (Briske et al. 2011), the Collaborative Adaptive Rangeland Management (CARM) project began in 2012 by engaging with a 11-member stakeholder group comprised of private ranchers (n=4, associated with the local grazing association, Crow Valley Livestock Cooperative, Inc.), non-governmental conservation organizations (n=3, The Nature Conservancy, Environmental Defense Fund, and Bird Conservancy of the Rockies) and public land management personnel (n=4, USDA Natural Resource Conservation Service, USDA Forest Service, Colorado State University Extension, and Colorado State Land Board). This resulted in co-produced objectives on vegetation, profitable ranching (including livestock weight gains), and wildlife habitat that formed the basis for the transdisciplinary science team to develop monitoring methods to collect baseline data in 2013 and apply experimental treatments (2014-2023, Augustine et al. 2024). Social learning objectives were added in 2015 (Wilmer et al. 2022).

The overarching goal was to examine how science can be conducted at ranch-level scales with manager involvement to evaluate the effectiveness of adaptive multi-paddock (AMP) grazing management for both production and conservation goals. In particular, we sought to examine an approach to rangeland management that responds to current and changing rangeland conditions, incorporates active learning, and makes decisions based on quantitative, repeatable measurements collected at multiple spatial and temporal scales.

Methods

At the USDA–Agricultural Research Service's Central Plains Experimental Range in northeastern Colorado, USA, a semiarid, shortgrass steppe rangeland ecosystem, and a site in the Long-Term Agroecosystem Research (LTAR) network, we compared CARM, designed to incorporate AMP principles, to traditional rangeland management which is a season-long (mid-May to early October) grazing approach widely used in the region (TRM, Bement 1969). Each treatment was implemented on 130-ha paddocks paired by soils, topography, and plant communities (n=10 pairs). For the first 5 years of the experiment (2014-2018, CARM 1.0), yearling steers in the CARM treatment were managed as a single herd using AMP grazing with rotational movement of steers among the paddocks with planned year-long rest in 20% of the paddocks (i.e., 2 of the 10). In the second 5 years (2019-2023, CARM 2.0), CARM steers were managed as 2 herds using AMP grazing to reduce negative effects of stocking density on livestock weight gains (Augustine et al. 2020) with the same planned year-long rest in 20% of the paddocks. For the TRM treatment, each of the 10 paddocks were grazed by a separate, small herd such that both treatments were grazed by the same total number of steers each year, thereby controlling for annual stocking rate. The stakeholder group was given full agency in deciding how to collaboratively and adaptively manage the yearling steers in the CARM paddocks. See the following papers for additional methodological details regarding vegetation (Augustine et al. 2020), livestock diet quality (Jorns et al. 2024), livestock weight gains (Augustine et al. 2020, Derner et al. 2021), foraging behaviour (Augustine et al. 2022, 2023), grassland birds (Davis et al. 2020, 2021), tiller defoliation (Porensky et al. 2021) remote sensing (Kearney et al. 2022a,b), social learning (Wilmer et al. 2018, 2022, Fernandez-Gimenez et al. 2019), economics (Windh et al. 2019, 2020, Baldwin et al. 2022), and rangeland modelling (Cheng et al. 2021, 2022).

Results

Vegetation: Biomass production did not differ between grazing treatments (Augustine et al. 2020). Ground data collected in the CARM experiment was used to calibrate a new model that predicts daily standing herbaceous biomass at a 30-m pixel resolution from satellite imagery (Kearney et al. 2022a). We observed that frequencies of grazing on a palatable, cool-season grass (western wheatgrass, *Pascopyrum smithii*) were more sensitive to stocking rate than grazing treatments, as roughly two-thirds of tillers remained ungrazed annually indicating that season-long rest is present in both CARM and TRM. Frequencies of tiller regrazing were low (5−15%) and similar between treatments. Although defoliation patterns were similar between treatments at the whole-ranch scale, CARM enhanced spatial and temporal heterogeneity in defoliation frequencies among individual paddocks, as those grazed earlier in the season or for longer experienced more defoliation (Porensky et al 2021). The Agricultural Policy/Environmental eXtender (APEX) model simulated forage production across years and among soil types (Cheng et al. 2021).

Profitable Ranching: Livestock weight gains were consistently lower (11%–16%) in CARM than TRM, except when forage availability and quality were very low due to drought, or exceptionally high due to a very wet year (Augustine et al. 2022). Reduced weight gains in CARM were attributed to the higher stocking density of steers which altered foraging behaviour (more linear grazing pathways) and spatial grazing distribution (Augustine et al. 2023), and reduced diet quality (Jorns et al. 2024). We quantified the contribution of adaptive grazing management (i.e., the stakeholder group' selection of paddock sequence and grazing rotation indicators) to cattle weight gains using a third herd of steers rotated in a randomly determined sequence (i.e., without adaptive management). This comparison indicated that weight gains of adaptively managed cattle were about 25% greater than gains expected under purely random rotational grazing management (Derner et al. 2021). Satellite time series were used to estimate forage quality (Irisarri et al. 2022), which in combination with estimated standing biomass (Kearney et al. 2022a) can provide reliable estimates of yearling cattle growth rates (Kearney et al. 2022b). Daily weight gain was adequately simulated using the APEX model, with dry matter intake, total digestible nutrients, and temporal distribution of dry matter intake the primary influencers of livestock performance (Cheng et al. 2022). Economic evaluations revealed substantially greater costs for fencing and water infrastructure, and for labour in the multi-paddock CARM compared to TRM (Windh et al. 2019). Economic analyses that included long-term market conditions and fluctuations in cattle prices during the seasonal cycle showed that net returns were highly variable between CARM and TRM (Windh et al. 2020).

Wildlife: Relative to TRM, CARM enhanced heterogeneity in vegetation structure across the landscape, benefiting some grassland bird species (Augustine et al. 2024). Resting paddocks for a full year can generate grassbanks that benefit grassland birds that prefer taller/denser vegetation structure such as Grasshopper Sparrow (Ammodramus savannarum), whereas intentional heavier grazing can benefit grassland bird species preferring shorter/sparser vegetation like the Thick-billed Longspur (Rhynchophanes mccownii) (Davis et al. 2020, 2021). These results helped the stakeholder group understand the spatial specificity of managing for grassland bird species and led to refinement in the wildlife habitat objective by accounting for site fidelity of certain grassland birds and trade-offs between suitable bird habitat and vegetation/plant community objectives.

Social Learning: Evidence of shared learning included the individual stakeholders and researchers acknowledging and examining one another's worldviews (Fernandez-Gimenez et al. 2019). We also observed an increase in sister projects implementing lessons from CARM, including Barta Brothers Ranch at the University of Nebraska, and the US Sheep Station initiating a Sheep Collaboratory project. Following the experiment's first major drought in 2020, the stakeholder group and science team co-revised the grazing management plan to more explicitly address drought using precipitation and soil moisture gauges to monitor the amount of precipitation received to date relative to the long-term mean. Stakeholders and researchers have collaborated to organize numerous field tours, develop a symposium on the CARM project at the 2018 Society for Range Management meeting, and produce a video (USDA-ARS CARM video) and a series of fact sheets about shortgrass bird responses to rangeland management, and the CARM project was used as a case study in a report on Agroecosystem Living Laboratories presented to the G20 Chief Scientists in 2019.

Conclusions/Implications

Stakeholders and researchers successfully implemented a participatory, collaborative adaptive management method to co-develop new knowledge about social, economic, and ecological questions in semiarid shortgrass rangelands. This process was often complex and challenging, but those challenges helped inspire learning and developed strong working relationships. Respect, trust, and shared understanding were essential for the collaborative processes and were enhanced by commitment and time for meaningful discussion, debate, and group reflection. This experiment has quantified relationships among adaptive management decisions, cattle grazing distribution, weather variability, and ecosystem services.

To address improvement of livestock performance and profitability, low- and high-vegetation structure for numerous ecosystem services, and greater drought resilience, CARM 3.0 (2025-2029) will have 6 larger paddocks, with 3 replicate pairs of short- and tall-statured vegetation paddocks (383-728 ha, total of 3388 ha), while the TRM treatment will be maintained as 10 paddocks of 130 ha (1300 ha total), each grazed by a separate herd. Stocking rate will remain the same in both treatments within a year, and adjusted annually as decided collaboratively by the stakeholder group. Each of the 3 pairs of CARM paddocks will be grazed by a group of cattle managed adaptively as either 1 or 2 herds depending on weather conditions. Under non-drought conditions, short-statured vegetation paddocks will be stocked at ~50% above the TRM level and tall-statured paddocks at 50% below the TRM level. This will create both a grass bank and more vegetation structure for wildlife habitat in the tall-statured paddocks, while maintaining low structure wildlife habitat and high livestock production in short-statured paddocks. Movements of steers between the short- and tall-structure pairs of paddocks in CARM will be based on near-real time remote sensing tools (Kearney et al. 2022a) to provide the stakeholder group with maps of vegetation biomass and greenness, combined with demand from recent cattle distribution data via on-animal sensors (GPS and accelerometers).

In addition to the larger scale of paddocks in CARM 3.0, the stakeholder group and science team are currently revising the study objectives, which are incorporating the small mammal black-tailed prairie dogs (*Cynomys ludovicianus*) explicitly into the experiment (they were intentionally not included in CARM 1.0 and 2.0), spatially-explicit zones of management within paddocks for some key wildlife species, a shortened grazing season (ending in early September rather than early October) due to economic benefits (Baldwin et al. 2022), and inclusion of an Amplifier Team for more input regarding public needs and concerns, and strengthening messaging of findings from the project to the public for application, impact, and policy.

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