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The application of state-and-transition models to remotely sensed vegetation cover datasets.

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Abstract

Assessing vegetation conditions in expansive rangeland ecosystems has long posed a persistent challenge. Recent advancements in remote sensing technologies have provided new tools for improving this assessment process. In this study, conducted at two ranch sites in Nevada, we integrated existing line-point-intercept monitoring data with additional field observations to evaluate the vegetation condition or “State” at various monitoring points. We then employed machine learning techniques to classify gridded raster datasets, aligning them with existing State-and-Transition models (STMs) specific to each study area. Leveraging Landsat-derived fractional cover datasets, as well as climate and soil predictors, we aimed to predict vegetation State in specific land types. The resulting vegetation State maps were then combined to generate a cohesive representation of vegetation conditions across the study sites. Our analysis revealed that relative functional group cover emerged as a superior predictor of vegetation state and ecological processes at the site level. However, we encountered variations in state mapping accuracy ranging from approximately 14% to 44% error. These discrepancies were influenced by factors such as study location, landscape heterogeneity, availability of training data, and species-specific challenges, all of which complicate the accurate classification of remote sensing datasets.

Introduction

For over a century, understanding rangeland dynamics has guided rangeland management. Central to this understanding are state-and-transition models (STMs), which describe vegetation changes driven by ecological processes (Westoby et al., 1989; Stringham et al., 2001). However, applying these models across large landscapes remains challenging, as ecological sites—the foundational spatial units for STMs—often vary at scales too fine for practical management (Stringham et al., 2016). To address this, recent efforts have focused on aggregating ecological sites into broader units known as Disturbance Response Groups

(DRGs), enabling the application of remote sensing to ecologically similar areas (Stringham et al., 2016; Phipps & Stringham, 2024).

Advancements in remote sensing have improved the ability to quantify vegetation cover by functional group, providing a cost-effective alternative to extensive on-ground monitoring (Rigge et al., 2021; Allred et al., 2021). However, integrating remotely sensed data with STMs at landscape scales remains limited, as current datasets often fail to contextualize vegetation conditions relative to ecological site potential (Briske et al., 2006; Smith et al., 2023). Digital soil mapping offers a promising solution, correlating soil properties with ecological sites to enhance STM application (Nauman et al., 2022, Phipps and Stringham 2024).

This project aims to create spatially explicit STMs by combining remotely sensed vegetation data, soil mapping, and ground-based monitoring. The resulting framework provides land managers with a scalable, spatially informed tool for effective rangeland planning and decision-making. The workflow, illustrated in Figure 1, highlights the integration of vegetation cover, soil data, and iterative refinements to advance landscape-scale STM applications. Details of the methodology are outlined in subsequent sections.

Methods

Study Area:

This study focused on two Nevada ranches participating in the Bureau of Land Management (BLM) Outcome-Based Grazing Alternative (OBGA) pilot project, emphasizing ecological, economic, and social outcomes. The Winecup Gamble Ranch (northeast Nevada) and Smith Creek Ranch (central Nevada) were selected for their contrasting fire histories and ecological characteristics, as well as representation of major Western United Sates eco-regions. Together, the study areas spanned approximately 464,525 hectares.

Data Collection:

State-and-transition models (STMs) for land types which respond similarly to disturbance were developed using ground-based vegetation data from multiple sources, including BLM, NRCS, and University of Nevada research plots. Data were analysed using the Landscape Level Ecological Inventory and Assessment (LLEIA) database. Plots were classified into varying land types based on ecological site and DRG determinations. Wyoming Sagebrush plant community plots underwent detailed clustering and ordination using Principal Component Analysis (PCA) and Non-Metric Multidimensional Scaling (NMS) to define vegetation states, such as Shrub and Annual Herbaceous States.

Remote Sensing:

Vegetation cover data were derived from USGS RCMAP (2009–2021), incorporating variables such as shrub, tree, annual herbaceous, and perennial herbaceous cover, averaged over six years to normalize precipitation variability. Additional environmental predictors, including elevation, precipitation, soil pH, and reflectance indices, were integrated into analyses. Predictor variables were aligned to a 30m pixel size for consistency with Landsat imagery.

Data Analysis and Modelling:

Relative vegetation cover for functional groups was calculated for each plot. A Random Forest model was trained using extracted predictor variable values at plot locations to predict vegetation states across the study area. Iterative model refinement reduced error by eliminating low-importance variables. Final predictions were validated with plot photographs and mapped to represent vegetation states spatially.

Output and Applications:
The resulting vegetation state maps provide spatially explicit tools for rangeland management, highlighting ecological conditions and guiding decision-making at the landscape scale.

Results
A Random Forest model was used to classify vegetation states across study areas based on pixel-level predictions for each land type. Accuracy was assessed using withheld training data, yielding error rates from 14% to 44%, depending on the plant community. Error terms for each land type are summarized in Table 4. Key predictor variables included the relative proportion of shrub, annual herbaceous, and perennial herbaceous vegetation cover, while absolute cover metrics performed poorly. Final maps were generated by combining land type-specific classifications and incorporating pasture boundaries for enhanced visualization.

Key Findings by Land Type

- **Wyoming Sagebrush**: Largest extent and highest accuracy, with error rates of 13.8% (WGR) and 12.5% (SCR). Errors primarily occurred in rare states, such as the Current Potential State at SCR (66% error).
- **Low Sagebrush**: High error rates (44% WGR, 35% SCR) due to spectral similarity between dominant species (e.g., Sandberg's bluegrass) and cheatgrass.
- **Low Sagebrush (High Resilience)**: Predicted only at SCR with a 33% error rate, primarily in the Annual and Tree States.
- **Black Sagebrush**: Error rates of 24% (WGR) and 18% (SCR). The Annual State at SCR showed 100% error due to its rarity.
- **Mountain Sagebrush**: Errors were 21.4% (WGR) and 36.8% (SCR), influenced by terrain complexity and sparse observations of certain states.
- **Shadscale Saltbush/Bud Sagebrush**: Errors of 40% (WGR) and 28.6% (SCR). Shrub State was consistently accurate. Alternative states may not be present in the study sites.
- **Winterfat**: Sparse observations yielded error rates split across Shrub and Annual States.
- **Greasewood**: Modeled only at WGR with a 15.8% error rate, mainly between Annual and Current Potential States.

Figure 1 illustrates vegetation state maps for WGR and SCR, aiding management and monitoring. Detailed accuracy matrices for each VGG are provided in Figures 7–14.

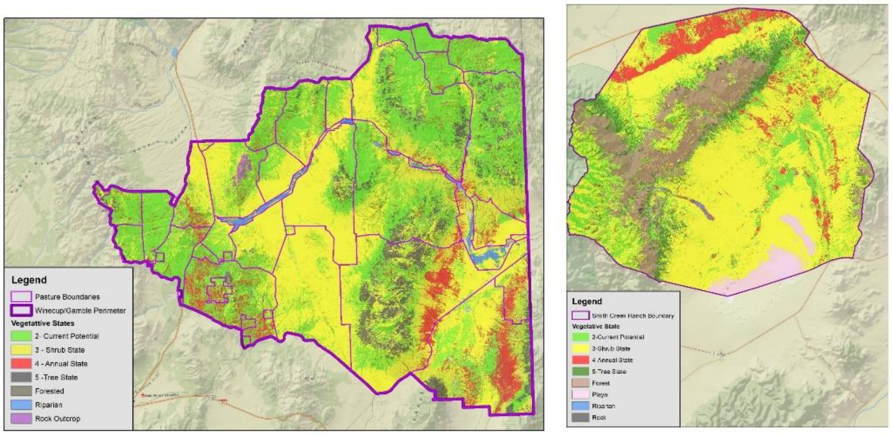

Figure 1: Vegetation state map of the Winecup-Gamble and Smith Creek Study areas. Showing states mapped across the management area, including pasture boundaries, to assist in management and monitoring decision making.

Discussion

This study highlights the effective application of fractional cover mapping technologies for spatially mapping vegetation states, adding a critical spatial dimension to State-and-Transition Models. This advancement enables practical management applications across scales, from pastures to regional planning, aiding proactive restoration and conservation efforts. It facilitates rapid assessment of areas that may have crossed ecological thresholds, requiring active restoration, or areas that could benefit from passive resilience-enhancing strategies.

While this analysis utilized vegetation monitoring data as training points, the approach can also work with visually assessed state conditions by experienced ecologists. Accurate soil and plant community mapping is essential, as plant community proportions vary significantly across these units. Relative cover emerged as a robust predictor of vegetation state, providing insights into the structural and functional dynamics of plant communities, outperforming absolute cover measurements.

The study focused on categorizing pixels into vegetation state categories to inform management priorities rather than tracking trends in vegetation cover or landscape outcomes. The RCMAP dataset effectively captured relative cover proportions, with perennial vegetation, shrub, and annual cover strongly predicting the Current Potential, Shrub, and Annual States, respectively. Climatic variables, including minimum and maximum temperatures and precipitation averages, further enhanced accuracy, particularly in the Wyoming Sagebrush land type, where they improved model performance by 7%.

Challenges remain in distinguishing areas seeded with agricultural cultivars, such as Crested Wheatgrass, from native perennial grass states. Secondary tools like the Monitoring Trends in Burn Severity dataset and the Land Treatment Digital Library can help identify seeded areas, though uncertainties persist due to historical mapping gaps. From an ecological perspective, these areas, while distinct in management context, may function similarly to native plant communities in terms of site dynamics.

Incorporating climatic variables and leveraging additional datasets can refine vegetation state mapping, providing greater precision for ecological assessments and management interventions, especially in expansive, heterogeneous landscapes like the Wyoming Sagebrush biome.

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References

Allred, B. W., Bestelmeyer, B. T., Boyd, C. S., Brown, C., Davies, K. W., Duniway, M. C., . . . Griffiths, T. V. (2021). Improving Landsat predictions of rangeland fractional cover with multitask learning and uncertainty. *Methods in Ecology and Evolution, 12*(5), 841-849.

Briske, D. D., Fuhlendorf, S. D., & Smeins, F. E. (2006). A unified framework for assessment and application of ecological thresholds. *Rangeland Ecology & Management, 59*(3), 225-236.

Nauman, T. W., Burch, S. S., Humphries, J. T., Knight, A. C., & Duniway, M. C. (2022). A Quantitative Soil-Geomorphic Framework for Developing and Mapping Ecological Site Groups. *Rangeland Ecology & Management, 81*, 9-33.

Phipps, Lucas, and Tamzen K. Stringham. "Digital mapping of vegetative great groups to inform management strategies." *Rangeland Ecology & Management* 94 (2024): 7-19.

Rigge, M., Homer, C., Shi, H., Meyer, D., Bunde, B., Granneman, B., . . . Xian, G. (2021). Rangeland Fractional Components Across the Western United States from 1985 to 2018. *Remote Sensing, 13*(4), 813.

Smith, J. T., Allred, B. W., Boyd, C. S., Davies, K. W., Kleinhesselink, A. R., Morford, S. L., & Naugle, D. E. (2023). Fire needs annual grasses more than annual grasses need fire. *Biological Conservation, 286*, 110299.

Stringham, T. K., Krueger, W. C., & Shaver, P. L. (2001). States, transitions, and thresholds: further refinement for rangeland applications.

Stringham, Tamzen K., et al. "Disturbance response grouping of ecological sites increases utility of ecological sites and state-and-transition models for landscape scale planning in the Great Basin." *Rangelands* 38.6 (2016): 371-378.

Westoby, Mark, Brian Walker, and Imanuel Noy-Meir. "Opportunistic management for rangelands not at equilibrium." *Rangeland Ecology & Management/Journal of Range Management Archives* 42.4 (1989): 266-274..