Society for Range Management

Case Study

Applying Ecological Site Concepts to Adaptive Conservation Management on an Iconic Californian Landscape

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On the Ground

- Managers of large landscapes with limited financial resources can use ecological sites and state-and-transition models to identify landscape divisions with the highest chances of responding favorably to management activities.
- This conceptual framework can help determine the optimal configuration of pastures and water developments so that conservation-focused grazing and response monitoring align with focal landscape divisions.
- As communication tools, these models can help conservation land managers and graziers to better understand how the variation in landscapes affects the distribution of conservation targets and the specific locations where management can be tailored to enhance biodiversity.

Keywords: ecological sites, state-and-transition models, conservation management planning, adaptive management, non-equilibrium.

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Tejon Ranch is a spectacular landscape valued for its cultural heritage, livestock production, and biological diversity. At 109,000 ha, it is the largest contiguous, privately owned property in California. Its varied terrain and types of rock demonstrate its complex geologic history, and this geophysical composition is ultimately responsible for many of the biological patterns seen in the grasslands, shrublands, savannas, and wetlands of the ranch today.

Tejon lies at the convergence of three of California's major biogeographic zones (Fig. 1). The Tehachapi Mountains, part of the Montane biogeographic zone, trend diagonally on the property. The Garlock Fault runs through the spine of the range. North of the fault at the base of the mountains lies the San Joaquin Valley in the Mediterranean biogeographic zone. The southern face of the Tehachapis gives way to the Antelope Valley, the westernmost wedge of the Mojave Desert. Overall, the climate of this ecotone is Mediterranean, with cool, wet winters, and warm, dry summers. The air temperature, on average, is 25°C in August and 9°C in January. Rainfall varies greatly among years, with an overall long-term average of 22 cm (Fig. 2).

Under the 2008 Tejon Ranch Conservation and Land Use Agreement, the Tejon Ranch Company (landowner) retained the right to conduct commercial ranching and other commercial uses within 97,000 ha of conserved lands, while the Tejon Ranch Conservancy established specific conservation objectives and grazing management tactics that govern livestock management on those lands. Ranch-wide management plans that determine the landowner's reserved land use rights are to be revised every 5 years. In June 2013, with the adoption of its first ranch-wide plan, the Conservancy became one of the first non-governmental organizations in California with a full-fledged adaptive management plan for grasslands. The Tejon Ranch Conservancy and University of California partnered to make testable predictions about the effects of management on the 44,000 ha of grasslands on the ranch.

Important Concepts Defining Ecological Site Groups and Vegetation Dynamics

California's Mediterranean climate, along with its active geology, creates regional islands of native species diversity. However, these regional islands are also susceptible to invasions by plants and animals from other Mediterranean areas of the

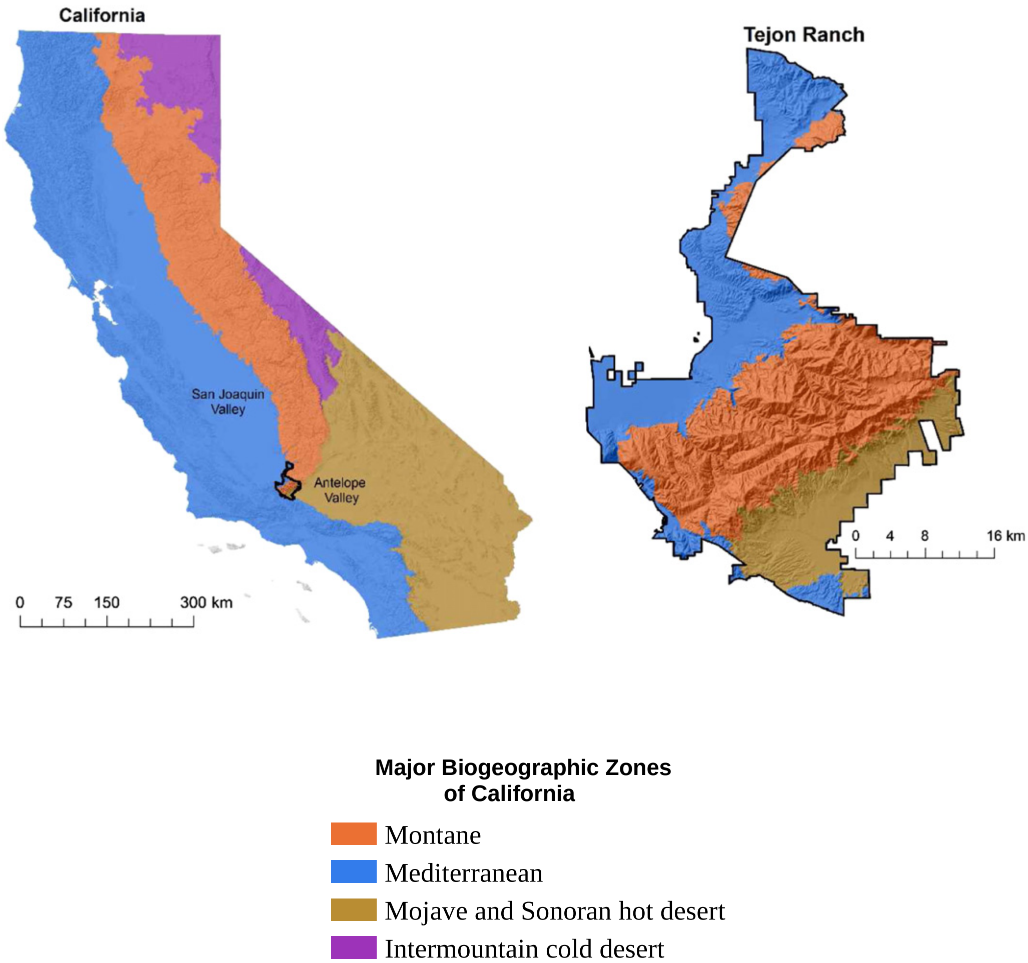

Figure 1. Three of California's four major biogeographic zones converge on Tejon Ranch.[6,18]

world.[1] Recently, anthropogenic nitrogen deposition has increased soil nitrogen, creating more hospitable conditions for exotics.[2]

In Californian annual grasslands, as in other rangeland types worldwide, soils and vegetation vary together across short distances,[3] and rainfall fluctuates greatly over time. Because annual plant production and species composition vary closely with these abiotic factors,[4] annual grasslands behave as persistent nonequilibrium systems, in which abiotic factors govern plant community dynamics more than biotic processes such as grazing do.[5] As a result, management is more likely to be successful if it is tailored within the constraints of abiotic factors such as rainfall events, fire, and particular soils.[6] Accordingly, cataloguing the variation in rainfall and underlying geo-topo-edaphic heterogeneity is critical for understanding the system and making predictions about the influences of management. Ecological sites and state-and-transition models (STMs) are conceptual tools ideally suited to the task.

Generalized State and Transition Models

When we began work in 2008, no official Ecological Site Descriptions had been developed for Tejon Ranch. Therefore, we developed a novel approach guided by the NRCS ecological site philosophy[7,8] but adapted to the immediate needs of the Tejon Ranch Management Plan. Through extensive reconnaissance of the landscape, use of local knowledge, and review of available geologic research and soil surveys, we conceptualized the Tejon grassland landscape as an assemblage of geologic landform classes.[9] We defined a "geologic landform" as a unit of land with a distinct combination of biogeographic region, elevation, slope, geologic material and age, and dominant formative geomorphic process. We hypothesized that each geologic landform class would support a distinct set of soils and vegetation dynamics (historical states, contemporary states and community phases, and probable responses to management) and therefore would form the basis for a distinct ecological site. We tested this hypothesis by establishing 57 permanent, 0.3-ha plots randomly sited in grasslands within strata defined by the geologic landform classes.

First, we assayed the plots' surface chemical and textural soil properties and estimated historical conditions using soil phytoliths[10] and historical accounts.[11] We then resampled the plots for several years on an annual basis during peak live

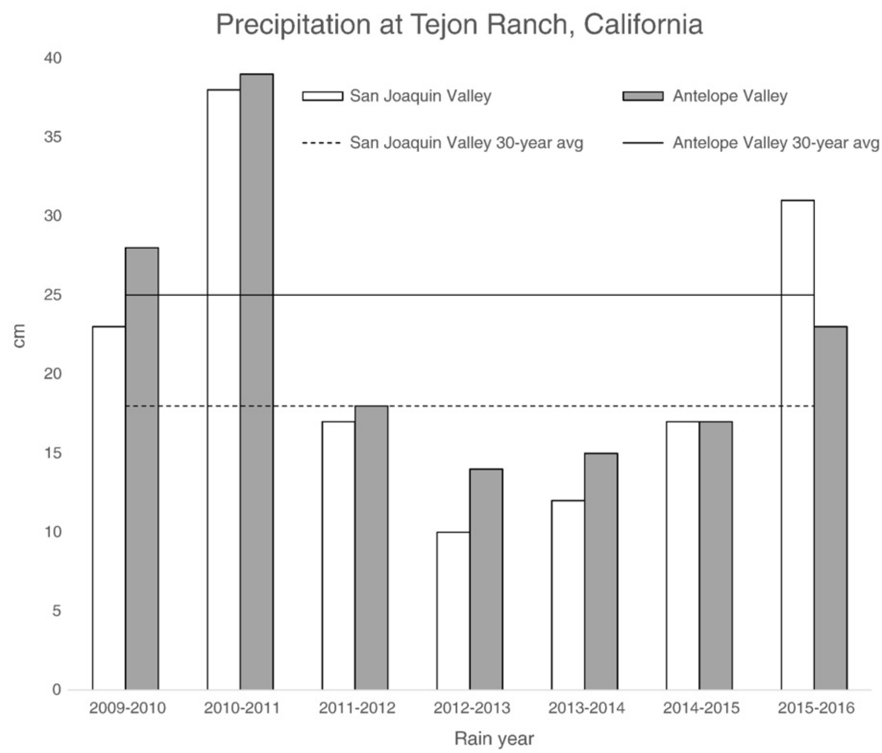

Figure 2. October - April precipitation in the broad alluvial valleys of Tejon Ranch.

biomass conditions, measuring plant species composition, photo-documenting the surrounding landscape, and estimating the previous year's cattle and wildlife use. We used our findings to statistically test our hypothesis that each geologic landform stratum supported a distinct suite of biophysical properties and spatial and temporal patterns. After using analytical results to refine our ecological site classification, we catalogued community phases, states, and transitions for each ecological site. The ecological sites we identified are analogous to Ecological Site Groups in scale and delineation criteria.[12]

We present STMs for four ecological site groups located north of the Garlock Fault on Tejon Ranch (Table 1, Fig. 3). Assessing the four STMs together revealed that in comparison to the other classified sites north of the fault, the Holocene Flats had the greatest potential to support native plant and animal conservation targets. Accordingly, we prioritized the Holocene Flats for conservation management. In the following sections, we explore the Holocene Flats STM and evaluate its potential to support specific conservation objectives.

Important Challenges for Conservation Land Management

Conservation management goals for Californian annual grasslands typically include preserving and enhancing native biodiversity.[13] Because grazing has a weaker influence on vegetation dynamics than physical factors in Californian annual grasslands, conservation management has emphasized site stability (soil protection) through maintaining desired levels of residual dry matter more than specialized grazing systems.[14]

For any management objective, the spatial and temporal complexity of the Californian annual grassland system means that approaches effective on one site at one time may not work on another site at another time.[15] For example, almost 500 species of native annual forbs are patchily distributed in Californian annual grasslands,[16] and they are common restoration targets. The abundance and diversity of native annual forbs at a given site depends on the physical features of the site, past management, and annual weather patterns.[12] Further, many San Joaquin Valley grassland vertebrates of conservation concern appear to be associated with specific plant species assemblages or grassland structural characteristics.[17] Because the factors associated with these desirable plant and animal species are heterogeneously distributed across space and time, management practices need to incorporate as much information as possible about spatial and temporal variability and to accommodate that variability in planning. This is a challenge for managers with large landscapes and limited financial resources.

Applications to Decision-Making and Recommendations for Improvement

The Native annual forbs and lupines community phase in the Current Annual Grassland State of the Holocene Flats (Fig. 3) shows the highest potential to support native plants of any classified unit north of the Garlock Fault and appears to provide the best habitat for the federally endangered San Joaquin kit fox (***Vulpes macrotus mutica***) and blunt-nosed leopard lizard (***Gambelia sila***). These conservation target vertebrate species prefer low biomass conditions, and their habitat quality is reduced when exotic annuals, particularly grasses, are abundant.[17] Native plant abundance and seed germination are also depressed by high levels of litter created

Table 1. Geo-topo-edaphic properties distinguishing four ecological site groups north of the Garlock Fault on Tejon Ranch

Ecological site group	Biogeographic region	Geologic material	Slope	Elevation	Dominant formative processes	Dominant soil great groups
Holocene Flats	Mediterranean	Sediment from adjacent mountains and hills	<5% slope	<300 m	Alluvial deposition by active streams	Xerofluvents, Haplocambids, Xeropsamments, Torriorthents
Pleistocene Terraces	Mediterranean	Sediment from adjacent mountains and hills	5%-30%	300-600 m	Alluvial deposition by former streams; dissection by younger alluvial fans	Xerorthents, Argixerolls, Xerofluvents
Miocene Hills	Mediterranean	Sandstone and conglomerate	15%-30%	300-600 m	Alluvial processes in shallow marine and deltaic waters during the Miocene; subsequent uplift	Xerochrepts
Mafic Bedrock Slopes	Montane	Mafic granite, quartz-rich granite, mafic gneiss; metasedimentary roof pendants	>30%	600-1000 m	Uplift of Sierra Nevada Batholith	Haploxerolls

when exotic grasses dominate. Our conservation management hypothesis for this ecological site group is that conservation targets are favored when native annuals dominate and residual biomass remains low (i.e., Native annual forbs and lupines community phase), and are not when exotic annuals dominate and residual biomass is high (i.e., Red brome community phase).

Transitions from the Historical State—a plant community free of exotic annual plant species—to the Current Perennial State (T1) and Current Annual Grassland State (T3) occurred with species invasions beginning in the late 18th century.[1] Much of the Current Perennial State transitioned to the Current Annual Grassland State (T6) in the 19th and 20th centuries, facilitated by cultivation, livestock grazing, and increased fire frequency and intensity associated with elevated fuel loading from exotic annuals.[11] Transitions T1, T3, and T6 are probably irreversible. However, ***within*** the Current Annual Grassland State, we hypothesize that we can create significant shifts between community phases dominated by exotic annuals or by native annuals. From our study, guided by the STM conceptual framework, we now know that exotic annual grass abundance on the Holocene Flats ecological site group is favored by steady rainfall early in the growing season with a significant spike in December.[12] We hypothesize that tailoring livestock grazing to modify vegetation structure under prevailing rainfall conditions is our best bet for achieving conservation goals.

Because Tejon Ranch is so extensive and employs little active herding, grazing management generally must be applied at the pasture scale. The very large pastures at Tejon Ranch, spanning 2,000 to 16,000 ha, were configured over many decades to achieve livestock production objectives. Since 2008 consideration of conservation goals has significantly increased. Our understanding of the distribution of the Holocene Flats has allowed us to identify needs for improved ranching infrastructure to better align pasture configuration with the ecological site group, design and apply an efficient geographically focused adaptive management monitoring program, and justify to private and public funding sources our management rationale and expected outcomes. This conceptual framework has also helped to enhance communication between the Conservancy and the ranching lessees,

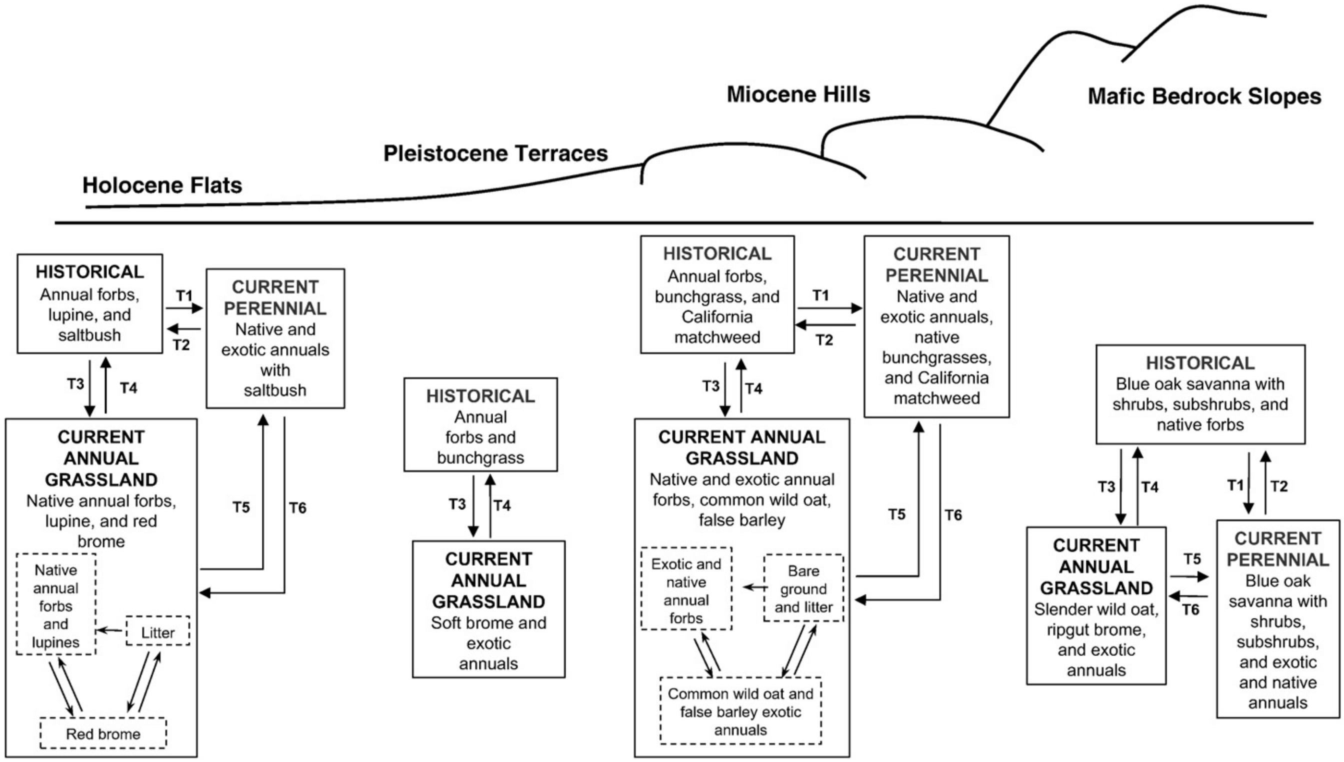

Figure 3. Schematic diagram and state-and-transition models for four ecological site groups north of the Garlock Fault on Tejon Ranch. States are represented in solid boxes, and community phases are in dashed boxes within the states. We have prioritized the Holocene Flats ecological site group for conservation management.

helping all to better understand how the variation in grassland landscapes can affect the distribution of conservation targets and the motivation for particular management strategies. Using the Conservancy's privately raised funds in concert with Environmental Quality Improvement Program cost sharing with the ranching lessee, a 2,225-ha pasture was divided along ecological site boundaries and new livestock waters were installed in a newly circumscribed Holocene Flats pasture. Further, on that and other Holocene Flats pastures, a collaborative NRCS Conservation Innovation Grant is funding adaptive grazing management trials to create low vegetative biomass conditions for grassland conservation goals and to evaluate the capacity for managed grazing to maintain low biomass conditions in the face of weather-driven community phase shifts to exotic annual dominance. Results of these adaptive management trials are forthcoming.

Characterizing the community phases, states, and transitions of grassland ecological site groups has helped us to better understand the nature of ecological change on the 109,000-ha Tejon Ranch landscape, identify landscape divisions with the highest potential to support our native biodiversity targets, and formulate testable predictions about the efficacy of livestock grazing as a conservation management tool. Accordingly, applying ecological site concepts to adaptive conservation management has allowed us to translate substantial spatial and temporal complexity into pasture-level management targets.

References

1. Bartolome, J.W., R.D. Jackson, and B. Allen-Diaz. 2009. Developing data-driven descriptive models for Californian grasslands. ***In:*** Hobbs RJ, & Suding KN, editors. New models for ecosystem dynamics and restoration. Washington, DC, USA: Island Press. p. 124-138.
2. Fenn, M.E., E.B. Allen, S.B. Weiss, S. Jovan, L.H. Geiser, G.S. Tonnesen, R.F. Johnson, L.E. Rao, B.S. Gimeno, F. Yuan, T. Meixner, and A. Bytnerowicz. 2010. Nitrogen critical loads and management alternatives for N-impacted ecosystems in California. *Journal of Environmental Management* 91:2404-2423.
3. O'Geen, A., R. Dahlgren, A. Swarowsky, D. Lewis, and M. Singer. 2010. Research connects soil hydrology and stream water chemistry in California oak woodlands. *California Agriculture* 64:78-84.
4. Heady, H.F. 1958. Vegetational changes in the California annual type. *Ecology* 39:402-416.
5. Jackson, R.D., and J.W. Bartolome. 2002. A state-transition approach to understanding nonequilibrium plant community dynamics in Californian grasslands. *Plant Ecology* 162:49-65.
6. Spiegal, S., L. Huntsinger, P. Hopkinson, and J. Bartolome. 2016. Range ecosystems. ***In:*** Ecosystems of California. Berkeley, CA: University of California Press. p. 835-864.
7. Moseley, K., P.L. Shaver, H. Sanchez, and B.T. Bestelmeyer. 2010. Ecological site development: a gentle introduction. *Rangelands* 32:16-22.
8. USDA (U.S. Department of Agriculture), 2014. National Ecological Site Handbook. First Edition. United States Department of Agriculture Natural Resources Conservation Service.

9. Tejon Ranch Conservancy, 2013. Ranch-wide Management Plan, Volume 1: Natural Community Descriptions. CA, USA: Tejon Ranch. p. 3-3 to 3-10.
10. Evett, R.R., and J.W. Bartolome. 2013. Phytolith evidence for the extent and nature of prehistoric Californian grasslands. *The Holocene* 23:1644-1649.
11. Minnich, R.A. 2008. California's fading wildflowers: lost legacy and biological invasions. Berkeley, CA, USA: University of California Press.
12. Spiegal, S.A. 2015. The ecological basis for grassland conservation management at Tejon Ranch, California [dissertation]. Berkeley, CA, USA: University of California, Berkeley.
13. Bartolome, J.W., B.H. Allen-Diaz, S. Barry, L.D. Ford, M. Hammond, P. Hopkinson, F. Ratcliff, S. Spiegal, and M.D. White. 2014. Grazing for biodiversity in Californian Mediterranean grasslands. *Rangelands* 36:36-43.
14. Bartolome, J.W., W.E. Frost, and N.K. McDougald. 2006. Guidelines for residual dry matter on coastal and foothill rangelands in California. Rangeland Management Series Publication 8092. Oakland, CA, USA: University of California Division of Agriculture and Natural Resources.
15. Eviner, V.T., and C.V. Hawkes. 2008. Embracing variability in the application of plant-soil interactions to the restoration of communities and ecosystems. *Restoration Ecology* 16:713-729.
16. Calflora, 2014. Information on California plants for education, research and conservation. Berkeley, CA, USA: The Calflora Database (a non-profit organization).
17. Germano, D.J., G.B. Rathbun, L.R. Saslaw, B.L. Cypher, E.A. Cypher, and L.M. Vredenburg. 2011. The San Joaquin Desert of California: ecologically misunderstood and overlooked. *Natural Areas Journal* 31:138-147.
18. Hickman, J.C. 1993. The Jepson Manual: Higher Plants of California. Berkeley, CA, USA: University of California Press.

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