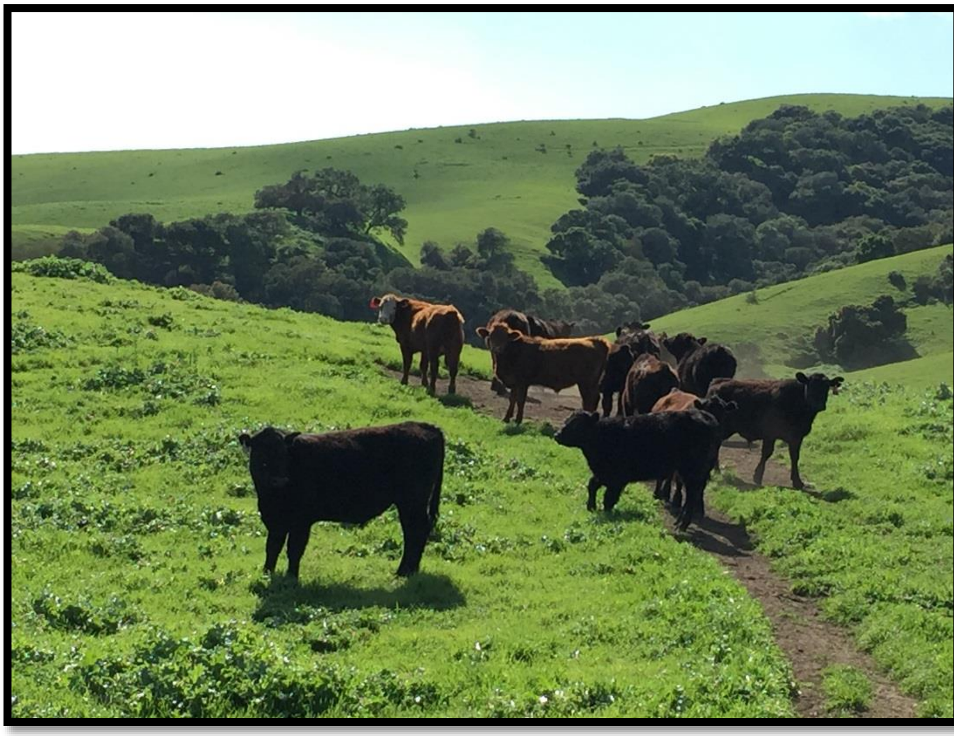
Alternative Grazing Monitoring Methodology Assessment

Final Report for Local Assistance Grant P1482106



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Executive Summary

Many threatened, endangered, or otherwise rare species in California rely on California annual grassland dominated landscapes. Without management, the quality of grassland habitat for species of management interest can become reduced through invasion by pest plants or overgrowth of annual grasses. Livestock grazing is typically used as a management tool to maintain a relatively short grass condition and reduce impacts on the ecosystem by pest plants. When public or private land conservation agencies and organizations take responsibility for managing grassland dominated landscapes as a means to provide habitat for managed species, there is a need to measure the effectiveness of that management, and to provide information that can be used to adjust management methods if needed.

Residual dry matter (RDM) it a generally accepted metric to determine whether grazing management is being conducted in a way that is sufficiently protecting the grassland ecosystem. Surveying RDM requires rangeland specialist to visit grazed lands to conduct assessments on foot or by vehicle. If done properly the methods are labor intensive, resulting in high monitoring costs for land managers. Agencies responsible for monitoring grazing effects on protected grassland habitats would benefit from adding a remote sensing based system to their toolkit. We evaluated RDMapper's costs, efficiency, and accuracy in tracking residual dry matter compliance. It identifies areas at risk of failing to reach management objectives, and thus where to focus limited monitoring resources. We tested RDMapper on California annual grasslands at parks and preserves of three agencies in the Coast Ranges of Central California. RDMapper processes, analyzes, and displays vegetation indices, then indicates the degree of compliance over the previous five years, and predicts future compliance.

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Publication Note

The contents in this report were submitted for publication to *Rangelands* on April 10, 2017. The submission was still under review when this summary was written. Ultimately if there are differences between what is represented here and the final publication that appears in *Rangelands*, the published version should rule.

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Introduction

Nearly 11% (or 10.9 million acres) of California is occupied by grassland (Table 1). California's annual grasslands occupy nearly 10.5 million acres (96% of all grasslands), of which nearly 20% (2.1 million acres) have legal restrictions to conserve open space or special resources, including conservation easements (0.5 million acres) or fee title ownership (1.6 million acres) (Table 2).[1]

Table 1. Summary of Types of Grasslands in California

Category of California Grasslands	Acres	Percent
All grasslands	10,904,137	11% (of land surface)
Perennial grasslands and forblands	433,805	4% (of grasslands)
Annual grasslands	10,470,332	96% (of grasslands)

Table 2. Summary of Protected Grasslands in California

Type of Legal Protection	Acres
Calif. annual grasslands with legal restrictions to conserve open space or special resources	2,091,518
Calif. annual grasslands protected through conservation easements	517,781
Calif. annual grasslands protected through fee title ownership, including federal and state lands	1,573,737
Total	**4,183,036**

Those grasslands that are publicly owned or have legal restrictions to conserve special resources are generally obliged to conduct monitoring due to permit or easement requirements or public demand. Many of the agencies and individuals responsible for monitoring the effects of grazing on these grassland habitats face a daunting task. Conventional methods for collecting and reporting the required data and for providing meaningful year-by-year assessments of

[1] Geographic Information System analyses reveal the current numbers of acres shown in Table 1 and Table 2 using publicly available databases—

- California Wildlife Habitat Relationships System vegetation types in the Fire and Resource Assessment Program (FRAP) database of the California Department of Forestry and Fire Protection (http://frap.fire.ca.gov/data/frapgisdata-sw-fveg_download, accessed 3 Mar 2016)
- California Conservation Easement Database, California Protected Areas Data Portal (http://www.calands.org/cced accessed 1 Jan 2017)
- California Protected Areas Database, California Protected Areas Data Portal (http://www.calands.org/data accessed 24 Mar 2017)

Data are not readily or comprehensively available on how many acres of California grasslands are grazed by livestock.

herbaceous cover (and indirectly its effects on soil conservation and habitat quality) tend to be time-consuming and resource-intensive, sometimes prohibitively so. Our team evaluated a new tool with the potential to significantly reduce the costs and improve the efficiency and accuracy of monitoring the effects of grazing, while also increasing opportunities for collaborative engagement among the parties responsible for habitat management. Developed by The Nature Conservancy (TNC), the tool—called RDMapper—tracks RDM (residual dry matter) compliance, a key element of grazing-effects monitoring, with relative ease compared to other methods. In doing so, it can identify areas in the spring that are at risk of failing to reach fall management objectives, making it possible to focus limited monitoring resources on the problem management units. We tested RDMapper's effectiveness for monitoring RDM compliance on California annual grasslands at park and preserve lands of three agencies in the Coast Ranges of Central California.

The Santa Clara Valley Habitat Agency (Habitat Agency), at whose request our team evaluated RDMapper, was formed in 2013 to implement the Santa Clara Valley Habitat Plan (Habitat Plan) (ICF International 2012). The Habitat Plan provides a framework for permitting development projects in habitat of endangered and threatened species. The Habitat Plan requires developers in these areas to avoid, minimize, or compensate for impacts to the special-status species habitat and special natural communities. The Habitat Plan includes two key approaches for protecting habitat: a) bringing some habitat lands into public ownership, and b) creating conservation easements on private habitat lands for their protection and management in perpetuity, as mitigation for habitat loss due to development within the covered region.

Grasslands cover 92,484 acres (20%) of the Habitat Plan Area (ICF International 2012), and are regarded generally as “hotspots” of biodiversity (Bartolome et al. 2014). A significant challenge for managers of these grasslands is the control of non-native herbaceous vegetation, which if left unmanaged can reduce habitat quality for the natives. Among the available methods for keeping non-native vegetation in check and for sustaining grasslands habitat in general, the most cost-efficient and effective—and likely to have the widest use—is livestock grazing. Two major alternatives, mowing and burning, are both very labor-intensive and therefore costly; also, both of these methods are restricted to small areas during the non-growing seasons, and neither one generates revenues for the property owner. Additionally, burning is uncommon because it requires obtaining permits from regional air quality regulators and coordinating with local fire management personnel. In contrast, grazing by cattle has the advantages of providing effective vegetation treatments in gentle and rugged terrain and of generating lease revenues. Moreover, it can be provided by a rancher who will conduct supplementary stewardship services, including friendly interactions with agency managers and public recreational visitors.

Monitoring grazing management in California annual grassland with conventional methods relies mainly on tracking residual dry matter, or RDM—the mass of herbaceous plant material left on the field at the end of a growing season. This measurement reflects the effects of a season's grazing on soil cover and habitat conditions in a given area, and helps grassland monitors ascertain prospects for the subsequent year's species composition, forage production, and habitat structure.

Measuring RDM often involves field-based labor-intensive methods, with travel to and from as well as across the property. Traditional RDM monitoring includes visiting each management unit, clipping and weighing vegetation samples at representative sites across the property, and using those sites to calibrate management unit- and property-based assessments of RDM conditions (Bartolome et al. 2006). The results of these field measurements are often tabulated by management units and displayed on maps showing zones (color-coded polygons) that represent categories of greater and lesser amounts of RDM across the property (Guenther and Hayes 2008). These maps are then used in monitoring reports to provide feedback to land managers and grazing operators on the effectiveness of their attempts to meet the property's management objectives during the previous year. This approach, especially over the large expanses of grassland covered by the Habitat Plan, can be costly and time-consuming, and it identifies ineffective grazing actions months after they have occurred.

In search of a better way, the Habitat Agency has been investigating more cost-effective methods for monitoring the Habitat Plan's grasslands since 2015, when the agency received a grant from the California Department of Fish and Wildlife for this purpose. Among the more promising options the investigation identified was remote sensing—that is, the use of satellite-based sensors to detect objects on earth, which has been studied since the 1980s as a potential tool for grasslands monitoring. The recent development of free, pre-processed satellite data as well as cloud computing platforms has made remote sensing an appealing method of land monitoring, including for RDM (Tsalyuk et al. 2016). Recognizing the promise in this approach, the Habitat Agency reached out to ICF and LD Ford Rangeland Conservation Science in 2015 to evaluate TNC's new RDM monitoring system, RDMapper (Tsalyuk et al. 2016, Butterfield et al. 2014). This interactive tool can inform decision-makers about current and expected grassland conditions, the degree of RDM compliance with grazing plans or conservation easements, and locations where on-the-ground monitoring might be needed.

Our study tested and evaluated the use of RDMapper at eight properties within the Habitat Plan area: six on the west side of the Mount Hamilton Range and two in the eastern foothills of the Santa Cruz Mountains (Table 3 and Figure 1).

Table 3. Properties Studied

Monitoring Agency	Property Name (Property Owner)	Acres
Santa Clara County Parks	Coyote Lake Harvey Bear Ranch County Park	2,775
	Edward. R. Levin County Park	1,021
	Joseph D. Grant County Park	8,437
	Calero County Park -- Rancho San Vicente	998
Santa Clara Valley Open Space Authority	Coyote Valley Open Space Preserve	348
	Coyote Ridge Preserve	539
The Nature Conservancy	San Felipe Ranch (private)	17,351
	Rancho Canada de Pala Preserve	1141
Total		**32,610**

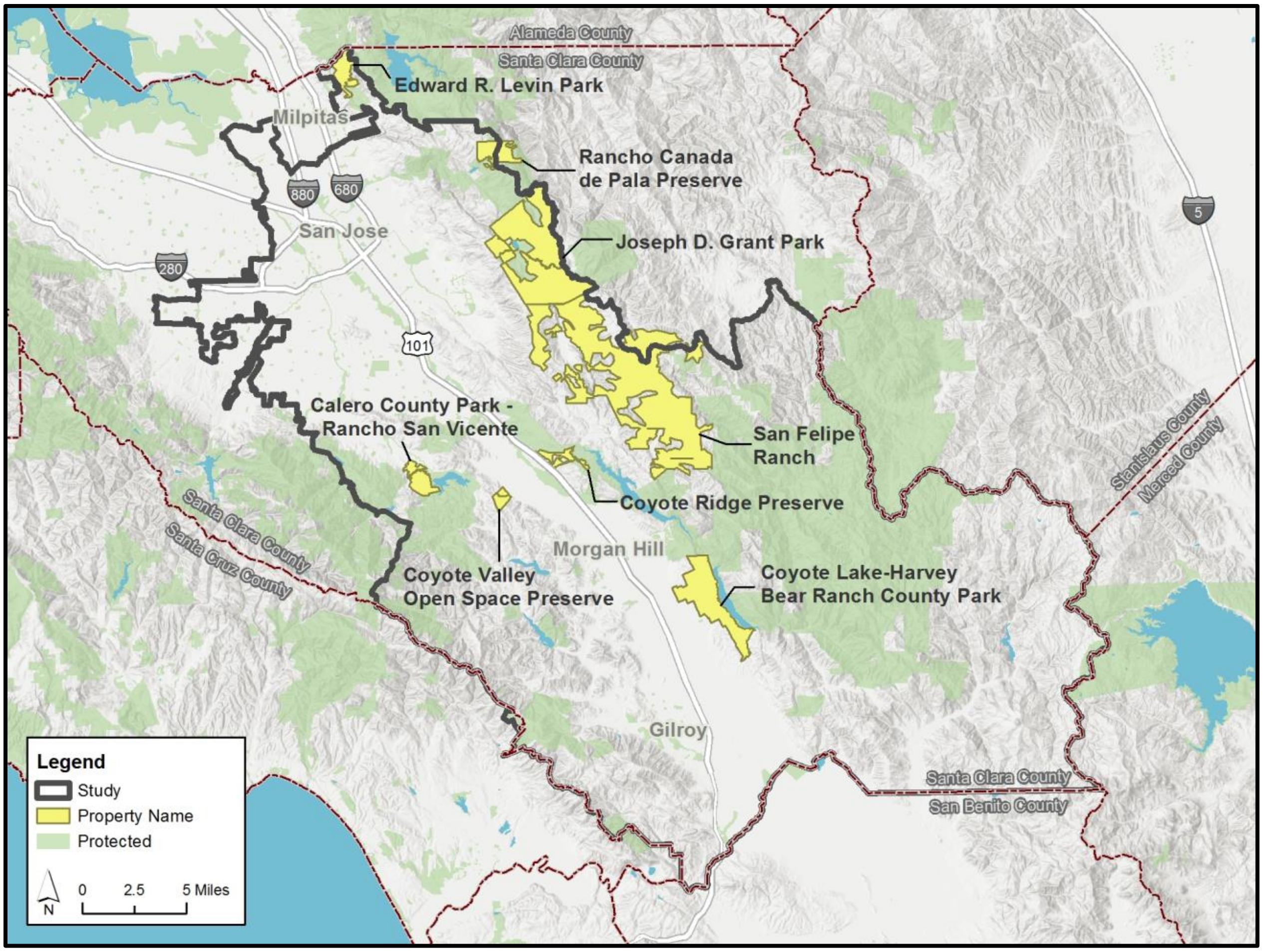

Figure 1. Properties Evaluated

RDMapper as a Grassland Monitoring Method

RDMapper processes, analyzes, and displays vegetation indices derived from satellite imagery for a property's management units (Figure 2),[2] indicating the degree of compliance with the conservation easement's RDM standard (Tsalyuk et al. 2016, Butterfield et al. 2014). The RDMapper method, and remote sensing for grasslands monitoring in general, presents many potential advantages over conventional methods for RDM monitoring:

- Reduction of monitoring costs, especially field-based expenses
- Promotes effective planning
- More objective and consistent monitoring data
- Standardized collection and storage of monitoring data

[2] Management units are generally fields fenced to contain the grazing cattle; there are usually multiple management units within each property.

- Proactive monitoring that allows mid-year management changes to improve compliance outcomes
- Greater ease of collaboration between property monitoring personnel and landowners or those holding conservation easements/deed restrictions; with RDMapper reports in hand, these parties together can identify and avoid potential conflict between grazing and land management goals

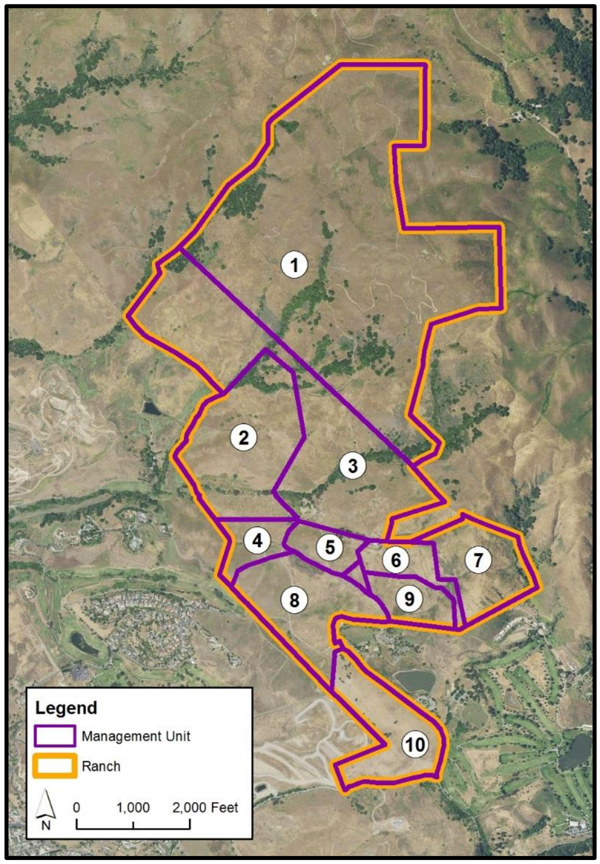

Figure 2. Example of management units

RDMapper draws on information from four free and public datasets derived from two sources, all of which taken together present a rather daunting "alphabet soup" of acronyms. The two data sources are Moderate Resolution Imaging Spectroradiometer (MODIS) and Parameter Elevation Regressions on Independent Slopes Model (PRISM). The MODIS instrument, riding aboard NASA's Terra satellite, captures a daily mosaic of images of the entire terrestrial surface, and provides RDMapper with three sets of data: a Normalized Difference Vegetation Index (NDVI), a Leaf Area Index (LAI), and a measure of the Fraction of Photosynthetically Active Radiation (FPAR). NDVI is captured every 16 days, LAI and FPAR are captured every 8 days, and PRISM data are based on monthly interpretations. The frequency with which these data are captured is a key asset to RDMapper, as they collectively allow for time series to be generated for each management unit. RDMapper extracts data from two derived products—MOD13Q1 (NDVI) and MOD15 (FPAR and LAI)—which provide an atmosphere-corrected, 16-day composite at 250 meters for NDVI [40] and an 8-day composite at 1 kilometer for LAI and FPAR. PRISM provides the fourth dataset: monthly precipitation data extracted from PRISM interpolated weather surfaces at 4-kilometer resolution.

RDMapper extrapolates a RDM measure from these data rather than attempting to quantify it directly. In developing its tool, TNC and its partners chose this more indirect approach to RDM estimation because: 1) it is very difficult to distinguish RDM from the soil background in autumn; and 2) direct quantification, if possible, would require expensive ground-truthing. RDMapper was designed primarily to reduce monitoring costs and to allow for proactive and collaborative monitoring and management with cooperating landowners and grazing lessees. It alerts users when insufficient RDM is expected (providing “red flags” during the growing season), and where RDM compliance is expected with high confidence (a “green light,” which allows the land manager to monitor a management unit's RDM with nothing more than a visual “drive-by” estimation).

RDMapper allows users to:

- Summarize and integrate large volumes of disparate data (on-the-ground RDM information, satellite remote-sensing data, precipitation data) across large spatial and temporal scales.
- Quickly and efficiently apply and present analytics to identify grassland condition, RDM compliance, and the need for on-the-ground monitoring for each property and management unit using a decision framework (Figure 3).

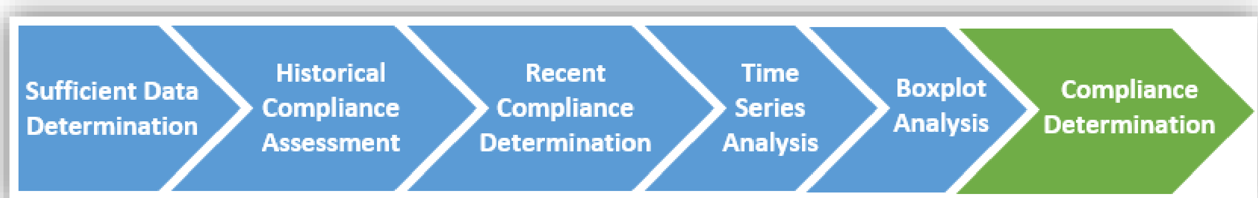

Figure 3. RDMapper Decision Framework

For each management unit (as defined by the user), RDMapper displays the vegetation index and precipitation data described above. Varying display colors of past years' data indicate at a glance whether each year’s measured RDM level was below or in compliance with (above) the RDM minimum standard for that management unit (Figure 4). RDMapper also presents the data as boxplots for compliant versus non-compliant years. This allows users to determine whether the current year resembles the compliant or non-compliant years, or whether there is not enough difference between the two to make a determination with confidence. TNC has developed a system of analyzing RDMapper data in the spring or early summer to predict, with the prediction's confidence level, whether a management unit will be in or out of compliance (see following section).

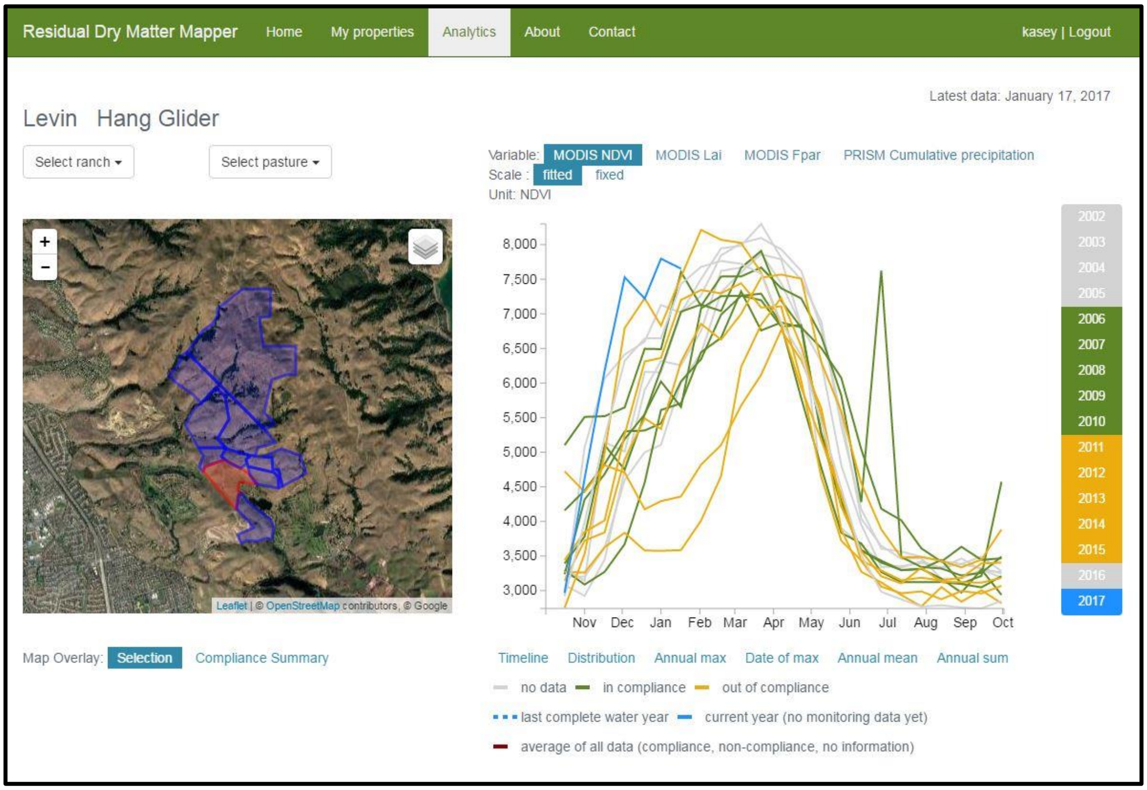

Figure 4. Example output showing variations in compliance across several years.

In In 2015, TNC tested RDMapper as a tool for predicting RDM compliance. They achieved 99% accuracy (107 of 108) when the RDMapper results indicated high confidence that management units would be in compliance.[3] This predictive power allowed TNC to adapt and streamline their RDM compliance fieldwork for the subsequent autumn of 2016. For management units that they expected to be in compliance, they then conducted a simple 'drive-by' visual confirmation of the RDM conditions, in lieu of the more cumbersome conventional method of clipping and weighing dry herbaceous material and producing detailed maps to determine average RDM.[4] In 2016, TNC achieved 100% accuracy (119 of 119) when they had a high confidence that management units would be in compliance. Since 2014, RDMapper results have allowed TNC to reduce the number of management units needing conventional RDM monitoring in their Central Coast Region, and thus total costs of their monitoring program, by 42% (from $23,600 to $13,600), mainly due to reduced contractor fees for conventional monitoring.

[3] In the TNC study, RDMapper results showed 107 of 108 management units with graphs of vegetation indices for the current RDM year that strongly resembled the compliant standard for past years.

Using RDMapper has also proven to be a valuable way for monitors to work proactively with landowners and grazing operators. The interactive system provides visual information that allows users to view herbaceous growth and rainfall over time, compare these conditions across different management units, and make decisions about adjustments in grazing practices, helping to better avoid non-compliance conditions.

Testing RDMapper at Conservation Properties in Santa Clara County, California

Our study focused on RDMapper's power to predict whether or not a given management unit will be in compliance with mandated RDM standards. In 2015, we began testing RDMapper for RDM compliance predictions across approximately 33,000 acres of agency-owned grassland properties in Santa Clara County, California (Figure 1). So that our use of RDMapper would be directly comparable to TNC's, we selected properties with at least five years of RDM monitoring data. We also selected relatively large properties that would allow us access for ground-truthing. We found that two agencies, Santa Clara County Parks and Recreation Department (SCCPRD) and Santa Clara Valley Open Space Authority (SCVOSA), had sites available with the data and conditions needed, as did two TNC properties (Table 3).[4]

Once we had selected our study properties, we gathered the data that RDMapper would need in order to do its job: RDM monitoring data; management unit boundary data; grazing history data. We also determined the history of compliance for each management unit (has the management unit always/sometimes/rarely been in compliance?), thus learning which management units we could expect to be compliant in the future assuming similar management conditions.

Now we were ready to use TNC's decision framework (Figure 3): the five-step process of the RDMapper system that land managers can use to make conservation-easement compliance predictions. Each of the steps helps a team of management staff—ideally with expertise in rangeland science and RDM monitoring—arrive at an informed compliance prediction for each management unit, as either above the RDM minimum standard or below that standard. A prediction of "below" can be used to limit grazing in the unit for that season. A prediction of "above" may embolden the managers to stop conducting standard field-based monitoring methods on the unit, thus saving time, labor and resources.

For the first step, sufficient data determination, TNC recommends a minimum of five years of RDM field measurements should be available in the standardized format. A major shift in

[4] In our initial survey we found five additional candidate properties of these and another agencies in the region, but determined the managers did not have sufficient RDM data from previous years for four properties or did not have RDM data. The University of California Natural Reserve System's Blue Oak Ranch Reserve, which would have been useful as an un-grazed comparison, was large enough and accessible, but its data from a recent fire ecology study could not be sufficiently translated to the required RDM data.

grazing management practices during the study period may lead to error; therefore, in order to count towards the five-year minimum, those practices should be consistent across all data-gathering years, and similar to those used in the current year. Requiring a minimum of 5 years of accumulated data also allows monitors time to build relationships with the landowner, and enables them to observe over those years how grazing and RDM results interact. (For our study, because we were using data from properties managed by others, we were not involved in building relationships with the landowner over years or observing grazing and RDM results.)

Moving on to the second and third steps, we assessed the history of compliance, including recent compliance, for each management unit. Some management units have been in compliance with RDM terms since the conservation easement was established, whereas others have failed to meet compliance standards historically or recently. Historically compliant management units are, not surprisingly, more likely to prove currently compliant.

Next, to complete steps four through six, we compared the current year's remotely-sensed environmental variables (NDVI, LAI, FPAR, and precipitation) to previous years' information and held them up against the corresponding compliance levels, using both comparisons of annual time-series and box plots. A time-series (i.e. the curve that describes the remote sensing data over time) for the current year that closely resembles the time-series of past compliant years is more likely to indicate compliance than a current time-series that resembles a non-compliant year. Specifically, for the non-precipitation environmental variables, the time series peak, width, and timing and steepness of the decline are important (Tsalyuk et al. 2016, Butterfield et al. 2014). When boxplots showed a significant difference between current and past years, we assessed whether current-year values fell within the range of in or out of compliance years.

To test the effectiveness of RDMapper, we compared predicted and actual compliance status for 2016. We correctly predicted RDM compliance at 20 of 27 management units (74%) (Table 4). Three units (11%) were incorrectly predicted to be below the RDM minimum standard (i.e. not in compliance). False negative errors like these are of relatively little concern, since they will lead to potentially unnecessary field monitoring, but will not lead monitors to overlook management units that are out of compliance, with the resulting potential negative impacts on soil cover and habitat conditions.

Table 4. Summary of Effectiveness Test Results for Non-TNC Properties

Prediction Success	Number of Mng. Units = n	Percentage
Correct	20	74%
Incorrectly predicted out of compliance (below standard)	3	11%
Incorrectly predicted in compliance (above standard)	4	15%
Low confidence	3	11%
High confidence	1	4%
Total	**27**	**100%**

We incorrectly predicted three other management units (11%) to be in compliance, but with low confidence. In RDMapper, these management units would still be monitored with traditional field-based RDM monitoring methods, so we would not have missed any management units that were out of compliance. Errors like this justify TNC's recommendation to replace traditional field-based methods only when you predict compliance with high confidence.

One management unit (4%) was incorrectly predicted to be in compliance, with high confidence. Possible reasons for our incorrect prediction in this case included: 1) this particular management unit had been in compliance for all prior years with available data, which meant RDMapper could not provide a clear representation of the satellite data for out-of-compliance years; and 2) in 2016, grazing timing changed from winter-only (livestock removed before rapid spring growth) to grazing that extended much further in to the spring. This is the type of error we are the most concerned about, because in such cases the TNC model would recommend replacing field-based RDM monitoring methods with a simple 'drive-by' verification of RDM conditions—potentially resulting in a failure to address significant soil or habitat impacts. This type of error reinforces the need for RDMapper analysts to be familiar with or have consistent access to each site's basic management history.

Our test of the RDMapper system on a multiple-landowner dataset made clear that the tool's usefulness depends upon a sufficient quantity and quality of RDM data, and also upon adequate knowledge of year-to-year grazing regimes—essential information in an ecosystem dominated by annuals. As our experience demonstrates, the accuracy of the tool's application and analysis can be compromised in a multiple-landowner context, without a third party to ensure consistent gathering and/or processing of information.

Our study demonstrated RDMapper's value for predicting RDM compliance; given the results we obtained, we feel confident in recommending the tool. Our experience also pointed to several lessons for broader application in California annual grassland. We recommend the following considerations for agencies interested in integrating RDMapper into their California annual grassland stewardship process:

- Work with agency staff and consultants currently developing RDM data and conducting monitoring to determine how much effort will be required to standardize the requisite data (RDM objective, RDM observations, and GIS data representing management units and properties).
- Use RDMapper in early spring to identify areas that appear to be headed for non-compliance, so that possible management adjustments or contingency plans can be discussed in a field visit or call with the land manager and grazing tenant.
- Use RDMapper in late spring/early summer to identify areas where RDM compliance is predicted with high confidence, so that compliance status there can be ascertained rapidly in the future without on-the-ground RDM monitoring. Time and cost savings would allow for increased assessment efforts in problem areas and high-priority habitats.
- Use RDMapper as a visual aid for discussions with the grazing tenant or other relevant stakeholders. RDMapper provides visual “summaries” of multiple years of RDM compliance data and allows the user to quickly “drill down” into a specific management unit or year. This can help stakeholders spot and discuss trends, landscape-scale patterns of non/compliance, and other big-picture take-aways.
- When RDMapper predictions are incorrect, the land manager should examine why the tool didn’t work. Among the most easily evident causes are wildfire or other dramatic management changes that would have made that field-year unsuitable for RDMapper analysis. The discrepancy could be due to a flaw in the RDMapper system, potentially indicating the need to refine the decision process. The incorrect result could also be due to a recent change in the environment (e.g. a new invasive species or washed-out creek crossing) that the grazing tenant may not have been aware of or thought to discuss with the landowner. Thus RDMapper can be used to highlight or uncover changes in the grazed landscape.

Conclusions and Recommendations

The predictive capability of TNC’s RDMapper can enable agencies to improve grasslands management by focusing their limited monitoring resources on those properties at risk of being below the minimum standard for RDM compliance. RDMapper could in fact be game-changing for state and federal lands-management agencies that currently struggle to manage tens or hundreds of thousands of acres of grasslands. Based on our experience applying RDMapper, we offer the following conclusions.

Potential advantages of using RDMapper include:

- Proactive grazing management: facilitated forage tracking throughout the year, helping grazing operators/landowners adapt management efforts to ensure compliance with RDM terms and protection of biodiversity values
- Collaborative management: promoting clear visualization of field conditions over time that allows explicit communication between all stakeholders
- Cost savings: reduced use of conventional on-the-ground monitoring methods
- Prioritized on-the-ground monitoring: focused monitoring on problem areas and priority issues (sensitive soils and habitats, under- or over-utilized areas, insufficient watering facilities for livestock distribution)

Potential issues with RDMapper include the requirement for:

- RDM data categorized by management unit, collected and stored consistently, and available for at least the previous 5 years[5]
- Consistent grazing regimes
- Clearly defined grazing objectives, including quantitative RDM standards

Recommended improvements to RDMapper:

- To increase the broad applicability of RDMapper, TNC should continue to test with a diverse set of large landholders to identify potential issues with the tool's application to grazing management and RDM monitoring
- To encourage broad usage, TNC should consider developing user guides, training videos, and/or a set-up service that provides potential users direct initial assistance with mapping and results interpretation
- To improve RDMapper functionality, TNC should consider adding higher-resolution Landsat NDVI data and an algorithm that automates removal/masking of non-grassland (i.e. woody) vegetation cover

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[5] The rule requiring at least 5 years of RDM data allowed us to see trends or inconsistencies; data for shorter periods would be valuable, create precedent for reporting and storage of data, and eventually be useful for use of RDMapper.

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