Prescribed Grazing to Restore Rangeland Soil Quality, Plant Diversity, Water Quality, and Agricultural Productivity

1. INTRODUCTION

This proposal focuses on Emphasis Area 1 – Rangeland Restoration – 2009 USDA Rangeland Research Program Request for Applications.

1.1. Background Information and Problem Statement

A Valuable Ecosystem – Annual Rangeland. California's winter rain-fed, annual rangelands cover approximately 6.4 million hectares, and produce 70% of the state's forage base (Huntsinger et al. 2007). Livestock production provides significant economic security for rural communities— annual gross value of cattle production in California exceeds $3 billion. California's rural communities are especially vulnerable in the current economy with rural county unemployment rates above 25.6% (Levy and Callori 2009). This ecosystem is also the most species-rich in California, with more than 300 vertebrate, 5000 invertebrate, and 2000 plant species (Allen-Diaz et al. 2007; Barrett 1980; Garrison and Standiford 1996; Verner 1980). Annual rangeland soils have the capacity to support high primary productivity and accumulate significant belowground organic matter and sequester carbon, which supports climate regulation and functional nutrient cycles. Additionally, over 85% of California's drinking water supply is generated and stored annually within rangeland watersheds (Havstad et al. 2007).

Widespread degradation of these annual rangelands is driven by:

1. Removal of oak trees for fuel wood and to increase livestock carrying capacity.
2. Persistent invasion of weeds, such as medusahead and yellow starthistle.
3. Continuous heavy wet season livestock grazing.

Oak Removal – Degradation of Soil Quality. Annual rangelands are typified by oak tree cover ranging from savannah to woodlands. Blue oaks (*Quercus douglasii* Hook. & Arn.) create islands of soil fertility and significantly enhance soil-plant ecological functions at the site, watershed, and ecosystem scales (Dahlgren et al. 1997; Dahlgren et al. 2003). Considerable oak tree removal has occurred over the past century for fuel wood harvest and short-term gains in grazing capacity (Kay 1987). However, the fertile soil conditions, which initially increase forage production immediately following tree removal, are lost within 15-20 years. This is due to depletion of soil nutrient and organic matter pools and fundamental changes in nutrient cycling processes following oak removal (Camping et al. 2002; Dahlgren et al. 2003; Kay 1987).

Weed Invasion – Degradation of Productivity and Diversity. California's annual rangelands are dominated by non-native, annual species, many of which have become naturalized and provide 70% of the state's livestock forage base. However, two key weedy species, medusahead (*Taeniatherum caput-medusae* (L.) Nevski) and yellow starthistle (*Centaurea solstitialis* L.), reduce livestock carrying capacity and plant-animal diversity. Yellow starthistle is considered to be one of the two most invasive plant species in the 17 western states, and medusahead is ninth (DiTomaso et al. 2007). Weed infestations on annual rangeland can reduce forage production by 75-80% (DiTomaso 2000; George 1992). Productivity and diversity losses on invaded sites are driven by mechanisms such as competition for soil moisture (Enloe et al. 2004). Yellow starthistle (*Centaurea solstitialis*) has been shown to significantly reduce soil moisture status,

which could result in huge water conservation losses (Enloe et al. 2004). The risks that weed invasion poses to diversity and agricultural productivity on rangelands in California and the western United States is difficult to overstate.

Grazing Management – A Restoration Challenge and Opportunity. There is broad agreement that improper grazing can negatively impact various rangeland ecosystem functions and degrade ecosystem services (Belsky et al. 1999; Briske et al. 2008; Fleischner 1994; Jackson and Bartolome 2007; Tate et al. 2004). Specifically on annual range, Tate et al. (2004) found that soil compaction increased along a gradient from long-term grazing exclusion to long-term heavy cattle grazing intensity on oak savannah. Allen-Diaz et al. (2004) reported lower insect richness in lightly and moderately grazed wetlands on annual rangelands compared to non-grazed wetlands.

However, grazing management can also enhance diversity and nutrient retention, suppress weeds, and mitigate climate change impacts on annual rangelands. Grazing exclusion increased hydrologic flux of nitrate from spring-based wetlands on foothill annual range (Allen-Diaz and Jackson 2000; Jackson et al. 2006). Marty (2005) found cattle grazing, compared to no grazing, and management of season of grazing significantly enhanced herbaceous plant diversity in vernal pools. Pyke and Marty (2005) predicted that grazing management could mitigate climate change impacts on vernal pools via maintenance of suitable hydrologic conditions for aquatic species. Additionally, prescribed grazing management has been successfully implemented to control noxious weeds (DiTomaso 2000).

California's annual rangelands are over 80% privately owned and managed primarily for cattle production enterprises (Huntsinger et al. 2007); therefore, to ensure success, grazing management must be incorporated into the restoration of this ecosystem. The depth of scientific evidence supporting the restoration and conservation effectiveness of prescribed grazing systems has been appropriately challenged (Briske et al. 2008). However, there is substantial observational and research evidence that management of grazing intensity, grazing season, and rest from grazing can restore various soil, plant, and water-based ecosystem functions and services. We provide support for this statement in Section 1.2.

We propose to collaborate with California's range management community to attain the following objectives and long-term goals (see Section 2 for specific objective statements):

1. Conduct a scientific survey of 1500 rangeland grazing managers to determine social-cultural-economic-institutional factors driving grazing decisions; to understand how managers receive, assess, and use grazing management information; and to determine their perspectives on managing grazing intensity, grazing season, and rest from grazing for ecosystem restoration. (see **Objective 1** in Section 2).
2. Establish a long-term, replicated, management-scale study to investigate and demonstrate prescribed grazing to restore ecosystem services. The multi-year study will use 200+ commercial-type beef cattle across 33 pastures covering ~1500 hectares of annual rangeland at the UC Sierra Foothill Research and Extension Center (SFREC) (see **Objectives 2a** and **2b** in Section 2).
3. Develop an online prescribed grazing – restoration management decision support tool that allows users to: access information about prescribed grazing and restoration; explore

site-specific grazing management and effectiveness monitoring options; and participate in prescribed grazing – restoration information exchange (see **Objective 3** in Section 2).

This proposal develops two global hypotheses, one addressing prescribed grazing effects on hydrologic, soil-geomorphic, and ecological conditions (as measured by services); and the other addressing the social, cultural, economic, and institutional factors determining adoption of prescribed grazing to promote restoration: 1) We hypothesize that prescribed grazing based upon grazing intensity, grazing season, and rest can restore multiple ecosystem functions and services on annual rangelands; and 2) We hypothesize that for any prescribed grazing recommendation to be implemented, it must address social-cultural-economic-institutional factors driving ranch/firm level management decisions.

Specific objectives and associated hypothesis are presented in Section 2. In the remainder of this section we provide support and relevance for the proposed project.

1.2 Support for Project Objectives, Hypotheses, and Treatments

Project objectives and hypotheses are based upon stakeholder input, our collective outreach and research experience, and the broader science-base for the annual rangeland ecosystem.

Survey of Rangeland Managers and Decision Support Tool (Obj. 1 & 3). University of California Cooperative Extension collaborated with rangeland stakeholders from 1990-1995 to conduct ranch management short courses, and from 1995-2003 to conduct ranch water quality management short courses. Richards and George (1996) surveyed 362 participants of the initial ranch management course series. Participants reported improved management on 14% of rangelands they managed; 50% increased ranch profits; and most implemented at least one practice presented in the short course. Changes were motivated by needs to increase on-ranch profits, cope with regulatory constraints, and improve land management for future generations. Larson (2005) surveyed 412 ranch water quality management short course participants, and reported that most completed ranch water quality management plans and implemented water quality best management practices. Less than 50% implemented monitoring to document practice effectiveness. These surveys demonstrate that traditional outreach can lead to management practice adoption, and that our team can effectively survey this stakeholder group. Additional research has shown that adoption of new or existing technology by land managers is influenced by age, education, income, goals, size of farm, land tenure, and level of community participation. (Coppock and Birkenfeld 1999; Huntsinger et al. 1997; Huntsinger and Fortmann 1990; Kreuter et al. 2001). Building from this base, we will conduct surveys to specifically identify the social-cultural-economic-institutional factors that determine decisions to adopt prescribed grazing management practices for restoration purposes (Objective 1).

In addition, research is needed to improve mechanisms of information sharing between researchers, extension educators, range managers, non-governmental organizations (NGOs), technical support agencies, policy makers, and other rangeland stakeholders (Objective 3). Lubell and Fulton (2007) provide a successful local example. They surveyed 1200 central California farmers to determine the effectiveness of local information diffusion networks composed of farmers, educators, and agricultural organizations for achieving adoption of sustainable agricultural practices. Diffusion networks are members of a social system that

communicate information about agricultural practices and issues through formal and informal connections and interactions (Chiffoleau 2005; Conley and Udry 2001; Rogers 2003). In the context of prescribed grazing – restoration, such a network could: 1. Provide information about innovations in grazing management; 2. Act as a repository of social capital for solving the collective dilemma of ecosystem management; and 3. Facilitate cultural change. Lubell and Fulton (2007) found diffusion networks increased farmer satisfaction with environmental policies, participation in water-quality management programs, and implementation of sustainable agricultural practices. We will employ a similar survey-based study with rangeland managers to achieve Objective 1 and inform development of a prescribed grazing – restoration decision support tool based on the effective aspects of diffusion networks (Objective 3).

Prescribed Grazing Management - Restoration Study (Obj. 2). Please see Table 2 and section 4.2.2 for proposed prescribed grazing study hypotheses and treatments. In support of proposed rest-based rotational and seasonal grazing treatments, we have found that timing of grazing impacts annual rangeland vegetation composition. For example, grazing March-April decreases end-of-season prevalence of annual forage species (grasses and legumes) and native species (annual and perennial grasses and forbs), and doubles noxious rangeland weeds and native legume frequency (Eviner et al. in prep.). Such vegetation shifts due to season of grazing impact ecosystem functions, including resistance to weed invasion, nutrient cycling and retention (Eviner and Chapin 2001; Eviner et al. 2006; Eviner and Firestone 2007), resistance to soil erosion (Eviner and Chapin 2002, 2003), soil moisture retention (Eviner and Chapin 2003), and soil C content and depth distribution (Eviner and Hawkes, in prep.).

In support of proposed grazing intensity treatments, Briske et al. (2008) determined that intensity is the dominant determinant of grazing management impact on ecosystems. We have found soil quality parameters, such as soil compaction-infiltration, to be negatively impacted by heavy grazing intensities. However, we have also observed that light to moderate grazing intensities and relatively short periods of rest from grazing can mitigate soil compaction (Tate et al. 2004; Fig. 1). The concept of prescribed seasonal rest from grazing for rangeland restoration is well founded (Gifford and Hawkins 1978; McGinty et al. 1979; Ratliff et al. 1972; Wood and Blackburn 1981). Gifford and Hawkins (1978) argue the importance of range condition (e.g., ecological state) as a determinant of hydrologic function. Rest-based grazing systems that rehabilitate site conditions, or shift a site to a state with greater function, should restore hydrologic-based functions such as infiltration, runoff attenuation, and soil moisture retention (Ratliff et al. 1972).

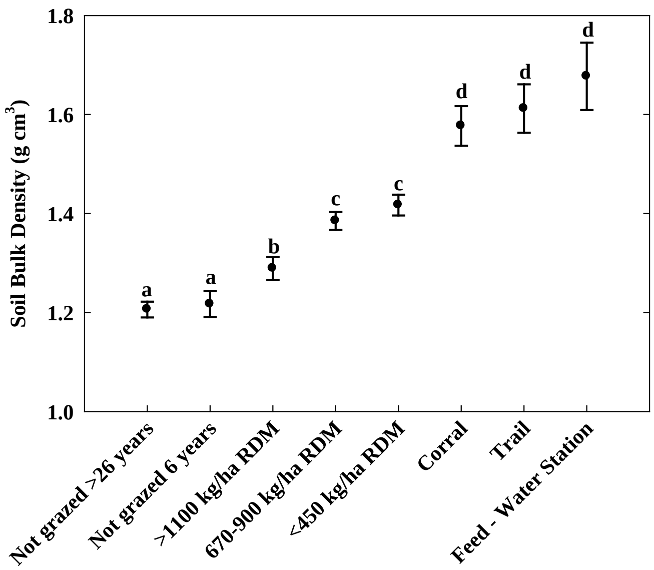

Figure 1. Soil surface bulk density (0 to 7.6 cm) for oak savannah subject to grazing management practices at the San Joaquin Experimental Range (SJER), Madera County, CA. Grazing management practices are: not grazed by livestock for >26 years and not grazed for 6 years; sites grazed annually by cattle for 15 years to residual dry matter (RDM) levels of >1100, 670 to 900, and <450 kg ha^{-1}; and cattle concentration areas. Bars represent 1 SE. From Tate et al. (2004).

We have observed greater soil hydrologic function beneath blue oak canopies compared to open grassland. Additionally, oaks appear to mitigate the impacts of grazing on soil hydrologic function (Fig. 2, Tate et al. – unpublished data). In remnant populations of native perennial bunchgrass – purple needlegrass (*Nassella pulchra* (A. Hitchc.) Barkworth) – we have documented an apparent facilitative relationship with blue oak, evidenced by greater *N. pulchra* densities under oak canopy compared to adjacent open grasslands (Fig. 3, Roche et al. – unpublished data). These results and other research strongly argue the overall importance of oak restoration to enhance site and watershed-scale soil quality, diversity, hydrologic function, and resilience to grazing impact. In support of proposed seasonal grazing treatments, McCreary and George (2005) reported that cattle grazing during the summer season, when surrounding annual forage species are dry and dormant, increased browse on the still-green oak seedlings and hindered recruitment.

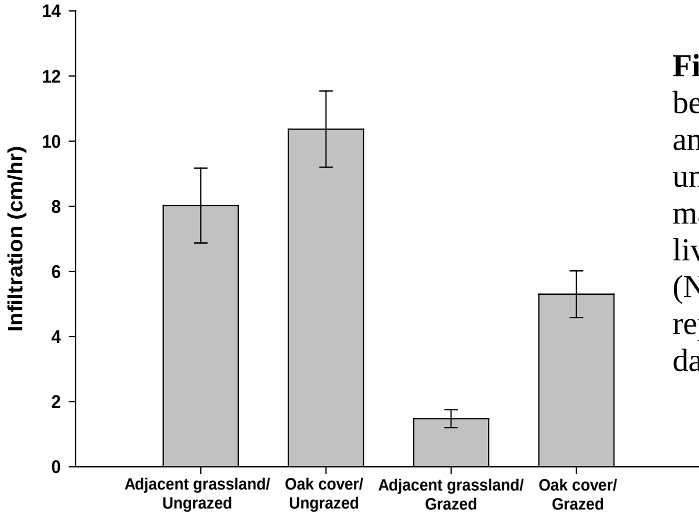

Figure 2. Differences in infiltration rate between blue oak (*Q douglasii*) understory and adjacent open grassland in grazed and ungrazed pastures at SFREC. Grazing management practices are not grazed by livestock for >30 years and wet season (Nov-Apr) grazing at 1.9 aum/ha. Bars represent 1 SE (Tate et al. – unpublished data).

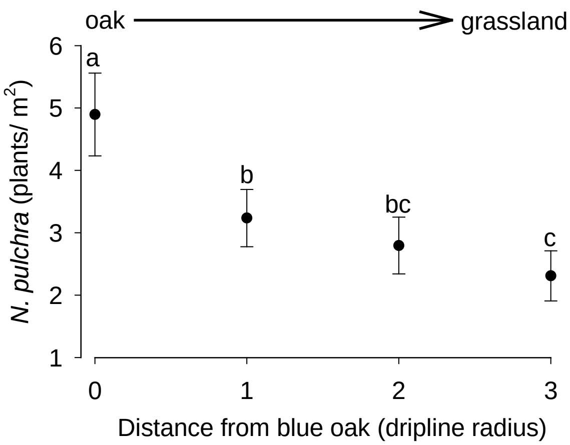

Figure 3. *Nassella pulchra* density as a function of distance from blue oak canopy at SFREC. 0 = under oak tree canopy, 1 = 1X, 2 = 2X and 3 = 3X dripline radius away from canopy edge, respectively. Bars represent 1 SE.(from Roche et al. unpublished data).

Finally, annual rangelands are naturally susceptible to flushing of N and dissolved organic C (DOC) during winter storm events (Lewis et al. 2006). We have found that sediment, N, C, and microbial pollutant transport from annual range is affected by wet season grazing intensity (Table 1, Tate et al. – unpublished data). *In addition to grazing intensity, we hypothesize that season of grazing – relative to seasonal annual rangeland nutrient cycling and streamflow generation processes – will affect stream water quality and nutrient flux at the watershed scale* (Chow et al. In Press; O'Geen et al. 2009; See Table 2 for specific hypotheses).

Grazing Intensity	TSS (mg/L)	NO_3-N (mg/L)	DOC (mg/L)	*E. coli* (cfu/100mL)
Non grazed	1.5	0.1	4.5	310
Moderate	6.5	0.4	3.2	425
Heavy	24.0	0.8	3.5	1250

Table 1. Concentration of total suspended sediments (TSS), nitrate-N (NO_3-N), dissolved organic C (DOC), and *E. coli* from 3 annual rangeland watersheds with different cattle grazing intensity treatments. Concentrations reported are means of ~125 samples collected from each watershed 2007-08 winter growing season (Nov-May, 7 mo.) Grazed watersheds (moderate=0.8 aum/ha, heavy=1.9 aum/ha) were grazed Nov-May, and non-grazed watershed had not been grazed for 10 years (Tate et al. Unpublished data).

1.3 Relevance to Stakeholders, Stakeholder Involvement, and Proposing Institution

Several key stakeholder organizations have written letters of support for this project, which are included at the end of this project narrative. The restoration and long-term sustainability of this rangeland ecosystem is of major importance to many diverse stakeholder groups, including the CA Farm Bureau Federation, CA Cattlemen's Association, CA Rangeland Conservation Coalition, Audubon California, CA State Water Resources Control Board, CA Department of Fish and Game, and USDA Natural Resource Conservation Service. Stakeholders have been involved in the development of this project via individual communication, formal planning meetings, and input sessions during recent outreach events such as workshops and field tours.

Stakeholders will continue to play instrumental rolls in this project. A project advisory committee will be established to provide input and assistance on all aspects of the project. Establishing the advisory committee will be the first project activity, and the committee will remain actively involved throughout the project. In addition, 1500 rangeland grazing managers will be invited to participate in a survey to inform educators, policy makers, technical assistance agencies, and others about the barriers and opportunities to prescribed grazing management – restoration practice adoption at the ranch-scale. This input will also have major influence on the development of the prescribed grazing – restoration decision support tool (Objective 3). We have already received extremely positive feedback from stakeholders about this tool. Stakeholders are very interested in information availability, information that can be put into context of their site-specific conditions and goals, and opportunities to communicate with peers about successes, failures, etc.

The University of California is the proposing institution, but the project is a collaborative effort between stakeholders, cooperative extension educators, and research scientists at UC Davis, UC Sierra Foothill Research and Extension Center (SFREC, Yuba County, California), and USDA-ARS. Our multi-disciplinary team represents expertise in outreach, grazing management, social science and policy, restoration ecology, hydrology, soil science, biogeochemistry, and water quality. We have significant collective experience in conducting large integrated projects of this nature. We have credibility and connectivity with the rangeland community, and their support in this project. Finally, the project will also include a controlled, experimental aspect utilizing 200+ commercial-type beef cattle across 33 pastures covering ~1500 hectares of annual rangeland at SFREC. SFREC has the cattle, land, facilities, and human resources required to support the

proposed project. Following completion of the project as described for this funding opportunity, implementation of prescribed grazing treatments will continue at SFREC for an additional 7 years (10 years total treatment implementation), as part of SFREC normal grazing practices. This will allow future research opportunities and the demonstration of project results at additional, future field days and workshops.

2. PROJECT OBJECTIVES AND HYPOTHESES

Our overall goal is to increase understanding of the interrelated social, ecological, and outreach aspects of prescribed grazing to restore annual rangelands. We will focus on restoration of the following ecosystem services: 1) biodiversity and resistance to weed invasion; 2) forage production; 3) water quality; and 4) retention of soil C, N, and soil moisture. We have established a specific objective for each aspect of the project, and have developed detailed hypotheses about the effects of three core prescribed grazing treatment factors on each ecosystem service (Table 2).

Objective 1: Conduct a scientific survey of 1500 rangeland grazing managers to determine social-cultural-economic-institutional factors driving grazing decisions; to understand how managers receive, assess, and use grazing management information; and to identify management perspectives on managing grazing intensity, grazing season, and rest from grazing for restoration of soil, plant, and water functions and other ecosystem services.

> **Hypothesis 1.1:** Grazing practice adoption and practice effectiveness perspectives are dependent upon manager/firm characteristics such as age, education, and perspective-experience with incentive programs.
>
> **Hypothesis 1.2:** Grazing practice adoption and practice effectiveness perspectives are dependent upon ranch/firm characteristics such as ranch size and if the ranch is leased versus owned.
>
> **Hypothesis 1.3:** Grazing practice adoption and practice effectiveness perspectives are dependent upon the number of information sources a manager/firm access and value, such as county Cooperative Extension advisors and technical service agency staff.
>
> **Hypothesis 1.4:** Grazing practice adoption and practice effectiveness perspectives are dependent upon the frequency of discussions with other ranchers and participation in outreach programs such as ranch planning short courses and the proposed decision-support tool.

Objective 2a: Quantify the differential effects of *season* and *intensity* of cattle grazing, and associated interactions, on multiple ecosystem services.

Objective 2b: Compare the response of multiple ecosystem services between a *rotational grazing system***,** which provides alternating seasons of grazing/*rest* across years, and a *continuous grazing system***,** which provides the same season of grazing/*rest* every year.

For Objective 2 we have developed 40 explicit, mechanistic hypotheses that we propose to examine (Table 2). These hypotheses result from the combination of 4 categories of ecosystem

service and 11 prescribed grazing treatments (Section 4.2.2). To demonstrate the logic behind the hypotheses in Table 2, we briefly discuss an Example – Treatment 7. We hypothesize that late season-high intensity grazing (treatment 7), relative to continuous-high intensity grazing (treatment 1), will greatly restore biodiversity and resistance to weed invasion/expansion and agricultural production. We also hypothesize that treatment 7 will restore provisioning of clean surface water and soil retention of C, N, and soil moisture. Our logic is that late growing season grazing allows growth and development of early season annual forage species, but prevents growth of noxious weeds, which are at the bolting stage during this period. Invasive species control via intensive grazing will increase the cover and abundance of forage annuals and native species, enhancing biodiversity and forage quality (Huntsinger et al. 2007). Restoration of resistance to weed invasion and subsequent increases in biodiversity may also improve water quality and retention of soil, C, N, and soil moisture. For example, higher annual forage grass cover results in greater C sequestration because of greater root biomass and litter accumulation (Jackson et al. 2007).

PRESCRIBED GRAZING TREATMENTS	**ECOSYSTEM SERVICES** Biodiversity and resistance to weed invasion	Forage production	Clean water provisioning	Retention of soil C, N, and soil moisture
1. Continuous-Heavy intensity	-	-	-	-
2. Continuous-Moderate intensity	No Effect	Restore	Restore	Restore
3. Rotational-Heavy intensity	Degrade	No Effect	No Effect	No Effect
4. Rotational-Moderate intensity	No Effect	Restore+	Restore+	Restore+
5. Early-Heavy intensity	Restore	Degrade	No Effect	No Effect
6. Early-Moderate intensity	No Effect	No Effect	Restore	Restore
7. Late-Heavy intensity	Restore+	Restore+	Restore	Restore
8. Late-Moderate intensity	No Effect	Restore	Restore+	Restore+
9. Dormant-Heavy intensity	Degrade	Degrade	Restore	No Effect
10. Dormant-Moderate intensity	Restore	Restore	Restore+	Restore+
11. Ungrazed	Degrade	Degrade	Restore	Restore

Table 2. Outline of 40 explicit hypotheses following Objective 2a and 2b. Hypothesized ‘long-term’ effects (Degrade, No Effect, Restore, Restore+) are relative to ambient management, which we define as continuous-high intensity grazing. See Section 4.2.2 for treatment definitions.

Objective 3: Develop an online prescribed grazing – restoration management decision support network that allows users to: access research and management derived information about prescribed grazing and restoration; receive assistance in developing grazing management and effectiveness monitoring options for site specific restoration applications; and participate in interactive prescribed grazing – restoration information exchange.

3. Rationale and Significance

Please see Section 1.3 for specific information on the relevance of the project to stakeholders, and how stakeholders have been – and will continue to be – involved in the project. Please see letters of support from California Cattlemen's Association, California Farm Bureau Federation, California Rangeland Conservation Coalition, and Audubon California at the end of this project narrative as verification of stakeholder support and involvement in this proposed project.

In general, grazing will continue to occur across this managed ecosystem. Thus, we must identify opportunities to manage grazing to simultaneously achieve short-term ranch/firm economic goals and advance long-term ecosystem restoration goals. Broad-scale restoration of a grazed ecosystem cannot occur unless restoration goals are fundamentally incorporated into ranch/firm grazing management decisions. Private land managers will make decisions to implement restoration grazing management based upon factors such as: availability of information they deem credible and relevant to their ranch/firm, short-term ranch/firm economic reality, long-term ranch/firm goals, initiatives and terms of incentive acceptance, practicality of grazing options, ranch infrastructure constraints, and ingrained behavior or habit. Some of these factors are dynamic, and all likely interact to determine daily and annual grazing management decisions at the ranch scale.

The rangeland management community, technical support agencies, policy makers, and academia must understand the factors determining ranch-level grazing management decisions. This will assist in developing research, policy, management recommendations, outreach, and awareness that advance restoration of rangeland ecosystems. **There has been no comprehensive, management-scale study of how prescribed grazing affects multiple ecosystem services on annual rangelands**. This project simultaneously examines soil, plant, and water based ecosystem service response to prescribed grazing. It is particularly unique in the integration of quantitative, scientific social survey, field ecological research, and outreach to extend the results of the project and facilitate grazing management supported restoration. Such a model has local, state, national and international relevance and application.

4. Methods and Approach

4.1 Rangeland Manager Survey-Based Study – Objectives 1 and 3

We will conduct a survey of 1500 rangeland managers to achieve Objective 1, and provide information needed to develop the prescribed grazing management decision support tool outlined in Objective 3. We will develop a survey list of range managers in collaboration with the University of California Cooperative Extension, Cattlemen Association, Farm Bureau, and Agricultural Commissioner in 26 California counties with significant annual rangeland and ranching operations. Counties will range geographically from Shasta (north) to Kern (south) and from the coast (e.g., San Luis Obispo, Mendocino) to the west-slope Sierra Nevada foothills (e.g., Yuba, Madera). The standard Dillman (2000) methodology of delivery introductory letter,

survey package, reminder, second survey package, and second reminder will be used to encourage response. We expect a response rate between 25 and 50% (Larson et al. 2005; Lubell and Fulton 2007; Richards and George 1996). Survey questions will be developed with input from all project team members to introduce multi-disciplinary interests, and with input and review from the project advisory committee. Preliminary personal interviews will be conducted with a subset of range managers to fine-tune the survey before mailing to the entire survey list.

The majority of responses will be yes/no or 7-point Likert scales. We will also collect information about specific grazing practices adopted, sources of information, structure of social networks, and participation in outreach activities. Data will be analyzed via a variety of multivariate techniques, such as linear regression or maximum likelihood, depending on the structure of data at hand. The primary analysis will use types of grazing practices adopted as a dependent variable, with operator characteristics (e.g., age, education), operation characteristics (e.g., acres, leased v. owned), number of information sources (e.g.; County Cooperative Extension, trade news), frequency of discussion with other ranchers, and participation in outreach programs (e.g., ranch planning short course, the proposed decision-support tool) as the main predictor variables. Multivariate analysis will also be employed to examine relationships between attitudes regarding the effectiveness of rangeland restoration practices (dependent variable) and these independent variables. Because ranchers self-select into outreach programs, we will try several specialized techniques (mainly treatment effects regression and propensity score matching) to control for any potential selection bias in evaluation of outreach effectiveness.

4.2 Prescribed Grazing Study – Objectives 2a and 2b

4.2.1 Study Site Description

The Sierra Foothill Research and Extension Center (SFREC; Yuba County, California) is a 2,300 ha University of California managed rangeland research facility located in the northern Sierra Nevada foothills. SFREC sits within a mosaic of annual grasslands, savannas, and woodland vegetation. Savannas and woodlands are dominated by *Q. douglasii* (blue oak), with *Q. wislizenii* (live oak) and *Pinus sabiniana* (foothill pine). Grassland and understory vegetation is dominated by annual grasses, such as *Bromus diandrus* (ripgut brome) and *Avena fatua* (wild oats). Soils are formed from basic metavolcanic bedrock and are classified as Haploxeralfs. Climate is Mediterranean with hot, dry summers and mild, wet winters. Annual precipitation occurs as rainfall and ranges from 22 to 110 cm with an average of 70 cm (1962-2008). Table 3 illustrates the progression of the annual rangeland forage production and hydrologic cycle at SFREC. Germination and initiation of annual forage crop growth occurs about 1-Nov, and peak standing crop is achieved about 15-May (1979-2008 data).

SFREC has over 50+ pastures available for enrollment in this study, including long-term (10 year) ungrazed pastures. There are 5 catchments (35 to 50 ha sub-watersheds) fenced as individual pastures, and fully instrumented for automated stream flow monitoring and water sample collection We have 3 years of existing stream flow, water quality, and weather data for these watersheds (O'Geen et al. 2009). A 250+ commercial-type cow-calf cow herd is maintained at SFREC year round, and is available for use in this study. Capacity to implement grazing treatments, existing experimental watershed infrastructure and baseline data, and soil-vegetation states representative of those across several million hectares of California annual rangeland make SFREC an ideal location for this project.

Grazing Season	Month	Rainfall (mm)	Runoff (mm)	Temp (C^{o})	Cumulative Green Forage (kg/ha)
Early Growing Season Germination ~1-Nov, forage growth limited by moisture and/or cold temperature	Nov	102	16	20	600
	Dec	124	43	13	
	Jan	145	76	13	
	Feb	119	71	19	
Late Growing Season Period of forage growth, peaks ~15-May	Mar	103	68	20	1500
	Apr	57	29	25	3200
	May	23	19	31	3400
Dormant Season Dry residual forage, summer drought	Jun	9	10	40	0
	Jul	2	4	45	
	Aug	3	2	44	
	Sep	10	3	40	
	Oct	46	6	32	

Table 3. Grazing season and average rainfall, stream flow, mean daily temperature, and forage accumulation at SFREC. Runoff data are from a moderately grazed watershed 0.8 aum/ha during the winter growing season (Nov-May, 7 mo.) (Lewis et al. 2000).

4.2.2 Prescribed Grazing Treatments

We have identified treatments that represent a gradient of potential effects (from degradation to restoration) of stressors on soil, plant, and water-based ecosystem services in this impacted ecosystem. The treatments are based upon annual and seasonal forage production, weed species phenology, hydrology, and management constraints typical of annual rangelands (Table 3). The ten prescribed grazing treatments to be examined are a combination of the following factors: cattle grazing intensity (moderate and heavy stocking rate), season of grazing (entire growing season, early growing season, late growing season, and dormant season – Table 3), season of rest (early growing season, late growing season, dormant growing season), and grazing system (continuous, rotational). An additional 10 year ungrazed treatment will be included as a long-term negative control. The 11 treatments are defined below:

1. ***Continuous Entire Growing Season-Heavy Intensity***–Cattle stocking rate set to consume 80% of the long-term average available forage (annual residual plus long-term average growth), pasture grazed continuously from germination until 1 month past peak standing crop (~1-Nov – 15-Jun) every year. Pasture rested dormant season only.
2. ***Continuous Entire Growing Season- Moderate Intensity***– Same as above, but cattle stocking rate set to consume 40% of the average available pasture forage.
3. ***Rotational Entire Growing Season-Heavy Intensity***–Cattle stocking rate set to consume 80% of the available pasture forage. Pasture is grazed in only one season during each year. Over a 3 year rotation period, the pasture will be grazed one year in the early growing season, one year in the late growing season, and one year in the dormant season—pasture is rested from grazing the remainder of the year.
4. ***Rotational Entire Growing Season-Moderate Intensity***–Same as above, but cattle stocking rate set to consume 40% of the available pasture forage.
5. ***Early Growing Season-Heavy Intensity***–Cattle stocking rate set to consume 80% of the available pasture forage. Pasture is grazed once during every year, only in the early growing

season from germination (~1-Nov) through February. Pasture is rested from grazing the remainder of the year.

6. ***Early Growing Season-Moderate Intensity***– Same as above, but cattle stocking rate set to consume 40% of the available pasture forage.
7. ***Late Growing Season-Heavy Intensity***–Cattle stocking rate set to consume 80% of the available pasture forage, pasture is grazed once during the year, only in the late growing season from March until 1 month past peak standing crop (~15-May). Pasture is rested from grazing the remainder of the year.
8. ***Late Growing Season-Moderate Intensity***– Same as above, but cattle stocking rate set to consume 40% of the available pasture forage.
9. ***Dormant Season-Heavy Intensity***–Cattle stocking rate set to consume 80% of the available pasture forage (residual), Pasture is grazed once during the year, only in the dormant season. Pasture is rested from grazing the remainder of the year. Dormant season is from 1 month post peak standing crop (~15-May) to germination (~1-Nov).
10. ***Dormant Season-Moderate Intensity***– Same as above, but cattle stocking rate set to consume 40% of the available pasture forage.
11. ***Ungrazed Control–***Pastures that have had no grazing by domestic livestock for ≥10 years.

4.2.3 Study Design

The proposed study will follow a completely randomized design in which all 11 grazing treatments will be replicated three times across 33 rangeland pastures. Pasture will be the experimental unit (n=33). Pasture size will range from 35 to 50 ha, with a total study area of approximately 1500 ha. With the exception of the ungrazed control pastures (n=3), all pastures enrolled in the study have received moderate, growing season grazing over the past 10+ years.

In order to examine water quality responses, 5 specific treatments will be randomly allocated to a subset of 5 of the 33 pastures in a stratified random manner (see below). This is necessary to capitalize on the 5 experimental catchments available at SFREC, and the existing 3 years of baseline water quality data already available for these catchments. One of the catchments has not been grazed for 10 years and will serve as the ungrazed control. One prescribed grazing treatment will randomly be assigned to each of the other 4 catchments: continuous-heavy intensity (treatment 1), continuous-moderate intensity (treatment 2), rotational- heavy intensity (treatment 3), and rotational-moderate intensity (treatment 4). The remaining treatments and replications will be randomly assigned to the remaining 28 pastures, for a total of 33 pastures.

In year 1, prior to implementation of prescribed grazing treatments, baseline data will be collected from all 33 pastures on key ecosystem service metrics, quantifying: 1) biodiversity and resistance to weed invasion/expansion; 2) soil retention of C, N, and moisture; and 3) forage production and quality. Also in year 1, baseline water quality and stream flow data will be collected from the 5 catchments/pastures. All pastures will be moderately grazed in year 1. This will add to the existing 3 years of baseline data for these catchments. Starting in year 2, we will implement the prescribed grazing treatments and collect data annually on ecosystem service metrics. In year 3, we will conduct statistical analysis of the data to determine initial ecosystem service responses to 2 years of prescribed grazing treatment implementation. Treatment implementation will continue past this grant period, to allow future examination (i.e., following 5

and 10 years of treatment implementation). Ecosystem service metrics, monitoring methods, and statistical analysis are described in Sections 4.2.4 and 4.2.5.

4.2.4 Baseline ecosystem service data collection

Biodiversity and Resistance to Weed Invasion-Expansion. Within each of the 33 pastures, we will establish a permanent monitoring grid of sample locations. Number of sample locations will vary with pasture size. Our first approximation for required sample location number (sample size) will be 1 sample location for every two hectares of pasture size (Figure 3: e.g., a 32 ha pasture will have 16 permanent sample locations). Baseline plant species composition, biodiversity, weed species cover and distribution data will be collected at each sample location using permanently marked Whitaker plots. The Whitaker plot has one 1000 m^2 main plot with 10 nested 100 m^2 subplots and 20 nested 1 m^2 sub-subplots arranged in an overall 20 by 50 m^2 nested plot design (Fig. 4; Keeley 2002). Herbaceous plant community composition by species and functional group (i.e., diversity) will be determined on all 20 1 m^2 sub-subplots at each sample location. Frequency of plant functional groups (e.g., native perennial bunch grasses, native forbs, native annuals, invasive annuals), density of blue oak seedlings and saplings, and overall species richness will be determined by searching the 10 100 m^2 sub-plots per sample location. These baseline data will be collected from each sample location in each pasture during year 1, prior to treatment implementation (year 2 = first treatment year) during April-May (i.e., main maturation stage of plant community).

***Forage Production*.** Forage availability, forage utilization by livestock (kg/ha), and total forage production (kg/ha/yr) will be measured across all 33 pastures on the same permanent monitoring grid as biodiversity and resistance to weed invasion-expansion sampling. Baseline values for these production metrics will be determined on three of the 20 1 m^2 plots at each sample location. Forage availability, forage quality, and forage utilization by livestock will be measured on each pasture at the beginning, midpoint, and end of the assigned grazing season (Table 3). Total forage production will be determined in each pasture at the occurrence of peak standing crop (approx. May). The comparative yield-paired plot method will be used to allow non-destructive repeated sampling of forage availability, forage production, and forage utilization by livestock (George et al. 2006; Haydock and Shaw 1975). A 1 m^2 cage will be established on each of the 3 sub-subplots to prevent cattle grazing and allow for determination of total forage production. A paired, grazed 1 m^2 plot will be located 3 m from the caged plot for determination of forage availability and forage utilization by cattle (caged plot forage wt - grazed plot wt).

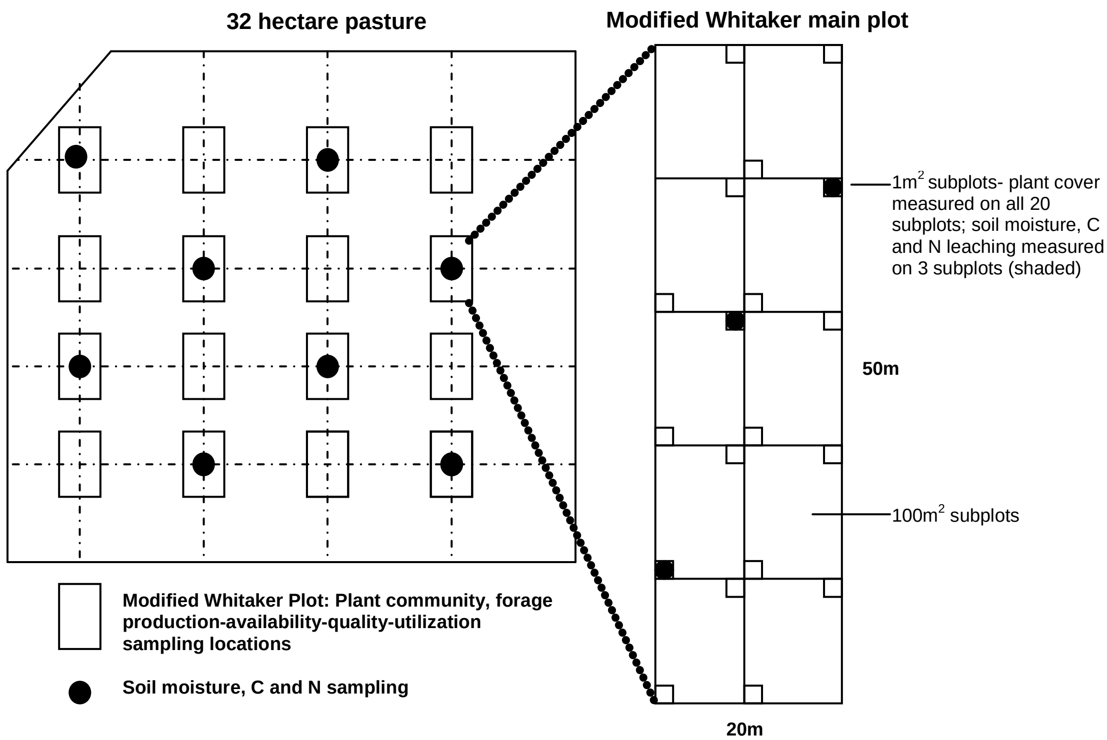

Figure 4. Schematic (not to scale) of a pasture unit and modified Whittaker plot. Modified Whittaker plots will be allocated across the pasture in a systematic fashion (see text). All plots will be sampled for plant, forage production, and livestock use. A subset of randomly chosen plots will be utilized for soil moisture and soil solution sampling (to be sampled from a randomly chosen sub-subsets of 1m^2 subplots). Modified Whittaker plot sampling design: 1m^2 subplots nested in outer corners of 100 m^2 plots of a 1000 m^2 site (Keeley 2002).

Retention of Soil Carbon, Reactive Nitrogen, and Moisture. N and C pools**,** leaching of DOC and nitrate (NO_3-N) below the rooting zone and volumetric soil moisture content will be measured across all 33 pastures on the same permanent monitoring grid as biodiversity and resistance to weed invasion-expansion sampling. N and C pools, soil solution/leachate and soil moisture will be sampled at every other sample location (Fig. 4; e.g., a 32 ha pasture will have eight soil solution/leaching and soil moisture sample locations). At these locations, we will install soil solution samplers at 50 cm – immediately below the plant community rooting depth. DOC and nitrogen (NO_3-N) in solution at 50 cm will potentially be leached from the soil profile and contribute to streamflow as lateral subsurface flow (O'Geen et al. 2009). Soil solution samples will be collected every 2 weeks during the rainfall-runoff season (Oct – Jun) (Bedard-Haughn et al. 2004, 2005; Jackson et al. 2006) and analyzed for DOC and NO_3-N concentrations. Soil volumetric water content sensors will be installed at the same locations at 30 and 50 cm (Topp and Ferre 2002). The 30 cm sensor provides data on soil water content within the rooting zone. The 50 cm water content sensor will be used to evaluate DOC and NO_3-N concentrations, as these constituents have been demonstrated to vary temporally as a result of leaching, mineralization, and plant growth stage (O'Geen et al. 2009). The sensors will also indicate the duration of saturation, which is a major pathway for C and N loss via lateral flow to streams.

At the time of instrumentation, the soil profiles will be described using standard soil survey techniques (color, structure, horizon thickness and topography, and consistence) and sampled to characterize nutrient and carbon pools (texture, total organic C, total N, bulk density, and aggregate stability). Two C fractions within the total soil carbon pool will be measured: 1) the light fraction, which is considered more labile; and 2) the occluded fraction within micro-aggregates, which is considered more recalcitrant. Both fractions are determined from methods of aggregate separation (Golchin et al. 1994; Rasmussen et al. 2005; Sohi et al. 2001). These properties will be re-measured at the end of the experiment to evaluate treatment effects.

Water Quality. Reactive nitrogen, DOC, sediment, *E. coli* and streamflow will be intensively sampled on the 5 catchments/pastures during the entire rainfall runoff season (Oct – Jun) starting in year 1 to establish a complete 4 year baseline dataset (year 1 and 3 existing years of data). These watersheds are intermittent, flowing continuously during the winter rainfall-runoff season (~Dec through Apr) and drying up during the remainder of the year. Each watershed is equipped with a Parshall flume, water stage sensor, and datalogger that records streamflow (m^3/s) every 15 minutes throughout the entire runoff season. An ISCO automatic streamwater sampler is located with each flume on each watershed, allowing frequent sample collection during storm events (every 1 to 3 hours). Weekly grab samples are collected during baseflow conditions between storm events. Our experience is that these catchments produce 10 to 16 storm runoff events per year, resulting in 100 to 200 samples to be collected and processed per year from each catchment. Samples will be processed for nitrate/nitrite-nitrogen ($NO_{3/2}$-N), ammonia/ammonium-nitrogen ($NH_{3/4}$-N), DOC, total organic C (TOC), total suspended sediment (TSS), and *E. coli*.

4.2.5 Quantifying prescribed grazing effects on ecosystem services

The effects of the prescribed grazing treatments on the selected ecosystem services will be determined by: 1) implementation of the treatments across the 33 pastures in years 2-3; 2) annual collection of all ecosystem service data described for project activity 1 on all pastures during years 2-3; and 3) statistical analysis in years 2-3 to determine if significant changes have occurred for each ecosystem service over the course of the treatment period relative to the original baseline conditions. We will use a mixed effects regression analysis to determine the significance and magnitude of each treatment on each ecosystem service (see hypothesis matrix in Table 2). Pasture identity will be used as a random effect to account for repeated measures on the experimental units (pasture). Dependent variables in these analyses will be all of the ecosystem services metrics (plant diversity, plant species richness, % cover weeds, frequency of weeds, % cover forage species, % cover natives; forage production, forage availability, forage quality, forage utilization by livestock; NO_3-N leached, DOC leached, soil moisture; stream concentrations and fluxes of NO_3-N, NH_3-N, DOC, POC, TOC, TSS, and *E. coli*). Independent variables will be prescribed grazing treatment (11 discrete treatments), year (yr 1=pre-treatment, baseline, yr 2 & 3=post-treatment), the interaction between prescribed grazing treatment and year, and covariates as appropriate (e.g., % oak overstory cover, stream flow volume). The treatment by year interaction will determine if there is an ecosystem response to each treatment, or if the service is changing from baseline conditions as the treatment is implemented over time (degraded, no effect, restored). Mean separations for significant treatment and year effects will be conducted with a conditional t-test comparison (Pinheiro and Bates 2000). A factorial based analysis utilizing linear mixed effects (Pinheiro and Bates 2000) will also be conducted to

examine how the individual prescribed grazing factors (intensity, season of grazing/rest, and rotation of season of grazing/rest) act independently and/or interact to affect each ecosystem service. This will be accomplished using: 1) a completely randomized 3-way mixed factorial analysis (accounting for repeated measures) with 3 factors (grazing intensity, rotational grazing, and year) at separate levels—moderate/high intensity; yes(rotationally grazed)/no(grazed continuously); and 2) a completely randomized 3-way factorial analysis with 3 factors (grazing intensity, season of grazing, and year) at separate levels—moderate/high intensity and early/late/dormant season. The overall analysis allows us to efficiently test our specific hypothesis presented in Table 2, and examine these 11 prescribed management options. The factorial-based analysis allows us to understand how each grazing factor affects ecosystem services and conditions.

4.3 Development of prescribed grazing decision support tool
Our goals for the online tool are to: 1. make research and management based information about prescribed grazing for restoration objectives easily available to users; 2. assist users to develop first approximations of site specific grazing management and monitoring options to enable adaptive grazing management for restoration; and 3. create a networking opportunity for users to share information about prescribed grazing and restoration. Starting in year 1, we will convene an advisory committee composed of rangeland grazing managers, technical support agency staff, restoration practitioners, extension educators, and scientists to provide guidance on user needs, integration of management and research-based information, and outreach strategies. In year 2, with results from the survey associated with Objective 1, we will finalize the conceptual layout and functions of the tool (information access, grazing option development, net-working). We will develop the layout and logic path of the decision support tool, incorporate and/or link to required data sources, compile existing scientific and management knowledge about prescribed grazing and these ecosystem services, and design and develop the software-programming-platform for this support tool. During year 3, we will develop the user interface for the support tool and populate the support tool with existing research and management/case study information about the relationships between prescribed grazing management and the ecosystem services. This information will be compiled from research literature, technical reports, management information, and the results of the prescribed grazing study (Objective 2). The system will be beta-tested with the advisory group, will be revised based upon feedback, and will then become available for use on the web, supported by the UC Davis Department of Plant Sciences server and Information Technology workgroup.

The support tool will be easy for the user to operate, and require a minimal amount of computer expertise. The support tool will be web-based and interactive, allowing the user to experiment with “what-if” scenarios examining the responses of multiple services under pasture/ranch specific conditions, The user can select from a set of prescribed grazing options (e.g., the 11 treatments described above), or the user can create alternative options by selecting different combinations of grazing intensity, season of grazing/rest, and rotation of season of grazing/rest. The user will select the specific ecosystem services he/she wants to restore, and prioritize these goals. Pasture/ranch specific information on soil type, ecological site type, forage production capacity, current weed invasion status, current native plant status and other factors will be required so that support information can be provided to meet site specific conditions. To facilitate this, the support tool will take the user through a step-by-step process for determining

pasture/ranch location and area. Once this has been determined the support tool will automatically compile soils, plant, and other needed information from credible sources such as the USDA NRCS Plants Database, Ecological Site Descriptions, and Soil Survey Geographic Database (SSURGO), among others. The system will summarize pasture/ranch conditions for the user to review and adapt. Based upon the user's identified ecosystem service restoration goals and pasture/ranch specific conditions, the support tool will provide the user a prescribed grazing recommendation. The recommendation will be presented in an adaptive management framework. There will be an initial recommendation for grazing intensity (stocking rate), season of grazing, season of rest from grazing, and pattern of rotation of grazing and rest across years. This recommendation is a starting point for the adaptive management process. The support tool will recommend ecosystem service indicators and simple field monitoring/observations that the manager should conduct in order to determine that grazing is being implemented as recommended, and that ecosystem services are responding as desired. Based upon these indicators, the user can adapt management iteratively until the desired levels of ecosystem services are achieved, or restored.

4.4 Expected outcomes

Specific outputs of this project will be: 1) establishment of a long-term, management scale study of how prescribed grazing affects (e.g., degradation or restoration) multiple rangeland ecosystem services; 2) research findings on the short-term effects (1 to 2 years) of prescribed grazing on multiple rangeland ecosystem services; 3) research findings on the social-cultural-economic-institutional factors determining prescribed grazing – restoration practice adoption, and rangeland grazing manager perspectives on grazing to restore rangelands; and 4) a prescribed grazing decision support tool to restore multiple ecosystem services on rangelands.

The outputs and outcomes of this project will demonstrate that by managing for multiple ecosystem services, managers can increase their economic opportunities (e.g., resistance to weed invasion and loss of agricultural value) and restore their natural resource base (e.g., restore native plant communities and diversity). By fully investigating a variety of potential ecosystem services associated with multiple management strategies (i.e., prescribed grazing), we are better able to represent the *breadth* of services that can be produced over *space* (e.g., multiple pastures managed under different grazing regimes) and *time* (e.g., from annual to decadal time scales). Additionally, the decision support tool will detail strategies to reduce the negative environmental impacts of improper livestock grazing while restoring multiple ecosystem services provided by these rangeland systems.

To realize these benefits, active outreach must be integrated into this project. We will extend the results and outputs of this project through the University of California Cooperative Extension (UCCE) outreach network. Over the past 100 years, UCCE has been a source of science-based, solution oriented information for ranchers, managers, policy-makers, conservation organizations, and natural resource agency partners across California. We will actively integrate the outputs and results of this project into presentations and workshops. For example, at the annual California Cattlemen's Association and Farm Bureau Conferences, Annual Beef Day and Trade Show at California State University-Chico and San Luis Obispo, annual meetings of the California Regional Water Quality Control Boards, etc. Funding has not been requested to conduct this outreach because Drs. Tate, O'Geen, and Eviner all hold academic appointments (CE and AES)

with responsibility and annual funding for conducting statewide training and extension activities. Our team typically conducts 40-60 extension events per year for rangeland managers, natural resources agencies, and community conservation and watershed organizations.

4.4. Pitfalls that might be encountered

Any project of this scope is vulnerable to various pitfalls. We must conduct outreach and use existing diffusion networks to insure adequate response rate to the survey described for Objective 1. We must keep the purpose and end user of the decision support tool firmly in mind – and resist technology that does not fit the purpose and end user. Fortunately, our multidisciplinary team brings together experience in all aspects of this project. The field research infrastructure and human resources required for this project is in-place at the UC Sierra Foothill Research and Extension Center (SFREC), and use of these facilities is available to the project team. Field facilities include: 50+ rangeland pastures, 5 instrumented catchments, and a 250+ animal herd of commercial type beef cattle. Drs. Tate, O'Geen, Eviner, and Lubell manage research laboratories on the UC Davis campus with all equipment and resources required to conduct all analyses associated with this study. The UC Davis Department of Plant Sciences maintains a well-staffed Information Technology workgroup and can provide web-design, web-support, and the computer support required for this project.

5. Project Time Table

This will be a 3 year project. Table 4 reports the schedule of activities over the project period. Following completion of the project as described for this funding opportunity, implementation of prescribed grazing treatments will continue at SFREC for an additional 7 years (10 years total treatment implementation), as part of SFREC normal grazing practices. This will allow future research opportunities and the demonstration of project results at field days and workshops.

Project Activity	Year 1	Year 2	Year 3
Convene project advisory committee	X	X	X
Conduct survey of rangeland grazing managers (Obj. 1&3)	X	X	
Analyze survey results (Obj. 1&3)		X	X
Collect ecosystem service data (Obj. 2)	X	X	X
Implement prescribed grazing treatments (Obj. 2)		X	X
Determine grazing effects on ecosystem services (Obj. 2)			X
Develop prescribed grazing decision support tool (Obj. 3)	X	X	X

Table 4. Project time table.

Appendix

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June 24, 2009

Dr. James P. Dobrowolski
National Program Leader for Rangeland and Grassland Ecosystems – NRE Unit
CSREES, United State Department of Agriculture

Dear Dr. Dobrowolski,

I am writing in support of the proposal titled "Prescribed Grazing to Restore Rangeland Soil Quality, Plant Diversity, Water Quality, and Agricultural Productivity" submitted by Dr. Ken Tate and colleagues to the USDA 2009 Rangeland Research Program Request for Applications.

Audubon California's Landowner Stewardship Program works with farmers and ranchers on habitat restoration projects in a manner compatible with their agricultural operations. We would like to emphasize the critical importance of restoring California's annual rangeland ecosystem both for the future viability of ranching and conservation of the landscapes where grazing takes place. There is an important need for extension of research-based prescribed grazing recommendations which restore ecosystems services such as pollination, water and soil quality and species diversity. We are excited to have been involved in discussions and meetings with Dr. Tate and his colleagues during the development of this proposed project.

If the proposal is funded, we will serve as a full partner on the project advisory committee. This project team has credibility and connection with stakeholders, as well research and outreach credentials required to translate project results into on-the-ground grazing management recommendations to restore this ecosystem.

Sincerely,

Vance Russell
Landowner Stewardship Program

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June 30, 2009

Dr. James P. Dobrowolski
National Program Leader for Rangeland and Grassland Ecosystems – NRE Unit
CSREES, United State Department of Agriculture
1400 Independence Avenue, SW
Washington, DC 20250-2215

Dear Dr. Dobrowolski:

On behalf of the California Cattlemen's Association (CCA), I am writing to share support for the project titled "Prescribed Grazing to Restore Rangeland Soil Quality, Plant Diversity, Water Quality, and Agricultural Productivity," by Dr. Ken Tate and colleagues.

CCA represents cattle producers throughout the state who are committed to improving the natural resources on their rangelands and implementing new practices to enhance their bottom line. CCA supports research projects that will provide results that will offer ranchers practices that can be voluntarily implemented to allow them to be better stewards of the environment and continue economically sustainable operations.

Dr. Tate's proposal addresses the critical importance of enhancing California's annual rangeland ecosystem, which is most prominent on private working cattle ranches. CCA agrees that there is a critical need for extension of research-based prescribed grazing recommendations that address ecosystems services provided by managed cattle grazing, such as controlling invasive species, reducing fire fuel loads, promoting native plants and creating wildlife habitat. As the primary group representing California's cattle producers, CCA is committed to working with Dr. Tate and his colleagues on this proposed project. Based on the research team and stakeholder support, we believe that the results of the research project will translate into positive results on rangelands for CCA members.

CCA requests your support of the proposed project titled "Prescribed Grazing to Restore Rangeland Soil Quality, Plant Diversity, Water Quality, and Agricultural Productivity," that will support the on-the-ground efforts of the members of the California Cattlemen's Association.

Sincerely,

Tom Talbot
President

CALIFORNIA FARM BUREAU FEDERATION
NATIONAL AFFAIRS & RESEARCH DIVISION
2300 RIVER PLAZA DRIVE, SACRAMENTO, CA 95833-3293 · PHONE (916) 561-5610 · FAX (916) 561-5693

June 30, 2009

Dr. James P. Dobrowolski
National Program Leader for Rangeland and Grassland Ecosystems – NRE Unit
CSREES, United State Department of Agriculture

Dear Dr. Dobrowolski:

I am writing in support of the proposal titled "Prescribed Grazing to Restore Rangeland Soil Quality, Plant Diversity, Water Quality, and Agricultural Productivity" – submitted by Dr. Ken Tate and colleagues to the USDA 2009 Rangeland Research Program Request for Applications. I represent the California Farm Bureau Federation and we believe this proposal will provide important information for the restoration of California's annual rangeland ecosystem. There is a significant need for research of prescribed grazing recommendations which restore ecosystems services.

Our organization is a key rangeland stakeholder, and we are excited to have been involved in discussions and meetings with Dr. Tate and his colleagues during the development of this proposed project. We are very pleased with the objectives, study approach, and outreach associated with this project. If the proposal is funded, we will serve as a full partner on the project advisory committee.

This project team has credibility and connection with stakeholders. I've had the opportunity to be on rangeland site visits with Dr. Tate, and have observed stakeholders' positive responses to his science-based approach to solving rangeland ecosystem challenges. Project team members also have the research and outreach credentials required to transfer project results into on-the-ground grazing management recommendations to restore this ecosystem.

On behalf of California Farm Bureau, I highly recommend this proposal for your approval. Feel free to contact me with any questions at 916-561-5618.

Sincerely,

Elisa Noble

Elisa Noble
Director, National Affairs and Research

June 30, 2009

Dr. James P. Dobrowolski
National Program Leader for Rangeland and Grassland Ecosystems – NRE Unit
CSREES, United State Department of Agriculture
1400 Independence Avenue, SW
Washington, DC 20250-2215

Dear Dr. Dobrowolski:

The California Rangeland Conservation Coalition (Rangeland Coalition) is proud to support the proposal for the USDA 2009 Rangeland Research Program Request for Applications by one of our cooperators, Dr. Ken Tate and colleagues, titled "Prescribed Grazing to Restore Rangeland Soil Quality, Plant Diversity, Water Quality, and Agricultural Productivity."

The Rangeland Coalition is an unprecedented group of California ranchers, environmental organizations and government agencies. Together, these partners are working to preserve private working landscapes, support the long-term viability of the ranching industry and protect and enhance California rangelands for both legally protected and still-common species. The Rangeland Coalition truly recognizes the critical role research and education plays in the development and application of science-based grazing recommendations. We also work to maximize the voluntary implementation of these recommendations on private lands to enhance rangeland ecosystem services such as forage productivity, wildlife habitat, invasive species control and reliable water supplies.

On behalf of the Rangeland Coalition, we respectfully ask for your support of Dr. Tate's project that is important to achieving the goals of this partnership. Our partners have worked on the development of this proposed project and are committed to serving as a partner on the project advisory committee. Furthermore, we are confident that this proposed project will translate to on-the-ground grazing management recommendations that will help maintain and restore rangeland ecosystems.

Sincerely,

Tracy K. Schohr
Rangeland Conservation Director
California Cattlemen's Association

Pelayo Alvarez
Conservation Program Director
Defenders of Wildlife

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