**Justification for the Programmatic Initiative**

This proposal requests seed funding for a project with high probability of receiving funding from the NSF RAPID program (based on our conversations with NSF program officers), as well as to build the foundation for an NSF Long-term Research in Environmental Biology proposal. The research focuses on understanding the controls over site-to-site variability in the effects of wildfire, and post-fire recovery in California's grasslands. It is a collaboration with staff at Hopland Research and Extension Center (HREC), where a fire this summer burned 2/3 of its 2,168 hectares. Funding is needed to take advantage of a very limited time window to gather baseline post-fire data on spatial variation in burn severity (level of thatch remaining and seed survival/germinability. This data will set the stage for our multi-year study on spatial variability in vegetation recovery from fire, and collaborations with diverse researchers at HREC, relating our baseline fire severity mapping to altered patterns in: hydrology, wildlife activity, and erosion and landslides.

**Overview of the proposed research**

Unlike most grasslands throughout the world, California's grasslands are dominated by annual vegetation, and thus rely purely on seed viability, germination, and seedling establishment post-fire. There is considerable debate about the vulnerability of seeds to California's wildfires, with all available data deriving from prescribed burns. In addition, there are critical gaps in our understanding of the ecological effects of wildfires, and on the spatial and temporal variation in ecological recovery post-fire. This is because most studies of wildfires only have post-fire data, and lack the critical pre-fire data needed for mechanistic and predictive understanding of how fires alter the key drivers of vegetation recovery across the landscape. Pre- and post-fire data is largely restricted to prescribed burns, which tend to be of lower severity, and at much smaller spatial scales than wildfires, thus providing limited insights into wildfire effects.

Pressing questions for understanding fire impacts in California's grasslands include:

* How does fire severity vary across the landscape in its effects on key factors that will regulate grassland recovery: remaining thatch, number and composition of viable seeds, soil nutrient availability, and soil hydrophobicity (water repellence of soil that develops due to fire)?
* How does post-fire vegetation recovery vary across sites in terms of: early-season seed germination and density, % cover throughout the growing season (critical for erosion control), and vegetation composition and biomass? How long does fire have an impact on vegetation?
* How does spatial variability in fire severity and post-fire recovery vary depending on:
  + Pre-fire grazing intensity
  + Pre-fire heterogeneity in grassland biomass and seed banks
  + Soil type, slope, aspect
  + Level of gopher activity (by removing vegetation cover, the fire has made it clear that there is a high variability in level of gopher disturbance (ranging from 0-80% of soil area), which is known to have strong effects on vegetation composition and nutrient cycling (Eviner and Chapin 2003, Canals et al 2005), and likely have strong effects on vegetation dynamics post-fire as well.
* How do vegetation dynamics differ in the areas affected by wildfire, compared to:
  + Unburned areas
  + Areas that experienced prescribed burns approximately 1 month before the wildfire

We have the unique ability to assess variability in fire severity and ecological impacts of fire based on long-term data (plant composition, biomass, density, seed production) collected across HREC by Eviner since 2007, and in HREC's long-term data on plant biomass production and grazing history across the station. This provides the only known example of a wildfire that has the critical pre-fire data to understand variability in post-fire vegetation recovery (e.g. level of reduction in viable seeds and thatch cover).

The project will build from diverse opportunities available at HREC:

* Eviner's long-term research at 24 plots across Hopland focused on site-to-site and year-to-year variability in vegetation composition, biomass, seed production, and seedling density, and their relationship to seasonal nutrient cycling dynamics.
* 33 additional sites where HREC has long-term measures on forage biomass and grazing history
* 3 prescribed burns from earlier in the summer of 2018
* 16 experimental long-term grazing exclosures.

Cadenasso's expertise in delineating and explaining landscape heterogeneity will provide the sampling and analytical approach to assess the patterns and causes of spatial variability in fire severity and ecosystem recovery, in response to the suite of multiple controllers.

**Background:**

California is projected to have longer and hotter dry seasons, leading to more frequent and more intense fires (Keeley and Safford 2016). Intensifying fire regimes not only have the potential to cause large changes in vegetation composition, but delays in vegetation recovery can lead to catastrophic landslides and flooding. In order to manage California's ecosystems under a changing climate, we need to understand the controls over the severity of fires, ecosystem recovery from fires, and long-term effects of fires. It is particularly critical to understand the spatial variation in fire effects, since the effects of burns are very patchy across the landscape, and post-fire restoration efforts need to be able to focus on the locations where vegetation recovery is most compromised.

While there has been extensive research on the fire ecology of California's forests and chaparral, there is limited understanding of the effects of fires (particularly wildfires) in our grasslands and oak savannas, despite the fact that these ecosystems cover 1/3 of California's total land area (Mooney and Zavaleta 2016). The dominant vegetation cover in both of these ecosystems is annual herbaceous species. The annual nature of these herbaceous dominants is unique- in most ecosystems throughout the world, annual grassland species are purely early-successional, but California's grasslands have been dominated by this annual state for at least 300 years, even in the absence of regular disturbance (Stromberg et al. 2007, Eviner 2016). Although there are many studies across the globe on fire effects on grasslands, these have largely been performed in perennial-dominated grasslands, which are controlled by multiple vegetation recovery pathways, including resprouting, fire survival, and seeds and thus provide little guidance for understanding California's grasslands.

Ecosystems dominated by annual plants are extremely vulnerable to degradation due to environmental changes and disturbances, such as fire. Post-fire, annual plant recovery is often limited by seeds (Seabloom et al. 2003), and in prescribed burns, heavily relies on dispersal of annual grass seeds from fire edges (Larios et al. 2013). However, dispersal will be limited in wildfires, which are typically at least an order of magnitude larger than prescribed burns. Thus, in wildfires, long-term recovery will likely be regulated by the seed bank (dominated by forbs and legumes), and grass seeds that survive fire (most annual grasses germinate each year, and thus they comprise less than 1% of the soil seedbank (Young and Evans 1989)). If seeds survive the fire, post-fire environmental conditions (microclimate, pulses of nutrients, etc.) can shape who germinates and survives, and can strongly stimulate or inhibit grass seed production, depending on the species (Dyer 2002, Berleman et al. 2016), and this seed production will likely be a strong determinant of the rate of grassland recovery post-fire.

Even without fire, the naturally high density of annual grass seeds drives the productivity and nutrient supply dynamics in this ecosystem. Eviner's recent work in California grasslands has shown that the high density of seeds specific to annual systems (200,000- 300,000/m2), coupled with high rates of seedling thinning (50-90%), provide 65% of plant available nitrogen, and controls seasonal patterns of N availability, and thus drives plant productivity. govern plant production and its variation from year to year (Eviner and Firestone 2007, Eviner 2016, Eviner in prep).

**Experimental setup:**

*Plots*

In order to assess variability in wildfire effects and recovery due to management and environmental variation, we will sample across 132 plots that vary in:

* Grazing history (long-term ungrazed, low-, moderate-, and high-intensity grazing)
* Soil type
* Slope and aspect
* Fire (wildfire vs. prescribed fire vs. unburned)
* Degree of gopher disturbance (some through experimental gopher exclosures, most with natural variability in gopher activity, which can be easily quantified post-fire).

*Measurements:*

*Before the fall germinating rain, we will sample:*

* Thatch biomass- from 3 subsamples of 20 cm rings per plot.
* Seed number and viability- from 3 subsamples of 10 cm diameter rings, inserted to 3cm below the soil surface. Thatch will be removed from the surface and seeds will be analyzed separately from those collected from the soil. Seeds will be assessed for: number, total biomass, and germination (by functional group- grasses vs. forbs and legumes)
* Resin bags will be placed 5cm deep in the soil, and incubated through February 2019, to assess early-season post-fire nitrogen availability
* Water infiltration using a double-ringed infiltrometer to test for hydrophobic soils

*5-6 weeks after germination:*

* % cover of bare ground and vegetation by functional group (grass vs. forb vs. legume)
* Depth to which water has infiltrated the soil and % soil moisture of that wet portion of the soil

*Spring of each year for 3 years post-burn*

* Plant composition
* Aboveground and belowground biomass
* Seed production

Across all sample points, thatch, plant, and seed samples will be archived for nutritional analyses under NSF funding.

**Budget justification:**

Funds are requested for critical baseline sampling work that needs to happen September-December 2018, which will provide preliminary data for NSF proposals (and allow for sampling to occur this fall, when NSF funds are unavailable (they are expecting to have a budget to fund such grants later this fall).

A big push of field sampling will occur "unfunded", led by the two PIs, and volunteers from their labs. To facilitate sampling and particularly sample processing, 4 undergraduate students are budgeted to equal a full-time position for 4 months. With oversite from Eviner's lab technician, David Mitchell, these undergrads will do biomass measurements, separate seeds from thatch and soil and measure seed number (on a seed scanner) and biomass, and perform germination trials of the seeds.

Funds are also included to cover Hopland Research and Extension Center's project fees ($1400/year) for the 1st year, mileage for 5 trips (300 miles/trip, at $.545/mile), and 10 nights of loding in their station ranch house (%80/night for 4 people).

Funds are also included for the 1st set of resin bags (the bags and their analyses for ammonium and nitrate), at $2.50/sample for 132 samples (1 per site).