Section 5: Project Description

1. ***Project Objectives:***

1. Enhance the carbon sequestration capacity of more than 1,750 acres of Sierra meadows by controlling invasive plants that are moving into meadows. Compared to a business-as-usual scenario in which invasive plants become the dominant vegetation in these meadows with consequent shifts to soil carbon flux, we estimate that this work will reduce future GHG emissions by 700 tons of CO2 equivalent per year.

2. Conduct a greenhouse study to quantify the effects of invasive plants on mountain meadow carbon sequestration and greenhouse gas emissions. This will measure carbon flux for native meadow vegetation versus invasive plant cover.

3. Improve and protect habitat for native plants and wildlife by removing invasive plants in and near mountain meadows in the Sierra Nevada.

2. ***Background and Conceptual Models:***

Wetlands are typically small components of landscapes, but they contribute disproportionally to biogeochemical processes that underlie key ecosystem services (Kayranli et al. 2010). The role of invasive plants in affecting biogeochemical process is not well understood, but studies to date suggest that some invasive plants may degrade soil carbon storage capacity. Our proposed project will provide baseline data on the impact of invasive plants on the carbon flux of Sierra meadows.

Invasive plants have long been recognized as a threat to the Sierra Nevada's wildlife for their range of biotic and abiotic impacts (D'Antonio et al 2004). The California Natural Diversity Database (DFW 2014) lists 65 sensitive species directly threatened by invasive plants in the Sierra, such as Tahoe yellow cress and the California red-legged frog. However, the Sierra Nevada is not yet impacted by invasive plants as much as other regions of California. It has been protected in part by the more challenging climate at higher elevations. As California's climate warms, many invasive plant species are expected to find hospitable range farther into the mountains.

Our proposal is consistent with several national and state plans addressing climate resiliency. California's Wildlife Action Plan and the National Fish and Wildlife Foundation's Business Plan identify climate change and invasive plants as top threats to wildlife in the Sierra Nevada (Bunn et al. 2005, NFWF 2010). The National Fish, Wildlife and Plants Climate Adaptation Strategy recognizes that actions to reduce existing stressors, such as invasive species, "may be one of the most effective, and doable, ways to increase resilience to climate change" (National Fish, Wildlife and Plants Climate Adaptation Partnership 2012). Invasive plants are also listed as a stressor to address specifically to restore functionality to degraded meadows in the Sierra Nevada (Stillwater Sciences 2012). The President's new Priority Agenda states that the establishment and spread of invasive species is one of the most pervasive threats to climate resilience and that eliminating them before they spread is both ecologically effective and cost effective (Council on Climate Preparedness and Resilience 2014).

Invasive plants can change soil moisture and chemistry, which can affect soil carbon storage. For instance, some invasive plants reduce soil moisture. In a wet meadow, this could result in a loss of soil carbon storage if drier soil leads to increased soil oxidation and plant decomposition. For example, yellow starthistle, an invasive species that is spreading in the Sierra Nevada, reduced soil moisture at a study site in the Sierra Nevada foothills through dry-season transpiration (Gerlach 2004). These redox fluctuations can lead to sinks and sources for both methane (CH4) and nitrous oxide (N2O) and affect the stability or sequestration potential for soil carbon. Depending on being a wet or dry meadow or seasonal soil moisture status, mountains meadows in Colorado were a sink at 109 kg CH4 Ha-1 y-1 in a dry meadow to a source at 179 kg CH4 Ha-1 y-1 (Wickland et al 1999). Generally, the more productive the plant species in the meadow under wet conditions the more CH4 is emitted (Bhuller et al 2014). As invasive species are often more competive and express more biomass production, they may lead to greater CH4 emissions. Estimates for N2O emissions from meadows are sparse and source/sinks relationships are not well defined. Estimates for meadow/grassland systems range from 0.18 to 1.02 kg N2O Ha-1 y-1 (Mummey et al 2000). Generally, N2O emissions are low but increase with dry periods and the extent of nitrogen deposition from human activities.

Our proposal includes a research component to quantify the effects of invasive plants on meadows. It includes a field and greenhouse component to determine the effect of invasive plant species on soil carbon sequestration potential and influence on CH4 and N2O emissions. Recent research shows that invasive plants can alter carbon storage in a variety of habitat types. In the western United States, the conversion of shrublands to grasslands by invasive cheatgrass changed sites from carbon sinks into carbon sources (Bradley et al. 2006). Soil organic C in cool and wet high-elevation meadows and wetlands turns over much more slowly than in temperate environments (Budge and others 2010). High primary productivity generates large quantities of plant-residue-derived soil organic carbon, which is partially decomposed and preserved (Kayranli et al 2010). A review of invasive plants and carbon sequestration in forests found both short-term and long-term effects of invasive plants, where indirect effects of invasive plants on species composition, nutrient availability, and primary productivity led to long-term changes in carbon storage (Peltzer et al. 2014). Linking soil carbon and nitrogen sequestration potential combined with CH4 and N2O emissions to the degree of invasive species ingress will provide important information for land mangers to assess meadow and wetland condition and to implement management to restore important ecosystem services.

Whether an invasive plant increases or decreases carbon storage may depend both on the decomposition characteristics of the invader and the soil characteristics of the invaded ecosystem (Tamura and Tharayil 2014). Previously degraded or disturbed wetlands can be resilient, however, and with improved management (i.e., species selection) and restoration of wetland hydrology, represents an important opportunity to restore ecosystem services such as increased carbon and nitrogen sequestration and sustained stream flows (Erwin 2009). However, information on this topic for mountain meadows in California (or elsewhere) is lacking. Dr. William Horwath in the Dept. of Land, Air, and Water Resources at UC Davis has done preliminary research in Sierra mountain meadows and will lead the research component of this project.

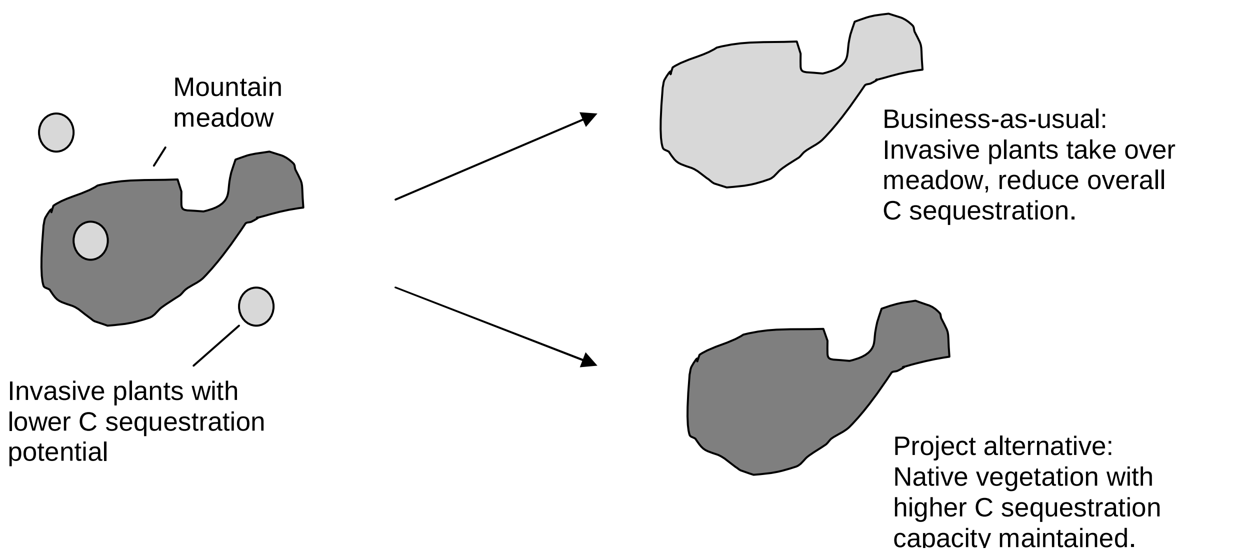
We have selected five Sierra meadow sites that represent a range of conditions and are in imminent threat of invasive plant incursion. Overall these meadows have not seen major disturbance historically (except for the Truckee River Wildlife Area) and are just beginning to see incursion by invasive plants. We have active relationships with local entities with authority to control invasive plants in and around these sites, which makes implementation feasible. Using our CalWeedMapper online decision-support tool, we have evaluated which invasive plant species are most likely to be most prevalent in the region under mid-century climatic conditions, and have already embarked on efforts to map locations of these plants in and around these important meadow sites. Our work takes a proactive approach by stopping populations before they grow so large that removal becomes extremely costly.

Conceptual Model

In a "business as usual" scenario, invasive plant populations in and near these Sierra meadows would likely expand much further into the meadows, potentially becoming the dominant vegetation. Several of our sites are located near highways, trails, or river corridors that can provide dispersal vectors for existing invasive plant populations.

Invasive plant species are believed to reduce the carbon sequestration capacity of meadows relative to native vegetation. (This will be investigated in our project.) Invasive plants can also degrade habitat values for native plants and wildlife.

By controlling invasive plants in and near these meadow sites, we are enhancing meadow capacity to sequester carbon relative to the business-as-usual scenario in which invasive plants take over the vegetation community. We are also protecting native plant and wildlife habitat by controlling invasive plants.



3. _Detailed project description, including all tasks to be performed_:

Tasks will be overseen by the Project Director, with day-to-day work carried out by the Project Manager. The Project Administrator will oversee sub-contracts, accounting, invoicing and reporting.

Task 1: Survey meadow sites. We will survey project sites to collect information on existing status of invasive plant presence, native vegetation communities, soil morphology and hydrologic conditions. Soils will be classified according to the Soil Survey Staff 1994 guidelines. Soil profiles (whole solum cores) will be described and sampled by horizon using a 3-cm-diameter soil core. Samples for bulk density and carbon and nitrogen analysis will be collected. In the lab, soil gravimetric moisture content will be determined and bulk density calculated. Total carbon and nitrogen will be determined by direct combustion.

Task 2: Characterize carbon storage capacity in meadow sites. From site surveys and soil analysis, we will model the typical fluxes in carbon storage from our study sites.

Task 3: Set up greenhouse experiment to test impact of invasive plants.

We will set up a 4-year greenhouse study at UC Davis. See Protocols under part 7 below.

Task 4: Control invasive plants in/near meadow sites. In conjunction with regional partners, we will use the CalWeedMapper online decision-support tool to determine which invasive plant species are most important to control in the field and study in the greenhouse.We will contract with local partners (county agricultural departments, nonprofit organizations, and California Conservation Corps) to survey for and remove invasive plant populations in meadows or that have the potential to spread to meadows, extending work currently underway through another grant. We will identify target invasive plants based on statewide maps previously developed by Cal-IPC. Species may include Scotch thistle, Russian knapweed, spotted knapweed, diffuse knapweed, yellow starthistle, musk thistle, Canada thistle, and tall whitetop. Partners will survey for and remove invasive plant populations using the most effective methods. All populations will be documented and posted on public websites (Calflora, www.calflora.org, and CalWeedMapper, calweedmapper.cal-ipc.org). GIS data will also be compiled for submission to CDFW.

Task 5: Analyze and present results. We will prepare a final report on the project results and disseminate results through conferences and a technical paper.

4. ***Timeline:***

	2015	2016	2017	2018	2019
Task 1: Survey sites					
Task 2: Characterize sites					
Task 3: Greenhouse study					
Task 4: Invasive plant management					
Task 5: Present results					

Year 1 (July 2015 – Dec 2015)

- Hire post-doctoral researcher at UC Davis.
- Plan greenhouse studies using mesocosms with a range of native and invasive species to assess the influence of invasive grass species of soil C sequestration potential and influence on CH_4 and N_2O emissions.
- Set up contracts with project partners for invasive plant removal in 2016-2018.

Year 2 (Jan 2016 – Dec 2016)

- Conduct on-the-ground invasive plant eradication work in partnership with county agricultural departments and local watershed restoration groups
- Document results of invasive plant removal through progress reports.
- Make GIS data publically available through the Calflora website (www.calflora.org).
- Survey meadow sites to determine site characteristics.
- Set-up greenhouse study at UC Davis.

Year 3 (Jan 2017- Dec 2017)

- Conduct on-the-ground invasive plant eradication work in partnership with county agricultural departments and local watershed restoration groups

- Document results of invasive plant removal through progress reports.
- Make GIS data publically available through the Calflora website.
- Maintain greenhouse study at UC Davis.

Year 4 (Jan 2018 – Dec 2018)

- Conduct on-the-ground invasive plant eradication work in partnership with county agricultural departments and local watershed restoration groups
- Document results of invasive plant removal through progress reports.
- Make GIS data publically available through the Calflora website.
- Maintain greenhouse study at UC Davis.

Year 5 (Jan 2019 – Dec 2019)

- Conduct on-the-ground invasive plant eradication work in partnership with county agricultural departments and local watershed restoration groups
- Document results of invasive plant removal through progress reports.
- Make GIS data publically available through the Calflora website.
- Complete greenhouse study at UC Davis.
- Prepare manuscript for journal submission.
- Prepare final project report to DFW.
- Submit GIS data to CDFW. Complete final report. Submit final invoice.

5. *Deliverables*:

Four years of invasive plant control on top priority populations in and near Sierra meadows, documented thorugh maps of invasive plant distribution, progress reports, photos, and assessment of treatment history.

Soil core analysis from meadow sites, with site characterization and analystical model of carbon flux.

Results of a greenhouse study on carbon flux in an invaded meadow versus a meadow with native vegetation.

6. *Expected quantitative results (project summary)*:

Based on published values, conversion of meadows from a native plant community to one dominated by invasive plants that reduce soil water could result in a loss of 299 kg C ha-1 y-1 or 1 ton of CO_2 equivalent per hectare. Our mountain meadow sites total 1,750 acres, resulting in an expected reduction in GHG emissions of 700 tons of CO_2 equivalent per year.

The limited number of studies on factors affecting soil carbon and emissions of GHG makes for a difficult challenge in assessing increases or reductions in global warming potential (GWP) in high mountain meadows of the Sierra Nevada. Based on the literature, changes in the hydrologic condition of meadows from invasion of invasive species may lead to increased transpiration resulting in dryer soil conditions. This would depend on landscape position and factors such as depth to water table among other factors. As water filled pore space decreases from increased transpiration, microbial decomposition of soil carbon increases. This could lead to a loss of up to 1 ton of carbon as CO_2 ha-1 y-1 or approximately 300 kg C ha-1 y-1 leading to a positive GWP. This value could be exacerbated if invasive species in addition to carbon loss from the change in the hydrological condition, lead to less soil carbon sequestration or maintenance as a result of changes in litter quality inputs that result in a reduced efficiency of the conversion of inputs to stable soil carbon. An increase in CH_4 consumption could potentially offset some of the loss in soil carbon. From literature values stated in “Background and Conceptual Models”, up to 109 kg CH_4 ha-1 y-1 or 82 t C ha-1 y-1 would reduce the GWP resulting in a net loss of 218 C ha-1 y-1 (subtracting from the soil carbon oxidation loss). Finally, an increase in nitrification or ammonia oxidation from the mineralized N in the oxidized soil carbon could increase N_2O emission by approximately 1 kg ha-1 y-1 (from background section) or 298 kg of CO_2 equivalents (~81 kg C ha-1 y-1).

Therefore the maximum loss of carbon would be 300 kg from soil oxidation and 81 kg from N_2O emission for a total of 381 kg C ha-1 y-1. This would be reduced by CH_4 consumption of 82 kg C ha-1 y-1, resulting in a potentially maximum loss of 299 kg C ha-1 y-1 or 1 ton of CO_2 eq per hectare. We must stress that there is insufficient research to clearly validate this estimate. However, we feel the estimation is a reasonable interpretation of the existing literature and therefore this provides the necessary rationale to pursue the assessment of the effect of invasive species on meadows.

7. ***Protocols:***

Greenhouse experiments will involve mesocosms to examine the effect of increasing invasive grass species in relation to natives. The dimension of mesocoms will be 30 cm dia. and 45 cm in depth. The greenhouse study will be temperature controlled to mimic field conditions and the rooting volume temperature will also mimic field soil temperatures. Treatments include 100% native species, 50/50 mix of native to invasive and 100% invasive species with three replicates of each treatment. We will determine species composition following a review of existing plant data form the meadows we list above. Soil moisture will mimic a typical meadow condition with water filled pore space decreasing from 80 to 100% (winter) to 20 to 40% (summer) over a 3 year growth cycle. Total biomass production will be determined annually to determine soil residue inputs. Total nitrogen uptake will be determined and will be used to assess changes in nitrogen cycling that could affect the potential to sequester or loose soil carbon under the imposed treatments (Horwath 2014). Estimates of CH_4 and N_2O emissions will be done on a weekly basis using a static chamber technique (Hutchinson and Livingston, 1993), and following the guidelines of the GRACEnet Project Protocols (Parkin and Venterea, 2010). We will use the estimates of CH_4 and N_2O emissions or consumption as a proxy to determine the role of invasive grass ingress to meadows and to estimate potential GHG reductions or increases. The experiment will run up to 3 years, after which the treatments will be terminated and the amount of soil carbon determined to assess whether invasive grasses influence soil carbon levels.

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