a. Date Submitted
5/15/2024

b. Project Title
Soil, plant, and hydrologic dynamics as indicators of ecosystem function and fire vulnerability across diverse forest health and fuel reduction treatments in the Coast Forest Southern Sub-District

c. Project # (leave blank; to be assigned by EMC)

____

d. Principal Investigator(s) (PI)
Christina Richardson[1]
Adina Paytan[1]
Sasha Wagner[2]
Stewart Wilson[3]

e. Affiliation(s) of PI(s) and Address(es)
[1]University of California at Santa Cruz, [redacted]
[2]Rensselaer Polytechnic Institute, [redacted]
[3]California Polytechnic University at San Luis Obispo, [redacted]

f. Applying Organization
University of California at Santa Cruz

g. Primary Contact Phone Number(s)
Christina Richardson, [redacted]
Adina Paytan, [redacted]
Sasha Wagner, [redacted]
Stewart Wilson, [redacted]

h. Primary Email Contact(s) of PI(s)
[redacted] (primary)

i. Name(s) and Affiliation(s) of Collaborator(s)
Grey Hayes, California Polytechnic University, Swanton Pacific Ranch
Tim Hyland, California State Parks, Santa Cruz District
Laurel Bard and Matt Abernathy, Santa Cruz County Resource Conservation District

j. Project Description. In not more than 2,000 words, provide a problem statement, research question, description of methods, including analysis and interpretation, and identified monitoring location(s). Include:

i) Project Duration (Years/Months)

2 years 4 months

ii) Background and Justification

Ecosystem resilience to disturbances, like wildfire and changing climatic conditions, is shaped by soil and hydrologic function. As wildfires and climate change stressors become more common, ensuring current management practices are optimized for resiliency is critical. With climate change, California forests face episodic and chronic perturbations, like drought and extreme heat, increasing fire weather days and risk (IPCC, 2021). Forest Practice Rules (FPRs) and other regulations (CEQA, Timberland Productivity Act, etc.) aim to increase forest resiliency via sustainable forest management and restoration, but whether current FPRs are effective and/or optimized for this goal in the face of climate change is unclear.

Forest health and fuel reduction treatments often involve salvage logging after a wildfire. However, questions remain about ideal canopy retention levels for forest resilience and, thus, long-term economic viability. Evaluating the effect of variable retention of post-fire canopy cover on ecosystem function could provide insight into what treatments lead to better forest health and resiliency outcomes. Similarly, post-fire reforestation efforts have faced difficulties in some regions of California, suggesting current stocking standards may not be optimized for survival or wildfire resilience. Evaluating how low- versus high-density stocking drives changes in soil, plant, and water dynamics could afford new insight into best management practices for long-term forest health and restoration outcomes. Finally, while prescribed burn treatments are often ascribed to positively impact forest health and mitigate more extreme impacts that could arise with high-severity wildfires, more work documenting such changes would prove useful in growing efforts to scale beneficial prescribed fires statewide. The USFS and the State of California have committed to treating at least 1 million acres by 2025.

iii) Objectives and Scope

This study aims to evaluate how a range of forest health and fuel reduction treatments impact soil, plant, and hydrologic components of overall ecosystem function. We will leverage sites on private and State forestlands of the Coast Forest Southern Sub-District with variable forest health and fuel reduction treatments, including salvage logging, thinning, understory treatments, and prescribed broadcast burns, to examine how current and potential changes to FPRs impact key components of ecosystem function, like plant water stress, soil and runoff chemistry, and soil water availability, that directly affect fire risk and forest resilience.

Soil and hydrologic components, like soil moisture, can proxy plant water availability and, thus, fuel loads (Sharma et al., 2021) and live/dead fuel moisture (Fan et al., 2018; Masinda et al., 2021). Soil moisture content can even predict fire vulnerability better than other common weather and drought indices (Krueger et al., 2022). Physical properties of soil can likewise shed light on water pathways and storage capacity, which are central to understanding fire resilience and forest health. Direct indices of plant water stress, like leaf water potential, can also provide key information on water availability across species with different rooting zone depths and is linked to live fuel moisture content, an indicator of flammability (Boving et al., 2023).

Other aspects of soil and hydrologic function, including soil and runoff chemistry, mediate forest ecosystem health. For instance, physical and chemical soil properties, often altered after wildfire and further manipulated due to varying post-fire management efforts, can influence forest structure (Royo et al., 2016; Serrano-Ortiz et al., 2011). In temperate forests, soil respiration, a central component of forest health, can occur via tree roots and microbes, accounting for most of the total ecosystem respiration (Goulden et al., 1996; Longdoz et al., 2000). Measurements of soil gas fluxes can be used to examine total ecosystem respiration.

In another example, “black carbon” (BC), produced during fire when vegetation is converted to charcoal and soot, has fundamentally different physicochemical properties from unburned biomass and, therefore, modulates ecosystem stability and resilience. Forest management practices, like salvage logging, prescribed burns, and fuel reduction, have been shown to alter soil BC content (DeLuca and Aplet, 2008; Ward et al., 2017; Busse et al., 2014).

<u>Research Questions</u>

- After wildfire, what canopy retention levels lead to better plant water availability and overall ecosystem function outcomes for fire and forest resilience?
- After wildfire, how do low- versus high-density stocking practices alter soil, plant, and hydrologic function for fire and forest resilience?
- How does prescribed fire alter landscape soil, plant, and hydrologic function relative to untreated areas?

iv) Research Methods. Describe the methods for collecting, analyzing, and interpreting the data.

<u>Monitoring Locations</u>

We will examine soil, plant, and hydrologic function (1) across experimental gradients in post-fire canopy cover treatments (no treatment versus 20%-80% retention), (2) across gradients in stocking density (low versus high) in a post-fire environment, and (3) before and after prescribed burn treatments in forested public lands (including an untreated site). Including post-fire sites is purposeful as they provide an important and timely statewide analog for understanding how to optimize forest recovery after a recent wildfire, a growing issue for California.

Specifically, the post-fire sites will cover regions of California Polytechnic State University’s Swanton Pacific Ranch (impacted by the 2020 CZU Lightning Complex Wildfires). Swanton Pacific Ranch has leveraged the post-fire recovery period to implement treatment gradients in canopy cover retention, mechanical understory work, and stocking densities to serve as natural experimental laboratories. In addition to the Swanton Pacific Ranch sites, our study will examine prescribed burn impacts. Through collaboration with California State Parks (Tim Hyland), our sites will focus on forests in Butano State Park, Big Basin State Park, and/or Nisene Marks State Park, depending on how burn plans and permits unfold together with our project timeline. All site locations within the treatment and non-treatment areas will be selected based on similarities in plant community, slope, aspect, and geology.

<u>Data collection and analysis</u>
Long-term monitoring will be paired with seasonal discrete sampling campaigns. Long-term monitoring will include high-frequency measurements (15-min) of soil moisture content and soil temperature at 6 depths, up to 120 cm, using a GroPoint sensor set in a series of five at each location. Light intensity will be measured using Hobo Pendant loggers at the surface. At the sites in Swanton Pacific Ranch, monitoring is expected to begin in ~April 2025 for at least a year. At the prescribed burn sites, coordinated communication and circumstances will determine how early we can deploy sensors pre-treatment. Sensors will be immediately redeployed following the prescribed burns.

Seasonal discrete measurements will include soil physical (water capacity, bulk density, field saturated hydraulic conductivity, hydrophobicity) and chemical parameters (carbon, black carbon fractions, nutrients, trace elements, extractable cations), soil leachate chemistry (carbon and black carbon fractions), soil gas fluxes (CO_2, CH_4, N_2O; LiCOR), runoff sediment content and chemistry (nutrients, carbon, black carbon fraction; Mini Rainfall Simulator), and leaf water potential (Pressure Chamber, PMS Instrument). Sample sizes for all variables will consider intra- and inter-site heterogeneity for robust statistical comparisons. All data will be publicly available.

<u>Data Interpretation</u>
At Swanton Pacific Ranch, we will leverage the existing experimental gradients to see what treatments lead to better outcomes for forest health and resiliency after wildfire. Specifically, the variable canopy cover sites will be compared to one another to evaluate how canopy cover retention drives changes in soil, plant, and hydrologic function and referenced to a site with no salvage logging for treatment-control comparisons. The low- and high-density stocked sites will be compared to assess if and how stocking standards might affect soil, plant, and hydrologic function differently. At the prescribed burn sites, we will include a control site and a before-after treatment setup for multiple comparisons using a Before-After Control-Impact (BACI) methodology.

v) Scientific Uncertainty and Geographic Application. Please consult Section 3.1 of the EMC's Strategic Plan13 for further information. Indicate the specific geographic locations, counties, or regions of the state to which this project may have benefits; if benefits are anticipated to apply across the state, indicate "Statewide". If the benefits are also anticipated to occur outside of the state, please explain. Projects may occur on sites under any kind of land ownership.

<u>Scientific Uncertainty</u>
The efficacy of current FPRs at improving forest resiliency to disturbances like wildfire and climate change impacts is understudied. For instance, with climate change, increases in extreme precipitation, drought, and fire weather days are expected. FPRs can help mitigate this increased risk, but few data exist on the effectiveness of FPRs in improving ecosystem function and resilience even outside of the context of climate change. Our proposal will address both elements by pairing discrete sampling with high-frequency measurements of indicators of water chemistry and availability, plant water stress, and soil health in public and privately owned

forested ecosystems undergoing diverse forest health and/or fuel reduction treatments in the Coast Forest Southern Sub-District. In addition, our plans to leverage long-term measurements of soil, plant, and water dynamics will likely converge with weather anomalies, like extreme heat and/or precipitation events, throughout the year. We can use these extreme events to understand how forestlands respond to select climate change stressors across treatment types and extents.

<u>Geographic Applicability</u>
While research results are most applicable to the Coast Forest District, the project is expected to have a widespread, state-wide impact and applicability due to our purposeful selection of sites with dynamic disturbance histories and fuel reduction treatments, which represent a range of conditions and treatments currently extant on California's forested lands.

vi) Collaborations and Project Feasibility.

This project collaborates with multiple agencies, universities, and community groups. Specifically, we will work alongside Cal Poly Swanton Pacific Ranch, the Santa Cruz County Resource Conservation District, CALFIRE, and California State Parks to accomplish the proposed work.

The project PIs have all been involved in evaluating how fire impacts landscapes in California through multiple projects and peer-reviewed studies. All PIs have recently worked in the region after the CZU fires, are familiar with site conditions, and have well-established relationships with local contacts. Dr. Christina Richardson will be the home institution lead in charge of the project, and funding will include salary support for her as an assistant researcher and multi-year summer support for one graduate student intern and an undergraduate student. Dr. Adina Paytan has expertise in soil chemistry and disturbance impacts and will provide key project support through lab and analytical access. UCSC will also be responsible for field plans, sampling, instrument deployment, and all hydrologic and plant data collection. Dr. Sasha Wagner will be responsible for black carbon soil and soil leachate measurements, and support will fund summer salary and one graduate student. Dr. Stewart Wilson will co-lead soil sampling and analyses with Dr. Richardson, as well as provide support for undergraduate students.

k. Critical Question Theme and Forest Practice Rules or Regulations Addressed. Please identify the Critical Questions by number and letter (as identified in the EMC's Research Themes and CMQs)14, and the associated regulations by number. Please also describe how your project will address these questions and the efficacy of each regulation.

This research proposal will address the priority Critical Monitoring Questions (CMQ) **12a** (Are the FPRs and associated regulations effective in improving overall forest wildfire resilience and the ability of forests to respond to climate change (e.g., in response to drought or bark beetle; reducing plant water stress) and variability, and extreme weather events (evaluate ecosystem functional response to fuel reduction and forest health treatments) and **6d** (Are the FPRs and associated regulations effective in managing forest structure and stocking standards to promote wildfire resilience?). By examining how varying treatment types and extents alter key components of ecosystem function, we can better anticipate how these systems will respond to ongoing fire hazards and climate change stressors. Our comparison of low versus high stocking densities will provide insight into what and how stocking standards promote wildfire resilience through changes to soil, plant, and hydrologic function.

In addition, our proposal will provide insight into **3a** (Are the FPRs and associated regulations effective in reducing or minimizing management-related generation of sediment and delivery to watercourse channels), **1e** (Are the FPRs and associated regulations effective in maintaining and restoring input of organic matter to maintain or restore primary productivity as measured by macroinvertebrate assemblages), **1f** (Are the FPRs and associated regulations effective in maintaining and restoring riparian function of Class II-L watercourses in the Coast District), and **1i** (Are the FPRs and associated regulations effective in filtering sediment that reaches WLPZs). These questions will be answered through our investigation of runoff and soil chemistry. Indirectly, our proposal will provide insight into CMQ Theme 5, as the proposed study areas serve endangered coho and steelhead salmon.

I. Requested Funding. Please provide the total amount of funding requested from the EMC, broken down by year of expenditure (by FY, i.e., from July 1 through June 30 of each year), with a brief justification of costs not to exceed 200 words.

	12/1/2024-6/30/2025	**7/1/2025-6/30/2026**	**7/1/2026-3/31/2027**	**Subtotal**
	7 months	12 months	9 months	
UCSC	$96,933	$132,171	$188,086	$417,190
RPI	$8,000	$100,925	$8,000	$116,925
Cal Poly	$10,000	$30,000	$25,000	$65,000
Total	$114,933	$263,096	$221,086	**$599,115**

Budget Justification
UCSC (Dr. Christina Richardson, Dr. Adina Paytan) - Funding includes partial assistant researcher support, summer graduate student intern support, equipment purchases, and project supplies for instrumenting seven field sites.

RPI (Dr. Sasha Wagner) - Funding includes PI summer support (1 month), graduate student support, and lab costs for carbon analyses.

Cal Poly (Dr. Stewart Wilson) - Funding includes PI summer support (1 month), undergraduate support, and lab/field costs for soil analyses.