CALIFORNIA STRATEGIC GROWTH COUNCIL

Climate Change Research Program

QUARTERLY PROGRESS REPORT

2020

QTR 4

Progress Report # 5 **For the reporting period:** October 1, 2020 **to** December 31, 2020

Grantee Institution: University of California, Irvine **Agreement #** CCR20021

Research Grant Title Innovation Center for Advancing Ecosystem Climate Solutions

Signature Line (authorized representative): Erika Blossom

RESEARCH GRANT PROGRESS SUMMARY

Provide information for each task in the research grant's scope of work, noting zero if work has not been started on a specific task:

Task # or Description	Description	Percent of Work Completed for this Period	Percent of Work Completed to Date	Reimbursement Amount Charged for this Period	Reimbursement Amount Charged to Date
1.1	Collect and homogenize data layers	5%	65%	$12,000.00	$250,786.23
1.2	Test, improve, and update data layers	10%	50%	$38,000.00	$183,623.72
2.1	Prepare data analysis	5%	55%	$19,000.00	$134,403.40
2.2	Analyze historical and current data	10%	35%	$30,035.26	$94,035.26
2.3	Extend data analysis via data science and machine learning	10%	20%	$10,000.00	$21,000.00
3.1	Actively engage stakeholders	10%	45%	$41,000.00	$187,244.11
3.2	Produce decision-making tools	5%	20%	$12,000.00	$36,000.00
3.3	Communication	10%	45%	$12,000.00	$78,000.00
4.1	Develop valuation framework	15%	50%	$17,000.00	$66,000.00
4.2	Develop and implement valuation tools	5%	5%	$2,000.00	$2,000.00
4.3	Develop financing strategies	5%	5%	$2,000.00	$2,000.00

PROVIDE A SUMMARY STATEMENT DESCRIBING THE MILESTONES (INCLUDE GO/NO GO MILESTONES), ACCOMPLISHMENTS, SUCCESSES, BARRIERS, AND OBSTACLES THAT HAVE OCCURRED WITHIN THE CURRENT REPORTING PERIOD:

The CECS Project team continued to make great progress in Q4 2020. Subgroups working on Tasks 1, 2, 3, and 4 have met frequently to discuss strategy and make steps toward deliverables, and much cross-task collaboration to bring all project components together into a working web tool have begun.

For Task 1, we further developed our mapping of vegetation cover and its change due to disturbance across California, which we are continuing to validate using Collect Earth Online. We also mostly finalized analyses on archival silviculture treatments on public and private lands.

For Task 2, we built out the framework to run the updated CASA-based model on UC Irvine's High-Performance Computing Cluster (HPC). The HPC will enable us to easily store and run analyses on data layers for all of California. Additionally, we modeled and analyzed long-term human- and lightning-caused ignition probability across the whole state and sub-ecoregions of California, as well as analyzed the effects of tree mortality on fire progression. We started to incorporate on-ground validation in chaparral ecosystems as well. We also began to work on ecosystem recovery responses to Californian fires, utilizing machine learning techniques.

For Task 3, the CECS outreach team engaged with 32 representatives at over 25 agencies, nonprofits, local collaboratives, and private companies for participation in interactive virtual workshops. In a preliminary analysis of the needs assessment survey responses, we found that ongoing work has identified a set of stakeholder needs which largely corresponds with the overall aims of this project, suggesting that the overall scope of our work is likely to be highly relevant for stakeholders. We continued to build and strengthen our partnerships with state and regional agencies, NGOs, and other research consortia through numerous listening sessions, data sharing opportunities, and synergistic discussions. We began to plan for an external review, which will be hosted in January.

As part of Task 4, a perspective paper was nearly completed. Additionally, work began on developing the CECS framework that provides a broad perspective and backbone for mapping and valuing key ecosystem services with forest restoration activities in California. Different frameworks were developed specifically for carbon storage, water resources, carbon-water balances, recreational services, and air quality.

Several papers have been published this past quarter as part of this project, and several more are in draft form and will be submitted to journals in Q1 2021. There were over 20 American Geophysical Union conference talks and poster presentations in December 2020 based on this project's research.

Aside from a slight delay in our timeline in some instances due to COVID-19, significant progress continues to be made.

ACHIEVING PROGRAM GOALS

1. Briefly discuss any successes the research has achieved in furthering the Climate Change Research Program's Program Goals:

   At Stanford, postdoctoral researcher Kyle Hemes is finishing an analysis of the carbon uptake recovery after fire disturbance in California. Initial manuscript is drafted, and in internal comment/review.

   At San Diego State University (SDSU) Professor Walter Oechel, graduate student Kyle Lunneberg, and team characterized carbon flux in chaparral from multiple perspectives during a historically devastating fire season. Q4 marked the completion of three year-long, chaparral datasets focusing on net ecosystem exchange of carbon, species-level photosynthetic rates with variable water stress, and

micro-site-level soil respiration. Determining the effects of drought, fire, and stand age on carbon flux in chaparral ecosystems through multiple avenues provided us with a better understanding of how the source-sink relationship of these chaparral ecosystems are affected by extreme weather events and climate change.

At UC Davis, postdoctoral researcher Bin Chen used the maximum entropy model (MaxEnt) driven by both biophysical and anthropogenic variables to predict the spatial distribution of wildfire ignitions statewide and across sub-ecoregions at 1-km spatial resolution. He also generated the decadal changes of ignition probability from 2000 to 2010, which are distinguished by human- and lightning-caused ignitions. He also isolated the impacts from human activities and climate change on shaping changes of ignition probabilities. The derived maps and resulting variable analysis have implications for understanding the shifts and controls on contemporary wildfire ignition distribution and collective fire management.

Additionally, Jian Lin, a postdoctoral researcher at UC Merced, developed frameworks to examine the impacts of forest management on carbon dynamics and integrated vulnerability. By considering different attributes of management (e.g., location, activity types, intensity, and retreatment frequency), the proposed research aims to assess the effectiveness of past and ongoing management activities on forests and inform future management strategies.

2. Describe any successes made in advancing the objectives of the applicable research focus area (i.e., carbon dioxide removal, methane reduction, or heating, cooling, and thermal storage):

We are working towards understanding the carbon implications of wildfire and forest management across California. This will help us understand the importance of fire fuels management in avoiding catastrophic wildfires and keeping carbon stored in California's forests. It will also help quantify in what ways the state can expect to count on forests and working lands as a long-term carbon sink.

Bin Chen's work at UC Davis elucidates the spatial patterns of wildfire ignitions and highlights which factors are shaping wildfires in California. It has implications for understanding the controls on wildfire ignition distribution and possibly also targeting forests. His research also provides region-specific guidance for forest management in the state. Given the severity of the 2020 wildfires, the timely investigation could limit risk in California in future years.

The work of Yuhan Huang, graduate student at UC Davis, promotes the understanding of wildfire behaviors in California. Considering the massive tree death after the extended warm drought in Sierra Nevada, together with the increasing number of destructive wildfire events, his research findings will reconcile some disagreements among previous studies and promote the understanding of the effects of drought-intensified dead trees on fire behaviors, providing guidance for fire suppression and forest management.

SDSU adapted its continuing measurement of chaparral carbon flux to support CECS' state-wide CASA-based modeling system. This including partitioning 15 measurement-years of eddy covariance data and modeling the spatial extent of sampled area. We also successfully completed eight drone-based, multispectral monitoring missions for the tower footprints, and have begun conducting missions in Coastal Sage Scrub Environments. To our knowledge, this is the first comparison of high-resolution, multispectral imagery to chaparral NEE/GPP. We expect this will be a useful tool for expanding and verifying modeled estimates for NEE/GPP in other chaparral landscapes. Drone-based data was further

used to estimate stand-level biomass for new- and old-growth chaparral. This is a critical step to verify existing modeled biomass data which has not been formally tested in shrublands.

We had an additional focus in Q4 on examining time-series response curves of forest carbon (e.g., live and dead carbon pools), and integrated vulnerability (e.g., carbon, water, die-off, and fire risk) after management activities. The findings should help increase forest resilience and advance our understanding of the contribution of forest lands to the California's carbon neutrality goal.

3. Summarize efforts taken during this report period to conduct Meaningful Engagement:

Despite challenges to outreach and engagement during the COVID-19 pandemic, we have continued to build new connections and strengthen previously-established partnerships. All of the engagement efforts listed below were completed entirely virtually, unless otherwise noted, to preserve the health of all parties involved.

On Oct. 20 Roger Bales presented virtually for Association of California Water Agencies "Economic Drivers of Sustainable Forest Management Panel participation, giving a talk on the importance of these drivers on headwaters in CA. His talk drew on his and others' research from CECS.

As a follow-up to a call with the Nature Conservancy (TNC) in September, 31 CECS team members joined Kristen Wilson and Dan Porter in early October to hear more about their work on the TCSI Project. While all benefited from hearing about this project, CECS researchers who are focused on ecosystem services and valuation were able to take some parts of the TCSI project as a model for which to frame their analyses. Collaboration with this group will be ongoing.

In another follow-up call with Pyregence, CECS Director Mike Goulden, UC Berkeley PI John Battles, and UC Irvine PI Jim Randerson joined 12 Pyregence team members to coordinate on scenario variables. Continued collaboration and data-sharing with Pyregence is ongoing.

On October 29, Project Coordinator, Raiven Greenberg, and UC Merced Stakeholder Specialist, Jaquelyn Lugg, joined SGC's Leah Fisher and round 1 and 2 Climate Change Research Grantees in a virtual convening to discuss outreach and engagement challenges during COVID era, and to share best practices for digital engagement. This discussion helped us to better our outreach practices in subsequent months.

In mid-November UC Merced PI Safeeq Khan hosted the French Meadows Project Partners Virtual Meeting.

Additionally, John Battles helped organize the presentation of CA Wildfire and Climate Institute to the CA legislatures and other state officials.

Stanford PI Chris Field hosted the "Identifying Research Opportunities in Global Carbon Management with a Focus on Natural Climate Solutions" workshop in conjunction with the Stanford Woods Institute for the Environment.

CECS's web developer, Mike Walkinshaw, met with folks from Pyregence, Salo, and EMapR to gain additional insights into user experience and also on hosting and delivering such large datasets in real-time and sharing best practices. Project Coordinator, Raiven Greenberg, met with UCI's Physical Sciences Computing Group to discuss the possibility of getting help with design and/or hosing of the CECS decision support tool. All of this collaboration and assistance will help us to make the tool an even better resource, and to improve upon it as the project progresses.

Walter Oechel's group at SDSU provided STEM learning opportunities related to work in this project for elementary-aged students from underrepresented areas of San Diego at the Elementary Institute of Science. This included all lab members attending EIS's "Meet a Scientist Day" to answer questions about their work in the chaparral. The SDSU team also gave a Specialist presentation to the San Diego Cooperative Extension, presented the "Effects of Drought, Fire, and Stand Age on CO2 Flux in Semi-arid Chaparral Ecosystems" at the 101st American Meteorological Society Annual Meeting, and met with members from the USGS Climate Adaptation Science Centers (Southwest and Northwest) to asses stakeholder needs for the developed tools.

UC Irvine postdoctoral researcher, Charity Nyelele, and UC Irvine PI Benis Egoh had meetings with the team at Blue Forest Conservation to discuss CECS' work on air quality and human health as well as how to evaluate issues of equity and environmental justice in forest restoration. Through Blue Forest, they were connected to other researchers doing similar work. They met with Kirsten Olesan's lab at University of Hawai'i Mānoa and spoke about equity and environmental justice in forest restoration, distinguishing private from public goods as well as mapping and valuing recreation related ecosystem services and benefits. During an NSF-funded Research Coordination Network on Biodiversity Across Scales, Benis presented our work in the TCSI as part of her keynote presentation to the group. Benis also presented at Duke's Nicholas Institute for Environmental Policy Solutions' Equity and Ecosystem Services webinar.

On December 3, members of the CECS Executive Committee met with Tony Rolfes, Jon Gustafson, Marcos Perez, Hue Dang, and Greg Barrett, all from the Natural Resource Conservation Service. On this introductory call we introduced CECS project, learned more about their work and how we may be able to help. Jon had suggestions for making data available in support tool broken down by ecoregion. Marcos is working on a plan for the State to prioritize certain areas for carbon sequestration and wants to follow up about this to see how CECS' work can support it. We will connect with Jon and Marcos again in Q1 2021.

Continuing our tradition of quarterly "CA Fire Science Working Group" calls with Salo, Pyregence, and the California Ecosystem Futures Project, we hosted our Q4 call in December. Michael Mastrandrea, the Chief Advisor for Energy and Climate Research at California Energy Commission, who is looking for groups to support the next state Assessment, joined to listen in. All projects provided updates, found additional means for sharing data and best practices, and discussed brining more project groups into the fold to collaborate. Calls with all three projects will continue on a quarterly basis, and we will continue to invite agency representatives to join as deemed appropriate.

In preparation for the first round of stakeholder workshops, Jaquelyn Lugg hosted calls with Micah Elias of Blue Forest Conservation, Byron Krempl of the Tuolumne River Trust, and Keali'i Bright of the Department of Conservation's Regional Forest Fire Capacity Program. These talks helped to solidify our workshop design, and these individuals helped to get other colleagues and organizations to participate in our survey and workshops as well.

The CECS outreach team engaged with 32 representatives at over 25 agencies, nonprofits, local collaboratives, and private companies for participation in interactive virtual workshops, hosted by Jaquelyn Lugg, and UC Merced Assistant Project Scientist, Max Eriksson. Workshops were held in November and December and consisted of each participant drawing two cognitive maps: one of weighted connections between eco-system services, and another of weighted impacts of management actions on eco-system services. These cognitive maps will be aggregated and analysis will be completed in Q1 2021 and shared with all workshop participants, as well as with other interested stakeholders.

Workshop participants included individuals from the following agencies/organizations:

- Blue Forest Conservation
- Board of Forestry and Fire Protection
- Burney Basin Fire Safe Council
- Butte County Fire Safe Council
- Butte County RCD
- CAL FIRE
- California Trails Conference
- California Wilderness Coalition
- California Air Resources Board
- Central Valley Water Board
- Environmental Defense Fund
- Falls River RCD
- Feather River RCD
- Latino Outdoors
- McMullin Area Groundwater Sustainability Agency
- Nevada Irrigation District
- Rabobank
- River Ridge Institute
- San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy
- Sierra Forest Legacy
- Sierra Institute for Community and Environment
- Sierra Nevada Alliance
- Sonoma County Water Authority
- Tuolumne River Trust
- USFS Region 5

CURRENT STATUS OF THE RESEARCH

4. Summarize the efforts taken during this report period to accomplish the task objectives for each project in the grant:

For Tasks 1.1 and 1.2, Jon Wang analyzed areas of repeated disturbance in California using his earlier-created remote sensing-based database of ecosystem disturbances to quantify the impact of previous fires and harvest disturbances on the probability and severity of future wildfires in forests. Jon also further developed his mapping of vegetation cover and its change due to disturbance across California. He trained a machine learning algorithm on the USGS National Land Cover Database's forest, shrub, herbaceous, and bare ground cover products, which are limited in their temporal coverage. Using the Landsat remote sensing data, he generated data layers of tree, shrub, and herbaceous cover for each year in 1984 - 2019 across California. We will soon analyze trends and spatial patterns of vegetation cover change throughout the state.

Additionally, UC Berkeley PhD candidate Clarke Knight, along with Jon Wang, John Battles, and Mike Goulden, mostly finalized analyses on archival silviculture treatments on public and private lands through time. In this manuscript, they also compare the timing and intensity of archival treatments to CCDC algorithm harvests. The results suggest over-reporting of treated area in archival datasets. This finding was expected, but to our knowledge, its quantification has not formally been undertaken before this work. Over-reporting of treated areas has important management implications for California because the State is actively working to achieve 500,000 acres treated/annually in an effort to modify fire behavior on the landscape but may be falling short of its goal. Although the paper is mostly formulated, Clarke and Jon are continuing to validate CCDC using the platform Collect Earth Online.

Based on the forest management data provided by Clarke Knight and Jon Wang, Jian Lin developed a classification scheme to organize management activities into different categories, extracted retreatment management polygons, and identified management polygons that also experienced wildfire events. The next step will be working on the impacts of management on carbon and forest vulnerability by utilizing the CASA-based model output.

For Tasks 1.2 and 2.1 Kyle Hemes has been involved in collecting and homogenizing existing data layers, developing Google Earth Engine (GEE) workflow, and preparing structure to produce Version 3, gap filled carbon and water results, for FRAP fires back to ~1950. Kyle has also been preparing input carbon and water monthly layers for the CASA-based model, using Landsat inputs. UCI graduate student Carl Norlen worked with Kyle to use the CECS-created GPP product to analyze fire recovery across California. Initial analyses of multi-decadal fire impacts are being explored using the whole library of FRAP fires and a manuscript is half written.

Additionally, UCI Project Specialist Mahnoor Khan worked with Jon Wang and Carl Norlen to run the updated CASA-based model on UC Irvine's High-Performance Computing Cluster (HPC). This process requires loading all the raw data inputs onto the HPC and running them through the CASA-based model code. John Battles worked on developing empirical validations of allometric scaling applied in the CASA model. He also began to assemble alternative decomposition rates for the dead wood pools from the literature. The CASA-based model will yield the majority of the data deliverables for the project.

As part of Tasks 1.2-2.3, Walt Oechel and Kyle Lunneberg at SDSU partitioned net ecosystem exchange (NEE) into ecosystem respiration and gross primary production and analyzed and modeled temporal trends of NEE from three varying-aged chaparral stands at Sky Oaks Field Station. This was accomplished through the maintenance of 3 eddy covariance towers. Automated and survey soil respiration measurements were collected continuously through the quarter and additional soil samples were manually collected to obtain the organic matter content and fine root biomass across microsites (redshank, chamise, and bare soil). SDSU also collected multiple, spatially comparable drone-based orthomosaics to compare species-level carbon flux measurements with various spectral indices. Each image consisted of Landsat-type bands at 1-6cm^2/pixel.

For Tasks 2.1-2.3, Bin Chen at UC Davis modeled and analyzed long-term human- and lightning-caused ignition probability across the whole state and sub-ecoregions of California. Bin developed machine learning algorithms to integrate historical ignition data since 1992, including anthropogenic and biophysical variables. The models showed that spatially, human-caused ignitions were distributed in areas closer to populated regions, while lightning-caused ignitions were distributed more remotely in the Sierra Nevada and North Interior. We have used the random forest models driven by both biophysical and anthropogenic variables, and US Forest Service Ignition dataset to generate an 8-km monthly ignition probability and frequency product in California for 1992 to 2015. The derived product differentiated specific causes in terms of human- and lightning-induced ignitions, and kept a consistent spatial distribution and temporal trend with the observations. This product will be used as the input for wildfire process modelling, and also has implications for understanding the short-term and long-term controls on wildland ignition distribution and collective ignition management.

For task 2, Yuhan Huang analyzed effects of tree mortality on fire progression. Fire progression was estimated as daily burned area, rate of fire spread along the prevailing direction, and the direction of the fire spread for fires from 2012-2020. He also analyzed the fire spread at the fireline level and derived tree mortality metrics from the Aerial Detection Survey, topographic information from SRTM dataset, weather information from GRIDMET and DAYMET datasets, and fuel characteristics from Landsat

imageries. Yuhan also further built an extreme gradient boosting model to integrate environmental factors and analyze their controls on fire progression.

UC Irvine Project Specialist Aurora Gutierrez worked to update her and UC Irvine PI Jim Randerson's analysis of temperature vs. fire perimeter to include two more years of data. They are in the works of building a future VPD dataset, to try to observe the relationships between future VPD and these fire parameters. Their paper revisions should be completed in Q1 2021.

As part of Task 2.3, UC Irvine graduate student Ved Bhoot worked with Kyle Hemes and Mike Goulden on ecosystem recovery responses to Californian fires. This team developed a method to fit exponential curves, make projections for time to recovery, and estimate integrated deficit of carbon and water to recovery. All work so far has been done using the R programming language. The overall goal of this method is to allow for input of data (initial deficit) into a predictive model to make predictions of "half-life" or a metric of similar sort for recovery of the system. So far, the success we've had has been on testing the exponential fit on the change in GPP from CECS-created datasets, and collecting the range of values for half-life and integrated deficit. What we found to be a challenge is with outlier cases where disturbance response follows the opposite of a deficit, where a system ends up with a flipped curve (and thus a negative half-life), as well as cases where there are more than two disturbances within a single time series. Along with a predictive model, the next steps would also be to look at these outlier cases to filter the data further and see if there is a viable method to take them into account.

As part of Task 3.1, Jaquelyn Lugg and Max Eriksson completed survey data collection for the needs assessment, receiving responses from 216 natural resource professionals and 1002 members of the general public in California. They nearly completed analysis of the survey data, which will be shared in a report to stakeholders, as well as publicly posted on the CECS website, in Q1 2021. As mentioned in section 3, the CECS outreach team engaged with 32 representatives at over 25 agencies, nonprofits, local collaboratives, and private companies for participation in interactive virtual workshops. Workshops were held in November and December and consisted of creating two cognitive maps: one of weighted connections between eco-system services, and another of weighted impacts of management actions on eco-system services. Combining these maps allows us to measure how participants perceive the interactions between management actions and eco-system services and capture indirect impacts on ecosystem services. For example, if a respondent connects clear cuts with timber production, we can calculate what impacts that change in timber production would have on air quality and soil retention given the structure of the respondents' map. Section 3 also highlights our continued meetings and listening sessions with stakeholders at agencies, NGOs, and parallel research efforts.

For task 3.2, programmer Mike Walkinshsaw, with input from Toby O'Geen and others, focused on developing a demo version of our decision support tool. This preliminary version has the capability to visualize any data layer produced by CECS in the form of interactive, online maps. Mike coded in functionality that enables users to answer focused questions within the tool. These answers guide the user experience and allow the tool to deliver information in a focused way. For example, users can choose to visualize a variety of conditions such as management history, surface fuels, carbon stocks, water fluxes and supply, effect of drought on tree stress, effect of drought on water supply, fire probability and integrated vulnerability for any year from 1986 to 2017.The tool also offers the ability to compare any two years. In addition, the tool allows users to evaluate the effect of management on these attributes. The user can evaluate the immediate effect of management, cumulative effect until full recovery, or the amount of time until the forest recovers from management. Currently a user can choose among two goals, wood harvest and restoration. Outcomes of the disturbance are based on how much canopy is removed. Once these conditions are answered by the user, map outputs are

retrieved by the tool. There is a tabbed interface in the sidebar that will allow for additional features to be added in the coming months. Currently the tool has several layers available for viewing, and more will be added soon. The app is available at https://soilmap2-1.lawr.ucdavis.edu/cecs/demos/tool/.

For Task 3.3, Jaquelyn Lugg launched a quarterly newsletter to stakeholders, created the CECS Project Twitter account (CA_CECS), and contributed to project film clips with The Chronicles groups. Clips on forest restoration to prevent destructive wildfire will be ready in February 2021. She, along with Raiven Greenberg, also completed an update of the CECS website, which now includes a new project fact sheet, publications list, new descriptions of research progress, and news blog posts about CECS research findings.

As part of Task 4.1, Catherine Keske took a leadership and authorship role with Kim Quesnel and Blue Forest to draft "Forest restoration in the Western U.S.: a synthesis of benefits to enable financing and create resilient ecosystems", which is tentatively planned for submission to Global Change Biology in Q1 2021. UC Merced Professor Roger Bales, UC Irvine Assistant Professor Benis Egoh, UC Merced postdoc Min Gon Chung, UC Irvine postdoc Charity Nyelele, and Kyle Hemes also contributed to the paper, along with UC Merced graduate student Nick Goncalves, who joined the project in Q4.

For Tasks 4.1-4.2 Min Gon Chung developed the CECS framework that provides a broad perspective and backbone for mapping and valuing key ecosystem services with forest restoration activities in California. This framework includes key actors, such as beneficiaries and implementers. Min specifically focused on carbon storage, water resources, and carbon-water balances. He generated conceptual models to show how forest restoration activities affect the values of carbon storage and water used STELLA software to develop a tentative valuation tool for carbon and water, based on these models. This valuation tool can be adopted to estimate the values of multiple ecosystem services in any forest areas that candidate for restoration in California.

Charity Nyelele and Benis Egoh worked in Q4 to build on the InVEST recreational model for the valuation of recreational services and assessing how restoration impacts these values. They downloaded Flickr geotagged images for both the TCSI study area and California which will be used together with the travel cost method to provide monetary values for recreational ecosystem services. They also downloaded air quality data from both long- and short-term air quality monitors in California, including data from EPA's Fused Air Quality Surfaces Using Downscaling Tool and the Community Multiscale Air Quality (CMAQ) model for use in our air quality and human health analysis in BenMAP.

Additionally, Catherine provided concrete suggestions on sense of place as an ecosystem service, for data collection and possible analysis. Catherine also provided training and direction for implementing real options modeling, which will inform task 4.3.

5. Summarize by task any deliverable or outcome completed during the current reporting period:

For Task 1.2, workflow to produce consistent input and output layers are being actively developed using Google Earth Engine. The basic infrastructure for this workflow is complete and will also be implemented in the CASA-based model.

For Task 1.2, SDSU completed year-length datasets for net ecosystem exchange in chaparral and concurrent, independent measurements of the major components (primary productivity and soil respiration).

For Task 2, Bin Chen at UC Davis further refined the static ignition probability maps at 1-km in the whole state and across sub-ecoregions in California. These maps are also distinguished by human- and

lightning-driven causes. He also generated the monthly ignition probability and frequency product in California at 8-km grids from 1992 to 2015.

Additionally, Yuhan Huang at UC Davis developed a modeling framework for disentangling effects of environmental conditions (especially tree-mortality related conditions) on fire progression. He also quantified several metrics at fireline level representing different aspects of fire spread for large fires in Sierra Nevada.

For Task 3.1, the needs assessment survey and workshops were completed. Findings from the preliminary analyses can be found in section 5 of this report. We have also continued developing high-quality communications and have continued to actively engage stakeholders.

For Task 4.1, we carried out a literature review as a first step towards understanding what research has been done, what is available, and the gaps we need to fill in our research. We also came up with working conceptual models that illustrate our modeling process and collected data layers for our analysis.

6. If applicable, what short-term value, interim findings or success stories can you produce as a result of your work?

Interim findings:

Through Kyle Hemes's work, we observe that the mean CA forest fire initially led to a GPP deficit of ~200 gC m^{-2} yr^{-1}, and recovered carbon uptake capacity after ~2 decades. The shape of the recovery curve, measured over thousands of fires across multiple decades, is broadly consistent with ecological succession theory.

Through Jon Wang's work across three forested ecoregions, we find that the probability of future fires is greatly reduced following a disturbance, and the fires that do occur are substantially less severe for a period of about two decades. We will continue to examine this through additional analyses.

Based on Bin Chen's observation record of ignitions, we found that the ignitions in California advanced significantly earlier, by 0.8 day/year, since 1990's. This trend was dominated by human-caused ignitions. Our findings will help reconstructing historical ignitions across the state, improve fire risk assessment, and provide guidance for fire prevention and land management to limit future fire hazard.

Additionally, Yuhan Huang's results indicate that daily burned area is strongly influenced by previous fire history, vegetation type, topography, and pre-fire mortality. Daily burned area decreased with the increase of the mortality percentage. For each day, along the prevailing direction, the rate of fire spread was highly influenced by the elevation, vegetation type, fuel continuity, and dryness. Mortality information have relatively less impacts on fire progression. However, areas with abnormally wet conditions, would have fires spread faster at the daily scale. Higher variability in fuel patterns first promote and then suppress the spread of fires. When examined at a finer resolution, for the spread of firelines, it was highly influenced by the elevation, vegetation type, fuel continuity, wind speed, and the percentage of mortality areas, Tree mortality have effects on fireline when there is low or moderate mortality. For both dead tree density and mortality percentage, they first promote but then suppress firelines.

We also have started to analyze responses to the needs assessment survey, and results are promising. Preliminary analysis of the survey data show that stakeholders have a need for spatially mapped data related to forestry and fire data. In addition to this, respondents also perceived lack of funding and

social capital as major barriers to their work and mentioned a need for collaboration and standardization of data collection efforts across the state. Our results also indicate that natural resource management believe the risk of negative natural events, such as wildfires and droughts, are likely to increase in the future.

In summary, our ongoing work has identified a set of stakeholder needs which largely corresponds with the overall aims of this project, which suggests that the overall scope of our work is likely to be highly relevant for stakeholders, and which can be further refined by additional survey and workshop responses. As the project progresses we will reconnect with survey respondents to ensure the relevance of our final products, such as the interactive web tool.

Success stories:

AGU posters/presentations:

Kyle Hemes presented a talk at the AGU 2020 Fall Meeting entitled: "The magnitude and pace of ecosystem service recovery in California's contemporarily altered wildfire regime". Kyle, along with Jon Wang, chaired a Global Environmental Change session entitled: "Immense Pressures and High Expectations: Managing Forest Ecosystems for Multiple Benefits Under Human Activities, Climate Change, and Disturbance".

Carl Norlen and Shane Coffield also participated in the UpGoer 5 Challenge, where they were tasked with explaining their research in the "ten hundred" most common words in English. This is a science communications exercise that is meant to help researchers explain their work to audiences who may have less of a scientific background, and showcased their work on the CECS project.

Our team also presented 16 different posters throughout AGU, based on their work on the CECS project. Presenters included: Aurora Gutierrez, Bin Chen, Catherine Keske, Carl Norlen, Clarke Knight, Jon Wang, Kyle Hemes, Mahnoor Khan, Roger Bales, Shane Coffield, Stijn Hantson, and Yuhan Huang, as well as posters from 3 of our 2020 summer interns- Cassandra Vo, Melissa Thayer, and Sarah Downs. If you would like access to any AGU posters, we are happy to provide links (links only work if one has an AGU account), or PDFs of the poster content.

Q4 2020 published and pending publications:

Bin Chen's paper "Climate, fuel, and land use shaped the spatial pattern of wildfire in California's Sierra Nevada" has been in press for Journal of Geophysical Research: Biogeosciences, and was also featured as AGU research spotlight.

Shane Coffield, Cassandra Vo, and Jim Randerson submitted their paper "Climate-driven limits to future carbon storage in California's wildland ecosystems" to *AGU Advances* and are continuing to analyze carbon trends in the forest offset projects.

Carl Norlen is close to submitting a manuscript on the impact of multiple droughts on forest health and drought resistance that uses many of the geospatial data sets we are preparing for the CECS project (ET, die-off, precipitation). The findings should provide useful information for managers on how drought disturbance will impact future resistance to drought. He plans to submit the manuscript by the end of January, 2021.

Kyle Hemes is finishing an analysis of the carbon uptake recovery after fire disturbance in California. The initial manuscript has been drafted and is under internal comment/review. It should be submitted in Q1 2021.

The ecosystem services and valuation group, along with Blue Forest wrote the framework paper entitled "Forest restoration in the Western U.S.: a synthesis of benefits to enable financing and create resilient ecosystems", which is tentatively planned for submission to Global Change Biology in Q1 or the beginning of Q2 this year.

7. Describe any challenges and/or opportunities encountered when accomplishing this portion of the Scope of Work:

One of the unique challenges in developing the decision support tool is that the CECS-created data layers and other layers we are ingesting into the tool are very large, and delivering these large files in an interactive web mapping application can be problematic. Mike Walkinshaw researched and tested a few different approaches for how to solve this problem, met with folks from Pyregence, Salo, and EMapR to gain additional insights and was able to come up with a solution that is working well so far. The size of datasets will continue to grow, and the tool will need proper hosting on reliable servers, which we are ensuring takes place in Q1 2021.

8. Is the research grant on budget and on schedule (Please refer to the Work Plan/Schedule for Implementation)? Please indicate here if a go/no-go milestone was reached this quarter, if it is behind schedule, and/or will not be met, and provide explanation. If other items are off budget and/or behind schedule, what issues need to be addressed and what steps are being taken to ensure that the grant is completed on time and on budget?

As we received a one-year no-cost extension, the expected date of project completion is now well within schedule. The budget for Year 3 and Year 4 will need to be revisited in Q1 2021, and a budget amendment request will be submitted to SGC at that time.

ADMINISTRATIVE/FISCAL OVERVIEW

9. Provide a brief narrative explaining the grant's financial expenditures and budgeted amounts for this period that includes cash and/or in-kind items.

UC Irvine spent $71,456.26 in Q4, mainly on salaries and benefits for the Project Coordinator, Project Specialist, Postdoctoral Researchers, Project Scientist, and graduate student assistance, in addition to administrative overhead.

UC Davis spent $73,271.18 in Q4, primarily on a Postdoctoral Researcher, Programmer, and graduate student salary, benefits, and overhead.

UC Berkeley spent $3,779.74 in Q4, primarily on graduate student salary and benefits.

San Diego State University spent $15,219.37 in Q4 on salary and benefits for a PI and graduate research technician.

Stanford spent $31,308.67 in Q4 on PI effort and Postdoctoral Researcher salary, administration, and overhead.

UC Merced completed substantial work during Q4, but an invoice had not yet been received from them at the time of submission of this report. Thus, we can expect a substantially larger charge from them in Q2 2021.

Total project spending amounts to $195,035.26 for Q4 2020. $1,055,092.68 has been spent to date.

10. Do you anticipate major modifications to the grant's budget or work plan in the next quarter?

We anticipate modifications to the budget and a slight change in workplan timeline to account for the one year no-cost extension awarded to our project in Q3 2020. These will be submitted to relevant SGC staff likely in Q1 2021.

ADDITIONAL COMMENTS

We appreciate the continued support of the SGC and all of our project partners during this trying time. Our project is moving forward as best as we can given the circumstances, and we have seen steady engagement in Q4, as people find their work on this project continually meaningful and engaging.