CALIFORNIA STRATEGIC GROWTH COUNCIL

Climate Change Research Program

QUARTERLY PROGRESS REPORT

2021

QTR 2

Progress Report # 7 **For the reporting period:** April 1, 2021 **to** June 30, 2021

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

Research Grant Title Innovation Center for Advancing Ecosystem Climate Solutions

Signature Line (authorized representative): _____

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%	75%	$5,000.00	$267,786.23
1.2	Test, improve, and update data layers	10%	70%	$29,000.00	$250,623.72
2.1	Prepare data analysis	5%	70%	$15,000.00	$184,546.77
2.2	Analyze historical and current data	10%	50%	$27,000.00	$136,035.26
2.3	Extend data analysis via data science and machine learning	10%	35%	$8,059.07	$32,059.07
3.1	Actively engage stakeholders	10%	65%	$38,000.00	$267,244.11
3.2	Produce decision-making tools	15%	50%	$42,000.00	$123,000.00
3.3	Communication	10%	65%	$6,000.00	$94,000.00
4.1	Develop valuation framework	10%	70%	$12,000.00	$90,000.00
4.2	Develop and implement valuation tools	10%	25%	$18,000.00	$38,000.00
4.3	Develop financing strategies	10%	25%	$8,000.00	$14,000.00

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 Q1 2021. Subgroups working on Tasks 1, 2, 3, and 4 have met frequently to discuss strategy and make steps toward deliverables, and cross-task collaboration to bring all project components together into a working web tool are well underway.

For Task 1, we further refined forest management and disturbance datasets, and continued to refine the CECS Ecosystem Integration Model parameters, generating complete first versions of many data layers.

For Task 2, we continued to build out the framework to run the updated Ecosystem Integration Model on UC Irvine's High-Performance Computing Cluster (HPC), and several researchers utilized this data to begin preliminary scientific analyses. We also began to incorporate on-ground validation in chaparral ecosystems, and continued to push on creating machine learning algorithms to predict ecosystem recovery post-disturbance.

For Task 3, one of our largest successes of Q2 was rapid iteration on our beta version of our decision support tool, the Ecosystem Solutions Toolbox, on which we made substantial progress. This preliminary version has the capability to visualize more data layers produced by CECS. The CECS Executive Committee begun to hold in-depth discussions about this tool, including demonstrating functionality and gathering feedback on desired improvements from groups including the USDA NRCS California Office, Blue Forest Conservation, and the North Coast Resource Partnership.

Additionally, our Fire Progression Tool, which can be viewed at https://cecs.ess.uci.edu/fire-progression/ was released for public view and use in late May. This is the first CECS web-based geospatial tool to be released, and is a smaller example of the kind of work that can be expected of our large Ecosystem Solutions Toolbox.

As part of Task 4, a perspective paper was nearly completed. Additionally, work continued 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 on CECS research are in the works, with a few submitted and 1 published during this reporting period.

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:

   One of CECS' goals is to develop and share geospatial data layers that can be used by land managers, decisions makers, the general public and scientists to better understand and manage the effects of climate change on California's ecosystems. CECS is combining data analysis and machine learning with mechanistic models to explore the current conditions, vulnerabilities, and potential benefits of alternative management options across the state. CECS has built a new ecosystem analysis model - the CECS Ecosystem Integration Model - to analyze the complete Landsat satellite record since 1984, and to produce state-wide, 30m resolution maps of ecosystem carbon budgets, vulnerability to drought stress, runoff amount, fuel load, and the potential benefits of management for fuel reduction and forest restoration. Most of these layers have been built into web-based visualization tools for easy access,

which we call the CECS Ecosystem Solutions Toolbox, and will be freely shared once finalized. This Ecosystem Integration Model and associated Ecosystem Solutions Toolbox are helping CECS integrate across the various areas of expertise on our science team, and will ultimately provide one of our most impactful deliverables to the State.

Additionally, in Q2, by utilizing and integrating forest management data and CECS Ecosystem Integration Model outputs, UC Irvine postdoc, Jian Lin, quantified the impacts of forest management activities on carbon outcomes, and examined if management activities play roles as intended. Jian will also examine how the effectiveness of forest management is moderated by past disturbance events (e.g., wildfire) and climatic conditions (e.g., increased warming trends and intensified drought events).

At UC Davis, graduate student Yuhan Huang's work has provided insight on the impact of drought- or insect-induced tree mortality on fire behavior. The models developed will inform land managers in their efforts to prioritize resources to reduce risk of catastrophic wildfires.

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 have created partial data layers for 13 out of 16 of the groups of data layers CECS plans to create (including management history, and current and recent carbon stocks), of which 11 layers are now included in the beta version of the web tool, the Ecosystem Solutions Toolbox.

California has devoted tremendous efforts to conserve, restore and manage its forest lands. The extent to which these efforts have impacted carbon outcomes and carbon neutrality remains unclear. By evaluating the effectiveness of diverse forest management activities, this study could provide crucial information for tackling the dual tasks of increasing forest resiliency and enhancing carbon sinks.

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

As rapid progress has been made on the CECS Ecosystem Solutions Toolbox, we have begun to hold in-depth discussions about the tool, including demonstrating functionality and gathering feedback on desired improvements. In Q2 the CECS Executive Committee engaged the USDA NRCS California Office, Blue Forest Conservation, and the North Coast Resource Partnership in such demonstrations and discussions. We will continue to interface with additional groups to solicit feedback on the tool and ensure its usefulness throughout the duration of the project.

Additionally, the Executive Committee met with personnel from the CNRA-funded California FORESITE project to share CECS progress and discuss potential synergies. We made plans to follow up again in several months to learn about FORESITE's progress and discuss data sharing opportunities.

CECS Co-Director, Roger Bales, had conversations with CA DWR to obtain a better understanding of their agency priorities and opportunities, as well as matches with CECS products and capabilities. He also continued our discussion with the French Meadows project around ecosystem service and multi-benefit framework, as a means of assessing relative values of benefits. Roger also met with Yuba Water to discuss their participation in the film "California's Watershed: Healing", for which they have agreed to be a partner.

We have also continued our close collaboration with Blue Forest Conservation, as work on the development of ecosystem service and multi-benefit framework has progressed, and a paper was nearly finalized, and should be ready for submission in Q3.

Before submitting her manuscript on historical forest management to the *Journal of Environmental Management*, UC Berkeley Postdoc Clarke Knight, along with coauthors Jon Wang, John Battles, Robert York, Ryan Tompkins, and Mike Goulden, spent additional time reaching out to CAL FIRE and USFS employees for feedback on their findings. In this process, they were alerted to an additional CAL FIRE dataset, which they have since incorporated into their manuscript. Clarke has also been in touch with other research groups from CAL FIRE and the University of Washington who have requested early access to the integrated data and our refined Continuous Change Detection (CCDC) data.

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:

TASK 1

During the last quarter, UC Irvine Postdoc, Jon Wang, made significant progress on a draft of a manuscript describing the CECS-created disturbance and vegetation cover datasets, focusing on how disturbances have reshaped the distribution of forests in California. This manuscript's first draft is complete and is circulating among co-authors for comments. As part of this manuscript, Jon extended the datasets to include the historic 2020 year of fires and vegetation change, and analyzed how climate interacts with these disturbance and vegetation dynamics. This manuscript forms the basis of an abstract he will present at the AGU Fall Meeting this year.

Further refining our forest management layers, Jian Lin unified names of management activities and deleted redundant management polygons within and across four management layers. In addition, Jian overlaid four management layers to identify locations that experienced more than one-time treatment and then examined carbon recovery curves after management events.

Also contributing to Task 1, Bin Chen, a former postdoc at UC Davis, further improved the ignition risk mapping and modeling for the whole state of California, and drafted a complete manuscript on the patterns and drivers of human and lightning caused ignition. Meanwhile, Yuhan Huang continued to supervise interns to create a high-resolution map of dead tree labels and phases from NAIP imagery. He has tested a deep learning model to map dead trees since 2015 and analyzed the impact of high-resolution tree mortality on fire behavior at the daily and fire line scale.

Yuhan has developed a deep learning computer vision model to improve the accuracy and completeness of current building footprint dataset. Initial analysis with machine learning models has been done to analyze the linkages of fire behavior and probability of building damage in the wildland-urban interface areas.

At SDSU, three undergraduate research assistants created an annotated bibliography of various papers on carbon sequestration in terrestrial, agricultural, and aquatic ecosystems to support this work and forthcoming papers. Meanwhile, graduate student Kyle Lunneberg and others from PI Walt Oechel's lab continued their efforts at Sky Oaks Ecological Reserve to analyze water stress of multiple plant species and measure leaf level photosynthesis. Kyle collected ultra-high-resolution multispectral drone imagery on a monthly basis to upscale microsite scale carbon fluxes. The team also transferred and processed eddy covariance data for 2020 and 2021 at Ameriflux sites SO-1 and SO-2. Automated chambers continuously measured soil respiration concurrently with soil temperature and soil moisture until the field project ended in May 21, 2021. Monthly survey measurements of soil respiration were done in April and May to increase the number of replicates and understand the spatial variability of the site. Soil organic content, soil water content, and fine root biomass were measured using the soil samples collected during late March 2021. Long-term respiration data is currently being cleaned and

analyzed as part of a master's thesis. Collected soil and litter samples for an undergraduate research project focusing on upscaling soil organic matter and litter biomass. Statistically analyzing EC carbon dioxide fluxes from the years 2015 to 2020 to determine the effects of drought conditions on CO2 flux in chaparral ecosystems. Identified and examined the temporal trends in carbon dioxide flux from 2015 to 2020.

On the Ecosystem Integration model side of things, our main successes have been a completion of first draft data layers of the following, many of which are now included in the beta version of the Ecosystem Solution Toolbox web tool:

- Disturbance and management history: Type (fire, die-off, management) and severity (% tree and shrub canopy loss)
- Water pools and fluxes: Evapotranspiration, runoff, plant moisture deficit (mm yr. -1)
- Water pools and fluxes after disturbance or management: Immediate effects
- Wild fire fuel loads: Dead and live fuel (1, 10, 100, 1000 hr., live herb, shrub, canopy, g m -2)
- Fuel load after disturbance or management: Immediate effects
- Carbon pools and fluxes: Stocks (leaf, wood, roots, detritus, g m 2) and fluxes (production, mortality, decomposition, g m -2 yr. -1)
- Carbon pools and fluxes after disturbance or management: immediate effects
- Vulnerability and Hazard (water supply, vegetation die-off, wildfire, carbon)
- Water supply vulnerability: Sensitivity of water supply to drought or disturbance (change in water supply with drought or disturbance, mm yr. -1)
- Water supply vulnerability after management: Avoided water shortfall during drought, immediate
- Vegetation vulnerability: Probability of vegetation die-off with drought (long term % yr. -1)
- Vegetation vulnerability after management: Avoided die-off, immediate
- Wildfire hazard: Rate of spread, intensity/flame length, probability (long term % yr. -1)
- Wildfire hazard after management: Avoided fire, immediate, Ros, intensity

TASK 2

UC Berkeley Postdoc, Carmen Tubbesing, improved and expanded upon analyses of GPP, biomass, and land cover type across severely burned polygons in California. First, she expanded preliminary analyses to all fires in California since the beginning of the Landsat record (1984). She developed code in R to process and save high-severity polygon data for each year to Google Earth Engine (GEE) Assets and then query GEE for GPP data for each of those polygons and save the results to Google Drive., and plotted the results in R using weighted means across fire polygons. She then masked out privately owned forest land to focus the study on less intensively managed forests, and created scripts for testing and cleaning GEE output in R. For example, she removed small polygons and areas that had been reburned in the study window, then added eMapR biomass estimates to the analysis and plotted biomass results alongside GPP results. She also added land cover data from Jon Wang's custom rasters of land cover types (shrub, forest, herbaceous, and bare ground). This required pre-processing the land cover data from GEE to link it to the high-severity fire polygons. She separately plotted results for forest and shrubland to compare patterns. The final product was a comparison of how land cover type, biomass, and GPP change over time since fire in shrublands and forests across California.

UC Irvine graduate student, Carl Norlen, worked with previous CECS team member Kyle Hemes to finalize a manuscript about GPP recovery following fire across California to submit in July 2021. He worked on an analysis on the effects of wildfire history on forest drought sensitivity. This work will

contribute to a manuscript target for completion in summer 2022. The results will contribute to better prioritizing management to mitigate the effects of future droughts on forests.

For Task 2.3, UC Irvine graduate student, Ved Bhoot, continued to work on code for the curve fitting for machine learning for ecosystem recovery post-disturbance, mostly focusing on efficiency and determining a standardized number of data points on which to fit the curve.

TASK 3

We hired three interns for our 8-week Summer Science Communication Internship. Interns began their work in late July, and started to hone in on the user guide for the CECS Ecosystem Solutions Toolbox, and will continue to engage with stakeholders to communicate the functionality and usefulness of the tool in Q3.

As stated in response to Point 3, above, further outreach calls were conducted in Q2 as well with an emphasis on live beta tool demonstrations, and tool sharing. We also kept stakeholders engaged and informed through a newsletter sent in late May, as well as through sharing of news pieces on our website.

Meanwhile, UC Merced Project Scientist, Max Eriksson, continued to analyze data from our stakeholder needs assessment survey and workshops. He began working on three different papers based on these analyses and results: one related to ecosystem evaluation, another centered on perceived efficiency of different management actions, and the final focused on trust and risk. The ecosystem evaluation paper is nearly ready for submission.

Our main accomplishment the quarter, however, was progress on developing and refining a beta version of the decision support tool, the Ecosystem Solutions Toolbox. This preliminary version has the capability to visualize more data layers produced by CECS. We spent a substantial amount of time coding for the tool to optimize presentation of layers and to facilitate the terabytes of data transferred from the Ecosystem Solutions Model to the tool. The tool now has state-wide coverage for multiple data themes with the option of interacting with multiple data years for each theme; between 1985 to 2019. There are many new data themes in the tool organized under three general topics: 1. Current and recent conditions; 2. Vulnerabilities; and, 3. Expected effects of management.

Within the theme *of Current and recent conditions*, seven sub categories exist: 1. Overview of Ecosystem Issues; 2. Vegetation type; 3. Management / Disturbance History; 4. Carbon Fluxes; 5. Water fluxes and Supply; 6. Carbon Stocks; and, 7. Fuels. Each subcategory contains multiple years of geospatial data.

There are three active subcategories within the theme of *Vulnerabilities*. These include: 1. Overview of current vulnerabilities, 2. Effect of drought on tree stress; and 3. Effect of drought on water supply. In both of the drought vulnerability subcategories, the user can select different drought severity scenarios to visualize a response (i.e. tree stress or water supply).

The theme of *Expected effects of management* has four subcategories of data exploration: 1. Overview of effect of management; 2. Effect of management on tree stress; 3. Effect of management on water supply; and, 4. Effect of management on surface fuels. To observe scenarios of effect of management, the user selects options to describe a hypothetical % reduction in tree and/or shrub canopy. The display shows a comparison of current conditions with the simulated canopy removal for each subcategory (e.g. change in surface fuels after management).

A considerable amount of effort was expended processing these data themes and associated years for each theme. Each individual file needs to be processed to become a viewable image. Legends were created and the ideal color ramp applied to view data trends appropriately, and the option to select a colorblind-friendly color ramp was also added. We also added the functionality to allow users to customize min/max values of the currently displayed layer. The tool is evolving rapidly, and at this point, it is mainly a visualization tool serving the critical need of data evaluation among team members.

TASK 4

Group 4, comprised of Co-Director Roger Bales, UC Irvine PI Benis Egoh, UC Merced PI Catherine Keske, UC Merced Postdoc Min Gon Chung, and UC Irvine Postdoc Charity Nyelele, continued to meet biweekly, and have nearly completed their paper in conjunction with Blue Forest Conservation. The paper should be put into review sometime in Q3 2021.

Additionally, Charity worked on finalizing the analysis on mapping recreational ecosystem services in the Tahoe Central Sierra Initiative (TCSI) using biophysical variables that have been shown to influence recreational activities in the literature, machine learning techniques and Flickr geotagged images as a proxy for recreational visits. She also started writing a draft manuscript based on this work.

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

Our Fire Progression Tool, which can be viewed at https://cecs.ess.uci.edu/fire-progression/ was released for public view and use in late May. This is the first CECS web-based geospatial tool to be released, and is a smaller example of the kind of work that can be expected of our larger Ecosystem Solutions Toolbox. Before its release, our app developer, Mike Walkinshaw, worked to create an information window with "About" and "How to Use" tabs, to provide all necessary information to the user. Detailed “About” pages will be included for each layer of the larger Ecosystem Solutions Toolbox as well. Mike also included 11 fires from the 2020 fire season to the list of viewable fires, so that managers can see how last year’s fire season affected the landscape. He also added CECS fuels layers as background layer option.

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

Success Stories:

Release of CECS Fire Progression Tool

Our Fire Progression Tool, which can be viewed at https://cecs.ess.uci.edu/fire-progression/ was released for public view and use in late May. Additional information about this tool can be found in section 5, above.

Decision support tool progress

As noted in Section 4, we continued to work on developing and refining a beta version of our decision support tool, the Ecosystem Solutions Toolbox, and made substantial progress. This is arguably the largest deliverable of the project, and we are happy to have a working version that we were able to start sharing with stakeholder groups to get feedback, refine the tool, and make it as useful for stakeholders as possible over the remaining 20 months of the project.

Ecosystem Integration Model

Progress was made on the CECS Ecosystem Integration Model layers to fill critical gaps, including statewide maps of disturbance, water balance, vegetation stress, fuels and ignition probability. CECS explores water, vegetation stress, fire, and carbon as a wholistic web of tightly-coupled ecological conditions. These relationships can now be explored by a select group of stakeholders who have started to beta-test the Ecosystem Solutions Toolbox, and data will be opened to additional groups in the coming months.

Research Findings and Papers:

UC Berkeley graduate student (and now USGS postdoc), Clarke Knight, prepared a journal manuscript that will be imminently submitted to the *Journal of Environmental Management*. Along with Jon Wang, John Battles, Robert York, Ryan Tompkins, and Mike Goulden, she analyzed archival silviculture treatments on public (USFS) and private (CALFIRE) lands through time. Before submission, the team spent additional time reaching out to CALFIRE and USFS employees for feedback on findings. Overall, they found that newly treated "footprints" of land have been decreasing since 2008, despite the long-standing goal of expanded pace and scale in forest treatments. This finding has important management implications for California because the State is actively working to achieve 1,000,000 acres treated/annually in an effort to modify fire behavior on the landscape. Our results suggest the State but may be falling short of its goal. Additionally, in this manuscript, they compared the timing and intensity of archival treatments to CCDC algorithm harvests and found close matching on private lands but large overestimation in federal archival data.

As part of another concurrent CECS research effort focused on carbon storage, a manuscript was accepted for publication at AGU Advances, titled "Climate-driven limits to future carbon storage in California's wildland ecosystems." Four CECS scientists - Shane Coffield, Kyle Hemes, Jim Randerson, and Mike Goulden - contributed to this study of climate vulnerabilities to forests and shrublands. They found that rising temperature and changing precipitation patterns are likely to drive a net loss of aboveground ecosystem carbon, especially in the northern coasts and low/mid-elevation mountain regions. Places where there are currently forest carbon offset projects are also particularly vulnerable to climate change, which has implications for the State's Cap-and-Trade program. The geospatial layers of future carbon change that come from this study fit in with the overarching goals of the CECS project and can help land managers plan for the future. They highlight areas where climate change may drive shifts in species composition, or where specific management interventions could have the largest impact on protecting existing carbon stocks. The manuscript was published on July 22, and can be found at https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2021AV000384.

A related CECS team is making progress on a research project focused more on the carbon offsets portion of that manuscript, analyzing disturbance histories and evaluating carbon trends in forest offset projects throughout the state. We expect to submit a manuscript on this work in the fall.

Presentations:

- A Research poster titled, "Effects of Drought, Fire, and Stand Age on Carbon Dioxide Flux in Semi-arid Chaparral Ecosystems" was presented at the Global Monitoring Annual Conference (GMAC) in May of 2021.
- Research on fog deposition was presented to San Diego Management and Monitoring
- A student working under this project competed and won the UC Davis 1st Annual CALESS Elevator Pitch competition
- Preliminary results for soil respiration were presented at the 49th Annual Virtual Global Monitoring Conference (eGMAC) by the NOAA's Global Monitoring Laboratory on May 24, 2021.

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

We encountered a challenge in reprocessing and cleaning forest management layers, such as deleting duplicate entries, cleaning errors where wildfire was mislabeled as management polygons, and unifying activity names across different data layers, which required a good amount of effort. It was also challenging to reorganize and customize forest management layers and associated attributes into a format that is suitable for statistical analysis.

Additionally, the challenge of recruiting a skilled postdoc to replace Bin Chen's position at UC Davis has slightly delayed some of the work at UC Davis, though it is still well within the project timeline overall.

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. A budget amendment request was submitted to SGC on June 23, 2021 and approved on July 15, 2021.

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 $136,513.90 in Q2, mainly on salaries and benefits for the Project Coordinator, Postdoctoral Researchers, Project Scientist, and graduate student assistance, in addition to administrative overhead.

UC Davis spent $23,014.13 in Q2, primarily on our Programmer, and graduate student salary, benefits, and overhead.

UC Berkeley spent $30,795.28 in Q2, primarily on graduate student and postdoc salary and benefits.

San Diego State University spent $14,217.32 in Q2 on salary and benefits for a PI and graduate student researcher.

Stanford spent $3,518.44 in Q2 on postdoc salary and benefits, and overhead.

UC Merced completed substantial work during Q2, 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 Q3 2021.

Total project spending amounts to $208,059.07 for Q2 2021. $1,499,295.12 has been spent to date.

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

None anticipated.

ADDITIONAL COMMENTS

We thank SGC for your continued support of this project, and look forward to sharing the CECS Ecosystem Solutions Toolbox with you soon.