Center for Ecosystem Climate Solutions- Year 1 Annual Report

The Center for Ecosystem Climate Solutions (CECS) is a collaborative research project funded by the Climate Change Research Program under the California Strategic Growth Council (SGC) and California Climate Investments. The CECS team is developing and communicating strategies to better manage California's natural lands for climate change. The CECS's main goal is to identify land management practices that simultaneously enhance carbon sequestration, reduce wildfire severity, protect watersheds, and increase ecological and community resilience. Our team of almost 50 researchers across 8 different institutions made excellent progress toward these goals in the past year. In this report we will outline the main deliverables completed and progress made to date, as well as how this work meaningfully engaged a variety of stakeholders with the SGC's Priority Research Areas and program goals in mind.

Research Progress

The CECS Project is comprised of four separate but interrelated goals:

1. Mapping ecosystem properties and services
2. Determining land management effects
3. Communicating and informing adaptive management
4. Valuing ecosystem services

Progress has emphasized the first three goals, and work on the fourth goal is just beginning. In this section we describe progress toward the objectives set for each of these four goals.

1. Mapping Ecosystem Properties and Disturbances in CA

The CECS is working to develop the remote sensing and geospatial tools needed to consistently quantify and integrate the effects of past and ongoing management on four critical characteristics of the land surface: 1) Biomass stocks and carbon dynamics over time, 2) Water balance and the delivery of runoff to rivers and groundwater, 3) Vegetation resilience and susceptibility to dieback during drought, and 4) Surface fuels and wildfire spread and severity across the landscape. The first step in the process of developing these tools was to inventory, collect and explore existing datasets. This step allowed us to identify gaps in the availability of key datasets and possible strategies to produce revised and new data layers. We are now creating layers to fill these gaps and are beginning to use these existing and new datasets for deeper analyses on fire behavior and post-disturbance ecosystem recovery.

Collecting and Homogenizing Data

Data layers were collected, cropped to California outline, and re-projected to 30m resolution when needed. Numerous PIs, graduate students, and project specialists contributed to identifying and vetting these layers. All input data layers have been added to our Shared Data Drive, which has been shared with researchers on other related projects as well. Categories of data we have collected to date include: carbon

biomass, water balance, vegetation health and drought resilience, fire spread, and management history sub-layers. The following are examples of datasets and variable types we are currently using:

- Historical polygons for management, die-off, and wildfire have come from ADS, FRAP, FACTS, and Cal Fire. For our remote sensing data, we have looked at dNDMI, CWC, CCDC, LandTrendr, using Landsat data from 1984 - 2019
- Topography from USGS
- Climate from PRISM
- Land Cover from eMapR and LANDFIRE
- Aboveground Live Biomass from eMapR and LEMMA
- Gross Primary Productivity based on new remote sensing analyses
- Evapotranspiration based on new remote sensing analyses

Improved Data Layers of Past Management and Disturbance

Our inventory and exploration of existing datasets identified a couple of critical gaps, including historical management, surface fuels and detrital carbon stocks. Work on homogenizing and extending historical management layers presented a time-intensive and critical challenge. To do this, UC Berkeley PhD Candidate Clarke Knight cleaned and merged four main datasets concerning California's management, including: FACTS's timber harvests and hazardous fuel reduction, as well as Cal Fire's timber harvest plans and non-industrial timber management plans. These datasets catalogued 286,000 management events spanning the twentieth century to the present day, which Clarke ranked qualitatively by intensity. With input from state and federal users of these databases, Clarke interpreted records, particularly the silviculture treatments, and documented their complexities and caveats. Along with UC Irvine postdoctoral researcher Jon Wang, UC Berkeley Professor John Battles, and others, she developed a preliminary methodology to integrate the refined written record with spatial information and aerial detection.

Many datasets, particularly management history layers such as "timber management" and "hazardous fuel reduction" provided by the USFS, were found to contain missing or incomplete information. In order to compile a more complete and accurate data layer representing management history in California, we determined that we would have to independently distinguish where and when each management type was completed. A refined data layer with this information could be of great use to State agencies and to other projects/programs. This is where the Continuous Change Detection Algorithm (CCDC) came in.

To identify where and when different management actions occurred, Jon Wang, a postdoctoral researcher at UC Irvine, has systematically mapped disturbances--harvests, fire, die-off--across the state with time series remote sensing (Landsat) and has characterized trends and interactions between different types of disturbances using the CCDC approach.

CCDC works by fitting harmonic models and identifying statistically significant "breaks" or changes in each pixel of the satellite imagery, which each represent a 30m x 30m piece of the landscape. These breaks represent a disturbance of some kind on the landscape, which can be classified using machine learning. Jon trained the machine learning classifier using harvest data from USFS FACTS and Cal Fire, fire history from Cal Fire (FRAP), die-off from USFS Aerial Detection Survey (ADS), in addition to unattributed browning and greening. Jon finalized refined management polygons, which combine satellite remote sensing and data from various agencies to represent the location and timing of forest management actions. These include data from an updated run of the revised CCDC algorithm. Jon worked with Clarke

towards a protocol for assessing the accuracy of these polygons using the Collect Earth Online platform to facilitate both expert assessment of high-resolution imagery and comparison with hand-drawn polygons.

Using the CCDC algorithm, Jon has also developed a dataset of point locations that have experienced a land change and that overlap with the vector-based datasets. This sample of approximately 125,000 points was used to train a machine learning classifier that uses Landsat data in combination with land cover and elevation data to predict the type of land disturbance that occurred there. The overall accuracy of this method is about 82%, which will only improve with refinement. The disturbance types mapped include high and low intensity harvests, high and low intensity fires, drought/insect-induced die-off, post-disturbance regrowth, and urbanization/ infrastructure development. This classifier will be used to map across California to see the occurrence of various disturbance types through space and time. Next steps include developing code to scale up the outputs of this machine learning classifier and to analyze trends and interactions between these disturbance types.

New data layers of surface fuels, detrital carbon stocks and carbon and water exchanges

In addition to our focus on refining historical management layers and classifying disturbance types, we identified key needs for more accurate information on surface fuels and detrital carbon stocks. Salo and others are already making a push to improve information on canopy and live fuels, and we identified the need for a parallel effort on surface fuels and dead, combustible material. Likewise, Lemma, eMapR, CARB and others are already making a push to improve information on the carbon in live biomass, and we identified the need for a parallel effort on detrital and dead carbon stocks. To accomplish this, we have built a new diagnostic model to derive monthly surface fuels, detrital carbon stocks and carbon and water exchanges across California since 1984. The model extends the Carnegie-Ames Stanford Approach (CASA), pioneered by CECS PI, James Randerson. The approach ingests monthly remote sensing imagery, precipitation, temperature and disturbance at 30 m resolution across the full state, which are then used to calculate monthly photosynthetic and water fluxes. These photosynthetic rates are then fed into a biogeochemical model that predicts the surface fuels and detrital carbon stocks over time. A draft version of the program has been completed and run for a 22,500 km^2 test region in southern California, and the program is now being transferred to a more powerful computer to allow state-wide runs.

Testing Revised Data Layers

Collect Earth Online is a free, open source tool for landscape monitoring (Saah et al. 2019). It allows multiple analysts to look at plots and satellite images and answer questions pertinent to land-use change or management events that take place over time. For this project, analysts are assessing data from remote sensing images and comparing to data from known historical datasets and the CCDC algorithm output for past management events. For example, an analyst will look at historical management polygons overlain on NAIP images between 2003 and 2018 to determine what year the management event occurred and check whether that matches the documentation. Analysts are also visually comparing the historical datasets, CCDC outputs, and the remote sensing images to determine how closely they match – this serves as an important check on the validity of the algorithm as well as the historical datasets. Determining the degree and magnitude of matching among CCDC, the historical management data, and the aerial images will inform the next iteration of the algorithm and our understanding of the historical dataset's accuracy.

Professor Walter Oechel's lab at San Diego State University is collecting landscape carbon flux data--a measure of carbon as it cycles through the atmosphere, vegetation, and soil--from three eddy covariance towers at Sky Oaks Ecological Reserve in Warner Springs, CA. Walt and his team also used unmanned aircraft systems (UAS), or drone, to survey chaparral/human interfaces; installed long-term sensors to measure soil respiration, temperature, and moisture; extracted over 100 soil samples to identify carbon content and root biomass; and began developing parameters for the Advanced Canopy–Atmosphere–Soil Algorithm (ACASA). These on-the-ground efforts will work toward validating carbon data layers and analyses collected and produced by other researchers on the CECS Project.

Some of our next steps in data validation include: continuing to refine disturbance classes and algorithms by adding severity classes, analyzing the size of spatial clusters of disturbances, and improving calibration and independent validation of disturbances in Collect Earth Online. Field data will continue to provide on-ground validation and help with refining these variables as well.

2. Determining Management Effects

Exploring Data Layers and their Implications

At UC Davis, postdoctoral researcher Bin Chen, Associate Professor Yufang Jin, and colleagues developed statistical models to predict probability of human-induced and lightning-caused wildfire ignitions for the whole state of California and further examined how humans, climate, and fuels affected fire ignitions. These models generated a monthly ignition probability product at an 8km resolution from 1992 to 2015, for human- and lightning-caused ignitions. The team also investigated the spatial patterns and controls of 1984-2017 wildfire risk in Sierra Nevada using multi-source geospatial datasets. Model diagnostics revealed that climate, especially vapor pressure deficit (VPD), temperature, and burning index dominated the spatial distribution of fire probability across the whole Sierra Nevada region.

To understand the association of burn severity with climate change and how local environmental variables further shape the burn severity variability, Yuhan Huang, a PhD student working with Yufang at UC Davis, built machine learning models to analyze the Landsat-derived burn severity during 1984-2017 in California's northern coastal mountains. He found an increasing trend of burn severity and areas burned since 1984. The drought of 2012-2016 nearly quadrupled the area burned severely, compared to the relatively cooler drought of 1987-1992, highlighting that climate warming exacerbated the severity of wildfires. Yuhan is currently investigating the impacts of pre-fire tree mortality on fire behavior in Sierra Nevada. A preliminary machine learning-based analysis showed that higher dead tree density within the mortality area enhanced fire spread.

In a first-of-its-kind analysis of geospatial patterns in fire rate of spread across California, UC Irvine Assistant Project Scientist Stijn Hantson generated a daily fire growth dataset based on VIIRS satellite active fire detections. He found that, on average, human-caused fires expand twice as fast as lightning-caused fires. Importantly, he also found that tree mortality is related to fire spread rate, with faster fires causing more tree mortality. This analysis shows that human-caused fires drive higher tree mortality and have a disproportionate impact on Californian ecosystems.

To better understand the impacts of new extremes in fire weather on wildfires in the Sierra Nevada, Assistant Specialist Aurora Gutierrez, Professor Jim Randerson, and colleagues quantified the sensitivity of wildfire occurrence and burned area to daily meteorological variables during 2001-2018. They found

that the likelihood of ignition of wildfire increases with daily average temperature during the summer, with a 1°C increase yielding a 19 - 22% increase in fire occurrence and a 20% increase in area burned. This analysis provides quantitative information about how increasing summer daily temperatures, including more frequent heat waves, influence the probability that wildfires will escape from human control. Combining this information with projections of future climate, we estimate that by the 2040s, the number of fires will increase by 30 ± 7% and burned area will increase by 34 ± 7%, relative to a 2011-2018 baseline. These positive trends highlight the threat posed to fire management by hotter and drier summer weather.

Post-disturbance ecosystem service recovery

To understand the climate impacts of disturbances, and the net benefit of management strategies that reduce the severity of wildfires, we need to better understand how ecosystem services recover after disturbance. Stanford postdoctoral researcher Kyle Hemes, and UC Irvine PhD candidate Carl Norlen have been working to analyze vegetation and ecosystem service regeneration for several decades post-fire to understand the long-term implications of fire on the landscape.

The approach utilizes Google Earth Engine's cloud-based Landsat archive (1984-present) and the entire FRAP database of fire occurrences since ~1900. Kyle and Carl computed vegetation indices across the entire state, aligning these data with FRAP fire perimeter areas. They then match each fire with undisturbed pixels from Jon Wang's CCDC disturbance analysis that are similar in elevation, latitude, and climate in order to create controls with which burned areas can be compared.

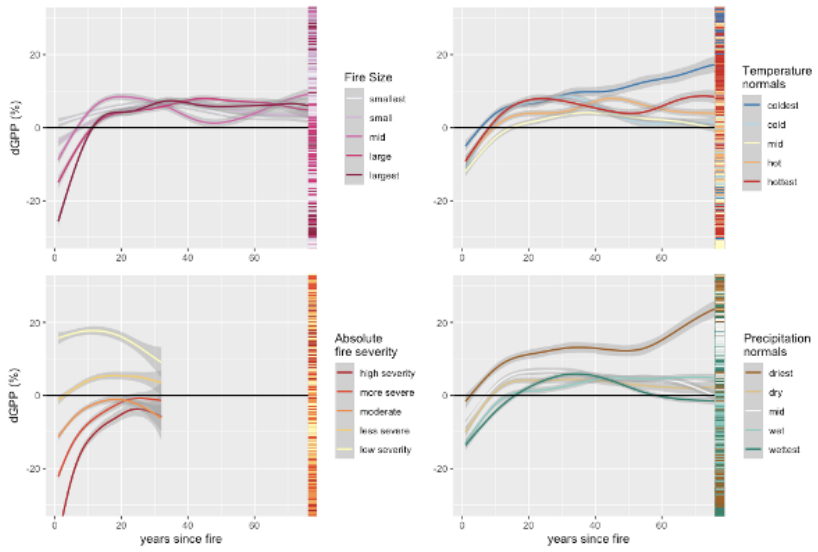

Figure 1: Gross Primary Productivity (GPP) recovery curves for ~4000 forest fires in California since 1900, split by fire size, severity, temperature and precipitation normals.

Across more than 15,000 fires that occurred over the last century, Kyle and Carl have found significant changes in important ecosystem services and recovery trends, with deficits in ecosystem services, like carbon uptake, of up to ~30% post-fire. The regeneration recovery curves they have generated can be split by multiple fire characteristics, like severity, size, temperature, and precipitation normals, to understand the underlying drivers of recovery.

Next steps include completing analyses of how fire, management, and die-off have impacted ecosystem services, integrating refined disturbance polygons/change maps from CCDC output, understanding the role of overlapping disturbances, and training a model to allow for prediction of ecosystem service recovery given a current or future disturbance.

3. Communicating & Informing Adaptive Management

The overall goal of the CECS engagement strategy is to co-create transdisciplinary knowledge with diverse stakeholders across the state. Our approach recognizes that integrating science and management is an iterative, multi-directional process, involving stakeholders throughout.

Engagement within the first year of the project centers around three linked efforts: 1.) the stakeholder needs assessment, 2.) collaborations with agencies, organizations, and parallel projects, and 3.) broader communications.

Needs Assessment Survey

The needs assessment component of the project launched in summer 2020, beginning with an online survey created by UC Merced Project Scientist, Max Eriksson, and distributed by Max, UC Merced PI Safeeq Khan, and UC Merced Assistant Specialist Jaquelyn Lugg. The goal of the initial needs assessment survey was to collect information from the broadest range of stakeholders possible in order to learn about how they perceive problems related to wildland management now, what the data and information gaps are, the nature of the barriers or challenges to wildland management, and values attributed to California wildlands. The survey was sent to approximately 100 different stakeholder groups, including state and federal agencies, non-profits, professional organizations, watershed collaboratives and partnerships, and more. Many of these groups assisted us with sharing the survey even more broadly to their colleagues and in relevant newsletters, email blasts, and more.

As of this report, we've received over 250 unique responses and expect to receive more before closing data collection for the survey in October 2020. We have also established a protocol to collect approximately 500 responses from a cross-section of the California general public using the Amazon Mechanical Turk platform. Responses to the survey will be analyzed in Fall 2020 and summarized in a report for stakeholders at the end of the year. They'll also be integrated with later components of the stakeholder needs assessment, including workshops and focused interviews.

Active Engagement

Outreach to State and Federal Agencies

The work of the CECS supports several important State initiatives, and we have been working closely with State and federal agencies to support their goals and to help fill in gaps in their data and provide additional analyses. We began full group outreach calls in early 2020, engaging Cal Fire, the Emission Inventory and the GGRF Groups within the California Air Resources Board (CARB), the California Natural Resources Agency (CNRA), and the US Forest Service (USFS) with our full CECS project team. On these group calls, these agencies provided CECS team members with more background on their work as well as information about the science bottlenecks that they are facing. We've had productive discussions and engaged in continual follow up with these agencies to bi-directionally share data and to continue dialogue about how the CECS's work products can be most useful.

Out of these calls with CNRA, and more specifically Loretta Moreno, CECS ended up being written in as an advisory group under CNRA's Request for Proposal entitled "AB 2551 Spatial Analysis and Priority Planning", released on July 24, 2020. CECS will work diligently to support the work of whomever is awarded this contract. Meanwhile, our conversations with CARB have been ongoing, as we provide data layers that will feed into analyses for their upcoming Scoping Plan.

Additionally, through outreach to stakeholders for the needs assessment, we've developed new connections with USDA Natural Resources Conservation Service, Governor's Forest Management Task Force, and the CalMAIN platform working group, which includes representatives from several state agencies. These groups are both participating in the survey and noted they are open to more interactions later in the project to coordinate progress on parallel efforts and provide feedback on the decision support tool and data CECS produces.

We keep connecting with new agencies through the course of the project as we take note of their interest and the applicability of our work, and will continue to actively engage these groups in the coming months as we prepare to test the Beta version of our decision support tool products.

Leveraging Other Projects Funded by Other Sources

While CECS is leading on several fronts in climate change and land management research, we know that there are others who are doing important related research and creating their own tools as well. We recognize that it is important to leverage and complement existing research funding and policy innovations to accelerate climate change research, innovation, and policy and technology deployment, and have thus held quarterly calls with three other projects: Salo Sciences' California Forest Observatory (funded by the Gordon and Betty Moore Foundation), Spatial Informatics Group's Pyregence Consortium (funded by the California Energy Commission), and UCLA's California Ecosystem Futures Project (funded by the UC Lab Fees program). On these calls, organized by CECS, we have shared project updates, findings, and data layers. Follow-up calls have ensued to delve deeper into topics like fire progression and modeling, especially with Spatial Informatics Group. These calls will continue on a quarterly basis, bringing in experts like Loretta Moreno at the California Natural Resources Agency, and Caroline Thomas Jacobs and colleagues at the California Public Utilities Commission, to provide insights and inform how this group can best collaborate to help them achieve their respective organizations' goals.

Nonprofit Partnerships

We have also developed strong ties to innovative nonprofit groups in the State. One organization with which we have established a strong working relationship is Blue Forest Conservation, a nonprofit organization whose mission is to create sustainable financial solutions to pressing environmental challenges. Their Forest Resilience Bond deploys private capital to finance forest restoration projects on private and public lands that reduce the risk of catastrophic wildfire. We've teamed up with Blue Forest for a perspectives paper on valuation of ecosystem services. We have also had much support from them in terms of talking through the science and the application of the tool to ongoing and planned projects and management via monthly calls. Blue Forest will also be Beta-testing our decision support tools. As of September, we have also just begun to foster a relationship with The Nature Conservancy (TNC), with whom we are partnering on analyses of the Tahoe Central Sierra Initiative project area. We hope to use this area as a case study for our valuation of ecosystem services as well and will be bidirectionally sharing data with TNC.

Internship Program

The CECS hosted its first Ecosystems & Climate Change Summer Internship cohort virtually this summer for 8 weeks between June 22 and August 14. There were over 40 applicants to the program, and we selected 11 interns from a very diverse pool.

Five interns focused on science communication projects for CECS. Mentored by UC Davis PI Toby O'Geen and Jaquelyn Lugg, the interns learned about core science communication concepts like attention to audience, distilling complex information, eliminating jargon, and more. Each intern focused on a topic area, like die-off or carbon sequestration, and applied what they learned about science communication to create several products. These included one-pagers, short video explainers, infographics, and a TikTok channel, all of which allowed the interns to channel their creativity and insights into meaningful communications about topics the CECS project is working to address. Each week, interns worked together and with their mentors to revise their products, all of which are now featured on the CECS project website.

Additionally, six interns focused on original scientific research, and were similarly mentored by a PI and graduate students whose research focus matched theirs. Topics ranged from creating a high-resolution tree mortality dataset using machine learning algorithms to examining sequestration or loss of aboveground biomass from forest projects under California's Compliance Offset Program. All interns presented their work at our project's first Annual Meeting to a virtual audience of nearly 50 individuals. Of the interns focused on scientific research, at least three have also submitted abstracts to present on the work that they did this summer at this year's American Geophysical Union conference.

To create a richer experience for our interns, especially in the fully virtual world of the COVID-19 era, we hosted 8 virtual workshops, Q&A sessions, and panels. These included: Python, R (in a 3-part series), Google Earth Engine, QGIS, Science Communications, and a Young Professionals in STEM Panel. Interns were also able to learn from and collaborate with researchers across all 6 universities involved in the CECS project through weekly sub-group calls, and were also able to meet and engage with several of our partners at Blue Forest Conservation, Spatial Informatics Group, and California Natural Resources Agency.

Ten of the eleven interns we hosted this summer identified as female, and over ⅔ of our interns come from ethnic minority groups traditionally underrepresented in earth system science. Five of our interns live in or on the border of areas identified as Disadvantaged Communities as defined by Cal OEHHA. More than half are also first-generation college students.

In an exit survey, 55% of interns reported an increase or strong increase in their interest in both a career in research and in attending graduate school. 91% of interns also reported more confidence in giving a presentation on their work and in communicating their work to diverse audiences. At the end of the internship, 100% of our interns felt more knowledgeable about science communication, and 91% felt more knowledgeable about forest management strategies. For this being a fully virtual internship, we considered this a large success, which will hopefully only be improved upon in the next two years.

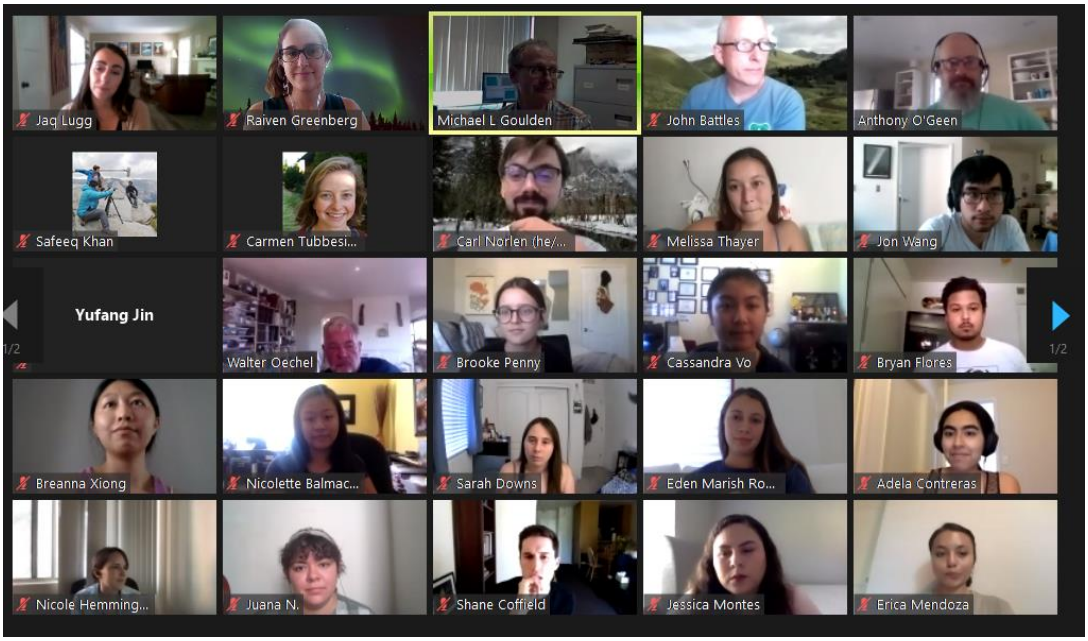

Figure 2: Interns and their mentors and PI's, along with other CECS team members celebrating the completion of their internship

Communications

Website

Communications about CECS are all channeled through the project website, https://california-ecosystem-climate.solutions, which was created and launched in January 2020 by Project Coordinator Raiven Greenberg with the purpose of informing stakeholders of our project and making our work accessible to both the academic community and to members of the public. The website summarizes core project tasks and objectives and also provides downloadable project reports.

Starting in summer 2020, the News and Communications section of the website was revamped by Jaquelyn Lugg to feature routinely posted stories about publications by the project team, ways to get involved, and updates about project progress. Features on forest management issues, complete with infographics, videos, and even a TikTok channel, created by the 2020 Science Communication Summer Interns were also posted to this section. Select posts are also being syndicated for broader audiences through university public information offices and the UC ANR website. The aim of these routine posts on the News and Communications section of the website, which will continue for the duration of the project, is to tell the story of our science in an accessible way and provide continued opportunities for stakeholders to see the impact and applicability of CECS projects.

Videos

UC Merced PIs Roger Bales & Martha Conklin worked with filmmaker Jim Thebaut of the Chronicles Group to create the film "Beyond the Brink: California's Watershed", which was shown at the Wild & Scenic Film Festival in Nevada City in January 2020. Roger and Martha continue to work with the Chronicles Group to distribute the film to PBS stations statewide and nationwide. As of Summer 2020, nearly all of California's stations have shown this 27-minute film, with most having multiple screenings. Stations in Oregon and

Florida have also shown it or plan to. Production has begun on the follow-on film, which will be more focused on forest management solutions.

Decision Support Tool & Extending Analyses

App developer Mike Walkinshaw and PI Toby O'Geen put heightened effort into planning for and developing the decision support tools. Currently, they envision a pallet of tools accessible from one main webpage. This decision was made based on virtual listening sessions we organized with various stakeholders. The four classes of tools we anticipate are as follows:

1. Data download tool that clearly displays all available spatial information for users to access.
2. Data/map visualization tool functioning as an interactive map that allows users to visualize geospatial trends of key attributes that define the physiographic state of the project area.
3. Decision support tool which is also an interactive map, but with functionality to deliver an assessment of change after disturbance/forest management practice for fire risk, above ground carbon, drought resilience, and evapotranspiration (as a proxy for water yield).
4. A site-specific ecosystem valuation tool with similar functionality as #3 above, but which allows for valuation of outcomes and likely site-based functionality.

In summer 2020, Mike developed two beta versions of apps: 1.) A fire progression app which allows users to choose a major fire and visualize the daily progression of aerial extent of each fire over time; and, 2.) A data download tool, which has the functionality to allow users to choose data layers, clip these layers to a watershed area, and download the data. The planning and evolution of this suite of tools will evolve as we learn more about user needs through the stakeholder survey and workshops.

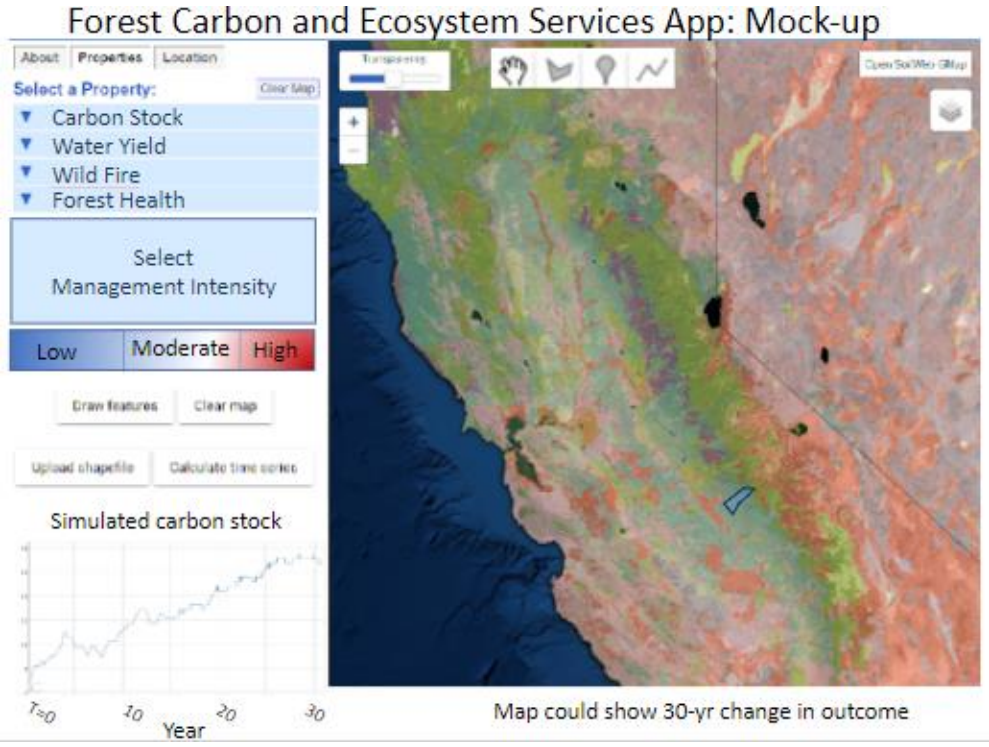

Figure 3: Mock-up of the interactive decision support tool. This tool will allow users to identify a project area, observe current conditions, and choose a management intensity for the project area. The tool will then forecast changes in carbon, water, fire probability and forest health 30-years into the future.

The tools are expected to be used by a variety of different stakeholders. Scientists with advanced modeling capabilities will use the unique geospatial products delivered by our tools to document the water balance and carbon balance of forests for a variety of land use projects. The public will use our visualization tools, for example, to understand the probability of fire in their vicinity and/or across the state. Finance groups and local land use planning agencies will use our decision support tool to demonstrate the multiple benefits/outcomes of forest management as a means to demonstrate added value from forest management projects and to incentivize projects.

4. Valuing Ecosystem Services

PIs Roger Bales, Martha Conklin, Catherine Keske, and postdoc Kyle Hemes initiated bi-weekly partner meetings with Blue Forest Conservation & related Innovations at the Nexus of Food, Energy, and Water Systems (InFEWS) project team around valuation of ecosystem services to prepare a framework paper. In addition, Roger and Martha also visited the North Yuba Project site with Blue Forest to assess methods for valuing ecosystem services, expanding financing partnerships, and identifying critical data needs for forest restoration projects. Our final postdocs were hired onto this part of the project in late August and early September, and energy will be put toward this portion of the project starting in early Fall 2020, furthering our partnerships with Blue Forest and TNC in the process.

Summary of Work Toward Priorities & Goals

Our project emphasizes the following SGC Priority Research Areas: 1.) Supporting and protecting vulnerable communities from the impacts of climate change.; 3.) Integrating land use, conservation, and management into California's climate change programs.; and 4.) Increasing data accessibility and planning support for local and regional climate change planning. Our work meets several of the SGC's threshold requirements, including clear ties to state climate mitigation goals, filling gaps across current State research programs by working in close conjunction with current agency initiatives, meaningfully engaging stakeholders throughout the entire project lifecycle, and leveraging and complementing existing research funding to accelerate climate change research, innovation, and policy and technology development and adoption.

In collaborating with State and federal agencies as well as nonprofit institutions, we are addressing the critical science bottlenecks, and adapting our work to better suit the needs of people who will utilize it to further climate policy and innovation. Over the past 12 months, we have engaged our partners in every phase of our work, from initial data procurement and refinement, to preliminary discussions of what would be most helpful in the decision support tools. Our needs assessment survey further ensures their input and feedback will be made a priority in our analyses and the development of the Beta version of the decision support tool interface and functionality.

Ultimately, our research and tool, when combined and synchronized with other efforts currently underway, will increase data accessibility, helping decision makers to create policies and programs to protect California's ecosystems and people from the detrimental effects of climate change, including communities that are particularly vulnerable.

Next Steps

The next ~6 will include the completion of version 1 of the data layers that will feed into the decision support tool. This will include the validation of all CCDC output through Collect Earth Online, as well as running the full CASA-based model. Simultaneously, the decision support tool will be built out, and a Beta version of both data layers and the interface will be shared with agencies and other partner organizations for feedback. Analyses will continue, and the ecosystem services and valuation portion of the project will receive increased focus.

Building on the survey, the stakeholder needs assessment will continue over the next several months. Efforts will begin diving deeper with stakeholders, focusing on interactive workshops and in-depth interviews. Integrated with the results from the survey, the outcomes of these continued engagement activities will inform the design and content of the decision-support tool our team develops. We will also continue sustained engagement with stakeholders after the needs assessment, including the development of an email newsletter and a social media presence to provide updates about the project, more opportunities to connect with our team and test the decision support tool, and reports on project findings. Progress will continue to be shared with SGC and other partners and stakeholders for continued feedback and evaluation, which will help to improve the quality of our outputs and extend the potential for their adoption and impact.