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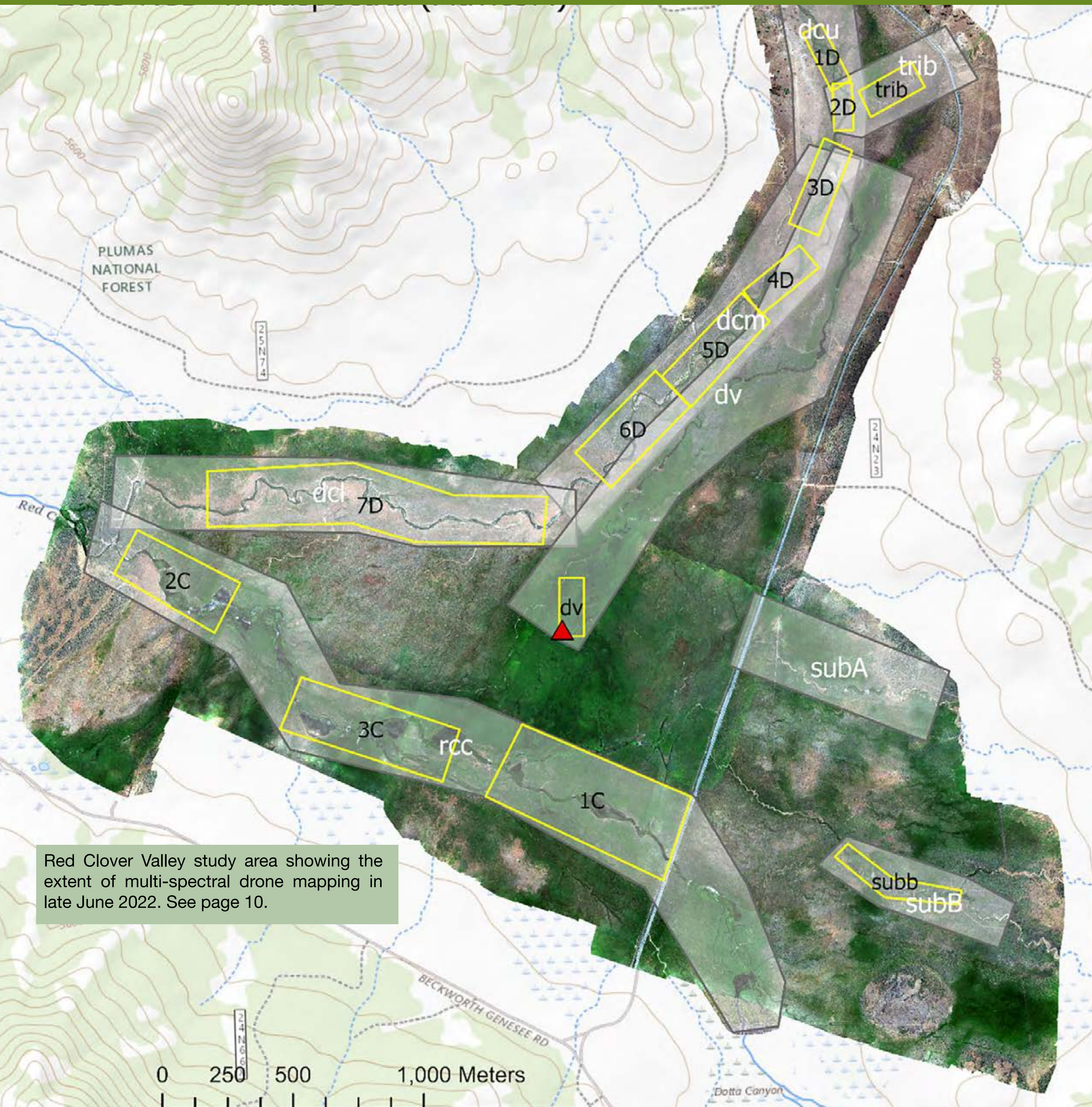

Red Clover Valley study area showing the extent of multi-spectral drone mapping in late June 2022. See page 10.

INSIDE

Embracing Transdisciplinarity with GISc

There appears to be a wave of departmental consolidations passing through the CSU these days. I'm now (since Fall 2023) a professor in a School of the Environment, which combined geography, environmental science, environmental studies, and earth & climate sciences with five undergraduate and four graduate programs; and we are not alone in the CSU. Part of the motivation certainly comes from budget cuts and low enrollments in some majors, but some of it came from the sense that there are many common interests in these areas, so there might be some benefit in being together.

While the internet has made it possible to collaborate with partners all over the planet, there are real advantages in working with colleagues, especially for field-based research. We've been able to take advantage of university research support such as vehicles and field research facilities, for instance, and that was especially useful during the pandemic—in summer 2020, our meadow research team members each had their own bathroom stall and sink at our Sierra field station!

Geospatial methods are especially well positioned to support a broad range of disciplines, and I'm sure all of us in our community have accurately used the term "interdisciplinary" or "transdisciplinary" to describe a common aspect of our research. Just picture any diagram illustrating Ian McHarg's (1969) overlay concept and you'll immediately see why: we bring together all kinds of things that inherently relate. Just from a biogeophysical perspective, plant biology relates to the hydrology through the soils, with fluvial geomorphic processes impacting the depth to the water table and mobilizing sediments to impact water quality, and organisms exchanging carbon compounds with the atmosphere, etc., etc. Now throw in social systems, human health relationships, economic pressures, and landscape change from human activity, and we have a massive palimpsest, which reminds us that there's also the time dimension.

So why not have lunch together and share research talks? That makes it sound so simple…

Jerry Davis, Director, CSU GIS Specialty Center
San Francisco State University

Using handheld LiDAR scans of *Heterobasidion irregulare* affected plots in Plumas National Forest, CA to determine the effects of disease spread on tree structure and competition

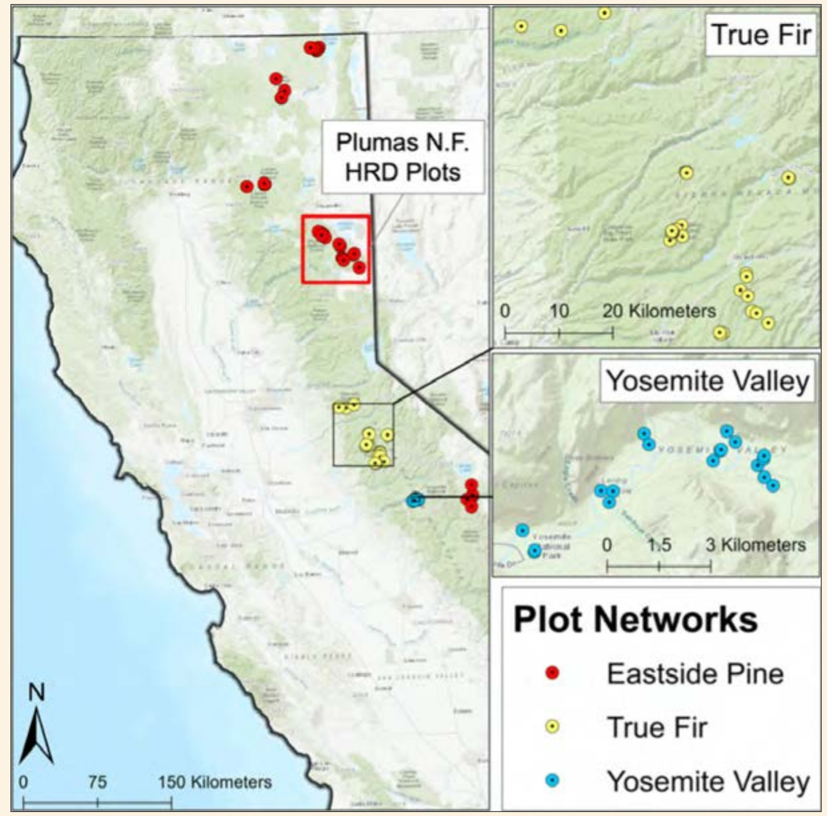

Figure 1: Map of Plumas National Forest, True Fir, and Yosemite Valley Heterobasidion Monitoring Plots.

Under anthropogenic climate change and fire exclusion policies, California's forests have reached unprecedented densities, leaving many economically and ecologically valuable species vulnerable to biotic disturbances (Shaw et al. 2022). In the Sierra Nevada, *Heterobasidion spp.* root pathogens are the most important native root diseases (Garbellotto and Gonthier 2013). Specifically, Heterobasidion pathogens create persistent disease centers, often associated with logging activities, which actively kill trees or reduce growth (Rizzo et al. 2000; Garbelotto and Gonthier 2013; Flores et al. 2023). Once established, these disease centers create persistent canopy gaps, reduce timber growth, and alter forest structure and composition (Garbelotto and Gonthier 2013; Flores et al. 2023).

Heterobasidion Root Disease (HRD) is caused by at least two distinct species in California, *H. irregulare*, a pathogen of pines (*Pinus sp*) and *H. occidentale*, a pathogen of fir (*Abies sp*). To document the effects of HRD, a plot network was established throughout the Plumas, Modoc, Inyo, Lassen, Eldorado, and Stanislaus National Forests and Yosemite National Park in 1972 by identifying Heterobasidion fruiting bodies on a cut stump in areas that had been logged at least 15 years prior. These plots were then manually re-measured every 2-3 years for the first decade following establishment, and every 6-9 years after that period (Slaughter and Parmeter 1995; Rizzo and Slaughter 2001). Surprisingly, although over 50 years of long-term monitoring data have been collected to date, little is known about how the disease gap might alter individual tree structure in the surrounding forest. Have HRD gaps changed canopy structure in a way that influences tree intra specific competition and leads to declining forest health and reduced forest value?

Figure 2: HMLS scanning of a plot.

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To address this question, we collected terrestrial LiDAR data from the Plumas National Forest, located in eastern Plumas County, California (Figure 1). The Plumas National Forest is 1,146,000 acres and forms the eastern side of the Sierra Nevada mountain range. On the eastern expanse of the Plumas National Forest, the most dominant tree species is Jeffrey Pine (*Pinus jeffreyi*). Terrestrial LiDAR scans of 17 plots in the Plumas HRD network were collected in July 2023 (Figure 2). Scans were collected using a GeoSLAM ZEB Horizon Handheld Mobile Laser Scanner (HMLS). Unlike other scanning methods, this method does not rely on fixed scan positions to prevent occlusion. The mobility provided by handheld scanning requires walking paths to follow looping patterns to scan objects from all angles. Scans were completed in 15 minutes or less to assure similar point density in all scans. Following scanning, post-processing of point clouds was performed using GeoSLAM Connect, LiDAR360 (GreenValley International, Berkeley, California, version 4.1) and RStudio software. Specifically, the spatial location of each tree was recorded to determine individual tree metrics as well as size of the center HRD-caused light gap (Figure 3). Individual tree metrics include a value for the strength of competition, crown asymmetry measurements, and live crown ratio.

Data analyses are currently underway, but preliminary results suggest that the HRD gap may not have as large of an effect on the individual structure or competition of trees outside of the gap as previously hypothesized, perhaps due to a relatively open canopy in these particular plots in the Plumas National Forest. Nevertheless, understanding the effect of disease gaps after 50 years of development can provide insight into the current state of gaps as special management areas and the role of canopy fuels in driving problematic wildfire-disease interactions (Cobb 2022). Importantly, we are creating a geospatial workflow that can rapidly analyze the effects of forest fragmentation due to biotic disturbances on tree growth and architecture. Since these disturbances are expected to worsen due to climate change driven increases in temperature and drought (Simler-Williamson et al. 2019), this is a crucial task that has implications for critical wild-land ecosystem resources, economic function, and the resiliency of local communities (Millar and Stephenson 2015; Cobb et al. 2020).

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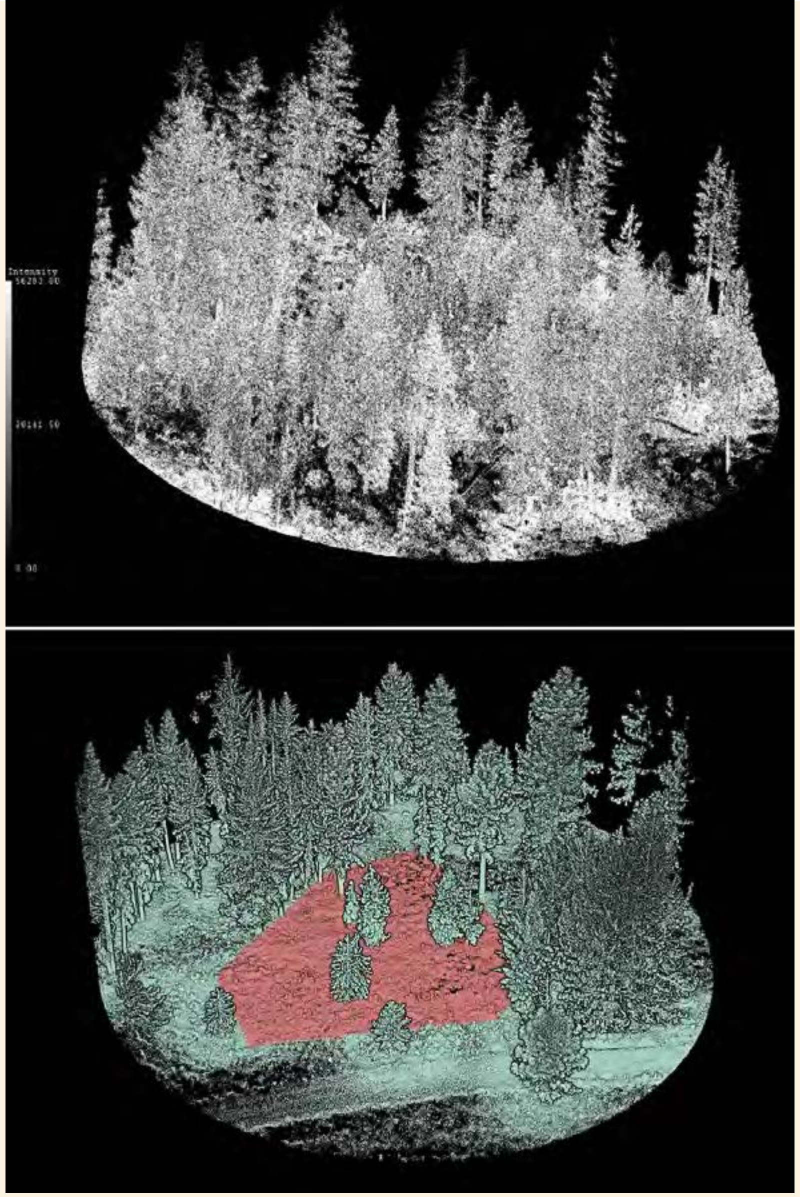

Figure 3: HMLS scan of a plot (top) colorized in red (bottom) to show the location of the central Heterobasidion Root Disease Gap.

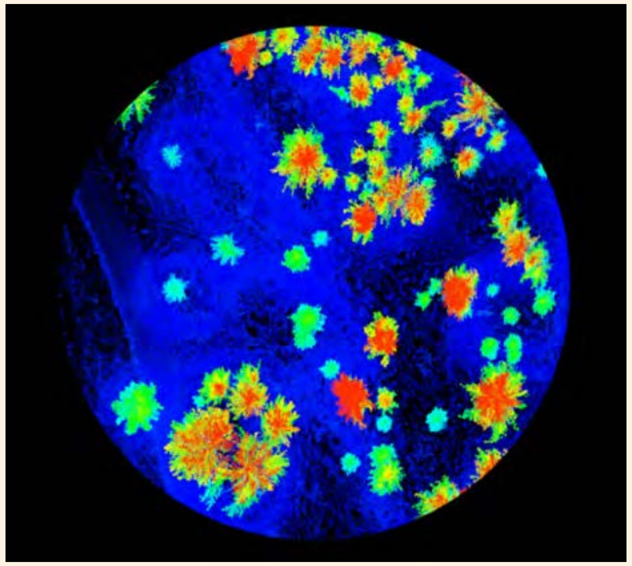

Figure 4: A top-down view of a HMLS plot scan to indicate how the crown shape and spatial location of individual trees can be used to determine the effects of disease on tree structure and competition.

Civic Engagement Through Little League

Students in my civic learning class took the opportunity to connect with their community through participant observation of Little League baseball. This hands-on approach aimed to uncover how social organizations collaborate to reach shared goals. This civic engagement activity serves as a platform for applying sociological concepts and theories to their communities outside of the classroom, immersing students in the shared spaces of public parks and recreation centers. By taking the tools of sociology to the fields where youth practice and play Little League baseball, students not only gained practical experience but also honed their skills as civically engaged members of their local community.

At its core, engaging with Little League through participant observation challenged students to discern the intersection of sociology-specific knowledge with active participation in civic life. Beyond an academic exercise, the approach fostered a deeper understanding of the dynamics at play in shared spaces.

Through their involvement with Little League, students were exposed to the rich diversity of communities and cultures within their city or suburb. This learning activity prompted students' reflection on their own personal attitudes and beliefs, drawing comparisons and contrasts with those of other cultures and communities, especially the parents participating in Little League. Through participant observation in a local Little League, students generated direct evidence from their civic engagement, shedding light on their evolving civic identity and commitment within their local community.

Observing the volunteers involved in running a Little League emphasized the desire for direct experience in leadership and civic action. The microcosm of a local Little League unveiled the intricate world of civic engagement that millions of parents regularly partake in across the United States. The activity showcased how, in the pursuit of creating a happy, healthy, and safe environment for children, adults set aside their differences to ensure a successful season. The objective of this learning activity was to enable students to explore how individuals collaboratively navigate their community contexts and structures to achieve a civic aim.

This learning activity requires students to identify a Little League, establish contact with the league president, and engage in observations of the league and/or teams throughout the season. To actively participate in their Little League community, students followed a local Little League baseball team over the months of the season that overlapped with the academic semester. They observed the conditions of the Little League Park and its facilities, such as lighting, waste bins, restrooms, and other areas for visitors. Throughout their ethnographic field research, they talked with members of the Little League community to identify their reasons for participating in Little League baseball.

In addition to their ethnography, students conducted a spatial analysis of their local Little League city and neighborhood. Using ArcGIS mapping tools, they examined various aspects, including walk-ability around their Little League Park, traffic collisions involving pedestrians or bicyclists within a twenty-minute walk from the park, and instances of vandalism, narcotics, assault, and theft within the vicinity of the park. The process equipped students with skills in spatial analysis and data visualization, as they learned to use geographic information systems (GIS) software to analyze data, map patterns, and identify trends to inform decision-making and action.

For their final project, students were tasked with creating a policy proposal for their city council, to be presented using the StoryMap app in ArcGIS. Their proposal aimed to advocate for community improvements focused on the areas surrounding their Little League Park. These StoryMaps served as platforms to highlight the sociological factors shaping their city, while advocating for a policy recommendation to strengthen connections between the city and its residents through active participation in the Little League community. Each StoryMap featured map layers detailing walking-time around their park, collisions involving pedestrians and bicyclists, and crimes data, supplemented with visual elements such as pictures, text, and other informative content to effectively convey the sociological characteristics of their community. Throughout their project, students were encouraged to consider the broader civic context and structures that impact their Little League community. ArcGIS mapping allows students to uncover insights which might not be directly apparent through participant observation alone. By incorporating layers depicting incidents collisions and crimes, students gained insights into official reports made to service agencies, providing a comprehensive understanding of their community's dynamics.

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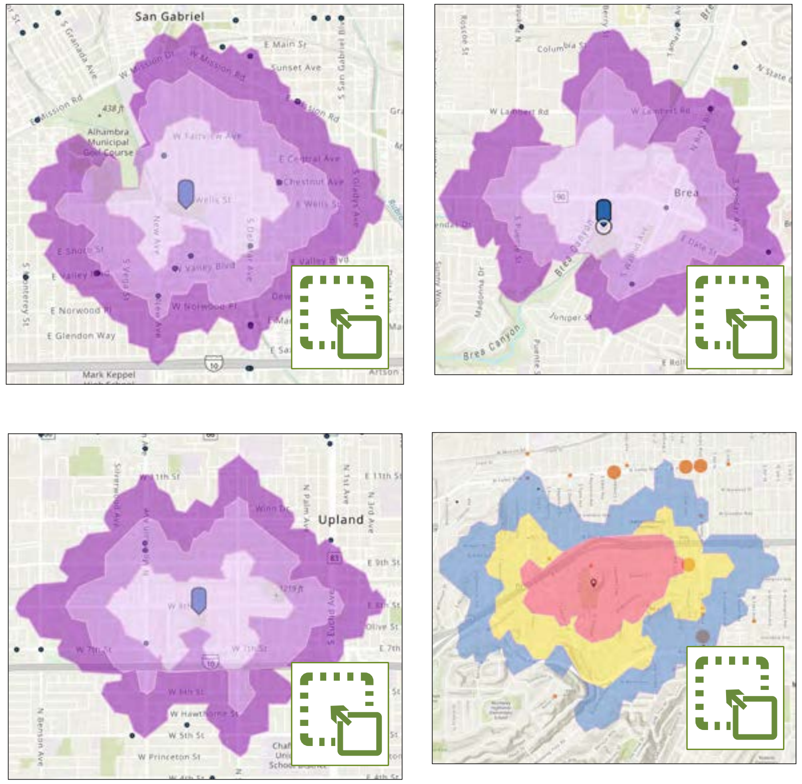

Figures 1-4: Walk-time maps around parks in the Los Angeles area where Little League teams meet, showing walking time, with black dots illustrating collisions involving pedestrian or bicycles and drug crimes involving narcotics.

Geospatial Applications of Deep Learning Across Time, Space and Ecosystems

The recent explosion in the use of Deep Learning in research and industry has been widespread across disciplines as researchers are finding new ways to leverage this technology to answer a wide variety of scientific questions. Geospatial science is no exception, and the increased availability of remote sensing data, from drones to satellites, provides a ripe data source to scour for information to better understand environmental and ecological problems. This research explores three use cases of Convolutional Neural Networks (CNNs) or Deep Learning technology applied to solve ecological issues at three spatial scales, from local to regional spatial scales.

Local Scale - Eelgrass in Morro Bay, CA

The first use case occurs at the local scale, where we use Deep Learning to analyze the spatial distribution of eelgrass in the Morro Bay Estuary of central California. Eelgrass (*Zostera marina*) is at the base of the trophic food web in West Coast estuary environments, and over the past 15 years in Morro Bay, experienced a massive decline and regrowth in distribution across the estuary and bay. In 2010, there was a massive loss in eelgrass resulting in erosion and morphological changes (Walter et al., 2020). Human GIS analysts meticulously digitized polygons of eelgrass from drone imagery, constituting thousands of hours of human labor to digitize the polygons so scientists could better understand the spatiotemporal distribution of eelgrass population dynamics and subsequent ecosystem impacts. Because of this tedious human task, the application of convolutional neural networks was particularly well-suited to handling mass classifications. The study by Tallam et al. (2023) found model recall, precision, and the harmonic mean of both were 0.954, 0.723, and 0.809 respectively, when using human-annotated training data and random assessment points (Tallam et al., 2023). Future research will focus on scaling our approach to include subsequent years and other similar estuary ecosystems. The variability of collection conditions present in drone imagery provides unique scientific challenges not found at broader spatial scales.

Statewide Scale – Urban Tree Detection in California

The second use case occurs at the statewide scale where we use Deep Learning to analyze the spatial distribution of urban trees in California using aerial 4-band National Agriculture Inventory Program (NAIP) imagery. Urban trees decrease surrounding temperatures, reduce pollution, increase aesthetic value, and provide shade and various human health benefits (Giacinto et al., 2021). The State of California intends to dramatically increase the urban tree canopy cover in the coming decade, though current baseline estimates of urban trees are based on sparse inventory data and extrapolations may not be reliable for continuous monitoring. We have developed a more direct measurement of urban trees to detect the presence of urban trees using a convolutional neural network, cloud computation and human annotated training points. A thorough evaluation of our method was performed, supported by a new dataset of over 1,500 images and almost 100,000 tree annotations, covering eight cities, six climate zones, and three image capture years. We trained our model on data from Southern California, and achieved a precision of 73.6% and recall of 73.3% using test data from this region. We generally observed similar precision and slightly lower recall when extrapolating to other California climate zones and image capture dates. We used our method to produce a map of trees in the entire urban forest of California and estimated the total number of urban trees in California to be about 43.5 million (Ventura et al., 2022). This estimate is considerably lower than previously published estimates of urban tree cover in California which were estimated at 173.2 million trees (McPherson et al., 2017). Underestimation by our research may be due to two main factors: underprediction due to density of tree stands and overprediction in previous estimates. A direct measurement approach may offer a more comprehensive inventory tool. Our 'Urban Tree Detector' research results can be found at Cal Poly's Urban Forest Ecosystem Institute website: https://ufei.calpoly.edu/. Future research will focus on converting our tree points into accurate canopy polygons and analyzing errors associated with our estimates to inform improved scientific recommendations for policy makers.

Regional Scale – Agroforestry in the Amazon Rainforest

Our third use case utilizes Deep Learning to classify a fused stack of remote sensing imagery to be able to analyze the spatiotemporal distribution of agroforestry in the Amazon Rainforest. The last decade has been characterized by increased anthropogenic impact in the Amazon/Agriculture/Rangeland interface, with humans encroaching into the interior of the Amazon to graze livestock, harvest timber and grow crops like Palm Oil, Cacao and Coca. Our research collaborates with local, largely Indigenous farmers in the Amazon to provide more transparent supply chains and traceability for consumer goods and curb illegal logging in the world's largest rainforest. The work is part of the National Aeronautics and Space Administration's SERVIR (NASA-SERVIR) program in collaboration with NASA's Jet Propulsion Laboratory (NASA/JPL) to prepare for the next-generation

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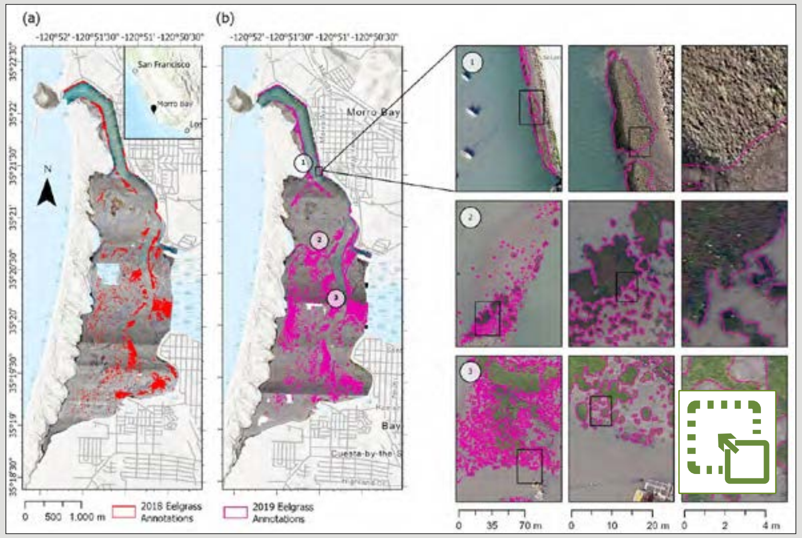

Figure 1: (Left) Human-annotated images of Morro Bay eelgrass habitats from (a) 2018 and (b) 2019. (Right) The three rows on the right highlight three regions of the estuary in 2019 at varying levels of zoom, as indicated by each inset. (1) Dense bed toward the mouth of estuary that is above water, appearing a light gray-green color; (2) partially submerged beds of varying size mid-estuary that are darker green and have some red-brown coloration and gleam off blades of eelgrass; (3) smaller, younger beds that are not submerged and appear lighter green in the images (from Tallam et al. 2023).

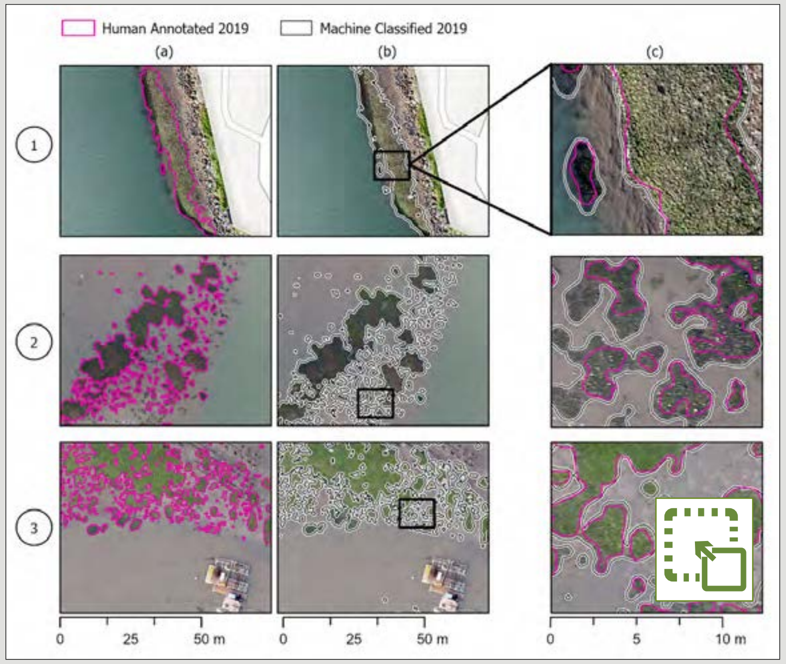

Figure 2: Model success cases. Human eelgrass annotations compared to machine-annotated classifications in the three areas of the estuary shown in Figure 1. Column (a,b) show the same area of the estuary with human and model annotations, respectively, while column (c) shows the two annotations overlapped and zoomed in to see differences in annotations more clearly. (1) The machine annotation can capture larger beds and accurately capture the perimeter on par with human annotations. (2) Smaller, patchy beds that the machine annotations more precisely outline beds than the human annotations. (3) The model can pick up on smaller beds that are missed or deemed too small to annotate in human annotations. (Tallam et al. 2023)

microwave remote sensing satellite, NISAR. NISAR and its predecessor microwave satellites such as ALOS and Sentinel 1 provide a way to 'look' through cloud coverage and analyze the vertical structure of the rainforest. In our study, we 'stack' a fused product of satellite remote sensing imagery from Landsat, MODIS, Sentinel 1 C-band SAR, and ALOS PALSAR to produce a product with spectral, structural, and temporally-relevant information. We then had teams of GIS analysts search for agroforestry plots in high resolution Maxar satellite imagery with the guidance of our local collaborators who provided information of known agroforestry locations in the relevant regions of South America (Fricker et al., 2022). We use Bayesian models to produce likelihood maps of Palm Oil agroforestry in Ucayali Province, Peru.

To better understand the vertical structure of these agroforestry plots, we fused our current data products with the Global Ecosystem Dynamics Investigation (GEDI), a NASA mission to measure how deforestation has contributed to atmospheric CO_2 concentrations. GEDI is a waveform LIDAR attached to the International Space Station to provide the first global, high-resolution observations of forest vertical structure. To provide simpler download paths for the public, we have created novel point filtering and processing algorithms to remove noise (Cooley et al., 2022). Future efforts will focus on expanding our research into the State of Para, Brazil and use Deep Learning to analyze laser waveform structure across agroforestry plots and extrapolate predictions of agroforestry across the region.

Our research demonstrates the extensive opportunities presented by Deep Learning technology and its applications to geospatial data to study ecological systems for students and professionals alike. The tools used here are flexible across spatial scales and well-suited for time series analysis and change detection. Now more than ever, these programs are easier to access and hold immense value in applications outside the scope of the three ecosystem-focused case studies described above. With the addition of the ESRI Deep Learning toolkit, quick extraction of information from imagery is all the more accessible to the general public. Before, Convolutional Neural Networks and Deep Learning technology were once exclusively available to skilled programmers, but now, students across the state and GIS analysts with foundational level skills can access this powerful technology.

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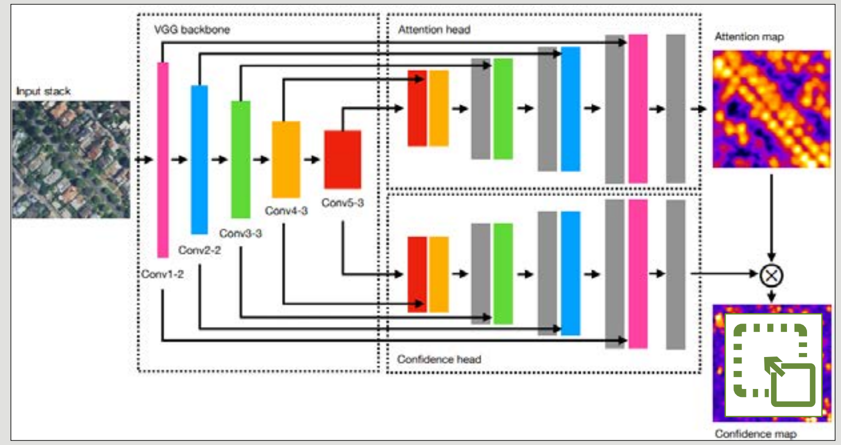

Figure 3: Tree Detection Network Architecture of the deep learning model from the input stack of imagery (left) to the output attention and confidence maps (right). This model shows the intermediate convolutional layers of our model and how they contribute to output locations, and also a measure of confidence in the predictions.

Figure 4: Comparison of a manual tree inventory with our tree detection results on three areas from Torrance, CA. Our tree detector can find trees on both public and private land, leading to a more complete inventory. Figures from (Ventura et al., 2022).

Figure 5: Hand Annotated NAIP image tile in Millbrae, CA. Tile 34/500 of 2020 imagery. Top Left: Input image. Top Right: Image after hand annotation ready for post processing. Bottom Left: False-Color Infrared image of Tile 34 (vegetation identified in orange). Bottom Right: False-Color Infrared image of Tile 34 after hand annotation.

Figure 6: Qualitative results of running our model on aerial imagery from Bakersfield, CA. Left: Input image. Right: Predicted canopy cover map in yellow overlaid on image.

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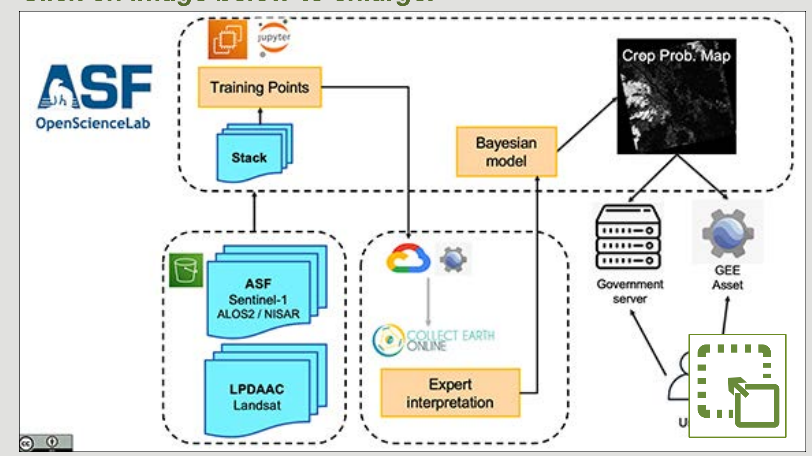

Figure 7: Diagram of methods. Fused Satellite Imagery Stacks are combined with Field Training Points, and Expert Interpretation to create a Crop Probability Map, and served up to users via servers and Google Earth Engine

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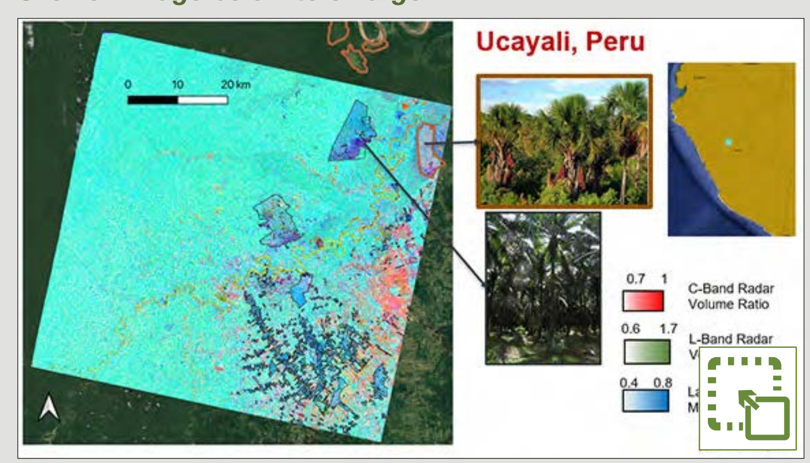

Figure 8: False Color Composite Image of fused data stack (Sentinel 1 – Red, ALOS PALSAR – Green, Landsat NDVI – Blue), highlighting the native palm stands (top), compared to palm oil agroforestry (bottom), in Ucayali Province, Peru.

students and GIS analysts who spent thousands of hours digitizing eelgrass polygons to train our models. Our urban forestry research was supported by the Cal Poly Urban Forest Ecosystem Institute, Dr. Matt Ritter and Dr. Jenn Yost (Cal Poly Biology) and Camille Pawlak (UCLA Geography). The research was supported by Walter Passmore with Cal Fire and a grant We thank numerous students who contributed to the digitization of urban trees across California.

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Firing up AI: Using AI-based detections of bird species to assess the impact of fires in Sonoma County

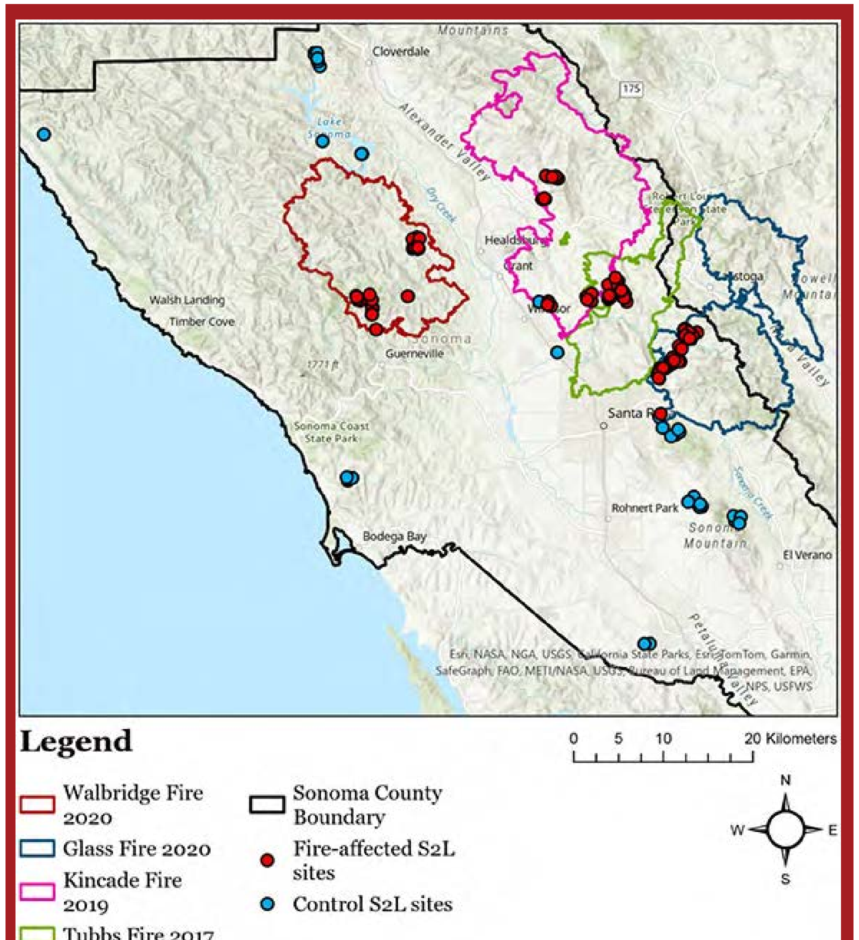

Figure 1: Map of Sonoma County fires from 2017-2020, including fire and control S2L site clusters.

Wildfires are a beneficial disturbance factor in Mediterranean-climate ecosystems. Heterogeneity in wildfire severity can profoundly affect bird species diversity by creating various stages in vegetative succession, which offer an array of niches that diverse bird communities occupy (Sitters et al., 2015; Taylor et al., 2012). At a broad scale, such as watershed or county, mixed-severity fires create patches of diverse habitat, and the ensuing shifts in avian biodiversity are thus mediated by diversity of fire severity, known as pyrodiversity (Stillman et al., 2023). Fires have increased in size and intensity over the past century in California due to more extensive droughts, rising temperatures, and unsuitable forest management, which have led to overgrown, fire-susceptible forests (Jones 2020). How might these factors affect bird diversity?

Here, we describe an analysis that explores how bird species richness responds to mixed-severity fires. Our study was based in Sonoma County, which has a range of Mediterranean-climate oak woodlands, mixed conifer forests, shrublands, and grasslands, as well as temperate conifer forests, such as coastal redwoods, and recently experienced five large wildfires (Figure 1). We compared changes in avian diversity by monitoring bird communities using artificial intelligence (AI) applied to audio recordings, a dataset resulting from the Soundscapes to Landscapes (S2L) project. This project is led by Principal Investigator Dr. Matthew Clark (Sonoma State) and involves multiple collaborators from Point Blue Conservation Science, Northern Arizona University, UC Merced, public agencies, non-profits, land-owners, and citizen scientists in Sonoma County (Snyder et al., 2022; Clark et al., 2023). The S2L project engaged over 250 citizen scientists through the deployment of low-cost AudioMoth sound recorders (Figure 2) and the creation of bioacoustic reference datasets for building the AI algorithm (Snyder et al., 2022; Clark et al., 2023). Project data include AI-based detections for 52 species and corresponding species richness values for 1,234 audio sample sites. The method entailed three ImageNet-based Convolutional Neural Network (CNN) architectures (MobileNetv2, ResNet50v2, ResNet100v2), which were fine-tuned with our study reference data. The trained CNN models functioned as a Mixture of Experts (MoE), whereby the model with the best balance of precision and recall was chosen for each species along with an optimal threshold for detection probabilities. When tested against exhaustively annotated, independent recordings of 1-min length, we found that our MoE approach had a total precision of 84.5% and an average species-level precision of 85.1%. The original S2L sampling design did not include fire in the design, but sampling of wildfire-impacted areas was added after wildfires and included a revisit of existing sites both within fire boundaries as well as control areas that did not burn (Figure 1). An overview of S2L work and publications can be found in this ArcGIS StoryMap https://storymaps.arcgis.com/stories/402443b576c146f7b2e5fd8c008376a6

We used ArcGIS Pro to aggregate site locations for consecutive years. When multiple consecutive years were available for a cluster, we chose the date closest to the fire start/stop dates. There were 142 sites with before-after data (284 total measurements of richness; 82 in control, and 202 in burned areas). A repeated-measures ANOVA was performed in R with a mixed-effect linear model to test if there was a significant difference in mean species richness due to fires. In this model, species richness was the response, treatment was fire vs. control, and time was pre- and post-fire conditions, including a treatment and time interaction effect. The test indicated that species richness did not independently differ between control vs. fire sites (Table 1 - Treatment) or between pre- or post-fire conditions (Table 1 - Time). However, there was a highly significant interaction effect of treatment and time on species richness, with the effect of post-fire conditions in burned areas increasing richness on average by four species (Table 1 - Treatment * Time). These trends can be seen in Figure 3, which shows an increased species richness in burned sites relative to pre-fire conditions. These trends align with findings from other studies that observed a difference in pre and post-fire species richness for related control and fire-treated sites, suggesting the possibility that fire plays a role in increasing biodiversity after fire occurrence (Sitters et al. 2015).

Figure 2: AudioMoth sound recorder (left) and device deployment in a burned area (right).

Treatment	Estimate	Standard Error	p
Intercept	19.9756	0.8518	< 0.0000 ***
Treatment (Fire effect)	-1.7007	1.0100	0.0935
Time (Post-fire effect)	-1.7683	0.9267	0.0584
Treatment * Time (Fire and Post-fire effect)	4.0528	1.0988	0.0003 ***

Table 1: Repeated-measures ANOVA assessing the fixed effects of Treatment (0=control, 1=fire) and Time (0=pre-fire, 1=post-fire) on bird species richness. A unique cluster identifier was included as a random effect to account for repeat measurements. AIC with no interaction = 1762.8; AIC with interaction = 1751.6; p = 0.0003. Sample sizes are: Control = 41 pre-fire, 41 post-fire; Fire = 101 pre-fire, 101 post-fire.

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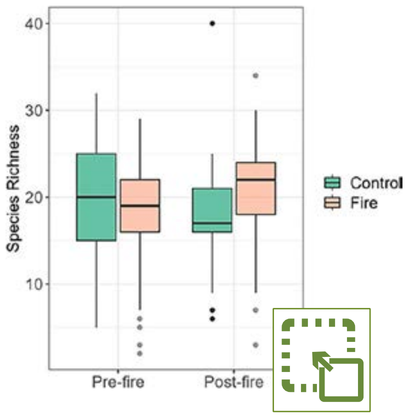

Figure 3: Species richness in fire perimeters and control areas from S2L site clusters (n=82 in control; n=202 in fires).

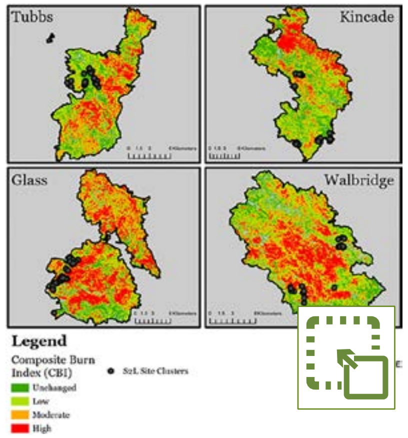

Figure 4: Map of Sonoma County fires (Tubbs 2017, Kincade 2019, Glass and Walbridge 2020), and corresponding Composite Burn Index Values (CBI).

We next assessed the effect of wildfire burn severity on the change in bird species richness with a linear regression analysis. Fire burn severity data were accessed from the US federal Monitoring Trends in Burn Severity (MTBS) program, which involves a multi-agency collaboration that maps wildfire burn severity throughout the United States using Landsat imagery (30-m resolution). We applied an empirically-based linear model (Miller and Thode 2007) to translate Landsat-based RdNBR burn severity to field-based Composite Burn Index (CBI), as seen in Figure 4. In our linear model, CBI was the predictor variable and post- vs. pre-fire change in bird species richness was the response variable.

Our analysis showed that increasing wildfire burn severity (CBI) significantly increased post-fire species richness relative to pre-fire conditions, although the model only explained 6% of the variance in the response ($y = -0.4268 + 0.2414$ CBI; s.e. = 0.0993; $p = 0.0169$; $r^2 = 0.06$). This result indicates that many other factors could explain changes in bird richness after recent fires. We tested the time since pre- and post-fire measurements (in years) in the model, but this addition was not significant. Our analysis did not consider changes in bird species composition or abundance. For example, there could be large shifts in the types of birds present after fire (such as woodpeckers due to standing dead trees) without necessarily changing overall species richness. Our AI-based bird surveys do not allow for accurate estimates of species abundance as species vocalizations are not easily distinguished as separate individuals. However, future research with our data could explore the overlap in richness between pre- and post-fire communities without abundance measurements (e.g., with the Jaccard Index).

This study benefited from recent advances in bioacoustics, including AI-based species detection. Bioacoustics data are valuable for long-term biodiversity monitoring at various spatial scales, and data collection with low-cost recorders is an excellent avenue for citizen science engagement (see, for example, Bird Weather, https://www.birdweather.com). As shown in our study, bioacoustic monitoring from a baseline can provide the basis for scientific analysis of wildfire impacts on bird communities in the short term; however, continuous monitoring could also provide insight into longer-term changes, such as those due to the combined effects of anthropogenic climate change, urbanization, and habitat restoration projects. Though AI-based species detections have been used to understand the impact of fires on individual species of birds, we are unaware of another study that assesses the impact on avian communities using AI-based species detections.

The growing impacts of anthropogenic climate change and rapid environmental shifts from baseline conditions obligate a deeper understanding of how biodiversity responds, such as in larger fires in California exacerbated by extreme weather (Williams et al. 2016; Goss et al. 2020). Future research should continue to explore the relationship between wildfire presence and burn severity on bird species richness while prescribing forest management (e.g., thinning, prescribed fires) that diversifies fire disturbance as a beneficial mode of conserving biodiversity. Such studies will benefit from remote sensing, a vital geospatial technology for measuring burn severity or assessing changes in vegetation structure (e.g., habitat and fire fuel loads) at multiple spatial and temporal scales.

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UAS-based biogeomorphic assessment of a large montane meadow in the northern Sierra Nevada

A team of geographers, biologists, and other environmental scientists from SFSU, UC Davis, CSU Chico, and other universities and agencies have been pursuing multidisciplinary restoration efficacy research in Red Clover Valley over a five-year period as part of a CA Department of Fish & Wildlife Greenhouse Gas Reduction Fund grant, in cooperation with The Sierra Fund and ranchers pursuing innovative process-based restoration methods ranging from grade control structures, stream diversion, cattle exclosures, and beaver dam analogs (BDAs). The long-term goal of process-based restoration projects is to aggrade entrenched channels to the level of their historical floodplain or to some other healthy stream condition that promotes channel-floodplain connectivity and more structurally complex and resilient fluvial systems (Cluer & Thorne 2014; Pollock 2014; Wheaton 2019; Lewis 2019).

Dixie Creek and Red Clover Creek are the largest surface inputs into Red Clover Valley, with each draining a watershed of 80 km^2 (31 mi^2) at their confluence (Figure 1). Upper Dixie Creek is home to a small population of beavers, and efforts to enhance this habitat with beaver dam analogs and reinforced beaver dams is one of the major restoration methods used in this study. For more visuals on some of the research, see our story map at: https://storymaps.arcgis.com/stories/37496b41088047c498b4d7b19493665b

The assessment research conducted by SFSU has included (above- and below-ground) biomass sampling, plant physiological measurements of stem flow, soil moisture monitoring, biogeochemical water quality monitoring, carbon flux measurements in chambers and eddy-covariance flux towers, and UAS-to-satellite multi-spectral remote sensing of land cover, vegetation phenology, and biogeomorphic channel changes (LeBeau 2019, Mousavi 2019, Simonin 2019, Fetherston 2022, Davis 2023, LeBeau 2023, Martin 2021, O'Brien 2023). While plant and water measurements allow us to look at seasonal and short-term effects of the restoration, this article focuses on the more long-term biogeomorphic changes along channel corridors from UAS-based multi-spectral and color (RGB) imagery; geomorphic processes such as stream incision and aggradation are the most significant cause and recovery mechanisms for these meadows.

Given that the project extended over more than five years, as well as the goals of the project, it shouldn't be surprising that we employed multiple UAS solutions. For multi-spectral imagery used for land cover and vegetation health assessment, the goal was five multi-spectral bands (B, G, R, NIR, RE) at 5.5 cm resolution, accomplished with the MicaSense RedEdge camera on 3DR Solo in 2018 (see Davis & Qiu 2018 for details on that system) and the MicaSense Altum camera (which also provided thermal) on a DJI Matrice 100 in 2019 through 2022; imagery in 2023 employed a DJI Mavic3M RTK system, providing four multi-spectral bands (G, R, NIR, RE) as well as RGB on the RedEdge-based system used early on. For biogeomorphic assessment of channel corridors, while multi-spectral imagery contributed to riparian vegetation detection, we primarily made use of RGB imagery, provided by DJI Phantom 4, DJI Mavic 2 Pro, and the DJI Mavic3M, each flown at 40 to 60 m above ground level (AGL), providing 1 to 2 cm resolution digital surface models (DSM) and 5 cm digital terrain models (DTMs). GNSS data provided sufficient accuracy to 10 cm for first part of the project, improving to 1 cm using the onboard RTK of the Mavic3M connected to the California Real Time Network for NTRIP processing in 2023, as long as we were careful to use good targets for ground control points (even for the RTK drone) and pay attention to vertical antenna offsets and use of height above ellipsoid (HAE) with the local geoid height established.

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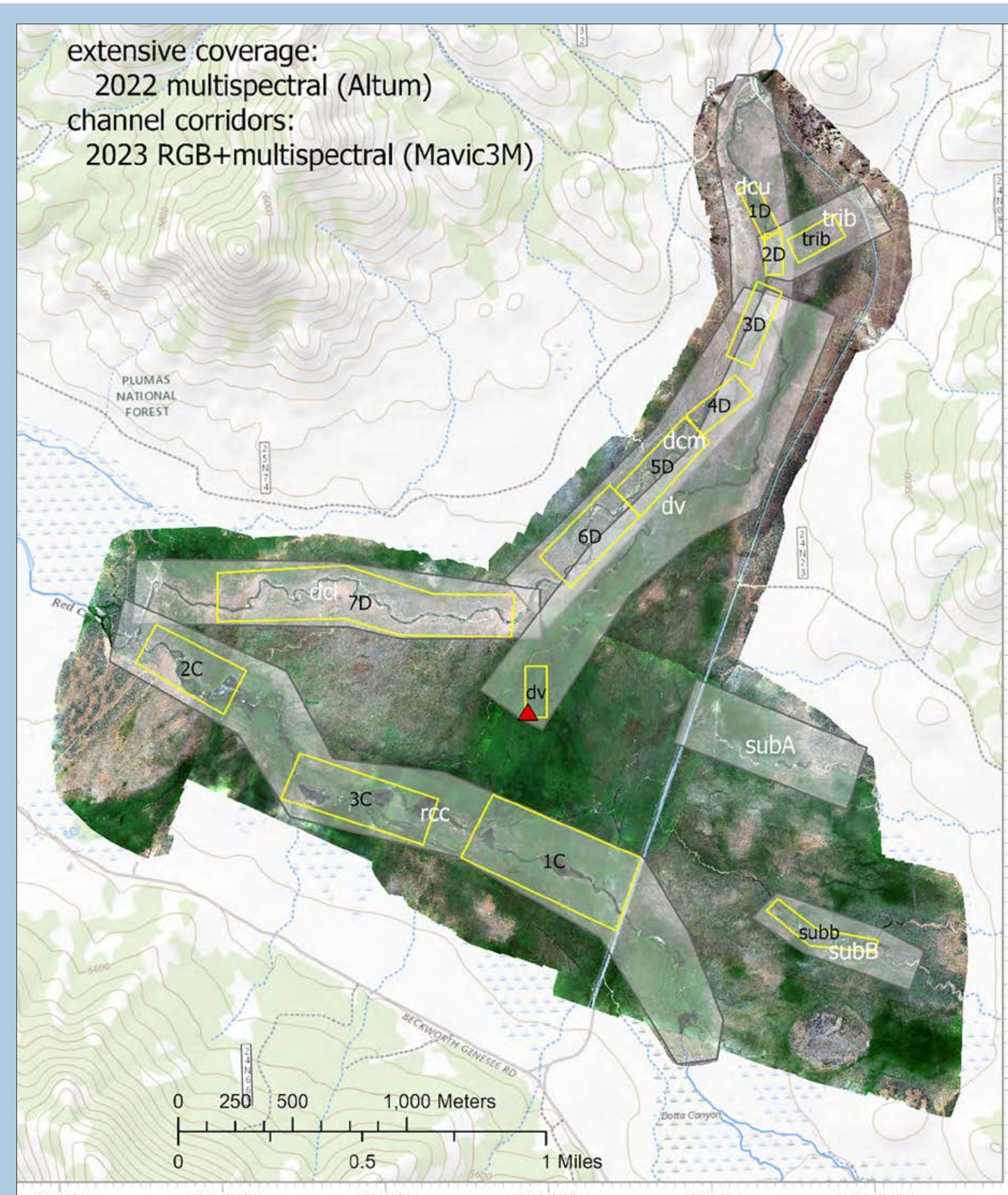

Figure 1: Red Clover Valley study area showing the extent of multi-spectral drone mapping in late June 2022 (using the MicaSense Altum camera mounted on a DJI Matrice 100 for 10 cm resolution) and RGB (2 cm) + DSM (2 cm) + DTM (10 cm) + multi-spectral (10 cm) drone mapping along labeled channel corridors in late June and early August 2023 (using the DJI Mavic3M). Multi-spectral mapping is covered in the Spatial Quantification of Carbon Sequestration section. The flux tower installed in 2020 is shown as a red triangle in the center.

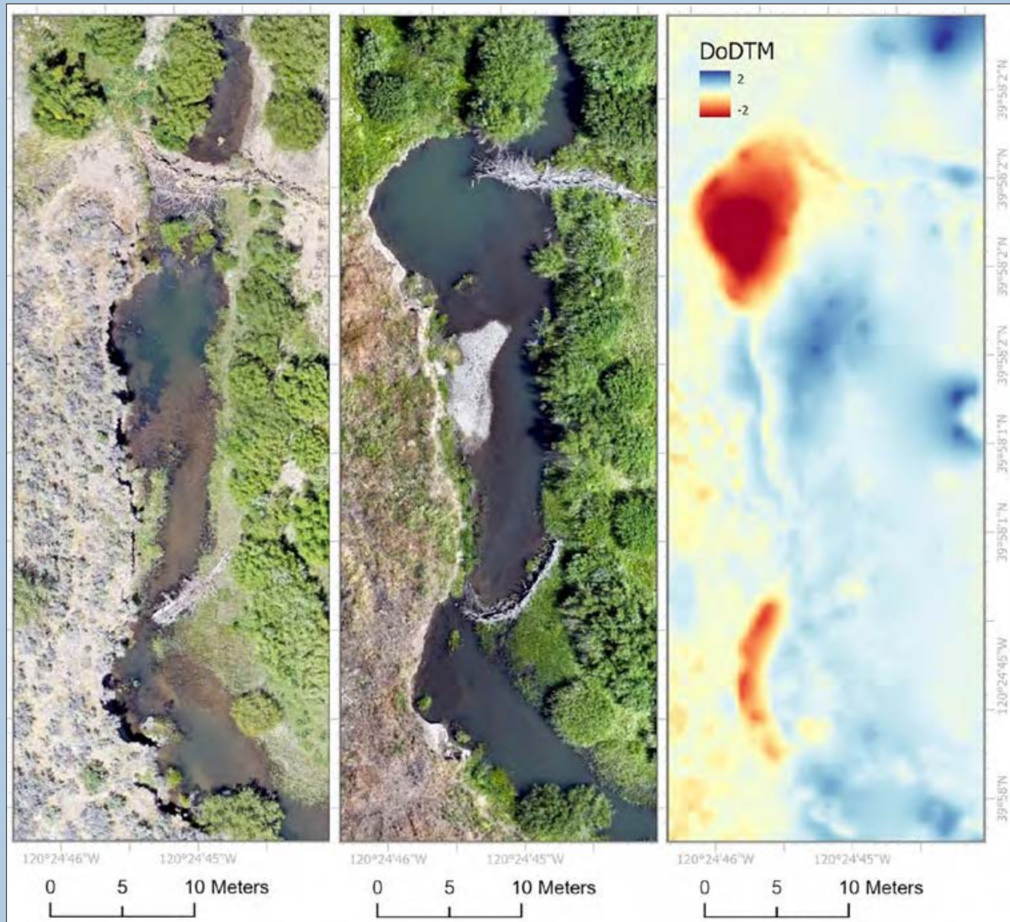

Figure 3: Geomorphic change detection in a reach of lower Dixie Creek, using the Geomorphic Change Detection Software described by Wheaton et al. (2019).

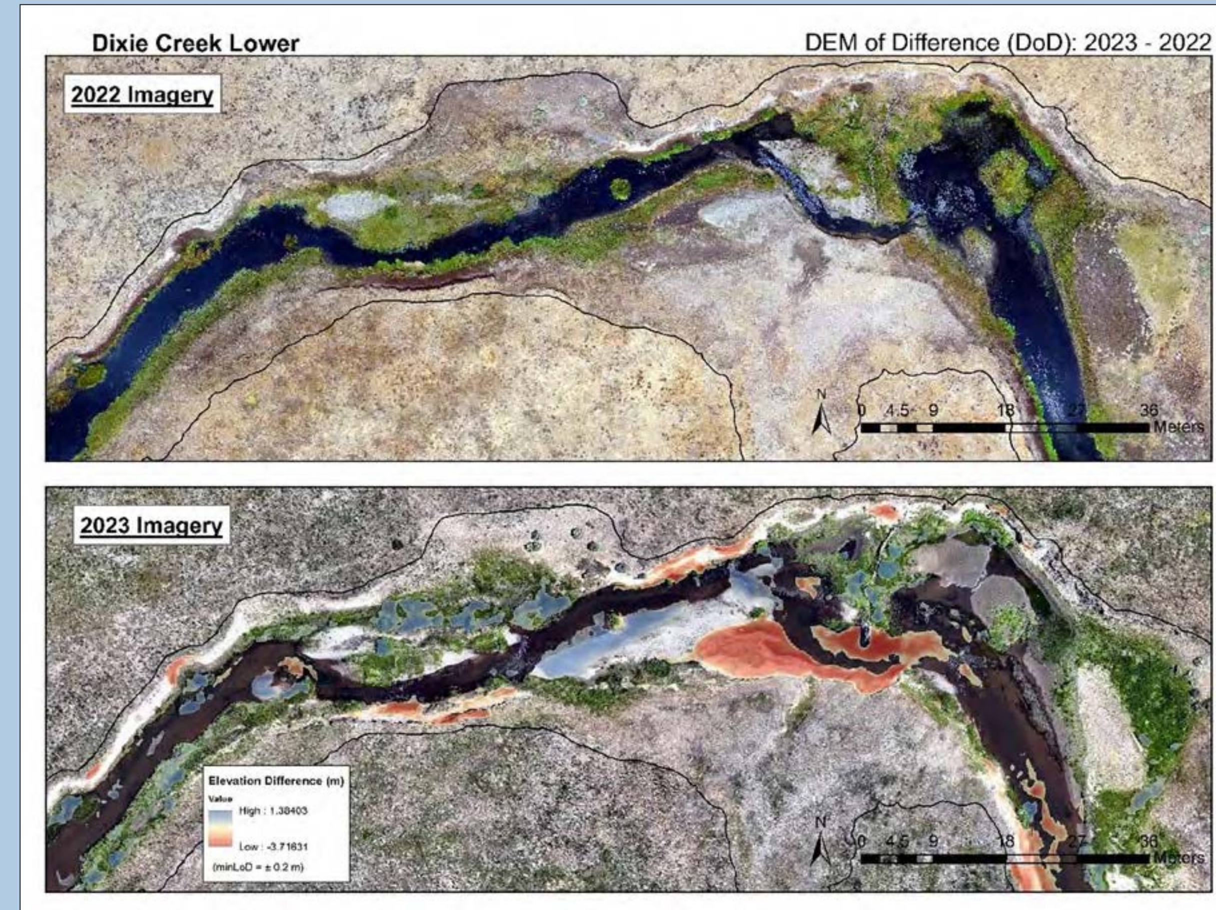

Figure 2: Example of channel widening resulting from BDAs apparent in the image. Effect of fire on right bank (left in image) removing sagebrush. 2020 at left, 2023 center, difference in DTM in meters at right.

See Figure 1 for the scope of multi-spectral and channel corridor surveys. Images were processed using Pix4Dmapper employing a Structure from Motion (SfM) photogrammetric approach (Christian & Davis 2016) to generate point clouds, orthoimages, DSMs and DTMs; the latter were inputs to the ArcMap Geomorphic Change Detection (GCD) add-in (Wheaton, 2010, https://gcd.riverscapes.net/) to facilitate (a) Raw DEM differencing, (b) DEM Error Modeling, and (c) DEM differencing with error thresholding (Figures 2-4)

Many locations along the more incised Dixie Creek provide clear illustrations of corridor widening where a BDA forced flow to the bank, increasing channel complexity as is a hallmark of the beaver meadow complex (see Figure 2). Here, the BDAs and the adjacent inset flood plain illustrate (a) the effect of BDAs in channel widening, typical of a beaver-meadow complex, with BDA breaching probably resulting from a flood in October 2021; (b) a gravel bar created just downstream of a BDA; and (c) the effect of the Dixie Fire that went through here in September 2021. By 2023 when the later image was captured (see Figure 3), a likely increase in groundwater and minor aggradation on the inset floodplain, and openings for herbaceous vegetation on the fan terrace can be seen in considerable greening of the landscape. The inset floodplain of Dixie Creek provides many examples (clearly visible in drone imagery) of hydric vegetation that were protected from the fire sweeping through in late 2021.

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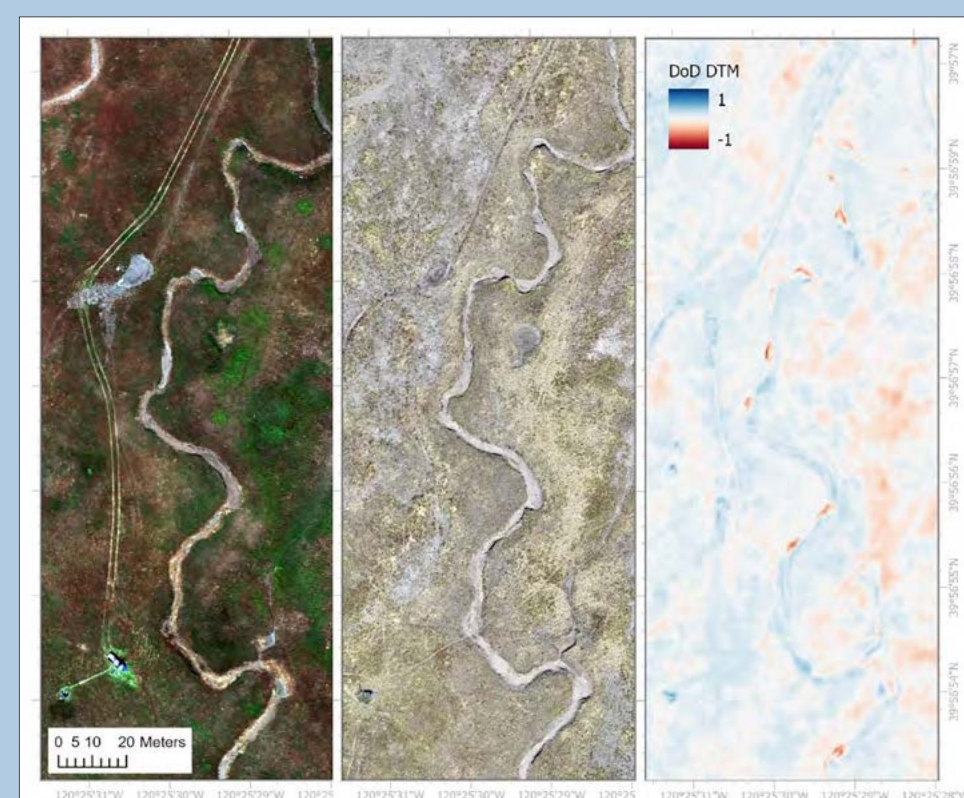

Figure 4: An intermittent diversion channel near the flux tower, seen in the lower left. The channel exhibits areas of ~0.5 m of scour as well as the same magnitude of fill. *Left:* Altum multi-spectral image from August 2020. *Center:* Mavic 3M RGB image from August 2023. *Right:* Difference of DTM (DoDTM).

Since channel incision (degradation) and or aggradation have a direct influence on meadow groundwater levels, and those in turn influence soil moisture, we should also expect a signal in vegetation communities on the meadow where this has been effective. For the BDAs and grade control structures, this signal is likely to follow multi-decadal cycle overall for the meadow as a whole and raising the groundwater table with hydric vegetation along the active channel floodplain. We should also expect the earliest signal in areas influenced by channel diversion as this directly influences the soil moisture, but we can also see the geomorphic change effects in these small intermittent diversion channels (see Figure 4).

In conclusion, drone imagery played an important role in directly assessing channel changes responding to the process-based restoration as well as the effects of the fire in 2021, as well as in ground truthing satellite imagery that could be collected more frequently to assess phenological and biogeochemical cycles. For channel changes over a relatively short period (1 to 5 years), fine resolution (1 to 2 cm) drone imagery is important, but getting good ground control points is essential.

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Gentrification in Los Angeles

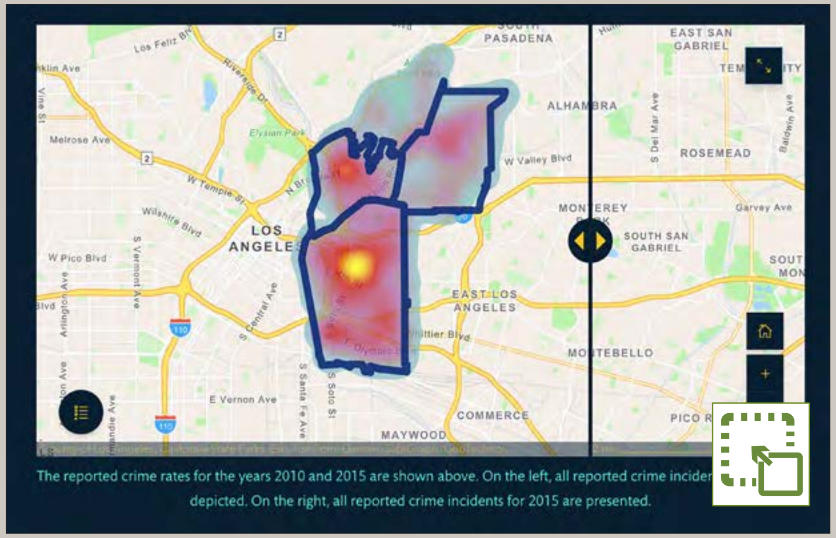

Figure 1: Reported Crimes in Hollenbeck 2010. Heat map of all crimes reported between January 1 through December 31, 2010 in the three neighborhoods of Lincoln Heights, Boyle Heights, and El Sereno in East Los Angles. The types of crimes reported include assault, theft, vandalism, and narcotics.

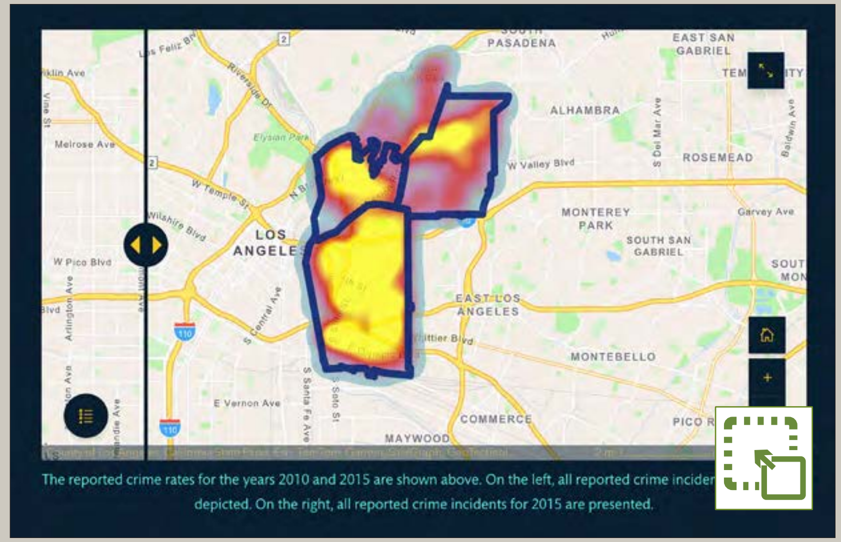

Figure 2: Reported Crimes in Hollenbeck 2015. Heat map of all crimes reported between January 1 through December 31, 2015 in the three neighborhoods of Lincoln Heights, Boyle Heights, and El Sereno in East Los Angles. The types of crimes reported include assault, theft, vandalism, and narcotics.

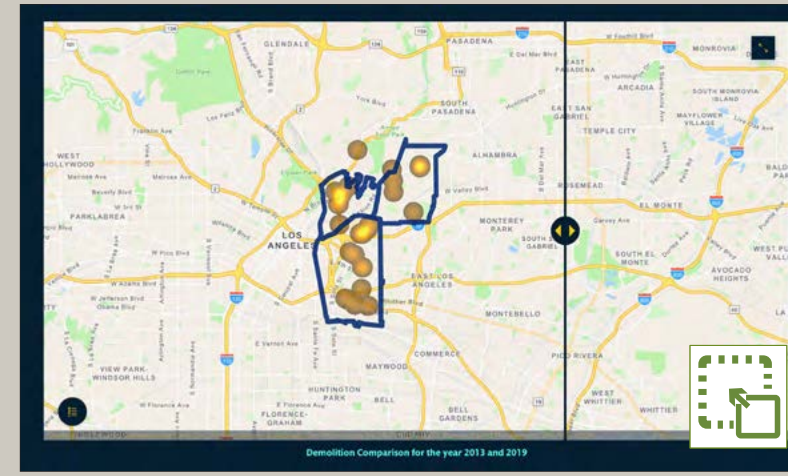

Figure 3: Demolitions in East Los Angeles, 2013. Heat map of demolitions reported in the Lincoln Heights, Boyle Heights, and El Sereno neighborhoods of East Los Angeles, 2013.

In my urban sociology graduate seminar, students delved into the intricate patterns of gentrification across Los Angeles. Gentrification can be understood as a large-scale social process where a new middle class moves into city centers and neighborhoods are transformed to align with the cultural preferences of this new demographic. This, unfortunately, often results in the displacement of working-class residents from their historic communities (Zukin 2016).

Within urban sociological studies on gentrification, two prominent paradigms exist (Brown-Saracino 2007). The qualitative paradigm adopts a micro perspective exploring changes within specific neighborhoods, detecting gentrification in diverse cities such as New York City, Portland, and New Orleans. The quantitative paradigm employs a macro approach, examining regions rather than individual neighborhoods. It highlights the emergence of dual cities marked by the disappearance of the middle class, replaced by both the affluent and the working poor.

To bridge this methodological divide, we introduced spatial analysis over time. Our objective was to evaluate the transformation in neighborhoods surrounding Downtown Los Angeles since 2000. Students acquired proficiency in ArcGIS to document spatial factors within distinct neighborhoods in Los Angeles, including Echo Park, Atwater Village, Mid-City, Mid-Wilshire, South Los Angeles, and East Los Angeles. The utilization of different data layers in ArcGIS enabled students to scrutinize the impact of car-centric versus transit-oriented

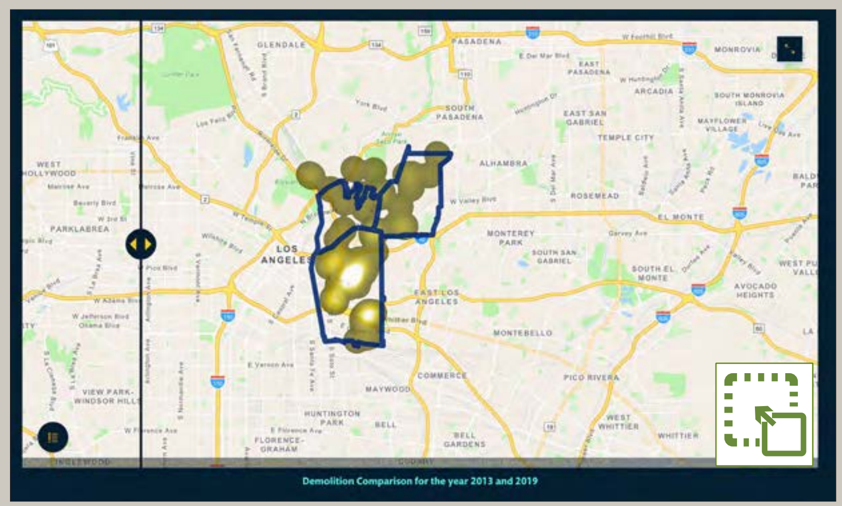

Figure 4: Demolitions in East Los Angeles, 2019. Heat map of demolitions reported in the Lincoln Heights, Boyle Heights, and El Sereno neighborhoods of East Los Angeles, 2019.

choices on the demographics and geographies of neighborhoods, as shown by Scheutz and colleagues in their research on 1990s Los Angeles (2018).

The communities that we inhabit within greater Los Angeles play a pivotal role in shaping its character. Los Angeles, a fragmented space intricately linked to forces of global capitalism, unites various cities, neighborhoods, and

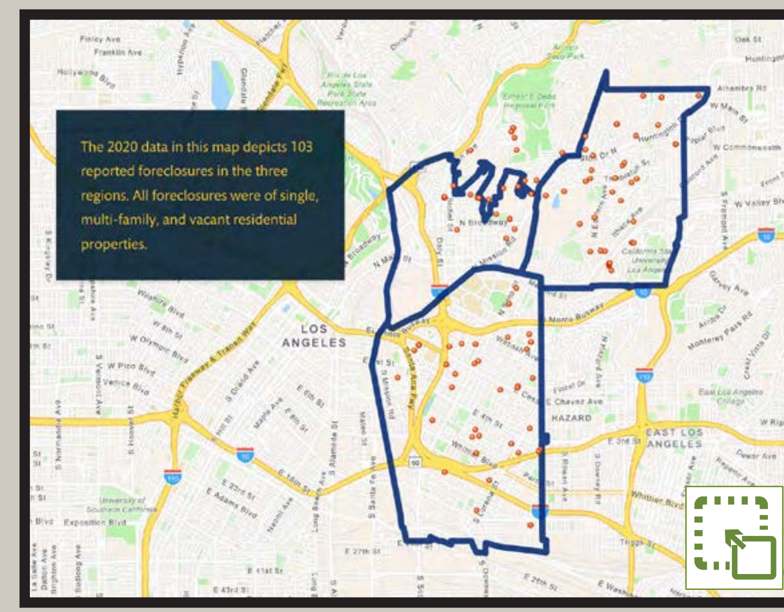

Figure 5: Foreclosures in East Los Angeles 2020. The reported foreclosures for the three neighborhoods of Lincoln Heights, Boyle Heights, and El Sereno in East Los Angeles, 2020.

communities across a vast expanse, spanning from the Southern California deserts to the east and north, the beaches to the west, and mountains to the south. Through spatial data analysis, students created story maps that visually depicted the social structure influencing how urban residents shape and are shaped by the city's space. These story maps blended text, maps, images, and videos to

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provide a comprehensive narrative about gentrification in Los Angeles.

The story maps crafted by students documented gentrified areas in West Los Angeles, gentrifying neighborhoods like Los Feliz and Atwater Village near Dodgers Stadium, and the working-class neighborhoods in South Los Angeles. Olivia Sanchez's story map analyzed the changing aspects of three communities in East Los Angeles: El Sereno, Boyle Heights, and Lincoln Heights. The three regions' historical accounts include several sociological components, most notably the relationship between race, ethnicity, and socio-economic status. Her story map utilizes information from the LA City GeoHub to provide detailed reports on the residential profiles of the three communities. Precise data from ArcGIS mapping software was incorporated into the story map, including information on home values, average household income, crime rates, educational attainment, and homelessness. Through an examination of the effects of gentrification on three traditionally redlined districts, the story map illuminates the significant repercussions of urban growth on those displaced and those who remain in regions that continue to undergo such changes. Moreover, the story map furthers the discussion on the driving contributors of gentrification, specifically, agents of change that can include local business owners and community members. A detailed analysis of the effects resulting from the gentrification of these communities adds essential context to the body of knowledge about the ongoing and observed changes in Los Angeles. This investigation strengthens our understanding of the changing urban landscape and its effects on the communities impacted by these lasting changes.

The first two maps illustrate heat maps of crimes reported to the police during two periods: January 1 to December 31, 2010 (Figure 1), and the same period in 2015 (Figure 2). These maps show a gradual increase in crimes reported to the police over time. This trend corresponds with the idea that newcomers to an area, often referred to as gentrifiers, are more inclined to report crimes to the police compared to long-term residents, who may have a strained relationship with law enforcement. The reported crimes encompassed various types, including assault, theft, narcotics, and vandalism.

The next pair of maps (Figure 3 and Figure 4) provide a similar visual representation, but this time focusing on demolitions in the years 2013 and 2019 in three neighborhoods: Lincoln Heights, Boyle Heights, and El Sereno in East Los Angeles. In 2013, only 29 demolitions were recorded across these neighborhoods, whereas in 2019 the number increased to 72. The final map (Figure 5) depicts a total of 103 foreclosures in 2020 within the same East Los Angeles neighborhoods. These foreclosures affected both single and multi-family housing units, as well as other vacant residential properties. Notably, listings on the REDFIN real estate search engine showed properties available for sale in 2022 ranging from $600,000 and $2.4 million, with a median home price at $747,500.

Taken together, the patterns of residents reporting crimes to police, the increase in property demolitions, reported foreclosures, and soaring home prices exemplify processes at play during gentrification.

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Plan Integration for Resilience Scorecard™ (PIRS™) for Wildfire: Pursuing WUI Fire Resilience through a Spatial Framework for Policy Evaluation

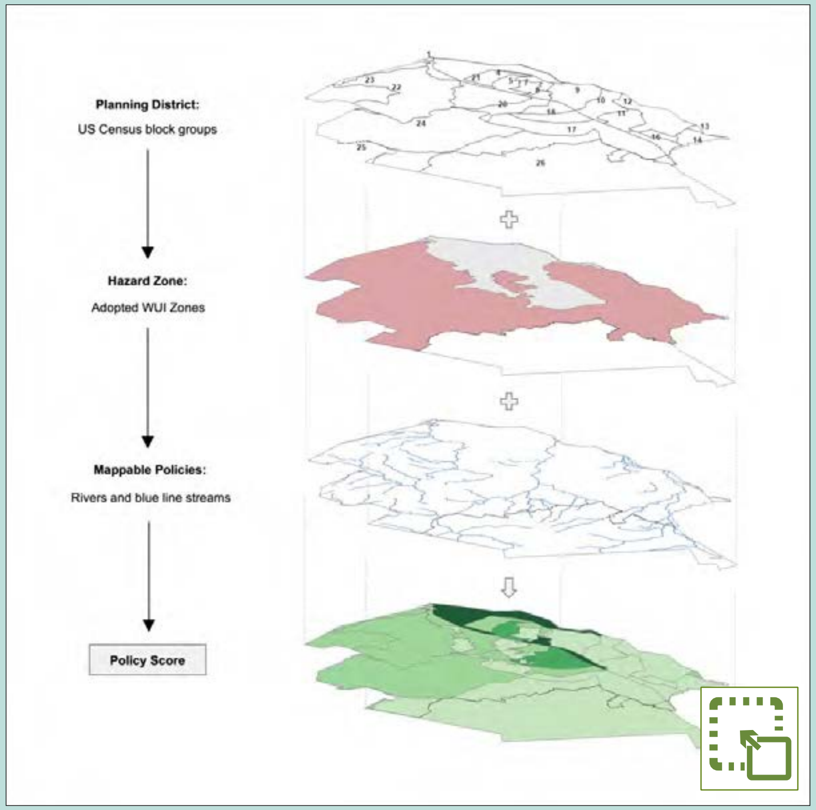

Figure 1: Schematic that illustrates the PIRS IM for Wildfire process from a geospatial perspective, using Atascadero, CA - the pilot community in the PIRS™ for Wildfire effort—as an example. Planning districts and hazard zones are merged to create district-hazard zones (DHZs), while municipal policies identified as having a mappable component and relevancy to the wildfire hazard are used to spatially evaluate plan resilience by DHZ.

Wildfires, expanding in frequency and intensity because of climate change, are increasingly impacting the natural and built environment. Seven of the ten most destructive fires in California have occurred in the last five years, and one in four Californians lives in an area considered high-risk for wildfires.

However, communities in California and across the United States increasingly adopt many different plans in their "network of plans"—e.g., General (Comprehensive) Plan, Hazard Mitigation Plan, Community Wildfire Protection Plan, Climate Action Plan, and various sectoral or area plans. Often produced by multiple "siloed" departments or stakeholder groups with limited coordination or spatial understanding,

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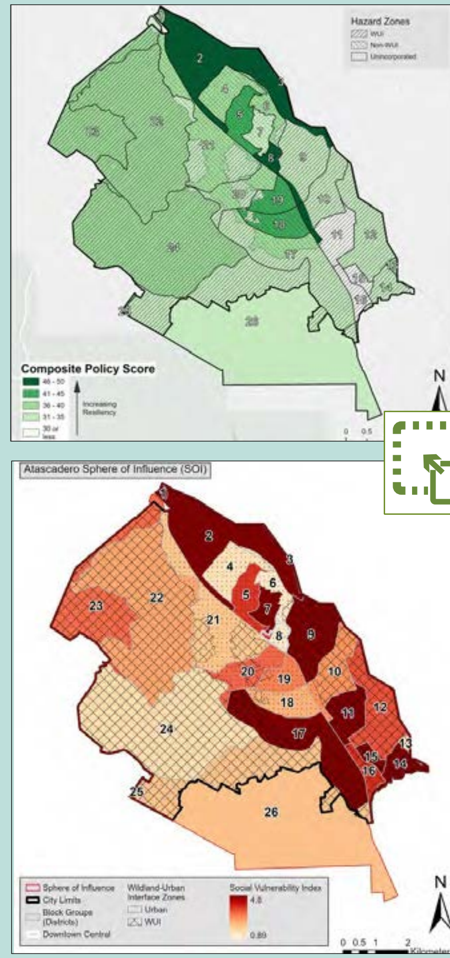


Figures 2 & 3: Composite (total) policy score versus social vulnerability index for Atascadero. Given the use of U.S. Census block groups as planning district in the analysis, plan resilience and demographic vulnerability to wildfire can be compared side-by-side.

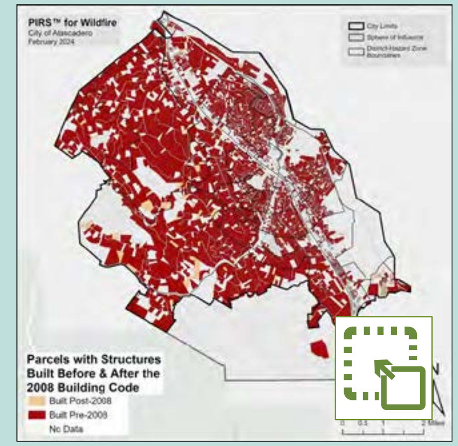


Figure 4: Parcels in Atascadero categorized by whether the structure was built before or after adoption of the 2008 California building code. More stringent codes were adopted in 2008 for fire-prone landscapes - with requirements for fire-resistant building materials, defensible space, and access and egress - increasing the resilience of structures built in the years since adoption.

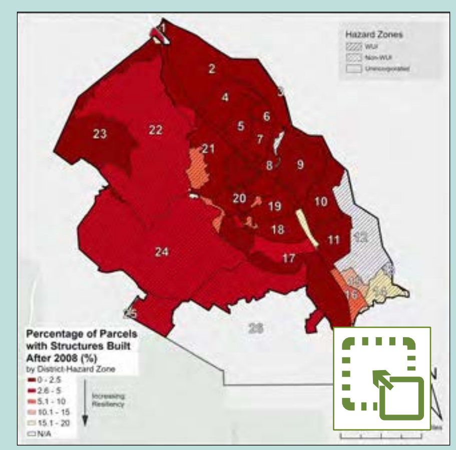
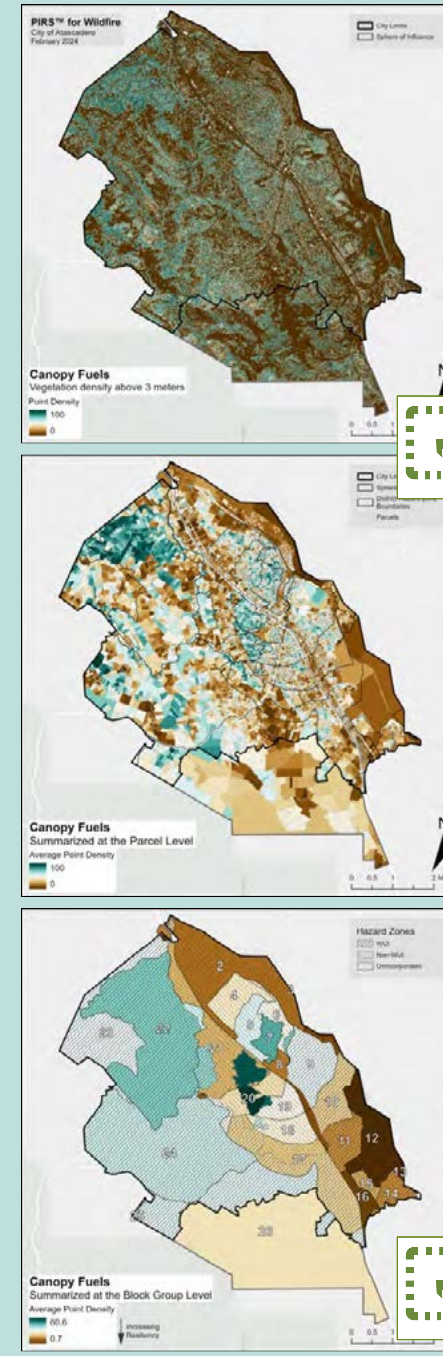


Figure 5: Percentage of parcels within each district-hazard zone with structures built after 2008. Presenting parcel-level data summarized to the district-hazard zone level allows for more direct comparison to the PIRS TM policy score and social vulnerability assessment results.



Figures 6, 7 & 8: Canopy fuel density summarized by parcels in Atascadero. LiDAR Point clouds were processed to create 30m resolution raster datasets of fuel density for three distinct height ranges (surface, ladder, and canopy fuels). These layers were used to summarize fuel loads within parcels by calculating average density within. When this data is mapped by DHZ, direct comparison to the PIRS M policy score, social vulnerability, and other mapping results is enabled.

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these plans are frequently poorly integrated and may, in fact, exacerbate vulnerabilities including the risk of wildfire especially in the wildland urban interface (WUI).

Fire suppression has proven inadequate as a mitigation strategy, and new approaches are needed. One such approach is the **Plan Integration for Resilience Scorecard™ (PIRS™)** for Wildfire, a method and tool currently under development in collaboration with several California communities that have high fire hazard risk. PIRS™ for Wildfire enables the systematic and spatial evaluation of a community's network of plans to strengthen wildfire resilience. It provides an informed way of helping the built environment to become fire safe.

By collaborating with several California communities (including the cities of Atascadero and Temecula and Santa Barbara County), we seek to harmonize the guidance provided by their networks of plans, assessing their plans spatially and through the lens of wildfire risk to facilitate adjustments that improve coordination, and strengthen wildfire resilience in the most vulnerable locations.

The PIRS™ method used on this research project was originally developed for flooding hazards with funding from the Department of Homeland Security Science and Technology Directorate. It has since been adopted as a preferred method by the American Planning Association (APA).

The PIRS™ for Wildfire Process Steps:

1. **Delineate "district-hazard zones":** To reduce "ecological fallacy" issues and enable spatial plan and policy evaluation, the community is first subdivided into relevant planning districts (e.g., neighborhoods, U.S. Census block groups) and hazard zones (e.g., Fire Hazard Severity Zones, WUI zones), which are combined using GIS to form a layer of mutually exclusive "district-hazard zones", the spatial unit of analysis for a PIRS™ for Wildfire analysis.
2. **Review the community's network of plans:** The community's network of plans (e.g., General Plan, Hazard Mitigation Plan, CWPP, Climate Action Plan) is then closely reviewed for actionable policy statements that are likely to affect wildfire resilience, either positively or negatively, and that contain some sort of place-specific term that helps identify where they apply (and where they do not). Relevant policies are added to the scorecard.
3. **Evaluate plans spatially:** Each policy is then given a score of "+1" (increases wildfire resilience), "-1" (decreases resilience), or "0" (neutral) and assigned to the appropriate district-hazard zone(s) based on its place-specific term. This is repeated for all relevant policies across the community's entire network of plans. Scores are then summed for each district-hazard zone (Figure 2).
4. **Assess other types of vulnerability (optional):** Social, physical, or other types of vulnerabilities can also be spatially assessed and compared to the spatial plan evaluation. The location of critical facilities or evacuation routes may also be considered (Figure 3).
5. **Analyze results:** Tables and maps of the results help identify spatial patterns, synergies, conflicts, and gaps in the community's network of plans and policies and how it is likely to affect wildfire risk.
6. **Advance plan integration and wildfire resilience:** Guided by the spatial and hazard focused PIRS™ for Wildfire analysis, community plans can then be improved by adjusting or adding policies (e.g., clustering development in the WUI) to resolve identified conflicts and strengthen wildfire resilience.

Primary geospatial objectives of the PIRS™ for Wildfire effort center around refinement of incorporated fire hazard delineations and increasing the tool's reach by improving accessibility. To provide an additional, finer-scale dimension to the geospatial assessment of wildfire hazard in PIRS™, data products at the parcel level were created. For the pilot community of Atascadero, CA, variables relevant to the wildfire hazard and community resilience – such as emergency response time, vegetation density, and the applicable building code based on the year of construction – were acquired at the parcel level. The resulting data were produced at the parcel level and summarized to the district-hazard zone level, providing planners multiple scales to assess and address hazards in policy revisions (Figures 4, 5).

A key effort in refining hazard mapping within Atascadero was incorporating fine-scale wildfire fuels data. Three-dimensional LiDAR point clouds of above-ground, terrestrial land features in the city were acquired and processed into raster layers depicting densities of vegetation at different height above the ground: surface fuels (0-1 meters), ladder fuels (1-3) meters, and canopy density (above 3 meters) (Figures 6-8). These maps, summarized at various spatial scales, provide firefighting and planning decision-makers with indications of potential wildfire behavior and areas of heightened hazard. In future PIRS™ for Wildfire applications with other partner municipalities, fuel mapping will be incorporated when possible.

The GIS team is producing comprehensive guidance as part of a forthcoming PIRS™ for Wildfire Guidebook that will enable any user to carry out the analysis for their respective municipality, regardless of their capability with GIS. To further accessibility, there are also plans to adapt the PIRS™ GIS methodology to free, open-source software like QGIS to allow users from municipalities of all sizes and budgets to undertake the analysis. In addition, the team is exploring the application of data science to streamline policy selection from the network of plans, scoring, and/or revised policy language to strengthen wildfire resilience.

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