A Strategic Wildfire Planning Process for Orinda: Transitioning from Basic, through Adaptive, to Transformative Wildfire Resilience in Orinda, CA.

A proposal submitted to the City of Orinda, CA (6/25/2022)

Note: this proposal is subject to agreement between the City of Orinda and The *Sponsored Projects Office* (SPO) at the University of California, Berkeley

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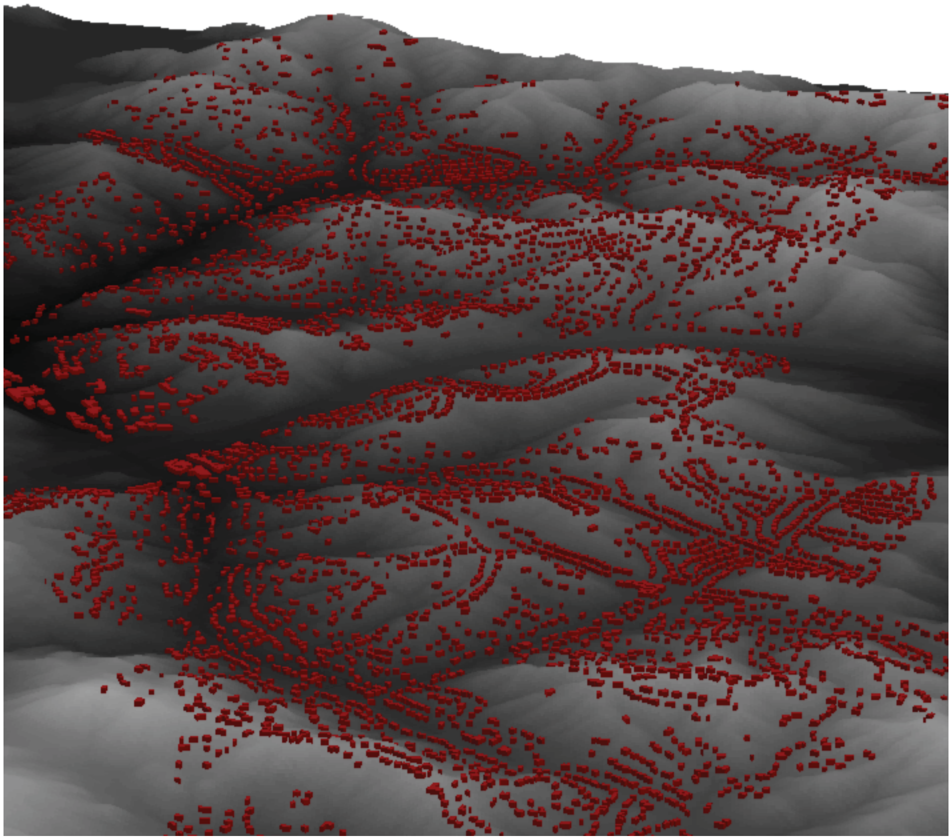

A Strategic Wildfire Planning Process for Orinda (5/11/2022)
Transitioning from Basic, through Adaptive, to Transformative Wildfire Resilience in Orinda, CA.

Introduction:

The City of Orinda needs a strategic wildfire planning process that is focused on defending individual property through a cooperative neighborhood mitigation initiative where the end goal is the reduction of fire intensity for all Orinda's citizens. If ignition occurs and the fire intensity escalates above a safe burn injury threshold, first responders must retreat, and property will be left undefended. This less than optimal strategy has been repeated over the many wildland-urban fires that have been witnessed since the record-setting 2017 fire season in California. The initiative we propose employs state-of-the-art scientific procedures to measure the fuels and assess the overall potential fire intensity of each neighborhood at a very high spatial resolution, in the City of Orinda. Our fire plan is focused on intelligent mitigation efforts where the stakeholder, i.e. the resident, is the center of the mitigation strategy, and the community at large can make more informed decisions about how and where their Measure R funds are best spent to maximize their return on investment. This research advances both wildfire mitigation strategies in general and introduces several new data gathering, processing and environmental modeling technologies in the academy.

Our proposal is to model the Orinda landscape at a very high spatial resolution of *one square meter*[1] and develop a plan for transformative resilience over a 26-month period based on research is driven by recent advances in information technology in the research fields of *Geographic Information Science* (GIS) and *Remote Sensing* (RS), as well as incorporating techniques driven by *Computational Geometry* (CG), and *Artificial Intelligence* (AI). Employing three students and a technical software programmer, this study includes support by experts from planning, landscape design, forestry, engineering, vegetation management, computer science, fire science and firefighters, who will be assisted by the residents of Orinda through web enabled crowdsourcing validation technology.

We propose a strategic wildfire plan that will address in its inventory both the vegetated landscape as well as the structural content of neighborhoods. Our study produces estimates of risk under various weather/climate conditions for each property, each neighborhood, and for the city as a whole. We do not follow the typical wildfire planning policy of *one-size-fits-all*, as many other communities in California do. Orinda's landscape is anything but homogeneous. We propose a strategic wildfire plan that is born out of a model of Orinda's risks, after which a coordinated hierarchical plan of where and how to mitigate will be implemented to build a wildfire safe community. Simply put, we solve the problem of what and where vegetation needs to be managed to most effectively mitigate and keep Orinda wildfire safe[2]. This dynamic wildfire safety plan will adapt and change over time as conditions improve, due to sound mitigation, or worsen, due to neglect or anthropogenic factors. Most of all our plan directly serves the stakeholders, those with the most to lose if a catastrophic wildfire event occurs, the citizens of Orinda,

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[1] Spatial resolution describes how much detail in an image is visible to the human eye and refers to the smallest possible feature that can be detected. In our proposed 1-meter image, each pixel represents a 1 meter by 1 meter square on the ground. Rather than several trees summarized in a pixel, we can see many pixels composing a tree.

[2] A wildfire safe community in our parlance means that fires may still occur, but the severity of the fires is controlled through the proposed mitigation strategies to reduce any fire's severity to a level where firefighter crews can effectively fight and control the fire.

the contributors to Measure R. Our plan delivers a dynamic system that has the capability of modeling, monitoring, and assessing neighborhood risk (and thus individual stakeholder property risk) of wildfire over time, allowing for iterative mitigation strategies to be modeled and outcomes quantified and evaluated.

After our dynamic wildfire safe community system is in place, egress strategies (exit routes) for numerous weather and wildfire scenarios can be formulated and coupled with evacuation strategies to build updated egress maps that can be published and delivered to the community as part of a safety pamphlet or online through a web enabled GIS for the public and emergency response community.

The Problem:

Orinda, surrounded by park-like wildlands, is a beautiful place to live. With picturesque landscapes, dramatic hills and valleys, lush vegetation, great open spaces and a much warmer and drier climate than those cities next to the SF Bay, Orinda is almost perfect. Unfortunately, many of these same characteristics make up the perfect conditions for a catastrophic wildfire.

Although often considered to be on the Wildland Urban Interface (WUI), Orinda is better characterized as a community where the “I” in WUI is better defined as Intermix (WUIx), as seen below in Figure 1.

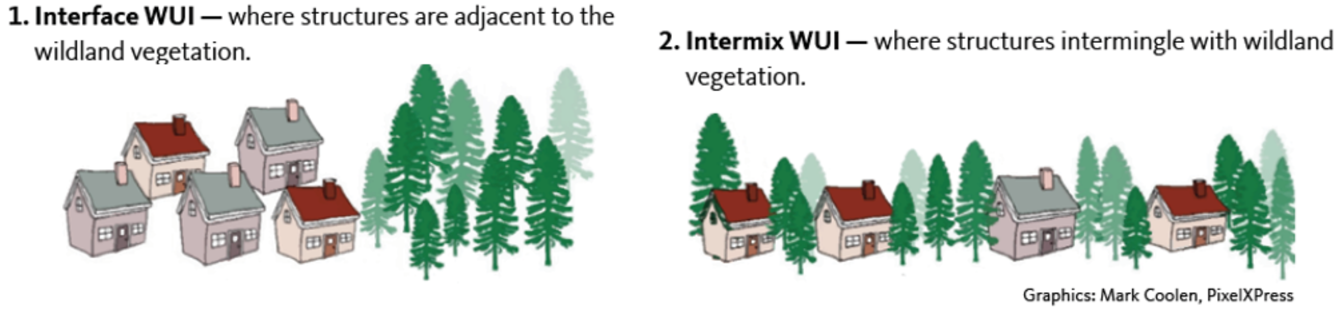
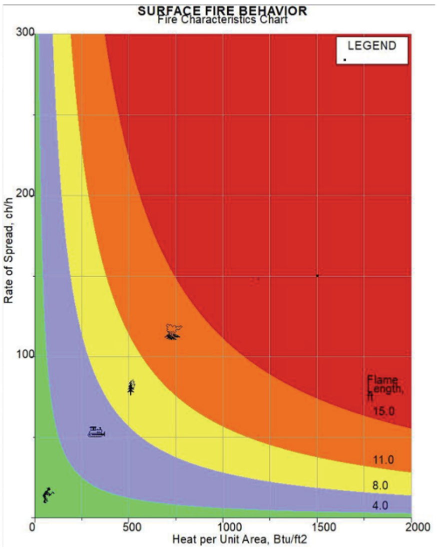


Figure 1: Wildland Urban Interface and Wildland Urban Intermix.

This Wildland Urban Intermix is much more difficult to defend and as safety must always be paramount, the probability of an uncontrollable firestorm is very real. If wildfire intensity rises beyond a safe burn injury threshold, firefighters will retreat because fire flame lengths of 8 feet or greater necessitate evacuating personnel for their safety, leaving the neighborhood undefended. The current wildfire strategies applied to wildland fires, while they may serve a regional need, do not directly address the complexity in Orinda’s Wildland Urban Intermix. A discussion of the Hauling Chart below may better explain wildfire behavior and suppression options that lead to first responder mitigation strategies.

Figure 2: The Hauling Chart



Increasing Control Difficulty

Metric Classes		Rate of Spread (ft/min)	Flame Length (ft)	Fire Intensity (BTU/ft^2)
Very Low/ None	🟩	0 - 5	0 - 4	0 - 100
Moderate	🟪	5 - 20	4 - 8	100-500
High	🟨	21 - 50	8 - 12	500 - 1,000
Extreme	🟧	50+	12+	1,000+

Fire is a series of ignitions. It begins with a source ignition and then spreads over the landscape. Vegetation is a key accelerant to spreading wildfires and therefore managing vegetation is one of the main mitigation strategies a community can undertake. From the *Hauling Chart* in Figure 2, we note that when a wildfire has a low *rate of spread*, a short *flame length* and is generating low *heat per unit area*, it is considered a very low intensity fire which can be suppressed by first responders, feet on the ground, up close and physically extinguishing the fire. This is a common suppression strategy used by most firefighting units called to extinguish a burning building in an urban area. Interpreting the *hauling chart* above, when the *rate of spread*, *flame length* and *heat per unit area* (or intensity) increases and moves from the *very low* (shaded in green) to *moderate* (shaded in purple), suppression strategies shift from boots on the ground to mechanical means such as cutting fire breaks with bulldozers. When the intensity increases to *high* (yellow), then to *extreme* (orange) and finally *beyond extreme* (red), suppression strategies involve retreating to a landscape downwind where a new defensive fire break can be established, and containment hopefully achieved.

We propose for Orinda a Strategic Wildfire Planning Process that delivers advanced impedance from such an intense catastrophic firestorm. This is a plan where various wildfire scenarios can be modeled, at-risk vegetation conditions can be targeted and mitigated, and where suppression strategies of retreat can be avoided, resulting in individual properties and neighborhoods being preserved.

This process aims to manage vegetation in new ways that allow firefighters to remain on site to effectively suppress any fire event, thus avoiding conflagration. We do this by identifying, modeling under various weather conditions, vegetation clusters where *rate of spread*, *flame length* and *fire intensity* are measured and classified from *acceptable* to *extreme*. We then map these conditions and iteratively apply mitigation strategies to reduce those identified as *extreme* to conditions that are manageable so that first responders can safely and effectively suppress the fire and save lives and property. Simply put, moving from the *red*, *orange,* and *purple zones* in the Hauling Chart, toward the *purple* and *green* zones.

Orinda, A Wildfire Plan for Transformative Resilience:

The resilience of communities to wildfire can be classified in three stages:

- **Basic Resilience:** Is the state that describes the ability of people and communities to recover or 'bounce back' from disasters.
- **Adaptive Resilience**: Is the state describing how human communities or social systems adapt to new or dynamic conditions by changing fundamental characteristics of the system, for example through regulation, zoning, and land-use planning.
- **Transformative Resilience**: The creation of fundamentally new systems. A transformative-resilience approach that requires a profound shift in the human relationship with wildfire—one that embraces the dynamic and rapidly changing role of fire in social–ecological systems.

Our plan emphasizes that **Transformative Resilience** is necessary if Orinda is to successfully armor itself against the threat of a catastrophic firestorm. In this scenario of resilience, neighborhoods will undertake targeted vegetation mitigation and produce landscapes that will become resilient to wildfire conditions that would cause fire fighters to retreat. Simply put, we will identify and remove dangerous fuels from the neighborhood *firesheds*[3].

Wildfire Plan Objectives:

Objective 1: Fire resistant landscapes

Establishing a safe and sustainable community in Orinda requires a comprehensive risk management approach and monitoring of the WUIx landscape through the lens of a transformative resilience framework.

- **Understand current landscape conditions using change monitoring**: Analyze landscape resilience to wildfires using effective vegetation return data.
    - Map pre-fire vegetation and calculate its density and estimating its biomass.
    - Model post-fire or post-mitigation vegetation regrowth and return using vegetation change monitoring.
    - Compare previous wildfire events in other northern California communities using burn area extent and burn severity with amount of regrowth based on NDVI time-series data.
    - Consider vegetation growth in WUIx (intermix) and WUI (interface) over time.

    ***Deliverable** → Develop a spatial risk metric based on vegetation density (spatial distribution), vegetation regrowth and burn severity history, vegetation fuel type.*
- **Explore wildfire hazards in the landscape:** Determine high risk fuel model types, ladder fuels, dense fuel build-up areas, etc. in the landscape.
    - Identify key wildfire hazards in the WUI (i.e. ladder fuels, fuel type distribution, firesheds) and classify into a risk matrix.

    ***Deliverable** → Develop a combined hazard risk map of Orinda that can be used to manage vegetation and risk, leading to landscape-scale wildfire response options for MOFD firefighters. Here we introduce a Burn Intensity Potential **(BIP)** metric.*

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[3] A *fireshed* is a landscape feature where both topography and fuels form a natural physiographic landform or ravine styled neighborhood, usually with three walls that form a steep and narrow chute, where wind speed increases and upslope radiation from burning vegetation increases wildfire risk.

- **Capture landscape resilience at high resolution for timely updates and fine detail:** Vegetation classification using high resolution remote sensing data with feedback from crowdsourced (citizen) reference data, fulfilling a transformative resilience framework.
    - Undertake a supervised classification of vegetation species using high resolution remote sensing data and LiDAR data using a deep learning model.
    - Produce high quality validation vegetation map results with the software system, *Spectobase*.

  Deliverable *→ Data-driven, spatio-temporal vegetation classification map with timely fuel conditioning update potential using feedback from Spectobase.*

Objective 2: Fire behavior modeling

Forecasting fire behavior under various conditions is crucial for effective early response and warning, thereby mitigating catastrophic damage to critical infrastructure, valued assets, and the livelihood of the citizens.

- **Understand fire behavior in current landscapes:** We will assess wildfire risk using **FLAMMAP** (fire probability map using *fireline intensity* and *rate of spread*) and **FARSITE** minimum travel time (MTT) fire modeling systems.
    - Compare *rate of spread* (ROS), *fire intensity* (FI) under different scenarios (average, extreme → *energy release component* (ERC) 80th and 97th percentile). Evaluate landscapes using the Hauling chart.

  Deliverable *→ Wildfire risk probability map for multiple fuel moisture and fire weather scenarios.*

- **Envisioning fire behavior by creating firefighter friendly communities**: Assess the effectiveness of current fuel breaks and vegetation mitigation in the landscape. In addition, adding optimal locations for mitigation and treatment practices on the landscape to create ideal, firefighter friendly landscapes where firefighters can remain to effectively fight fires because the magnitude of any potential fire is constrained in flame lengths, rate of spread and fire line intensity to values safe for in the field firefighting response.
    - Implement synthetic fuel breaks and harvesting in fire spread simulations where parameters are estimated using historic wildfire events.

  Deliverable *→ Wildfire risk probability map of idealized landscape scenarios under the same fuel moisture and fire weather scenarios.*

- **Fire weather modeling using crowdsourcing:** Leverage weather measurements from citizen's backyards using real-time PurpleAir measurements and model fire weather at local/community scale. The measurement data can be ingested via a data-driven pipeline to model and predict future fire weather and fire behavior simulations, especially with climate change projection model data.
    - Utilize PurpleAir weather measurement sensors to model fire weather using machine learning. In addition, use PurpleAir measurements to support RAWS (Remote Automated Weather Station) measurement data used in fire behavior simulations.

  Deliverable *→ Wildfire risk probability map for downscaled fire weather data.*

Objective 3: Best Wildfire-Safe Orinda: The Defensible Neighborhood

Creating a fire resistant, wildfire-safe Orinda requires high resolution mapping of the wildfire hazards needed to characterize the neighborhood for each property. The greater detail is crucial in informing citizens with an up-to-date diagnosis of landscape resilience, exposure to wildfire risks, and customized recommendations for defensible space and mitigation requirements. This strategic planning process, founded upon transformative resilience, will facilitate, and maintain the Orinda's sustainable landscapes against potential catastrophic damage from wildfires.

- **Identify landscape wildfire hazards at neighborhood scale**: Compare vegetation fuel maps and wildfire hazards (from Objective #1) as well as wildfire risk probability (from Objective #2) with respect to residential housing parcels and buildings. Also consider key spatial units such as *high-risk severity zones* and *high risk critical infrastructure* (i.e. power stations and utility lines).
    - Map residential parcels based on wildfire hazards using high resolution images to create a comprehensive high resolution wildfire hazard risk map for the community.

  Deliverable *→ Classification map of landscape resilience to wildfire for individual residential parcels.*

- **Identify accessibility of first responders:** Model the transportation network and run various accessibility, connectivity, vehicle routing and location/allocation analysis.
    - Map residential parcels based on first responder accessibility including analysis that considers *suppression difficulty index*.
    - Map residential parcels based on egress time using mobility traffic data and evacuation models.
        - Compare first responder accessibility and egress time for any discrepancy issues
        - Optimize school, nursing home, daycare and neighborhood evacuation under various conditions learned from Objective #1 and Objective #2.

  Deliverable *→ Classification maps of accessibility including choke point metrics to help guide wildfire response and evacuation routing.*

- **Create citizen-customized defensible space recommendations**

  Compare vegetation fuel maps (from Objective #1) and wildfire hazards (from Objective #1) as well as wildfire risk probability (from Objective #2) in terms of travel time (i.e. fire spread arrival time + required egress time) with respect to residential housing parcels to generate customized defensible space measurements.
    - Develop robust delineation of defensible spaces for residential parcels based on wildfire hazards, fuel type distribution, wildfire risk probability, and egress time.
    - Assessment of unallocated space in defensible space recommendations, considering land proprietary rights and mitigation feasibility.
    -

  Deliverable *→ Map of customized defensible spaces for Orinda. Identification and recommendation for priority areas for home hardening.*

  Deliverable *→ Develop a spatial unit (or metric) based on collective proprietary risk against wildfire risks. In addition, considering unassigned and overlapping areas. (Delineated defensible space such as those illustrated in Figure 3 below from Norton, 2021).*

Defensible spaces diagrammed for a set of neighbors neighboring the Santa Monica Mountain National Park

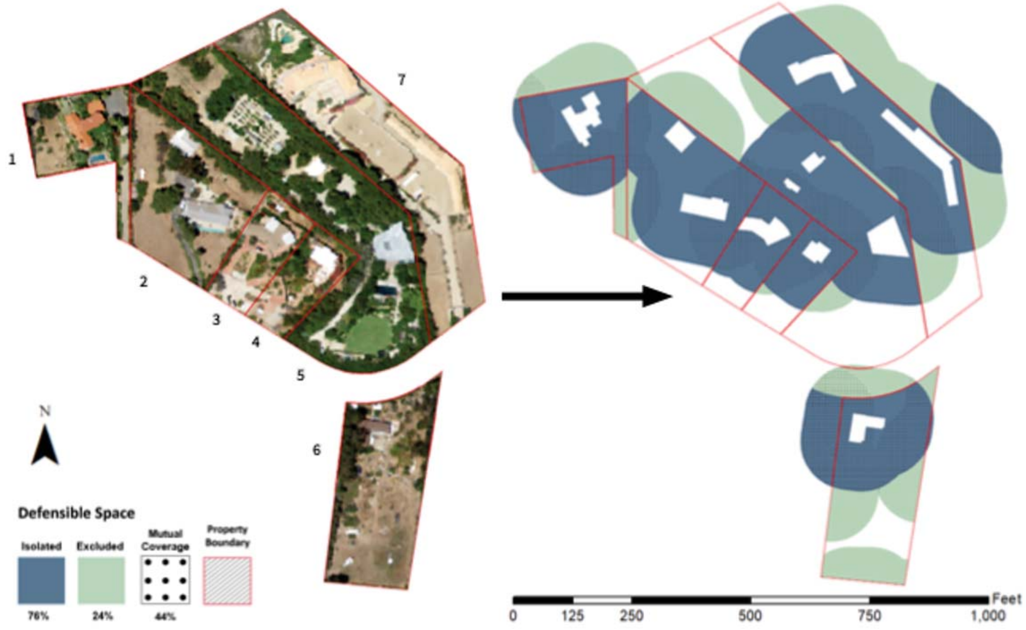


Figure 3: Defensible Space – Defined (Norton, 2021)

To achieve these **Planned Objectives**, and to better understand a chronology for our proposed planning, we break the project into numerous **Tasks**.

Work Plan Tasks and Methods:

Over the next 26 months, our team (three graduate students, a technical software programmer, two colleagues and myself) will accomplish the following tasks. While many tasks will be done concurrently, during the first 12 months, we will focus on Tasks 1-7. Once we have the data compiled, we will test our models, continue to refine them through crowdsourced data, and develop recommendations in months 12-24. The final months (25-26) will be focused on transferring the database and system to the City of Orinda so that they can use this infrastructure as part of the City planning efforts.

Task 1: Technical Advisory Committee

We begin by forming a *Technical Advisory Committee* (TAC) to guide us in refining the problem of citizen engagement, participation, communication, and fuel management. Members of this committee will come from various community groups such as: the Orinda City Council, the Supplemental Sales Tax Oversight Commission (SSTOC), the Orinda Firewise Council, the Moraga-Orinda Fire District (MOFD), and other identified relevant community organizations. The TAC will be briefed, on a monthly basis, of the progress of the research and asked for input during the process.

Task 2: Data Discovery

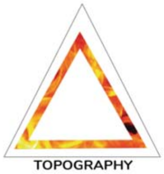
We begin the Data Discovery task by setting up a hierarchy of locations on our computer servers where we will store, preprocess, verify, sync, and certify all ancillary data and remotely sensed imagery. We will formalize and post (on a project web site) a list of all the ancillary data; its origins, spatial resolution, date, and other critical meta-data being used in the modeling and analysis phase of the project.

Task 3: Remote Sensing & Image Processing of Fuels, Vegetation and Structures

We will explore and analyze various remote sensing products to achieve an accurate estimate of Orinda's landcover and fuels inventory at a very high spatial resolution. We will assemble and process optical remotely sensed data from the National Agriculture Imagery Program (NAIP) from years 2016, 2018 and 2020. We will download Light Detection and Ranging (LiDAR) data from 2018 to create high-resolution models of ground elevation and objects with a vertical accuracy of 10 centimeters. We will download and assemble PlanetScope imagery from 2018 and 2022 to be used for rapid change detection in landcover. In addition, we will use multispectral satellite images from Sentinel-2 to help improve vegetation classification and hazard identification.

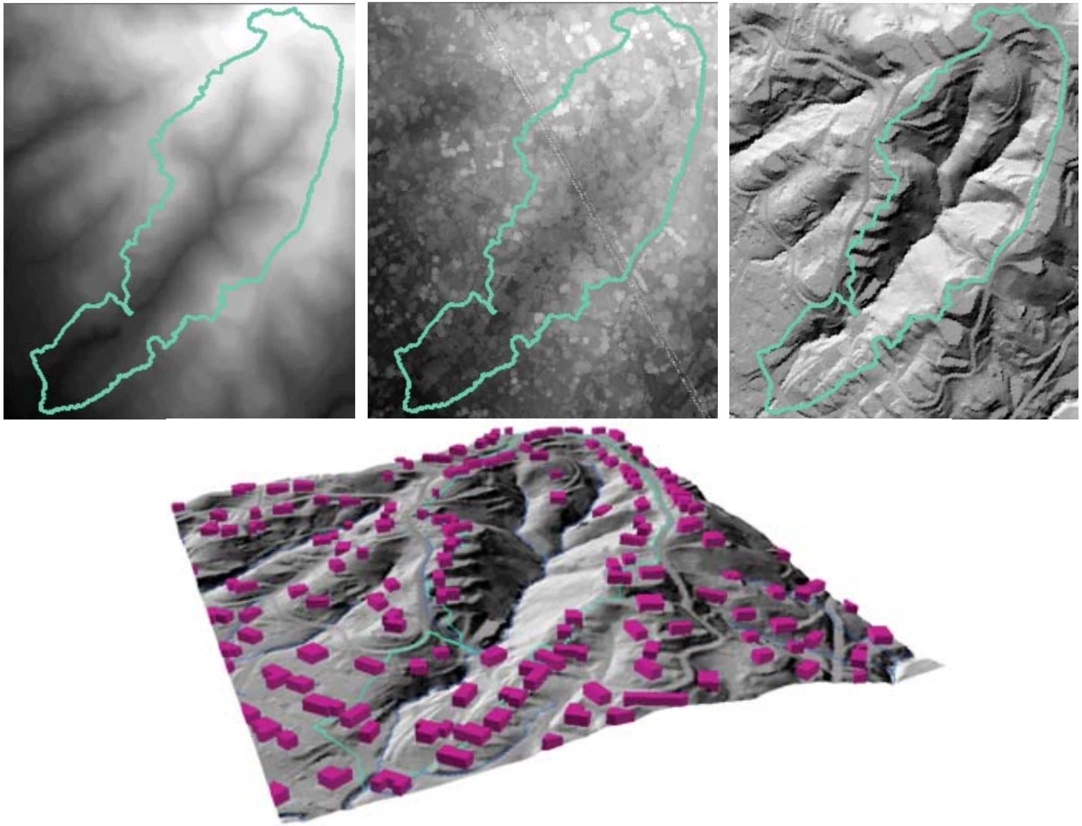
Figure 4: Remotely Sensed Data

Task 4: Building Metrics of Topography



We have already developed technology tools (in the form of software scripts) to characterize high risk *firesheds*, topographic features with three walls that form a steep and narrow chute where wind speed increases and radiates upslope vegetation. We begin the characterization process of *firesheds* by building a number of topographic features that include a Digital Elevation model (DEM) and a Digital Surface Model (DSM) from the Lidar dataset acquired in Task 2 and processed in Task 3. From here our technology normalizes the surface data and calculates the height of all objects on the ground surface. With a very high resolution model of both the ground and objects on the surface, we will employ software tools to characterize and delineate *firesheds*. An example *fireshed* is outlined by the teal polygon edge in Figure 5 below.

Figure 5: Topographic Surfaces with Fireshed Delineated in Teal



These *firesheds* define a new neighborhood where properties in the *fireshed* have a common goal to reduce the *fire intensity*, *rate of spread* and *flame lengths* to reduce the risk of an uncontrollable firestorm.

Task 5: Building Machine Learning Tools for Initial Trials in Identifying Fuels and Structures

We have already developed technology tools to undertake unsupervised classification of multiband remotely sensed imagery. We will use both pixel-based and object-based image analysis (OBIA) for an initial trial in identifying and classifying detailed structures and vegetation that fuel wildfire. This classification will be trained with input from on-the-ground data. Here we will employ both the spectral bands of the imagery and the spatial dimensionality as well as the height of the objects from the LiDAR data to improve the land cover fuel classification.

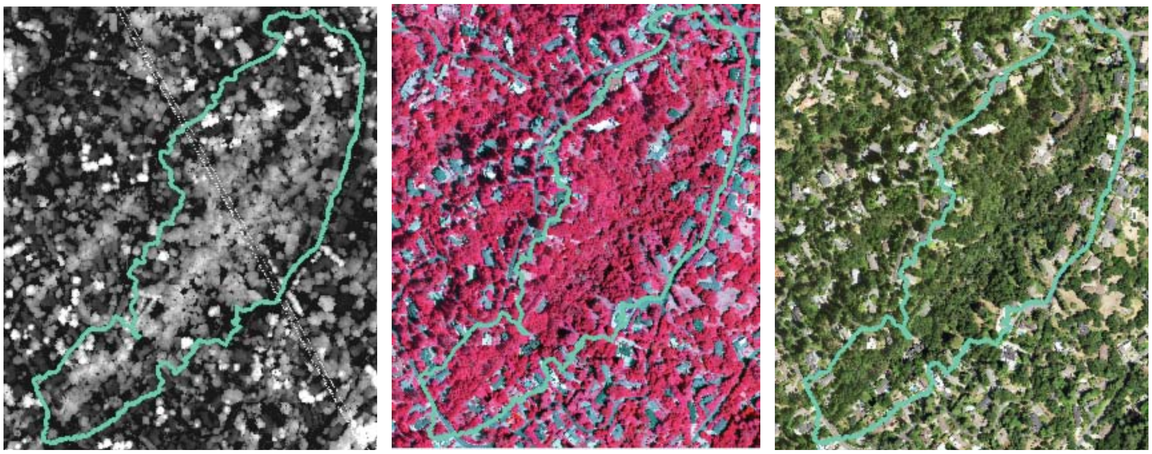


Figure 6: Height of Objects and Spectral Bands for Fuels Identification

We will employ spectral bands of the imagery to generate a Normalized Difference Vegetation Index (NDVI) to quantify vegetation greenness to better understand vegetation density and detect changes in plant health. We will generate a Soil Adjusted Vegetation Index (SAVI) to correct the NDVI for the influence of soil brightness in areas where vegetative cover is low. This often occurs after vegetation mitigation has been undertaken and facilitates a quantification of its effectiveness.

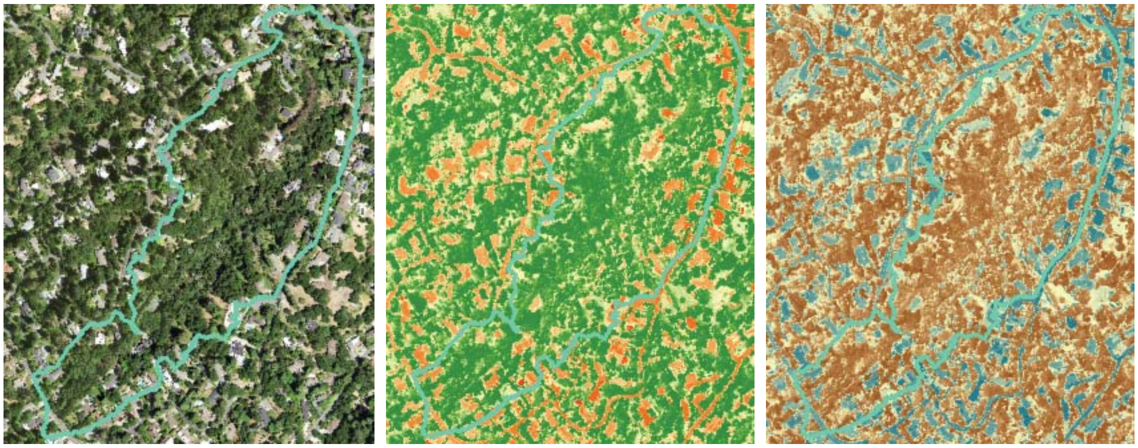
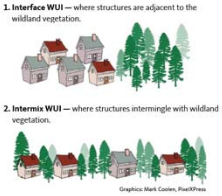


Figure 7: NAIP image, NDVI and SAVI for Plant Health

We will check the accuracy of the remotely sensed fuels classification by means of in-situ observations (direct observation and measurement in the field, commonly referred to as ground truth).

Task 6: Defining the Wildland Urban Interface (WUI) and the Wildland Urban Intermix (WUIx)

Orinda's Wildland Urban Interface will be delineated and after consulting with MOFD, fuel breaks will be designated, virtual prescriptions will be adjusted, and vegetation models prepared for simulations in our wildfire modeling Task 10. The rest of the mapping and modeling process will focus on defining and characterizing various Wildland Urban Intermix landscapes and preparing them for the Task 10 wildfire simulations.



Graphics: Mark Coolen, PixelXPress

Figure 8: Wildland Urban Interface (WUI) and the Wildland Urban Intermix (WUIx)

Task 7: Building Models of Extreme Weather Conditions

In this Task we will review weather conditions for: 1) a sample of weather conditions during extreme wildfires that occurred since 2017 in northern California, and 2) a sample of local (Orinda based) extreme weather conditions over the past 5 years. We will prepare a series of weather databases (*weather stream* (.wxs) considering several factors (*trends in the Vapor Pressure Deficit (VPD), dates, temperatures, relative humidity, precipitation, wind speed, wind direction and cloud cover)* for use in FlamMap/FARSITE simulation (in Task 8 and Task 10) through several possible red flag day conditions that occur in Orinda.

Figure 9: Diablo Wind conditions and Data for Weather Stream .WXS files

Task 8: Prototyping Fire Models in 3 *Fireshed* Neighborhoods

We choose three characteristically different *fireshed* neighborhoods to use as prototypes for our data: collection, processing, field verification, validation, and to optimize our geoprocessing and wildfire modeling workflow. We apply current mathematical models for fire spread that are primarily derived from laboratory, wind-tunnel experiments, and numerical simulations. These *Surface Fire Spread Models*, based on R.C. Rothermel's original research (Rothermel, 1972), are the primary wildfire intensity and spread models developed by the US Forest Service's Missoula Fire Sciences Laboratory and applied worldwide in the suppression of wildfires.

We apply two surface fire spread models, FlamMap and FARSITE, to the three *fireshed* neighborhoods. FlamMap is a fire behavior-modeling program designed to examine spatial variability in fire behavior. The model's basic features allow the characterization of fuel hazards and potential fire behavior, while the more advanced features allow for the investigation of fire movement and fuel treatment interactions. With this model we will simulate the potential wildfire behavior characteristics (*spread rate, flame length, fireline intensity*, etc.) for the three *fireshed* neighborhoods.

FARSITE computes wildfire growth and behavior for longer time periods under heterogeneous conditions of terrain, fuels, fuel moistures and weather. It uses similar model inputs to FlamMap and estimates surface fire, crown fire, spotting, post-frontal combustion, and fire acceleration displaying results as a two-dimensional fire growth map.

We will compute wildfire growth and behavior with detailed sequences of weather conditions from actual past weather events in Orinda. Along with integrating science to measure the fuels and assess the overall potential fire intensity of each neighborhood in Orinda, through simulation modeling of various mitigation strategies, we can quantify the reduction in burn intensity and reference the Hauling chart to determine when the neighborhood is becoming safe for first responders to engage the fire.

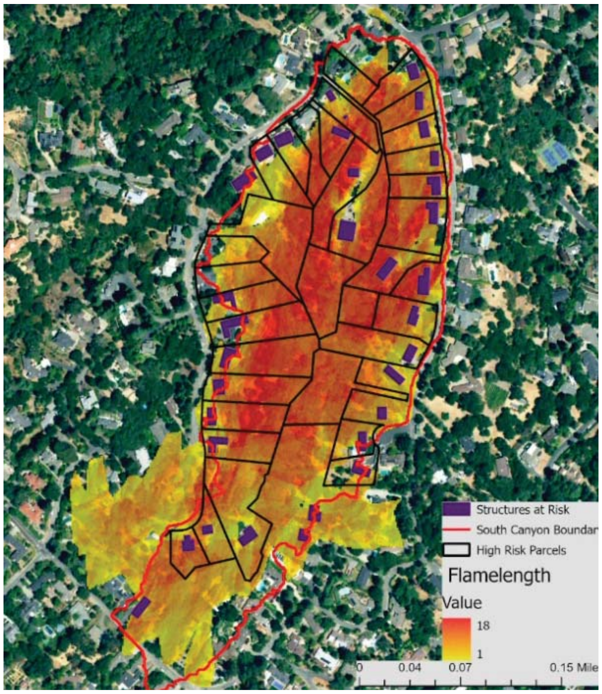


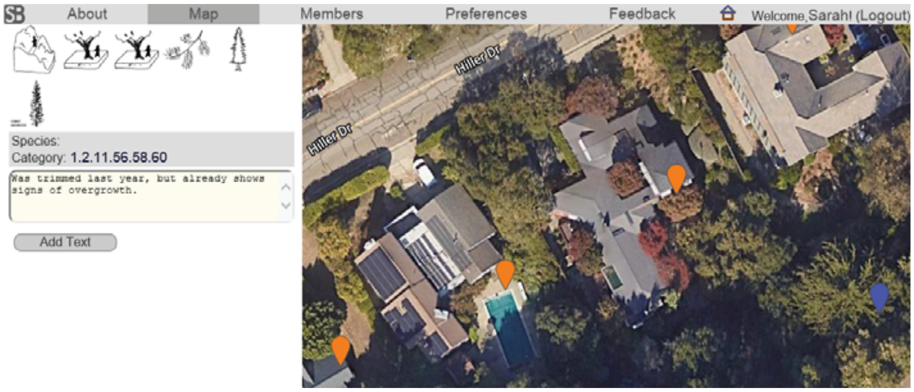
Figure 10: Prototype *fireshed* neighborhood simulated Flame Length (Raine, 2022)

Task 9: Citizen Crowdsourcing for Vegetation Validation

One of the critical ingredients to successfully modeling wildfire and establishing a sound mitigation strategy to reduce *fire line intensity* is to correctly identify *fuels* on the ground. Although our classification strategy uses multi-band, high resolution imagery, LiDAR, object-based image analysis, support vector machines, and machine learning accompanied with sampled direct observation and measurement in the field, it would be nearly impossible for our research team to find ground truth for all the properties in Orinda. However, Orinda's citizens have access to their own properties and with a little effort, accompanied with some online technology, citizens can become key stakeholders in a crowdsourcing effort to help validate our initial identification of vegetation conditions. This validation will increase the accuracy of our model simulations and help us better recommend strategies to make wildfire safe neighborhoods. Most importantly, the contribution from the citizens will establish a transformative form of resilience where homeowners can play a pivotal role in reshaping the sustainability and safety of their community's landscape.

In the past year we have developed online software for citizens so that they can contribute to identifying and validating the vegetation on their property. This software system is called ***Spectobase*** and is a privacy-oriented data management system designed for cataloging and manipulating data about vegetation used in creating models to assess and reduce wildfire risk. *Spectobase* facilitates vegetation identification and assessment through citizen validation (e.g., uploading images, picking species from a lookup database, typing in names and descriptions, answering a questionnaire). It assists with neighborhood mitigation strategies and provides an ongoing library of landscape conditions. This system is designed to become part of Orinda's digital infrastructure and will live on well after this proposed project is complete, keeping track of changes in vegetation.

Figure 11a: *SpectoBase* - web enabled software Interface



Species:
Category: 1.2.11.56.58.60

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Was trimmed last year, but already shows
signs of overgrowth.
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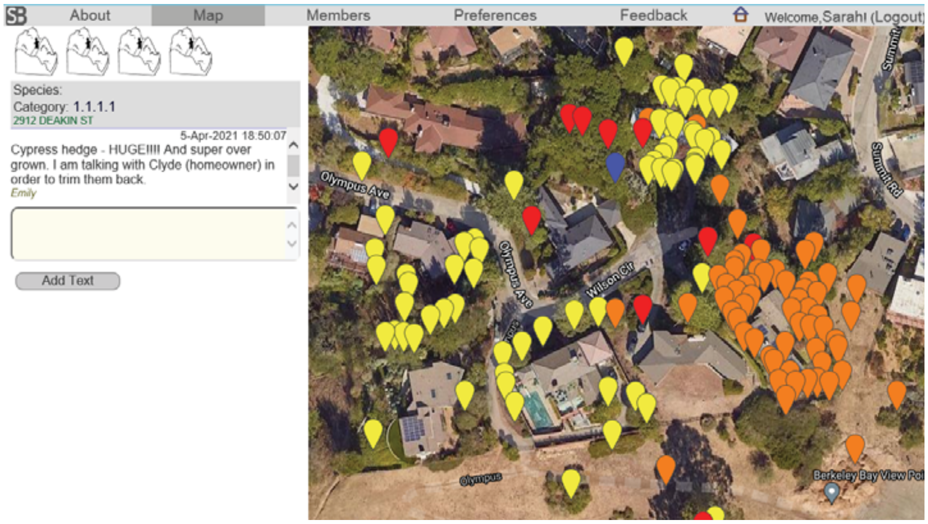
Figure 11b: *SpectoBase* - web enabled software Interface



Species:
Category: 1.1.1.1
2912 DEAKIN ST

5-Apr-2021 18:50:07
Cypress hedge - HUGE!!!! And super over grown. I am talking with Clyde (homeowner) in order to trim them back.
Emily

Figure 11c: *SpectoBase* - web enabled software Interface

We believe the most difficult part of this citizen crowdsourcing effort will be identifying the plant type and species. However, there are several smart phone apps that will identify the vegetation for you by simply taking a picture and searching for the plant's identity.

Task 10: Virtual Fire Model Scenarios in **all** *Fireshed* Neighborhoods

Once validation of the fuels is complete we will run city-wide wildfire model simulations in both FlamMap and FARSITE for various ignition sites with Red Flag Warning weather conditions. Weather and *fuel moisture codes* (FMCs) will be consistent with Red Flag Warning conditions (Diablo Wind Events), or high fire danger, extrapolated from historic red flag weather conditions: temperatures of 70-95°F, humidity 10-30%, and wind speeds 15-35MPH, and Wind Orientation. Iterative fire modeling scenarios (Figure 12) can be applied on a city-scale to support hazard area identification. Both ignition points and spotting probabilities will be discussed with the Technical Advisory Committee.

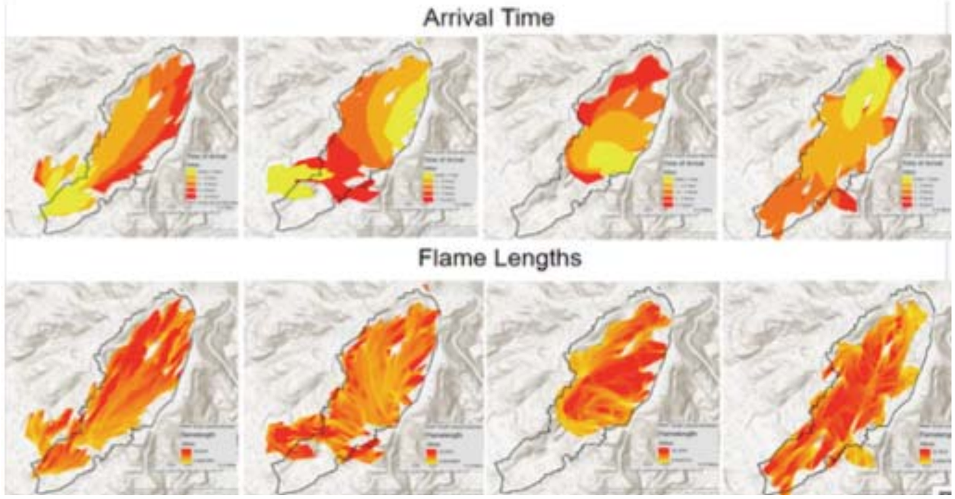


Figure 12: Arrival Time and Flame Lengths (Raine,H. 2022)

Task 11: Compliance Capability

Property owners can influence firefighter defense strategies by managing the fuels within defensible spaces. Well-managed vegetation on a property will serve to slow the *rate of spread*, reduce *fuel* load which will shorten the *flame lengths* and result in a lower *fire line intensity* therefore creating a firefighting friendly landscape making it possible for firefighters to effectively suppress the fire. When defensible spaces widely vary in a neighborhood, tactical firefighting defense strategies become limited. A patch work of indefensible spaces will quickly turn a neighborhood into one that is difficult to control on the ground and can possibly overwhelm efforts to suppress. California's State legislature passed CA PRC § 4291 in 2007 requiring all buildings in *high fire risk* areas to maintain defensible spaces (100 feet from each side of the building) sufficient for defending against wildfires burning under average weather conditions. However, in Orinda this is limited to within the property line, and it is highly likely that many building structures are within 100 feet of indefensible spaces on neighboring properties. In communities where structures are near property lines and where properties are relatively large and often irregularly shaped, like many of those in Orinda, this policy creates areas of exclusion where, although compliance is met, building structures remain at *high fire risk*.

In this Task we model all buildings and property lines in Orinda and classify defensible and indefensible spaces, highlighting those spaces where the policy is inadequate. Here a transformative-resilience approach builds a fundamentally new system that embraces a social–ecological system, where a neighborhood *fireshed* defines what spaces need to be defensible to ensure improved safety of all the properties in the neighborhood as well as firefighters needing to suppress fires.

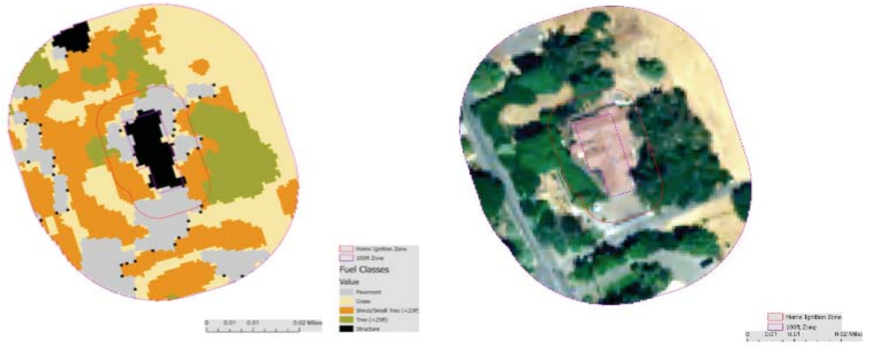


Figure 13: Defensible space of 100 feet around building structures (Raine,H. 2022)

Task 12: Mitigation Strategies

Once the model is complete and we have characterized and classified all *firesheds* in Orinda, we will meet with the TAC and discuss Mitigation Strategies for each neighborhood and possibly each property. After agreeing on vegetation management strategies, we will virtually modify the fuels in our database and rerun the simulations. We will follow this with a map of Orinda quantifying what improvements we can expect in *spread rate, flame length and fireline intensity* if the proposed fuels mitigation strategy is implemented. By combining this information with expert judgment from the TAC, we aim to recognize the most cost-effective approach to transform Orinda into a firefire friendly and resilient neighborhood.

Task 13: Tracking Mitigation Efforts on a 6 Month Cycle

We have developed technology to quantify vegetation change and thus track fuel mitigation over time from high resolution satellite images. Although mapping is possible on a weekly or monthly basis, it is more cost effective to do this seasonally or on a yearly cycle. We can characterize and quantify mitigation efforts in the city and track progress toward a safe Orinda.

This technology uses Planetscope imagery (4-band images at 3-meter *ground sampling distance* (GSD)) to generate a Normalized Difference Vegetation Index (NDVI) to quantify vegetation greenness, useful in understanding vegetation density and assessing changes in plant health. We then produce a Soil Adjusted Vegetation Index (SAVI) to correct the Normalized Difference Vegetation Index (NDVI) for the influence of soil brightness in areas where vegetative cover is low. We then compare data from the time periods in the chosen cycle and produce a change model. If our mitigation is successful, we hope to see a reduced NDVI. If vegetation has gone unchecked, we would likely see an increase in NDVI over time.

Below is an example of this process where we quantify the fuels mitigation efforts undertaken by PG&E near its Moraga substation on Valley View Drive between 2018 and 2021.

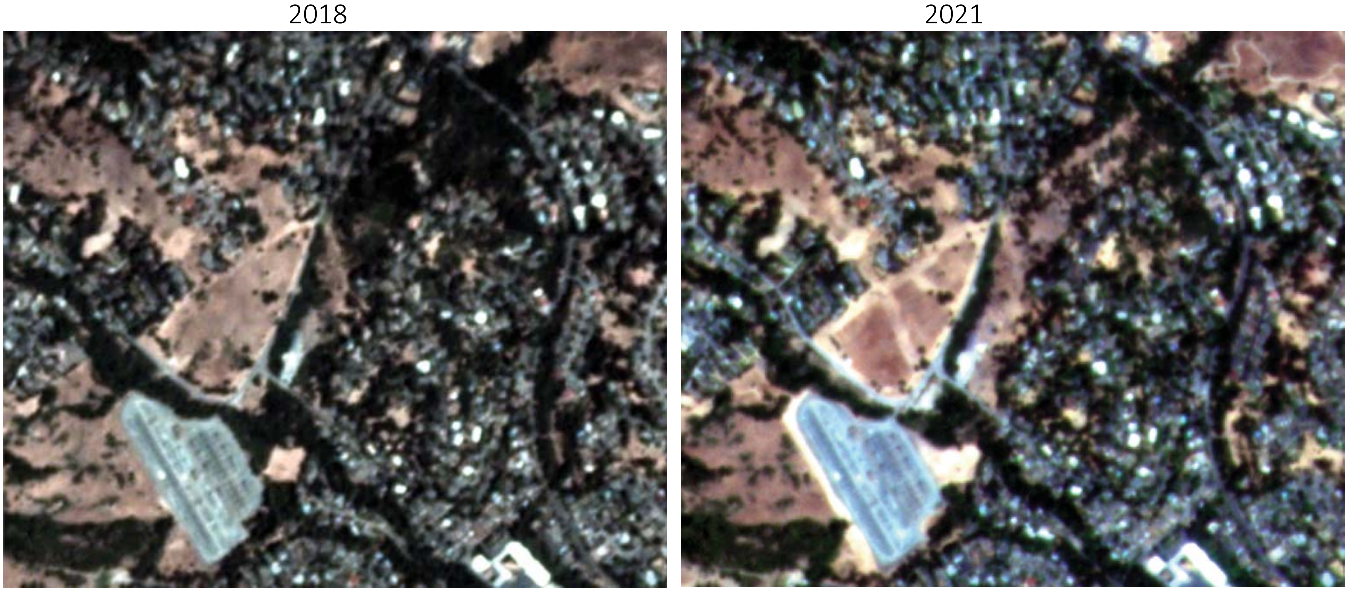


Figure 14a: Visible spectrum (bands 1,2,3) – Planetscope Imagery 3m GSD

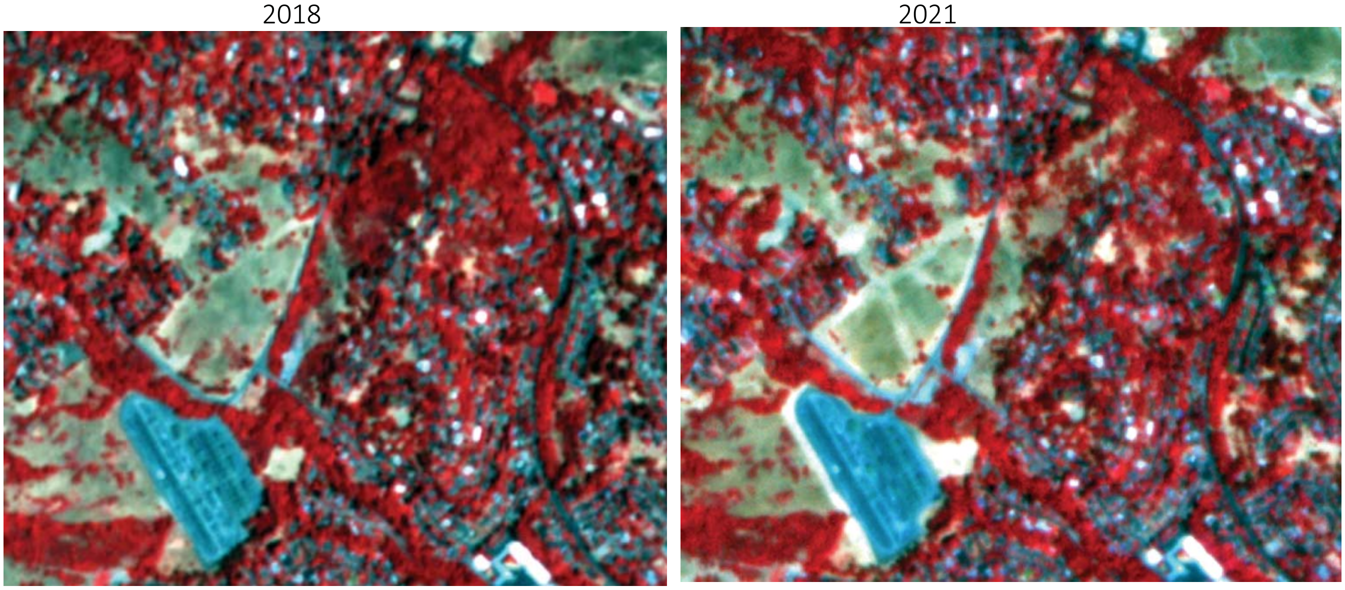


Figure 14b: Near Infrared *false color* (bands 4,3,2) – Planetscope Imagery 3m GSD

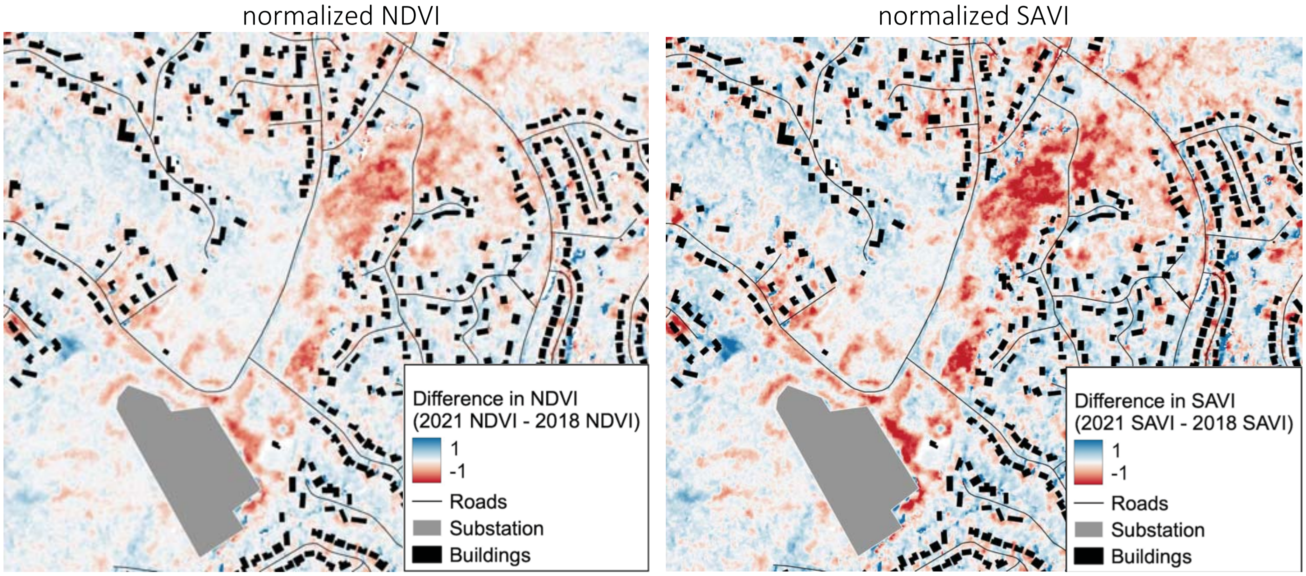


Figure 14c: Two Year Change in NDVI and Change in SAVI – Planetscope Imagery 3m GSD

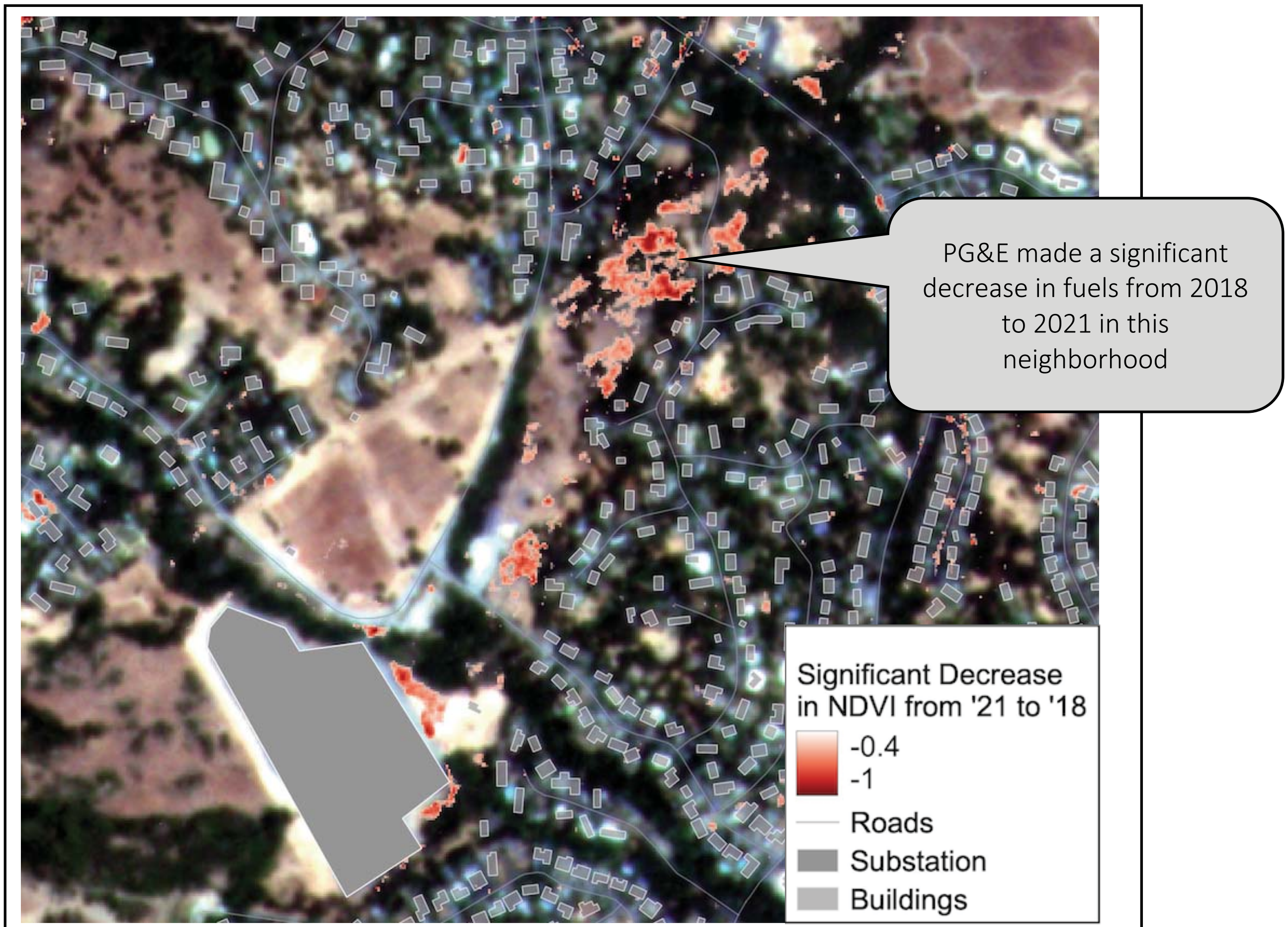

PG&E made a significant decrease in fuels from 2018 to 2021 in this neighborhood

Figure 14d: Significant Decrease in NDVI from 2018 to 2021 – Planetscope Imagery 3m GSD

Task 14: Egress scenarios

The final mapping of the current wildfire risk will leave us with targeted *hot spots* in the City of Orinda. We will have also built a topological network where we can undertake network analysis. We will use these data to identify critical nodes or intersections or narrow roadways where under various wildfire scenarios they could become impediments to egress. This will support stakeholders in their efforts to mitigate high risk areas of the city and alert first responders to possible *choke points* and provide them with a mechanism for developing Wildfire Response Options.

Task 15: Citizen Workshop

The results of this study will be presented at a public workshop and livestreamed to the Orinda public where we will explain the process, show much of the interim analysis and results, and close with the final results. It is our hope that the *Spectobase* dataset will live on as part of Orinda's digital infrastructure and that it will be used to track vegetation management for many years to follow.

We will present different fuel treatment scenarios at this workshop and be prepared to answer questions about individual homeowner landscape mitigation strategies.

Task 16: Dissemination of results

The results of this research will be made available in a printed report to the City of Orinda. In addition, the report will be accessible on the website where many of the products from this study will reside.

Summary:

Our proposal models the Orinda landscape at a very high spatial resolution of *1 square meter* based on our research driven by recent advances in information technology in the research fields of *Geographic Information Science* and *Remote Sensing*, incorporating techniques driven by *Computational Geometry*, and *Artificial Intelligence*. This study includes support by experts from planning, landscape design, forestry, engineering, vegetation management, computer science, fire science and firefighters, who will be assisted by the citizens of Orinda through web enabled crowdsourcing validation technology.

The results of this research will equip Orinda with a dynamic Geographic Information System that is unprecedented, one where vegetation is known, best strategies for mitigation can be implemented, and results can be quantified and monitored over time using remote sensing and citizen science.

This community wildfire safe plan is dynamic and will adapt and change over time as conditions improve due to sound mitigation (transformative wildfire resilience) or worsen due to neglect or anthropogenic factors. Our plan delivers a dynamic system that monitors, models, and assesses neighborhood risk (and thus individual stakeholder property risk) of wildfire over time, and allows iterative mitigation strategies to be modeled, evaluated, tracked and assessed. Orinda will be left with a valuable piece of digital infrastructure that could serve as a workbench for many other community efforts.

After our dynamic wildfire safe community system is in place, egress strategies (exit routes) for numerous weather/wildfire scenarios can be gamed and coupled with location/allocation strategies to build updated egress routes/maps that can be published and delivered to the community as part of a safety pamphlet.

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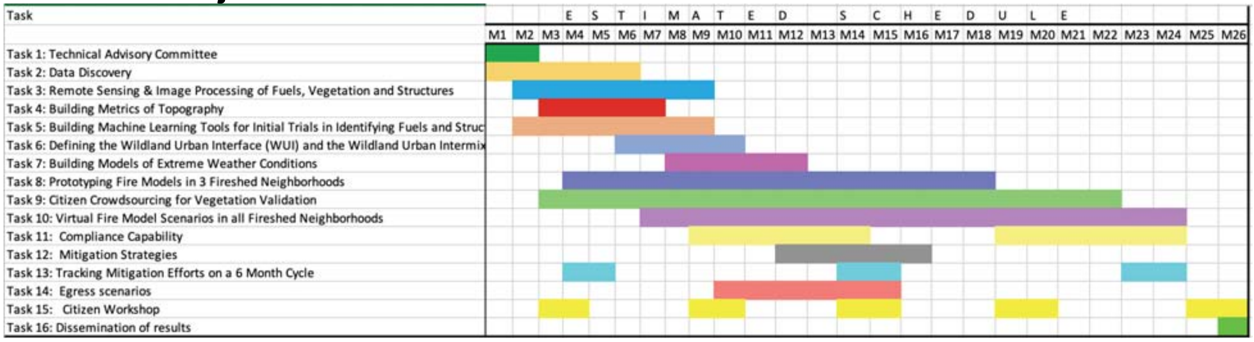
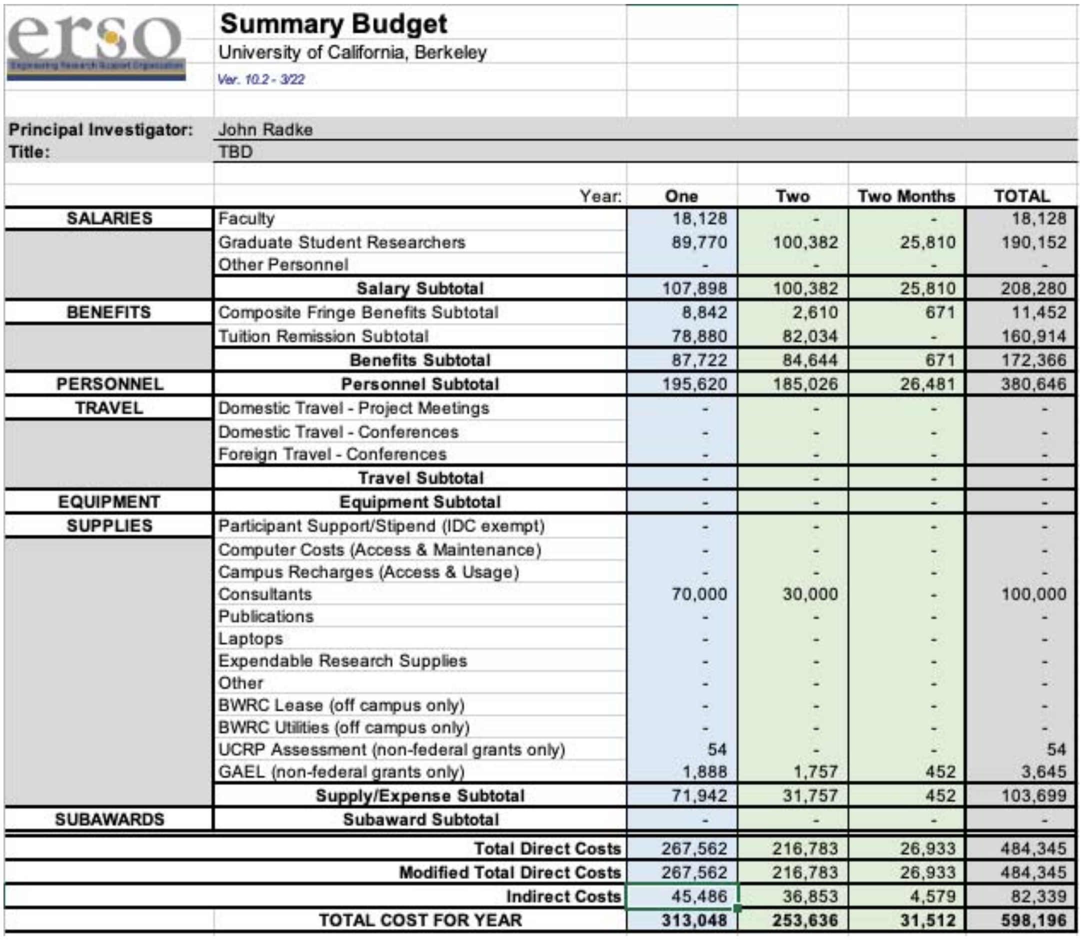
Personnel:

John Radke, Principal Investigator (PI) in charge of *fireshed* delineation, fire modeling, overall project
Marta C. Gonzalez, Co-PI in charge of networks, egress scenarios and strategies
Gregory Biging, Co-PI in charge of biomass and fuels assessment
Vladimir Ullyshin, Contract Programming of *SpectoBase*
3 Graduate Students, data acquisition, processing, modeling, analysis, and results.

Estimated Project Schedule:


Task
Task 1: Technical Advisory Committee
Task 2: Data Discovery
Task 3: Remote Sensing & Image Processing of Fuels, Vegetation and Structures
Task 4: Building Metrics of Topography
Task 5: Building Machine Learning Tools for Initial Trials in Identifying Fuels and Struc
Task 6: Defining the Wildland Urban Interface (WUI) and the Wildland Urban Intermix
Task 7: Building Models of Extreme Weather Conditions
Task 8: Prototyping Fire Models in 3 Fireshed Neighborhoods
Task 9: Citizen Crowdsourcing for Vegetation Validation
Task 10: Virtual Fire Model Scenarios in all Fireshed Neighborhoods
Task 11: Compliance Capability
Task 12: Mitigation Strategies
Task 13: Tracking Mitigation Efforts on a 6 Month Cycle
Task 14: Egress scenarios
Task 15: Citizen Workshop
Task 16: Dissemination of results

Proposed Budget:


Summary Budget
University of California, Berkeley
Ver. 10.2 - 3/22

Principal Investigator: John Radke
Title: TBD

	Year:	One	Two	Two Months	TOTAL
SALARIES	Faculty	18,128	-	-	18,128
	Graduate Student Researchers	89,770	100,382	25,810	190,152
	Other Personnel	-	-	-	-
	Salary Subtotal	107,898	100,382	25,810	208,280
BENEFITS	Composite Fringe Benefits Subtotal	8,842	2,610	671	11,452
	Tuition Remission Subtotal	78,880	82,034	-	160,914
	Benefits Subtotal	87,722	84,644	671	172,366
PERSONNEL	**Personnel Subtotal**	195,620	185,026	26,481	380,646
TRAVEL	Domestic Travel - Project Meetings	-	-	-	-
	Domestic Travel - Conferences	-	-	-	-
	Foreign Travel - Conferences	-	-	-	-
	Travel Subtotal	-	-	-	-
EQUIPMENT	**Equipment Subtotal**	-	-	-	-
SUPPLIES	Participant Support/Stipend (IDC exempt)	-	-	-	-
	Computer Costs (Access & Maintenance)	-	-	-	-
	Campus Recharges (Access & Usage)	-	-	-	-
	Consultants	70,000	30,000	-	100,000
	Publications	-	-	-	-
	Laptops	-	-	-	-
	Expendable Research Supplies	-	-	-	-
	Other	-	-	-	-
	BWRC Lease (off campus only)	-	-	-	-
	BWRC Utilities (off campus only)	-	-	-	-
	UCRP Assessment (non-federal grants only)	54	-	-	54
	GAEL (non-federal grants only)	1,888	1,757	452	3,645
	Supply/Expense Subtotal	71,942	31,757	452	103,699
SUBAWARDS	**Subaward Subtotal**	-	-	-	-
	Total Direct Costs	267,562	216,783	26,933	484,345
	Modified Total Direct Costs	267,562	216,783	26,933	484,345
	Indirect Costs	45,486	36,853	4,579	82,339
	TOTAL COST FOR YEAR	**313,048**	**253,636**	**31,512**	**598,196**

John D Radke

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John D. Radke is a faculty member in the College of Environmental Design at the University of California, Berkeley. He is a co-founding member of the Center for Catastrophic Risk Management and founded the Center for Geographic Information Science. He conducts research in the design and development of analytical methods that assist in recognizing spatial structure, measure changes in complex landscapes, and assess exposure under future climate change conditions. He advances and integrates high-resolution spatial data within data-rich multivariate models to predict the consequences of anthropogenic impacts on infrastructure in human habitats.

EMPLOYMENT HISTORY

Assoc. Professor, University of California, Berkeley, 1996-present, Berkeley, CA USA
Assist. Professor, University of California, Berkeley, 1991-1996, Berkeley, CA, USA
Research Assist. Professor, University of Pennsylvania, 1985-1990, Philadelphia, PA, USA
Information Scientist, AGRA Engineering Group Limited, Toronto, ON, Canada
Assist. Professor, Wilfrid Laurier University, Waterloo, ON, Canada

EDUCATION

- Ph.D. - 1983, Department of Geography, University of British Columbia, Vancouver, B.C.
- M.A. - 1977, Department of Geography, Wilfrid Laurier University, Waterloo, Ontario
- B.A. - 1975, Department of Geography, Wilfrid Laurier University, Waterloo, Ontario

SELECTED PUBLICATIONS (*: directly supervised students, postdocs, mentees, visiting professors):

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- Garcia-Ayllon,S.*; **Radke**,J. (2021) Geostatistical Analysis of the Spatial Correlation between Territorial Anthropization and Flooding Vulnerability: Application to the DANA Phenomenon in a Mediterranean Watershed. *Appl. Sci.* 2021, *11*, 809. https://doi.org/ 10.3390/app11020809
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Marta C. Gonzalez

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Marta C. Gonzalez's research team develops computer models to analyze digital traces of information mediated by devices. They process this information to manage the demand in urban infrastructures in relation to energy and mobility. Her recent research uses billions of mobile phone records to understand the appearance of traffic jams and the integration of electric vehicles into the grid. Smart meter data records to compare the policy of solar energy adoption. . Prior to joining Berkeley, Marta worked as an Associate Professor of Civil and Environmental Engineering at MIT, a member of the Operations Research Center and the Center for Advanced Urbanism. She is a member of the UC Berkeley Institute of Transportation Studies and the Berkeley Institute for Data Science (BIDS). She has participated in the scientific council of technology companies such as Gran Data, PTV and the Pecan Street Project consortium. Her mission is to put science and technology at the service of social well-being.

EMPLOYMENT HISTORY

2019 – Present	Associate Professor Engineering	University of California Berkeley
2017 – Present	Associate Professor Urban Planning	University of California Berkeley
2017 – Present	Faculty Research Scientist Physics	Lawrence Berkeley National Laboratory
2017 – 2019	Visiting Professor Engineering	MIT
2015 – 2017	Associate Professor Engineering	MIT
2009 – 2015	Assistant Professor Engineering,	MIT

EDUCATION

Universidad Simon Bolivar	Caracas (Venezuela)	Physics	B.S. 1999
Central University of Venezuela	Caracas (Venezuela)	Statistical Physics	M.S. 2001
Stuttgart Universität	Stuttgart (Germany)	Computational Physics	Ph.D. 2006
Northeastern University	Boston (USA)	Postdoc Statistical Physics	2006-2009

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EDUCATION

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Undergraduate: Natural Resource Sampling; GIS and Environmental Spatial Data Analysis Graduate: Advanced Natural Resource Sampling

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- Weise, D.R. and G.S. Biging. 1997. A qualitative comparison of fire spread models incorporating wind and slope effects. *Forest Science.* 43(2):170-180.

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