Wildfire’s Effects on California Chaparral and Management for the Future

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INTRODUCTION

Many environmental issues are becoming more prevalent than in recent years due to their significantly impact on human life. For example, sea level along coastal areas is rising, waters that support large populations are running dry, and areas of the world are experiencing extreme temperatures that were previously unheard of. One major environmental threat is wildfires in the western United States. Wildfires are a natural process necessary for ecosystems to maintain healthy growth, but human activity altered this process with high suppression management practices and rapidly increasing populations creeping into wildfire-susceptible areas, in addition to climate change. The current problem, specifically in California, is that wildfires are increasing in size and intensity and spread more rapidly than ever before. California wildfires are predicted to continue to follow this pattern, causing concern from residents, state government, and national government on how to effectively manage and prepare for the future.

California is the second largest state in the continental US. Of California’s 100 million acres, forest covers approximately 33 million acres or 33%, and is important for the state’s water system, economic income through timber sales and recreation, and wildlife/vegetation (Bedsworth et al. 62). The state has a growing population, with ~39 million people in 2017 that is expected to reach 44 million by 2030 (PPIC). A majority of California’s population “lives in lower elevations dominated by hazardous chaparral shrublands susceptible to frequent high-intensity crown fires” (Syphard et al. 1388). A crown fire is a forest fire the spreads from treetop to tree top (Image 1). The state is
ranked first for the number of households, ~2 million, that are at high or extreme risk from wildfires (Facts), making current and future wildfire management an important subject.

There are a wide range of temperature and precipitation patterns across the state due to California’s topography and proximity to the Pacific Ocean (Image 2). Because of this, the state exhibits many unique ecosystems, ranging from coastal regions to shrubland to deserts such as Death Valley to mountains such as the Sierra Nevada’s. Each of these geographic features result in varying climate systems, which is a key player in wildfire’s role, frequency, intensity, etc. of an environment (Image 3). The geological history across the state is very unique and one of the most complex systems in the Western Hemisphere due to the conjunction and movement of plates (Halsey and Keeley 2016). The highest and lowest points, Mt. Whitney (14,505 ft) and Death Valley (-282 ft), are 80 miles from one another indicating major uplifting activity and the San Andreas fault run SE to NW shifting land masses past each other.
Image 3: Classification of climate systems (Kaufmann)
PURPOSE AND NEED

The main question, and the focus of this thesis is: “How do the natural and human systems related to California’s chaparral wildfire regimes influence ecological and social management decisions?” Due to the past management of fire, urbanization introduced into wildland areas, and the growing pressures of climate change, this issue is important because it could dramatically change the look and understanding of California’s landscapes. The aesthetic changes of a landscape post-wildfire are easy to see, however factors such as erosion and hydrology are more difficult to identify. The first goal of this paper is to address chaparral vegetation and its relationship to fire to then discuss current models for erosion and hydrologic changes in a landscape post-fire. Knowledge on these natural processes is important and require accurate data and predictions in order to plan land management actions accordingly. Knowing how chaparral landscape’s erosion and hydrology respond pre- and post-fire will indicate what to expect if fire patterns change. How do this knowledge and science inform decision making?

The second goal is to look at past fire management in the United States, current management, and the future of fire management in California. With the complexity that comes with cooperation and politics among many groups, I conducted an interview with an expert in fire management and fire science to fill in the gaps of knowledge and explain the processes required for effective decision making regarding fire management in the present and future.
Overview of Chaparral

Chaparral is a significant Mediterranean vegetation community on the Western Coast of the United States. The iconic vegetation ranges from southern California, extending to the lower elevation Coastal Ranges, and western slopes of the Sierra Nevada (Underwood et al. 2018) (Image 4). Central Chile, Mediterranean Basin, South Africa, and Western Australia are the four other Mediterranean climate types located around the world that host similar vegetation (Halsey). The Mediterranean climate in California is characterized by three variations based on region: (1) cool summers/cool winters along the coast and western Sierra Nevada, (2) frequent summer fog along the coast, and (3) inner valley has hot summer/cool winters (Kauffman). The majority of precipitation occurs during the winter with dry summers (Kauffman).

Chaparral covers coastal mesas, canyons, foothills, and mountain slopes mostly below 5,000 ft. elevation (Halsey, North American Chaparral). Soil that the vegetation grows in tends to be young, but can range from deep, weakly developed soils to shallow, rocky soils with relatively low nitrogen, potassium, and phosphorous (Halsey, North American Chaparral). These soil types are typically well drained, course grained, and composed of highly weathered minerals creating a
situation where soil is very susceptible to erosion and landslides without the added influence of fire (North American Chaparral).

Chaparral is generally composed of diverse, sclerophyllous shrubs (Halsey). Sclerophyll vegetation is “characterized by hard, leathery, evergreen foliage that is adapted to prevent moisture loss”, which is especially important due to the hot, dry summers in California (Sclerophyll). The distribution of chaparral vegetation consists of 35% annual herb, 39% perennia herb, 19% shrub, and the remaining 6% is trees and other species (Underwood et al. 2018). California’s chaparral can be referred to as “hard” (ex: Sierra Nevada foothills) or “soft” (ex: coastal scrub) chaparral depending on the local habitat or geographic region (Loáiciga et al. 2001). “Soft” chaparral vegetation is non-sclerophyllous, or has soft leaves, occurring on plants 0.5 to 2.0 meters tall covering areas of sparse to complete degrees of vegetation density, whereas “hard” chaparral exhibits complete vegetation coverage that is sclerophyllous, or hard-leafed, and ranges in heights of 1.5 to 4.5 meters (Loáiciga et al. 2001). A variety of common vegetation species in coastal scrub exists (Image 5). The abundances of plants vary by region and elevation and the local distribution varies by soil and slope aspect (Loáiciga et al. 2001).

Chaparral in Mediterranean climates hosts the highest species diversity (plant and animal) throughout California and supports 7x more species richness on per-area area basis than the rest of the continental United States (Halsey and Keeley 2016). For this reason, the state has 25 locations designated as biodiversity hot spots, with many losing an exceptional amount of habitat (Halsey and Keeley 2016). Chaparral has 18% more total number of rare plant species per area than other plant communities (Halsey and Keeley 2016). In addition, the state itself ranks 1st in mammal diversity, 4th in bird diversity, 5th in reptile diversity and is home to 25% of all world’s
Coyote Brush/ *Baccharis pilularis*

Poison Oak/ *Toxicodendron diversilobum*

California Sagebrush/ *Artemisia californica*

Black Sage/ *Salvia Apinana*

Purple Sage/ *Salvia Leucophylla*'

White Sage/ *Salvia apiana*

Bush Sunflower/ *Encelia californica*

Brittle-bush/ *Encelia farinosa*

Coastal Mugwort/ *Artemisia suksdorffii*

Munz’s Sage / *Salvia munzii*
butterflies, 600 native bee species and many other insects, all of which are present in chaparral. Biodiversity located in chaparral is an indicator of the importance of this type of environment. Many species rely on chaparral for survival, but it is threatened by wildfire due to its own climate and vegetation. Because of the high species richness supported by these areas, it is critical that the areas are managed properly for healthy fire occurrences (Image 6). Although the present distribution of chaparral vegetation systems may appear steady, that does not necessarily reflect the future of these environments as climate changes and populations increase resulting in fire patterns and natural habitats to change in response.

Chaparral and Wildfire

As discussed previously, chaparral consists of shrubs ranging from 1-5 meters tall that form a dense closed canopy, where substantial amounts of dead material accumulate underneath (Underwood et al. 2018). This accumulation of dead material combined with hot temperature and other climatic conditions are the perfect complement to one another to start a fire. Once a fire ignites, the closed canopy of chaparral and underlying material form crown-fire regimes.
Crown-fires are a natural processes for California chaparral, characterized by their high intensity and 30-150 year return interval.

Chaparral environments require fire to support the regrowth and diversification of vegetation. The presence of fire cues long-lived dormant seeds, bulbs, and corms in the soil to germinate and resprout (Halsey and Keeley 2016). After a fire, plant diversity significant increases due the new growth in certain plants that only immediately grow post-fire (Halsey and Keeley 2016). After 10-15 years, the vegetation profile returns to “normal”, dormant seed banks grow, and diversity decreases.

The recovery of chaparral after fire is around 10 years, with the highest susceptibility for another fire occurring within the first following five years due to high live/dead plant ratio (Underwood et al. 2018). Although the fire recurrence interval has a range, regionally or locally it can be largely unknown. This is due to lack of documentation, but low relative humidity, drought stress, and high temperatures make chapparel highly flammable at any age and able to reoccur at any time (Underwood et al. 2018).

Although fire is a good thing in these ecosystem, too much fire has negative impacts. For chaparral to be “extraordinarily resilient and vibrant”, it is imperative that chaparral reaches the lower limits for fire reoccurrence of 30-40 years (Halsey and Keeley 2016). Areas receiving fire in more frequent intervals risk losing biodiversity because the post-fire sprouting plant will stop
growing (Halsey and Keeley 2016). Studies have shown that if chaparral experiences more than one fire in six years, typical sprouting vegetation ceases to grow giving room for stronger, invasive non-native plant species to overtake an area (Halsey and Keeley 2016). When the invasion of non-native plants and grasses occurs, it is possible that nonnative grassland can outcompete and completely replace the native chaparral. This chaparral vegetation distribution and hot, dry summers create perfect conditions for wildfire, a natural component of chaparral environments, but if occurring too frequently, can be detrimental (Halsey and Keeley 2016) (Image 8). For this reason, the call for proper fire management on a landscape has never been greater because of more anthropogenic ignitions and persistent fires.

![Image 8: The conversation of native chaparral to non-native grassland (left to right) due to the short fire interval.](image)

Erosion and Hydrology Background

As vegetation cover changes due to fire, so will a landscape’s geomorphic and hydrologic features. Burning vegetation elevates sediment supply in a system that is typically stabilized (Florsheim et al. 2017). Hillslopes no longer have vegetation in place to hold soil together to
prevent erosion. In chaparral environments, dry ravel, the transport of sediment primarily under the force of gravity and transfer of weathered sediment from hillslopes to channels, is the dominant erosion process (Florsheim et al. 2016). Dry ravel is important to note in semi-arid environments because unlike other post-fire erosional processes, it occurs in dry weather, regardless of storms and precipitation (Florsheim et al. 2016). As climate changes, aridity, and fire in chaparral regions increases, understanding the dry ravel erosional processes, will become increasingly important for predicting how much erosion could occur and how much sediment is being moved into water systems downhill (Florsheim et al. 2016).

Wildfire significantly impacts the dynamics of the soil that relate to erosional processes. Depending on the intensity of the fire, it will reduce soil aggregate stability and alters the soil water repellency, having implications on water infiltration, overland flow, and rainsplash detachment (Shakesby et al. 2006). Soil water repellency is an important player because that could reduce the soil wettability for months to year, causing the redistribution of sediments due to water erosion on the surface that can no longer be absorbed into the soil (Shakesby et al. 2006) (Image 9). The way
soil responds to fire depends on the type and the related properties- it is not uniform across a landscape. Heating the soil not only changes its physical properties, but directly kills or alters the reproductive capabilities of microorganisms living in the soil (DeBano). Impacts on the microorganism too depend on the type and are particularly more sensitive in moist soils versus dry, but still important in a landscape none the less (DeBano). In addition, fire is a weathering agent on rocks that too depends on the type of rock, so the response to fire is different (Shakesby et al. 2006).

The following models can be valuable in estimating sediment movement in an area post-wildfire. Many factors post fire are major drivers of landscape response and evolution, for example, rainfall after a fire can proceed to cause flood generation, surface erosion, and slope failure (Ebel et al. 2016). The information provided by the available models is valuable for management purposes because it will help make informed decision on how to deal with landscape erosion due to fire and the watershed that are impacted by sediment moving into the system. If we can identify what certain drivers may look like in chaparral, necessary actions or planning can occur.

With relation to hydrology, knowing the effects wildfire disturbance depend on knowledge of runoff generation processes impacted- such processes being rainfall interception, surface roughness, soil sealing, littler/duff water storage, soil-water repellency, soil-water retention, soil-hydraulic properties controlling infiltration, macropore flow, and water flow processes involving ash effects (Ebel et al. 2016). These processes are all important because they will effect how water will respond to a hillslope. Wildfire, in addition to insect-driven disturbances, are the most important disturbances in the Western US, so understanding how the combination of these processes impact hydrology in a landscape is necessary to properly move forward.
The impact of wildfires also alters the physical and chemical hydrologic cycle and water quality of California. The physical effects of fire on a body of water is the increased sediment load impacting ecological health and drinking water operations (Meixner et al. 2004). An increased sediment flux impacts the safety of drink water in several ways. First, the sediment can be moved downstream and fill and damage existing reservoirs and infrastructures (Meixner et al. 2004). This can cause dams, for example, to require sediment removal which is costly. Next, post-fire erosion and transport can cause debris to move downstream into water supplies, treatment plants and other ecosystems (USGS). Chemical impacts on water are not well documented, but it is suggested that nutrient loads, particularly phosphorus and nitrogen, dissolved organic carbon, major ions, and metals increase after fires. (Meixner et al. 2004)(USGS). This can cause changes in water chemistry, altering the processes necessary for drinking-water treatment. Understanding increased erosional processes with respect to fire that influence the movement of sediment into water systems is important because it could eventually impact our drinking water. It is something that we need to recognize.

MODELS

Mass Balance Model

The purpose the Mass Balance Model is “to predict ravel flux following fires due to the evacuation of sediment stored behind vegetation on hillslopes with gradients steeper than the angle of repose” (Lamb et al 2011). The purpose for designing this model was to focus on the cause for the general trends in ravel-yield averages (Lamb et al. 2011) (Figure 1). The Mass Balance Model requires a few steps. It begins with the change thickness of inorganic sediment stored on a hillslope over time as shown by the equation (1). The parameters in the equations are
represented as the following: \( w \) is the width of the hillslope, \( \rho_r \) and \( \rho_s \) are the bulk densities of bedrock and soil respectively, \( t \) denotes time, \( x \) is the downslope coordinate, \( Q \) is the volumetric sediment flux, and \( E \) is the rate of bedrock to soil conversion (Lamb et al. 2011). The total sediment flux due to dry ravel integrates equation (1) with the assumption the \( E \neq f(x) \), thus given by equation (2) where \( A_b = wL \) is the surface area of the hillslope, \( L \) is the length of the hillslope in the downslope direction, and \( V \) is the volume of sediment stored across that area. Equation (3) represents the total volumetric capacity stored on hillslopes by vegetation dams, where \( V_{ci} \) is the volume of sediment stored behind each plant and \( c \) is the number of plants per unit area of land surface (i.e., the vegetation density) (Lamb et al. 2011). This incorporates sediment that is built up behind vegetation such as stems, branches, leaves, and litter, impacting the additional sediment flux when fire burns away the barrier.

It is possible that the volume of sediment stored across that area is less than the volume of the vegetation density (\( V < V_c \)) because not enough time has passed to fill the space behind vegetation to capacity, represented as a volumetric fraction (\( \psi \)) (Lamb et al. 2011). Incorporating
equation (2) with the constraints of equation (3) lead to the rate of volumetric change of sediment stored behind vegetation as equation (4). As a result of fire, vegetation density $c$ or stage capacity of individual plants $V_i$ is decrease thus reducing storage capacity (Lamb et al. 2011). Finally, by combining equations (2) and (4), the model for sediment yield ($Q/A_b$) delivered by dry ravel to the base of a hillslope is shown in equation (5) (Lamb et al. 2011). If $\psi=1$, then $Q=0$ in (5a) because all sediment is captured behind vegetation; and if $d(cV_i)/dt = 0$ in equation (5b), it “predicts that all sediment is delivered to the base of the hillslope at a rate proportional to the soil production rate ($E$) and the hillslope area ($A_b$)” (Lamb 2011).

All in all, this is a quantitative model used in post fire situations to determine sediment yield transportation from steep hillslopes to lower channels. Using the mass balance framework allows storage capacity of individual plants, vegetation density, and contributing hillslope area to be put into a function of the storage sediment on steep hillslopes (Lamb et al. 2011). When the angle of repose is greater than a slope, loose sediment is gravitationally unstable without the support of vegetation that is lost from wildfire (Lamb et al. 2011). This model provides a simple way to predict ravel fluxes in response to fire on steep slopes (Lamb et al. 2011).

**Probabilistic Post-Fire Erosion Model**

This model uses the Erosion Risk Management tool (ERMiT), an interface to the Water Erosion Prediction Project (WEPP) model from the USDA Forest Service’s website (Robichaud et al. 2007). The WEPP model was created for agricultural use to simulate rain splash, sheet flow, and concentrated flow erosion processes and their interactions, but not practical for step, mountainous regions because they are no uniform like agricultural fields (Robichaud et al. 2007). Because of
missing variables in the WEPP model alone, the ERMiT was designed to predict the probability of sediment delivery exceedance from stochastically generated rainfall or snowmelt events on unburned, burned and recovering forest, range and chaparral hillslopes (Robichaud et al. 2016). First, ERMiT tests a 100-year event at high-severity conditions, followed by calculating exceedance probabilities for sediment delivery for 20-, 10-, 5-, 2- and 1.5-year events in the most severe conditions (Robichaud et al. 2016). The program then chooses possible rainfall and snowfall events based on location to determine sediment delivery, while it is also possible to produce no sediment delivery due to no runoff (Robichaud et al. 2016).

The WEPP produces a 100-year runoff record with the use of a 100-year stochastic weather file to combine soil and burn severity conditions, thus providing the highest potential for runoff and sediment delivery in a specific area (Robichaud et al. 2016). ERMiT uses field derived values such as interrill erodibility, rill erodibility, effective hydraulic conductivity, and critical shear, and observed spatial variability in burn severity to create a probability distribution of potential erosion rates, thus generating probability exceedance (Robichaud et al. 2016).

**Structural Equation Model**

Structural Equation Modeling can be used to evaluate the roles of many factors that determine fire severity and ecosystem responses such as erosion, vegetative regeneration, and community regeneration (Keeley et al. 2008). This approach allows the input of any variables to test hypothesized models of direct and indirect effects against the expected model (Keeley et al. 2008). In a wildfire study that used this approach, one model (a) to determine fire severity had direct factors of stand age, shortest interval between fires, pre-fire community structure, and fine-grain topographic variation, while the model (b) for ecosystem responses had fire severity as a direct effect and stand age, pre-fire structure, coarse-grain and fine-grain topographic effects, and
substrate (Keeley et al. 2008) (Figure 2). Variables picked for these methods are observed indicators or measurable variables. A path coefficient is determined between an indicator and variable, with error included in the model. Fitting the data into a model can be based on maximum likelihood in MPlus, and then evaluating the fit model using chi-square and associated P value (Keeley et al. 2008). An example of the results showing the relationships between variables using this method is in Figure 3.

Figure 2: Visual representation of the hypothesized models to be tested in the structural equations models and factors relationship to each other

Figure 3: Example of results from study, values are standardized path coefficients that have been determined.

**MIKE SHE Model**

The **MIKE SHE Model** can be used as an important tool to determine changes in the hydrologic cycle of an environment before and after a fire. Mass and energy balances and empirical
relations related to the hydrologic cycle are represented to create the model’s simulation of surface and subsurface water dynamics (Jaber 2012). The MIKE SHE is derived from the original spatially distributed hydrologic model, SHE or Système Hydrologique Européen, used to study groundwater environments with diverse climate and hydrologic regimes (McMichael et al. 2006). Modifications were made to the SHE Model so all hydrologic processes occurring in the land phase could be simulated (Jaber 2012).

Components modelled in the MIKE SHE include: (1) interception and evapotranspiration, (2) undersaturated zone flow, (3) overland flow, (4) saturated zone flow, (5) channel and river flow, and (6) Water Quality (Jaber 2012) (Figure 4). One of the most important factors to focus on due to wildfire is land cover change represented by the leaf area index (LAI), total leaf area per unit ground area (McMichael et al. 2006). LAI is represented in the computations for interception

Figure 4: Visual representing the components of the MIKE SHE Model
DISCUSSION
Models

Determining the impacts of fire on an environment can be a difficult task because different, complex factors exist in each place, such as landscape slope, precipitation, vegetation, fire severity, etc. Erosion specifically in chaparral landscapes responds differently than erosion in forests because the areas experience more frequent fire. Many field methods and data collection can be used to determine relationships between erosion and fire, but existing models are important because they can help us predict future erosional events due to fire based on information and data that we already know. From the three models discussed, the Mass Balance Model, Probabilistic Post-Fire Erosion Model, and Structural Equation Model, each has its strengths and weaknesses when it comes to evaluating our overall question, how does fire move sediment in a system? Overall, the combination of various available information and models will be useful in determining fire’s relationship with chaparral communities.

The Mass Balance Model is useful because it can be specifically applied to chaparral landscapes because of the dry ravel process that is frequent in semi-arid environment. As climate warms and makes these areas even more arid, dry ravel will increase because it occurs regardless of precipitation. This shows the growing importance of models that can predict sediment movement in a system. The problem with the model as used in the related study is it focused on sediment catchment behind vegetation. This makes sense because the majority of sediment that will moved in a system because of fire will be when vegetation is removed. It may be important to combine this model with others to consider sediment that is not being trapped behind vegetation.
Overall, using mass balance as a way to predict sediment flux due to fire appears to be a method that could be useful for land and water managers monitoring sediment in a landscape.

The *Probabilistic Post-Fire Erosion Model* seems to be the most effective model to determine how fire impacts erosion rates in chaparral. The model uses current data and historical climate data to determine erosion based on the type of surface such as burned or unburned. This appears to be a great baseline to determine what erosion after a fire or with a future fire may look like, but it brings for the question how it considers processes such as dry ravel that were determined in the previous model. An effective solution may be to consider both models in a study to determine how much erosional processes change when fire has impacted a landscape.

The final model, *Structural Equation Model* is useful when deciding what factors are important and how they relate to each other. This model could be practical in many ways because the variables/inputs are interchangeable based on hypotheses being related. For wildfire and erosion, the two hypotheses proposed in the example study are useful because it models fire severity based on how the landscape looked like previous to the fire, vegetation, etc and then used that to show how the landscape would respond. It shows a tangible relationship between the many factors that play into a scenario and their coefficients. This model could be used by land managers to plan how varying fire severities can alter erosion based on event. The model also can be applied to different environments based on how many inputs are included. One downside to the model in the study was it did not include climate factors that would change the severity of a fire.

The *MIKE SHE Model* is a useful to study changes in hydrology because it incorporates vegetation and related streamflow dynamics into environments that have been altered by fire. This model provides insight into semi-arid shrubland environments such as the chaparral that are constrained by limited spatial and/or temporal scales (McMichael et al. 2006). For a fire manager
in California that deals with fires very large scales, not enough field data collection can be completed, so a distributed hydrologic model that represents changes in vegetation patterns is important for understanding how hydrology has changed post-fire (McMichael et al. 2006). This model can be and has been successfully used to show hydrological consequences of climate change, which also largely influences the size, intensity, and frequency of chaparral wildfires (Jaber 2012).

This model could be a useful tool in a situation where there is too much land to cover or not enough people to collect data in order to baseline data to show hydrologic changes, but may not be the best tool. For example, the study performed by McMichael et al. 2006 investigated a catchment north of Santa Barbara, Ca to characterize uncertainty and error associated with using the MIKE SHE Model, and found a general lack of information and data regarding subsurface conditions (McMichael et al. 2006). This suggests that if certain parameters are not available, this model may be harder for a fire manager to use because necessary information is missing that is required to give an overall model of the hydrology. The results of fire cannot be determined if information pre-fire is unavailable. Another potential problem with MIKE SHE is it’s modelling very complex environments with parameters requiring necessary calibration and validation in order to accurately represent the various physical processes and interactions (Jaber 2012). Without the knowledge and understanding of hydrological systems of an expert, it is possible that these natural processes can misrepresented since an area does not homogeneous parameters, thus causing errors in the mathematical calculations.

Overall, the use of this model as a way to characterize large areas affected by burns such as chaparral environments will be important for determining hydrology post-fire. It could even be used as a predictive measurement by altering inputs such as LAI. If the right specialists are
present to correctly collect, obtain, and input data, the MIKE SHE Model should be used by fire managers to examine the effect fire has had on hydrology of their land. These models should be fashioned with a side of caution because they are natural processes with varying parameters across a landscape.

Gaps in Knowledge

It is also important to note that although current research data and modeling exists, there are still many gaps in the field involving wildfire and landscapes. Most of the gaps involving this topic can be divided into 4 subsections as determined by a study of current research related issues: rainfall, infiltration, erosion, and runoff, with the middle section representing the impacted processes (Moody et al. 2013) (Image 10). Identifying where that lack of information stands is essential because it shows where we need to improve research and where efforts should be focused for the future.

This poses the question, how can we predict the impacts of wildfire on a landscape if we are lacking critical information that determines the relating processes? A simple answer would be we cannot. If there is a gap in information that is essential to make determinations or future predictions, we cannot come to solid conclusions that are needed to inform smart decisions. In order to properly prepare for the future, the science must be improved, but many challenges are presented. One challenge is the scope of an area. A small area could have many hillslopes with different soil, vegetation cover, infiltration rates, etc depending on the location, so combining all the complexities accurately across a landscape could be nearly impossible. All of the complexities in a small area only show how difficult it is to model the effects of wildfire on a large scale, which fires tend to occur and is now occurring on more frequently. Another reason why this data and
information may not exist is because we have no way to predict when an event will occur, and as a result we cannot take the necessary measures to prepare. If you do not know when a fire will occur, data about the current conditions of a landscape may not exist. Therefore, there is no information showing how processes have changed pre-fire to post-fire. It is possible that no data has been collected on certain areas of chaparral because of the expansiveness that it exists in California. Another difficulty that could exist is there simply is not a pressing need to do the research in certain areas. Although many people involved in fire management may agree that the need exists, other outside factors such as distribution of populations with respect to chaparral growth or need to protect a specific location may determine why some places may get more priority in research efforts over others. If we want to be able to predict chaparral’s response to wildfire, we
must do our best to fill in lacking information. By doing this, more accurate information will be available to use and its possible that better models can be created.

Why does this matter?

A frequent question asked is why does chaparral matter, and a good response is that it matters for numerous reasons. The first reason that previous data and predictive models matter is because we need them to inform. If information does not exist, decisions can not be made. There are many risks associated with poor land management in fire-prone landscapes. First, we risk the loss of biodiversity. Chaparral species are very sensitive to fire return intervals. If return intervals are too frequent, many vegetative species will cease to return. This leaves room for non-native vegetation to overtake and alter the natural populations, thus lowering the high biodiversity that thrives in Chaparral.

Poor wildfire management also risks geomorphic alterations, specifically to a hillslope and water system. If we do not properly prepare and anticipate how a chaparral ecosystem’s features will respond to fire, the result could be a very dramatic change to what is currently occurring. For example, fire could initiate an entire slope to erode away if it lacks vegetation and develops hydrophobic soil conditions.

This leads to another impact, which is on the overall aesthetic value of chaparral. As previously stated, chaparral is California’s iconic vegetation surrounding many of the most populous areas in the state. If frequent fire on a landscape dramatically alters the natural vegetation, hills, and water systems, it changes the aesthetic value that many people appreciate. Not properly managing an area for fire risks losing this valuable piece of an ecosystem that has
the potential to never recover, or if it does than not without intervention, great costs, and a lot of time.

It is important to include that although chaparral may appear healthy now, that does not necessary account for what may happen tomorrow or in the future. This gives reason for why having accurate information, models, predicive measures, etc. need to be collected and done now because we never know how chaparral will change in the next few years or decades. A question to follow this is if we do not properly manage chaparral now with the current conditions, how will we account for climate change? Based on California’s Fourth Climate Change Assessment, models predict that burned areas are going to significantly increase across the state (California Climate Change Assessment) (Image 11). A correlation occurs between the predicted increases in average annual area burned and the distribution of chaparral, particularly impacting chaparral in the Sierra Nevada foothills.

Image 11: Projected Average Annual Area Burned by Wildfire
Climate change and wildfire is a tricky issue to tackle, but if we can anticipate where fire may increase the most then efforts can be focused on those areas. We must take properly management what we have now because climate change will only make the results of wildfire more difficult to handle because it adds in an additional complexity to an already complex system. Many pieces put together the puzzle of wildfire and chaparral, and it is our duty to have the best informative science possible to manage fire and related processes on these increasingly vulnerable landscapes.
FIRE MANAGEMENT

Wildfire History in Chaparral

Human influence has been one of the leading causes of large scale wildfires due to two primary mechanisms that alter fire regime: anthropogenic ignitions and fire suppression. (Syphard et al. 2007). Anthropogenic ignitions are ignitions that originate from human activities, “resulting in abnormally high fire frequencies” (Syphard et al. 2007). One of the main suggestions to explain the increase in large scale fires is “that the problem stemmed in large part from the burgeoning population and poor zoning regulations attendant with urban sprawl into the foothills” (Keeley et al 2008). Growing populations in the susceptible foothills has increased anthropogenic ignitions and caused more fire to occur on the fringe of urban areas than backcountry (Syphard et al. 2007). Anthropogenic activities account for approximately 85% of all fire ignitions in California (Bedsworth et al. 2018).

Fire suppression includes processes that lead to fire exclusion, or an attempt to exclude fires from a certain landscape. Fire suppression began shortly after 1910 when several large fires occur. People at the time were concerned about timber conservation because of its growing place in the economy (Haefele). In the early 1970’s fire suppression programs were excited about how they “successfully” solved the fire problem, but this caused major consequences. By eliminating fire for many years from wildland ecosystems, “it has been widely held that we have exacerbated the situation by allowing unnatural fuel accumulation” (Keeley et al. 2008). For example, the California chaparral “fuel massive high intensity wildfire” that despite the amount of suppression have caused “increased loss of property and lives” (Keeley et al. 2008). Now, due to the population increase in fire prone areas combined with highly fire-suppressed ecosystem, fire management faces its toughest challenge- controlling large, high intensity fires.
Although two separate factors that cause different environmental changes, the combination of climate change and anthropogenic ignition or fire suppression is a deadly. Human activities and climate change effect on fires have been shown to have significant variation by region, according to a climate change assessment produced by the state of California (Bedsworth et al. 2018) (Image 12) main suggestions to explain the increase in large scale fires is “that the problem stemmed in large part from the burgeoning population and poor zoning regulations attendant with urban sprawl into the foothills” (Keeley et al. 2008).

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A document published by CalFire outlines the current largest wildfires that California has experienced (Image 13). The fires in this list did not all occur in chaparral, but many did. In the history of California, three out of 20 of the largest fires experienced occurred in 2018, showing the significance and need for proper fire management as the challenge with large scale fires becomes greater. In addition, there is a dire need for cooperation among various groups because fire does not know boundary. It is a cooperative effort across the state and nation to supply enough people
and resources to properly fight fires. In another document released by CalFire, the distribution of wildfire land by jurisdiction is shown from 1987-2016 (Image 14). The data is useful because it shows that the fires occur on land of all types of ownerships and it varies from year to year. Typically federal firefighting agencies have more jurisdiction due to owning more area in fire prone areas. But overall, fire management is a cooperative effort that requires all jurisdictions to work together.

Image 14: California wildfire and acres for all jurisdiction
Q & A

For this portion, I decided that the best approach to really understand the relationship between fire science and fire management of chaparral in California was to get a local perspective. The person of choice for this interview was Michael Chiodini, a previous co-worker during my internship with the Bureau of Land Management in the summer of 2018. Mike is the Battalion Chief of the Central Coast Field Office for the US Department of the Interior’s Bureau of Land Management. Due to Mike’s extensive experience in California and his enthusiasm about fire education, I thought he would be the perfect person to fill in the gaps to any questions I had.

1) *How long have you been on a fire crew? Where has the geographical scope of your work occurred?*

I have been fighting wildland fires since long ago-1984! Started in college when I needed some practical experience and my councilor gave me the opportunity to work on the Sequoia National Forest in California for the Fulton Interagency Hotshot crew. I enjoyed it so much that I stayed on after graduating and held positions in Sequoia National Park, Arrowhead Interagency Hotshot crew, Arizona Grand Canyon National Park-North Rim Helitack, Inyo National Forest Mammoth Lakes Engine Captain, and finally received a promotion to Battalion Chief for the Bureau of Land Management in Marina, Ca.

2) *Do you find your career fulfilling? What has made you stick with it?*

Yes, I do find my career very fulfilling and rewarding as we get to work as a team and accomplish difficult assignments. You really feel a sense of accomplishment and know that you are improving the situation at hand. We make order out of chaos.
I have stuck with this career path because of the teamwork and friendships created. You make friends for life in this occupation because you go through so many difficult situations and encourage each other along the way. In addition, each day is totally different from the other. One day you have paperwork to do, and the next you are off on a fire assignment to North Carolina, or Oregon, or Idaho, or Texas.

3) How has fighting wildfires shifted during your career? Have shifts been in a positive or negative direction?

I was just discussing this last week at our Annual Fire Refresher course, early in my career if we had one 20,000 acre fire that destroyed 1-2 structures in a year, it would be incredible-a huge event. However, today we are having multiple 100,000-acre fires in a single season with entire neighborhoods destroyed and multiple lives lost.

In California we no longer have a “fire season”, it is a year round event now. In my opinion, the shifts have been extremely negative as it affects so many more people, structures, and wildlands. We are building homes farther out into the wildland-urban interface and now they become fuel for the wildland fire moving thru, resulting in more destructive and damaging events.

4) In your opinion, what is the best way to prevent large, severe fires?

Well we can never fully prevent wildland fires occurring, it is part of our planet and is very beneficial on the landscape. Natural lightning cause fires are necessary and important to
many species. In fact, numerous pine and Sequoia trees have serotinous cones covered in resin/sap and only open when fire heats them up and releases the seeds.

We can reduce the severity of wildland fire by conducting prescribed burns where applicable to remove hazardous fuels. This will provide a barrier when a fire does come thru, it will run out of fuel and fire personnel can now contain the incident.

In addition, I feel that educating the public on hardening their property and homes with fire resistant building materials and creating defensible space (lean and green) so when a fire moves thru there is less chance of loss of life or property.

5) Does outreach and education work as an effective way to inform the community about current issues and prevention? What works and what does not work with education of the public?

Great question. I feel outreach is very effective tool as it builds strength within the community as they are all in this together to protect property and resources. In this educational process, we have numerous local Fire Safe councils made up of community members, agency personnel and landowners. By working together ideas can be shared and discussed creating the most beneficial manner to create a fire resilient community.

6) How should people that live in highly-fire prone areas be prepared? Should they considering moving now since it is predicted that fires will only get larger and more intense?
There are 350,000 Californians that live in towns and cities that exist almost entirely within a very high fire hazard severity zone.

These communities at risk need to be educated that California is in the fire environment with a Mediterranean climate with hot dry summers with Santa Ana North winds that blow fiercely in the fall and wildland fires will occur. The best way they can be prepared is to harden their homes and create defensible space around their property. In addition, removing hazardous fuels/ creating fuel-breaks in and around the community will lessen the intensity of the fire. Thus making the homes and property survivable.

Moving is not a viable option for many of the population. What is needed is state of the art building codes that will make homes more fire resistant and able to withstand a wildland fire event. Also more communities need to adopt the FireWise concept and take responsibility to make their property fire resilient.

7) What is the relationship between agencies? Are policies and management similar or different? How can cooperation be improved (or if no room for improvement, what is working)?

The relationship between agencies is strong here in California as we all need resources to assist in containing a large urban-interface fire. No single agency can do it all by themselves. We have a strong working relationship and cooperation framework. There are some differences throughout the agencies in that some are land management based and benefit the public with recreation areas, wilderness, and National Monuments
and Parks. Whereas other agencies are strictly engaged in city, county or private interests. So each has its strengths and limitations, but we work together and incorporate the expertise of each on large wildland incidents.

8) Who are the largest agencies or groups that handle fire in chaparral?

The largest agency in the chaparral environment is the USDA Forest Service on the Cleveland, Angeles, and Los Padres National Forests. Cal Fire covers large areas of this fuel type in addition to Ventura County FD, Los Angeles County FD, and Kern County FD.

9) What does an organization chart for the BLM or any other involved agencies look like?

Who leads and makes decisions on how to handle an incident?

We utilize the Incident Command System that can grow or shrink to fit the needs of the incident.

You have an Incident Commander who is in charge of the entire emergency and is responsible for all decisions on an incident.

The Information Officer communicates with the press and local communities on the fire status.

Next will be the Safety Officer who is responsible for risk management and safety of the firefighters.

Then comes the Operations Section who are responsible for tactical decisions on the fire line.
The **Logistics Section** is responsible for supplying and feeding the firefighters on the ground.

The **Planning Section** is in charge of ordering additional resources and developing the overall Incident Action Plan for the fire.

Here is an example of an organization chart for wildland incidents utilizing the Incident Command System:

10) **Reactive, adaptive, or proactive fire management?**

Definitely **PROACTIVE** fire management. Being reactive is NOT working.

We cannot control the weather or the terrain, but we can reduce hazardous fuels by prescribed burning, thinning, creating defensible space on our landscape, increasing the health of the landscape and improving the resiliency of the environment.
Prior to European settlement, the Native Americans would treat their landscape with fire in the fall and the burn would be extinguished with the winter rainy season. This would provide for fresh grasses and seeds to harvest clear out dead vegetation, thin the timber stands, create a healthier landscape for wildlife for sustenance, and improve water sources. With the European occupation, the mindset was that ALL fire was bad and extinguished as quickly as possible. This has led to our thick dense overgrown dead/decadent fuel challenges we have today.

11) If California had to pick is greatest struggle with wildfires, what would it be?

California cities continue to grow into high wildfire risk areas, so I would say that structures and people in the wildland/urban interface is our greatest struggle. With no defensible space, or resilient building materials, one-lane roads, and overgrown/decadent landscapes, rugged brushy canyons that have not burned in a century it is difficult to prevent loss of life and property in a fast moving wind driven firestorm.

12) How do you view climate change, and how is it being planned/anticipated for by the federal government?

My personal view and every firefighter on the ground is that climate change is increasing the severity and intensity of wildfires due to droughts, beetle killed timber, drying out the vegetation, creating dead fuel landscapes and therefore causing the current era of fire hazards and increasing the number of mega-fires each year.
13) In your experience, what would you improve with respect to preparedness, communication, funding, etc. for the future of California and wildfire?

I would like to see more improvement of stringent fire-resilient building codes in the at-risk communities by hardening the structures with intumescent building materials in the wildland/urban interface, and building with consideration for fire. If folks choose to live in these areas, this is the preparation needed to prevent the loss of life and property.

In addition, I would like to see improvements in thinning/removal of decadent overgrowth, prescribed burning, and building strategic fuel breaks to create increased fire adapted landscapes.

14) What is the most important emergent need for the future, immediate or long term?

Education of the public needs to be immediate. Here in California we live in a fire-dependent environment. We will have to co-exist with this natural element by creating communities and landscapes more resilient to a fast moving wind driven fire event.

For future priority needs, I feel that creating tenable structures with intumescent building materials which will create a more survivable structure and reduce the loss of life and property.

An additional need will include improving apparatus for hazard fuel removal that can increase the amount and expeditious removal of decadent vegetation.

Improve biomass tools that create less waste/ emissions and provide clean energy from the fuels removed.

Future invention of a silica coating for power lines and transformers that coat the energized equipment and prevent sparks to occur and reduce the risk of causing a wildland fire event.
Finally improved unmanned aerial instruments that will assist in reconnaissance, monitoring, and aerial ignition on a large scale making these tasks less firefighter-dependent and reducing risk. With these immediate and future needs, we can be increasing the resiliency and health of the landscape in California while providing protection of life, property and resources.
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