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California's Wildfire Problem:

The Neglected Role of Class and Housing

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Dedication

I would like to say a big thank you to my parents for supporting me throughout this thesis. To my mom, thank you for always helping me come up with the best words. To my dad, thank you for all the long, in-depth conversations. You both work so hard and inspire me. This thesis is my promise to you that I will always work hard to make our lives better.

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Abstract

Wildfires are one type of natural disaster increasing in size and severity, especially in the state of California. While climate change is more studied as a contributing factor, one under-researched area is the construction of housing in wildlands (known in the literature as the wildland-urban interface, or WUI). Housing construction in the WUI makes good fire practices, like performing controlled burns in ecosystems prone to regular burning, more difficult. This thesis examines the class dynamics of housing construction in the WUI through a political ecological framework that exposes the ecological distribution conflicts that arise from unequal distributions of wildfire-related costs, responsibilities, and risks. In order to better understand why people are moving to ecologically fragile areas in California that are prone to wildfire, I perform a first of its kind income analysis on all WUI areas in California to determine the class breakdown of those living in these areas, using income as a proxy for socioeconomic class. I find that lower and middle class households make up the majority of those residing in the WUI, constituting 72 percent of WUI population, 75 percent of WUI housing units, and 84 percent of WUI acres. I also use the Camp Fire in Paradise, California as a case study to illustrate the relationships between wildfire, class, and the WUI. Geographic Information Systems (GIS) technology is used to map the fire perimeter, median household income, and the WUI as a means for visualizing these relationships. Paradise was both almost entirely WUI, and inhabited by low- and lower-middle income residents. This one case study is part of a much wider problem in California since 1 in 13 houses is in a WUI area, where fires are more likely. These findings together show that addressing the wildfire problem in California will require tackling not only the climate crisis, but also the affordable housing crisis that is pushing low and middle class households to the more affordable, yet ecologically vulnerable WUI.

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Chapter 1: Introduction

Natural Disasters

Natural disasters affect millions of people around the world, and generate economic and social damage to communities that stretch far into the future. Natural disasters destroy lives, harm livelihoods, and displace communities, and these effects are not isolated to just a few places. In the United States, 99.7 percent of counties have experienced notable property damage from natural disasters, demonstrating the ubiquity of the problem (Howell and Elliott 449). Globally, natural disasters do not discriminate between developed and developing countries or between the rich and the poor, however there is deep inequality in terms of resource availability for preparation and recovery.

In the United States, every region has geographical particularities that create unique vulnerabilities to natural disasters. These events can be geophysical, such as earthquakes and landslides, hydrological, such as floods, climatological, such as drought and wildfires, or meteorological, such as hurricanes (IFRC). These conditions make areas more prone than others to specific types of natural disasters. For example, hurricanes form in the ocean and therefore primarily affect Southeast coastal regions. Flooding causes the most damages in coastal regions and near smaller bodies of water, such as rivers. Additionally, tornadoes are most common in the central United States and wildfires are more common in the western United States.

Individuals, communities, businesses, and governments are all impacted by the negative consequences of natural disasters. The initial impacts of natural disaster events result in mortality, morbidity, and the loss of physical infrastructure, which can include roads, telecommunication, and electricity networks (Cavallo and Noy 14). Residential housing, businesses, and government buildings can also be physically damaged. Consequent impacts on the economy include effects on income, employment, and inflation (Cavallo and Noy 14). Negative changes in income and employment status can also have huge impacts on individuals. Additionally, both individuals and communities can be displaced either temporarily or permanently by natural disasters, depending on the extent of damage. Negative impacts from natural disasters range from short-term to long-term, depending on the level of displacement and the degree of reconstruction and effort needed to bring displaced people back. For example, extreme natural disasters like the volcanic eruption in Montserrat led to permanent displacement because half the island is no longer inhabitable. Additionally, individuals must cope with the emotional and psychological aspects of experiencing a natural disaster event, and these sometimes escape easy estimation in monetary terms.

Natural disasters pose systemic problems, one of which impacts the insurance industry as a whole, and the constituent companies who take the largest hit when a disaster event occurs. In the United States, insured losses from natural disasters ranged between $19.2 billion and $130.8 billion from 2010 to 2019 (Insurance Information Institute). The most expensive natural disaster in U.S. history was Hurricane Katrina in 2005, which caused approximately $170 billion in costs (NOAA). However, the insurance industry is designed to handle idiosyncratic arbitrary risk, not systemic risk. Idiosyncratic arbitrary risk is associated with disasters that affect specific areas randomly. Systemic risk is the opposite and is associated with disasters that broadly affect larger areas. I will discuss these two kinds of risk in the context of this thesis and what can happen when the insurance industry is overwhelmed by systemic risk in Chapter 2 of this thesis.

Wildfires

Of the natural disasters that occur with frequency in the United States, wildfires have gripped national attention even in the midst of a global pandemic. While countries around the world experience wildfires, including Australia, Canada, Portugal, Chile, Turkey, Spain, France, Italy, and Greece (Kramer at al. 641; Balaban and Fu 820), I focus primarily on wildfires in the United States, which have been increasing in size, intensity, and cost. Across the United States, 52,934 wildfires have burned more than 9.5 million acres this year, as of December 4, 2020 (NIFC). In my empirical analysis in Chapter 3, I use data on California to show that housing in California's ecologically fragile wildland-urban interface is a primary contributor to the state's growing wildfire problem. This year's wildfire season has been record breaking for the state of California with 9,639 wildfire incidents burning more than 4.1 million acres and damaging or destroying 10,488 structures, as of December 12, 2020 (Cal Fire). The fire season of 2020 has seen the most acres burned in California since Cal Fire, California's Department of Forestry and Fire Protection, began keeping records (CDP). Additionally, the total acres burned in California during 2020 exceeds the combined total acres burned from the past three years; five of the six largest wildfires in California history, since 1932, have occurred in 2020 (CDP). In addition to all the crazy, unexpected events of 2020, the stories of loss, grief, and survival in California's wildfires took over mass media during August. Approximately 50.43 percent of the total acres burned in California during 2020 occurred during the month of August (Cal Fire).

In beginning work on my thesis, I came across videos and stories of survivors from wildfires. Survivors shared moving stories of experiencing a wildfire firsthand and literally how life can change so very quickly (wildfires can travel and burn the length of an entire football field per second). For people evacuating their home as a wildfire approaches, every second is critical. I was struck by the stories of survivors who reported that most of them did not expect they would survive. Although I have never experienced a wildfire myself, hearing the emotional pain in their voices inspired me to contribute to the growing body of research that is trying to better understand the social dynamics of wildfires in an effort to improve the worsening situation.

Political Ecological Framework and Ecological Distribution Conflicts

Natural disasters at large and wildfires specifically can both be analyzed through a political ecological framework. This next section of the thesis will set up this political ecological framework and introduce the concept of political ecological distribution conflicts, which will aid in analyzing and interpreting the growing wildfire problem in California and the western United States broadly. The relevance of this concept to natural disasters and wildfires will also be discussed. Although the political ecological framework has been used in previous literature to tackle concepts regarding environmental resource use, such as the extractive sector or sustainability (Pérez-Rincón et al.; Scheidel et al.), this framework and the concept of ecological distribution conflicts have never been used in relation to California's wildfire problem and its causes.

The field of political ecology is concerned with the intersection of political, social, economic, and cultural forces that both affect and are affected by environmental and ecological trends (Minch 24). These relationships are created by the impact of human institutions on the natural world and nature's effects on human life and institutions (Minch 24). And inside those relationships, the antagonisms and conflicts that arise have come to be studied as "ecological distribution conflicts", a term coined by Martinez-Alier and O'Connor in the 1990s (Scheidel et al. 587). These conflicts occur because of social, spatial, and temporal asymmetries or inequalities in the use of environmental resources and services by humans (Martinez-Alier and O'Connor 160). The distributional aspect of this term focuses on the distribution of both environmental benefit and the burden of cost, with an emphasis on who gets what and how these benefits and burdens are distributed unequally (Scheidel et al. 587). Conflicts also arise because of differing interests, values, and norms that result in clashes among either individuals or groups (Scheidel et al. 587). All of these conflicts also entail disagreement over the distribution of environmental responsibilities and responsibilities for damages (Martinez-Alier 73).

Environmental benefits include “access to natural resources, fertile land, or ecosystem services” (Scheidel et al. 587). Environmental burdens, on the other hand, include pollution and waste or damage and destruction of the environment (Scheidel et al. 578). Conflict over access to natural resources, such as pastures and water, are considered classic ecological distribution conflicts (Martinez-Alier 78). Conflict over the responsibilities and damages of increased fuel extraction and the subsequent production of more carbon dioxide, which is impacting climate change, is an example of an ecological distribution conflict on a global scale (Martinez-Alier 73).

Unequal distribution of environmental resources can strongly and negatively affect the poor. For example, the resources provided by a forest or water ecosystem fuel the livelihoods of the poor who utilize these resources and an unequal distribution of these resources can thereby negatively affect the livelihoods of the poor. Due to this dependence on the environment for their livelihoods, citizens of poorer nations are often equally concerned, or more concerned, about the well-being of the environment than those of wealthier countries (Martinez-Alier 58). Additionally, in comparison to the rich, the poor are significantly less mobile and may also have less ‘choice’ in terms of livelihoods and housing (Martinez-Alier and O’Connor 170). It is important to note, however, that the definition of “poor” is heavily dependent on the living standards and conditions of each individual country.

Negative externalities often cause ecological distribution conflicts. Evaluation processes often leave out the calculation of these negative externalities, since market and monetary values take precedence over ecological values. This also means that the negative consequences resulting from those externalities are borne by third parties not directly responsible for environmental damage or destruction, but are nonetheless bearing the costs. These externalities can result in struggles over which valuation processes are appropriate for a given project, in which market and monetary values, livelihood values, and ecological values need to be carefully considered (Scheidel et al. 587). Martinez-Alier and O'Connor argue that the valuations of externalities depend on the distribution of property rights, income, and power (176). In terms of political power, the ability to set a decision and the power to set a particular decision-procedure and standard of valuation are the two levels at which political power appear (Martinez-Alier 87). The unintended consequences of the events that create ecological distribution conflicts also act across time. These externalities are inter-generational because future generations will be impacted by the present distributions of environmental benefits and burdens and the subsequent conflicts over these unequal distributions. Cost-shifting can also occur when competitive enterprises seek lower input costs by off-loading costs onto other parties, which include the government, communities at large, and future generations (Martinez-Alier and O'Connor 161).

Applying the Framework to Natural Disasters and Wildfires

While natural disasters are environmental events in terms of their physical occurrence, there are political, social, economic, and cultural factors that can shape how these events impact different communities post-disaster. Regarding the political economy of natural disasters, Cohen and Werker argue that in the case of poorer countries, "the presence of outside relief can increase the severity of the initial disaster" because of the bailout effect, which is when governments underspend on disaster prevention because prevention is costly and relief is free (810). In the context of Cohen and Werker's argument, 'relief' is referring to free international aid to poorer countries from wealthier countries. Outside of international aid, relief can be very expensive for countries. In the case of wildfires, relief entails shelter and firefighting, which are costs that a wealthy country like the United States will have to pay for with its own government funding. Social forces that shape natural disaster impacts can include the differential effects of race in how communities of color may be more negatively affected by a natural disaster than more homogeneously white communities. This phenomenon was highly evident in the case of Hurricane Katrina and the different impacts of this event on communities of color as compared to whiter communities. Another social force could be income inequalities among citizens affected by a natural disaster. Those with more income and accumulated wealth are more likely to possess the resources necessary to prepare for natural disasters. The economic stability of a county, state, or country can also shape how resilient an area is to the economic aftershocks of a natural disaster. Different cultural communities can also be affected differently depending on their level of resilience.

These forces that shape the impact of natural disasters on different communities occur because of human institution's impacts on nature and vice versa. Infrastructure, agriculture, and pollution shape the natural world through the restructuring of land, removal of natural resources, and contamination of environmental resources. Nature can also shape our built world through things like disease, erosion, and, more importantly for this thesis, natural disasters. In the case of wildfires, nature is shaping our built environment, but we are also shaping the natural environment. There are two primary reasons that wildfires are increasing in severity, cost, and number of acres burned. The first reason is climate change, to which humans are contributing through unsustainable environmental activities. While we are shaping the natural environment through our impact on climate change, the consequences of climate change on the Earth are also shaping our built environment through changing temperatures and longer fire seasons. These are in turn creating worse wildfires. The second reason that wildfires are becoming worse is that forest managers are not doing enough prescribed burns on wildland that evidence shows might be good for preventing really bad wildfires (Charnley et al. 331). Prescribed burns, or controlled burns, are fires set intentionally by fire crews who control how long the fire lasts and how much area it reaches. These fires are set for the purpose of reducing fuel accumulations that would otherwise feed large wildfires. Prescribed burns shape both the natural and built environment by reducing fuel accumulations and subsequently protecting the built environment from severe wildfires. However, if prescribed burns can reduce the severity of wildfires, then why are we not implementing them as often as we should be? There are two major reasons for this, the first of which is the United States' historical focus on fire suppression rather than fire prevention, a problem that still persists today. The second reason is due to large amounts of housing interspersed with wildland vegetation in the ecologically fragile wildland-urban interface, or WUI, which is very vulnerable to wildfire.

The WUI is the area where housing and undeveloped wildland vegetation meet or intermingle. Fighting wildfires and performing controlled burns are both becoming more difficult because housing is continuously popping up in these WUI areas. Fighting wildfires is more difficult because firefighters need to put more time and energy into protecting these homes rather than working towards suppressing the wildfire. More homes in the WUI means more homes need firefighter protection during a wildfire. Additionally, forest managers must strategically perform prescribed burns where communities will not face adverse health effects from smoke or be inconvenienced by the presence of smoke, which makes performing prescribed burns more difficult. With more housing being constructed in relatively undeveloped areas, forest managers have fewer options of where to perform prescribed burns, and these areas where housing is being built in the WUI are the areas that need prescribed burns the most.

The term "ecological distribution conflict" is traditionally used to describe conflicts over the use of environmental resources and services, but it also applies to both the WUI and wildfires because of how humans are using the environment to develop land and construct housing in ecologically fragile areas that are prone to wildfire. The WUI and wildfires are interwoven in the creation of distributional conflicts. The conflicts over responsibility for damages, the assumption of risk, and responsibility for the wildfire problem are not caused by only wildfire or only the WUI. Instead, these conflicts are created from the interconnection between the WUI and wildfires. Therefore, we cannot consider one without considering the other, but also considering each individually can help us see how they are interwoven. The WUI contributes to the creation of ecological distribution conflicts because real estate development is a commodification of land and therefore is the use of environmental resources and services. Land is an environmental resource with services that is being used in the WUI to sustain California's growing population and provide desirable environmental amenities and affordable housing. Ecological distribution conflicts are caused by asymmetries or inequalities in the use of environmental resources and services that have social, spatial, and temporal dimensions. Wildfires generate these asymmetries and inequalities. They generate social inequalities because high-income households are better able to pay for pre-wildfire mitigation strategies and post-wildfire damages than low-income households. Wildfires have spatial asymmetries because some areas are more fire-prone than others, which can generate spatial inequalities in terms of insurer willingness to cover homes in areas of high wildfire risk. The consequences of wildfires are also temporal because high-intensity wildfires that form due to excessive fuel accumulations can damage fire-resistant tree and plant species, therefore resulting in rapid growth of fire-prone species which serve as fuel for future wildfires. This process creates a cycle of fuel accumulations that will impact future generations through more large, high-intensity wildfires.

Asymmetries in the distribution of benefits and burdens are a key component in ecological distribution conflicts. Environmental benefits in the context of this thesis include the benefits that are associated with housing construction and living in the WUI. At the household level, these benefits may be environmental amenities and affordable housing. More houses means more income from property taxes, regardless of wildfire risk, so residential development in the WUI is a benefit at the county level. Fires can cause benefits when low-level fires prevent future catastrophic damage. For example, prescribed burns remove fuel accumulations and thereby reduce the severity of future wildfires. While prescribed burns are a type of fire that is beneficial, many people have a misconception that all fire is bad and do not realize that prescribed burns are good fire. This has resulted in prescribed burns not being implemented enough to utilize their full benefit. Instead, wildfires are occurring more frequently than prescribed burns and these unwanted wildfires are imposing enormous burdens on society. Burdens are primarily derived from the costs associated with wildfire, including fighting wildfires, implementing mitigation efforts to reduce wildfire damage, and rebuilding after wildfires. Unequal distribution of the benefits from living in ecologically fragile areas and the burdens of wildfire among the different parties involved create distributional conflict. Determining how these parties are affected by this unequal distribution can be accomplished by considering a series of questions as they relate to distributional conflicts in the context of wildfires and the WUI.

One question that should be asked in evaluating the distributional conflicts of wildfire costs is, who pays? There are several different parties that may be involved to cover both the costs of suppressing the wildfire and the subsequent damages on properties. Regarding suppression costs, it depends on where the wildfire starts. If the fire begins on federal land, then the Forest Service or Department of the Interior spend money from their budgets, which can often be at the expense of other priorities (Adams). If a fire begins on non-federal land, then states use money from their own budgets (Adams). However, states can also appeal to the Federal Emergency Management Agency (FEMA) for help in cases of large or extremely damaging fires (Adams). Insurance companies carry the bulk of the costs from property damage following wildfires. Standard homeowners policies cover destruction or damage from fire, including wildfires, and the insurance company will pay to repair or rebuild damaged homes and remediate smoke damage (Insurance Information Institute). However, it is important that homeowners check that their policy will cover the costs needed to completely rebuild a home if necessary. With inadequate coverage, some homeowners may need to borrow loans, seek charitable aid, or build inferior or smaller replacement homes (Howard). Those who cannot rebuild a destroyed home often find themselves living in rentals (Howard). Homeowners with no homeowners insurance will be left to pay for damages entirely out of pocket in the event of a wildfire. Due to the growing number of wildfires and acres burned annually in California, many homeowners may soon lack insurance coverage not by their own choice. Millions of homeowners in California were at risk of their insurance either being cancelled or non-renewed due to their zip code before "Insurance Commissioner Ricardo Lara issued a mandatory one-year moratorium on insurance companies non-renewing policyholders" (California Department of Insurance). This action by Lara took place in 2018 and was made in response to Governor

Newsom's declaration of a statewide emergency in October of that year due to the wildfires and extreme weather conditions (California Department of Insurance). Tax payers across the country are also paying for the costs of wildfires. Each year, billions of tax dollars are used to fight wildfires that endanger private property in the WUI (Reilly 554).

The biggest distributional conflict over the allocation of wildfire costs, in terms of wildfire damages, is between insurance companies who don't want to cover houses in very fire-prone areas and homeowners who feel that they have a right to be covered. There is significant controversy over this conflict because neither party wants to bear the full costs of wildfire damages. On the one hand, the insurance industry is designed to handle idiosyncratic arbitrary risk, not systemic risk. Extreme losses from frequent wildfire incidents can be very damaging to insurance companies if losses occur too frequently. On the other hand, most homeowners cannot be expected to have the financial means to pay for all wildfire damages out-of-pocket. Protecting one group hurts the other group and therefore it is difficult to clearly assign responsibility for costs to only one specific group. There is no controversy over who pays for the costs of fighting wildfires because it is either the federal government or the state government, depending on where the fire started. However, there exists a distributional conflict within the allocation of government funding for wildfires because when wildfire budgets are increased to accommodate more frequent and severe wildfires, there is less money for other budgets, such as transportation or education. While taxpayer money could be used to sustain societal progress towards things like better transportation or better school systems, the money is instead going towards fighting severe wildfires that could be more preventable if more controlled burns were occurring where they need to be occurring. Both the insurance industry and homeowners conflict and the government budget allocation conflict are only capable of being resolved if the wildfire problem is solved and considering the role of the WUI is crucial for resolving this problem.

With any natural disaster, including wildfires, there is always uncertainty and risk, which brings up another question of, who bears the risk? The two primary bearers of risk when it comes to wildfire damage are insurance companies and homeowners. In congruence with paying the bulk of costs from damages, insurance companies bear these costs because they take on the most risk. With wildfires increasing in frequency, intensity, and cost, it is no wonder why insurance companies don't want to cover property in high risk areas. Homeowners also bear a substantial amount of risk due to insurance companies wanting to withdraw coverage. With no insurance coverage, homeowners will have to bear the most risk and expensive costs. The distribution of who bears the most risk is dependent on whether insurance companies are refusing to provide coverage to homeowners in a specific area. The question of who bears the risk renders the same distributional conflict as the one over who pays. Neither insurance companies nor homeowners want to bear a disproportionate amount of risk that will directly harm them.

Another question that arises from distributional conflicts is, who is responsible? More specifically, this question is referring to who are the key parties responsible for contributing to the growing wildfire problem? Real estate developers are one group that is contributing to the wildfire problem by building houses in areas that are at risk of wildfire. The WUI occupies less than one tenth of the land area of the United States, but in a study on the rapid growth of the WUI, it was found that 43 percent of all new houses were built there (Radeloff et al. 3316). This has made it the fastest growing category of real estate in the United States during the last decade (Reilly 554). Additionally, "61 percent of all new WUI homes were built in areas that were already in the WUI in 1990 (and remained in the WUI in 2010)" (Radeloff et al. 3316). Although the WUI is not directly the most at-risk area for wildfire, it does have a higher likelihood of wildfire (Alvarez). Similar to real estate developers, politicians bear some responsibility in the growth of the WUI that has made millions of people vulnerable to wildfire. Many elite politicians advocate for development and fight over land and resources (Balaban and Fu 821). Politicians may also be influenced by locals whose interests are not in favor of land-use planning and regulation. Wildfire-related regulation and land-use planning are particularly unpopular in rural areas (Mockrin et al. 214). As mentioned previously, counties benefit from the property tax revenue of additional houses. In California, land-use planning decisions are left to local governments and communities since the federal government does not regulate land-use planning, except for floods (Kramer et al. 642).

Relations between real estate developers, politicians, and local governments are all feeding the growing wildfire problem and thereby creating distributional conflicts between other groups. When local governments give real estate developers the approval to build homes in the WUI, they are making controlled burns more difficult to implement because there is more housing interspersed with wildland that needs to burn periodically to prevent severe wildfires. The appeal of life in nature and the affordability of these homes as compared to those in the city will attract people to live in the WUI. However, while there is a desire to live in the WUI, there is not a desire to deal with wildfires and this then creates distributional conflicts between homeowners, insurance companies, and tax payers over who is to bear the most risk and who is to pay the bulk of the costs associated with wildfire damage.

The conflicts that develop from the distribution of burdens are due largely in part to varying interests and values. Real estate developers, politicians, and local governments each have different interests and values that shape their role in these ecological distribution conflicts.

Real estate developers are driven by the prospective profit of selling WUI homes to Americans seeking life in nature. Politicians are driven by the desire to either get voted into office or stay in office. If they do not follow the desires of the local people, then they jeopardize their position in office. Homeowners have varying interests and values depending on why they choose to live in the WUI. Some may live there for the natural amenities and beauty of nature, while others may live there for the affordability given that proximity to the city is more expensive and these houses are often further away from the city. Conservative homeowners can be especially influential on politicians because they may have resentment towards government intervention in terms of building codes and defensible space. Another conflict that exists is between conservationists and builders who both have very different interests and values. While conservationists are interested in sustaining the environment, builders are much more interested in the profit of developing land and selling newly constructed houses. There is also conflict between the federal government and the state government of California. In August of 2020, President Trump threatened to withhold federal aid from California because he believed the state was suffering from wildfires due to not taking his advice to thin trees and clean debris from forest floors (Rosenhall).

There are also several negative externalities associated with wildfires that are relevant to this thesis. One of them is the valuation processes used in determining the ecological value of forests. While wildfires have been found to be beneficial for forests, such as fertilization and seed distribution, extremely hot fires can actually go past the bark of trees and be damaging. It is important that we make efforts to understand the ecological values of forests and the various life forms within forests, not just their market or monetary values. It is also important to understand the ecological value of healthy forests for future generations. For example, what is the valuation of lost biodiversity for future generations? The impact of continued increases in size, intensity, and cost for future generations also needs to be considered. There are also livelihood values that need to be considered when individuals and families lose all their belongings to a wildfire or need to resettle in a new area. Another externality of wildfires is the process of real estate developers building homes in the vulnerable WUI to make profit and essentially shifting the costs of wildfires onto state governments, the federal government, tax payers, insurance companies, and homeowners. It is not the real estate developers who pay the costs of wildfire damages. Rather, it is the state that pays for wildfires that start on non-federal land, the federal government when fires start on federal land or when states request aid from FEMA, taxpayers that pay towards federal aid, insurance companies who pay for homes to be repaired or rebuilt, and homeowners who pay out of pocket if they don't have insurance.

This political ecological framework, using the concept of ecological distribution conflicts, is also relevant to my work on wildfires and the WUI because of how the poor can be disproportionately affected by the consequences of wildfires. Although the income of "poor" people in the United States, and especially California, is much higher than that of the "poor" in developing countries, contextually speaking, the poor are always affected differently by the repercussions of ecological distribution conflicts than other groups. In the case of forests and housing, the poor are dependent on access to the WUI for more affordable housing rather than as the source itself for their livelihoods, but they are no less dependent on access to this land. While the poor are guaranteed to face very different outcomes from wildfire than other income groups, such as the very wealthy, no one has actually examined the class distribution of people living in the WUI before to find out who lives in these ecologically fragile areas. While researchers have explored many aspects of wildfire in the past, including economic impacts, perceptions of wildfire risk, and the growth of the WUI, this work will be the first to empirically determine the socioeconomic class to which people belong in WUI areas. The distribution of income in the WUI will have significant implications for designing progressive solutions to the growing wildfire problem in California. In my empirical analysis in Chapter 3, I will use data on California to evaluate population, households, and acres in the WUI in relation to income quintiles. This will reveal which income class composes the largest portion of the WUI in California. Examining the reasons that low income, middle income, and high income people move to the WUI will highlight the larger underlying problems that are pushing people into vulnerable areas and therefore making California's wildfire problem worse.

There are three central questions that will be answered throughout the rest of this thesis. The first is, why is the WUI a major area of importance to even examine if we are interested in wildfires? As has already been discussed and will be explored more, we cannot only be concerned over one or the other. Wildfires and the WUI are intricately related issues and part of the solution to wildfires lies in resolving the issues with the WUI. This thesis will also consider, how is the WUI contributing to the problem? After establishing the relationship between the WUI and wildfires, the final question is, who is moving, in class terms, to the WUI and why are they moving there? While it is important to understand how the WUI is contributing to the wildfire problem, it is also integral to also understand the people that make up this large contributor to the problem and why they are unintentionally contributing to it.

Chapter 2: How Wildfires Became An Even Bigger Problem

Wildfire Trends and Dynamics

Although wildfires affect various areas throughout the United States, the growing wildfire problem does not affect all areas equally. Some areas with certain climates, seasonal weather patterns, and vegetation types are more ecologically vulnerable to wildfire than others (Stein et al. 13). For example, much of California has a Mediterranean climate with warm, dry summers and mild, wet winters. This type of climate is especially prone to wildfires due to the warm, dry summers and prevalence of droughts that create fuel for wildfires by drying the wildland. This type of climate is also typically dominated by evergreen sclerophyllous-leaved shrublands, semi-deciduous scrub, and woodlands, which are also vulnerable to wildfire (Keeley 125). When these various factors combine with the presence of housing in fire prone areas, such as the wildland-urban interface, the risk of wildfire increases even more. The presence of housing and people as a factor that increases wildfire risk is one way in which wildfires and the WUI are interconnected.

Wildfires can be caused by a myriad of things, but the most common cause is humans, who cause approximately 85 percent of wildfires in the United States (National Park Service). Specific human-related causes of wildfire include unattended campfires, burning debris, equipment use and malfunctions, cigarettes discarded negligently, and intentional acts of arson (National Park Service). The presence of humans in fire prone areas increases the chance of wildfire by increasing the probability of human negligence. Dryness from summer heat and lack of rainfall is a big part of the reason that fire prone areas are vulnerable to wildfire in the first place and combining dry conditions with human negligence in a fire prone area is a recipe for disaster. California is sometimes so dry that even the sparks created from a tire going flat on the highway can start a wildfire. While some causes of wildfires are easily preventable, such as not leaving camp fires unattended, others are less preventable. For example, lightning is the most common cause of natural wildfires (Indian Affairs). In August of 2020, almost 14,000 lightning strikes created more than 900 wildfires during a 72-hour period in California (Arango and Baker). While wildfires caused by lightning cannot be completely eradicated, very large wildfires can be prevented when land is pre-treated with prescribed burns so that a wildfire does not quickly get out of control.

One of the best indicators of the United States' growing wildfire problem is the numbers. Examining the number of fires each year together with the number of acres burned each year provides clarification as to how wildfires are becoming a gradually more and more concerning problem. Figure 1 depicts these two trends between 1990 and 2019 for the entire United States. Although each line follows a jagged path, it can be observed that the number of fires per year takes on the appearance of a somewhat decreasing trend, while the number of acres burned per year appears to have a more upward trend. The downward trend of fires per year with an upward trend of acres burned per year is a concern because this suggests that while wildfires may not necessarily be increasing in frequency, they are definitely increasing in intensity and scale. Fewer wildfires are now starting to burn more acres. Fire prone areas are especially vulnerable to large wildfires and this is a problem because these types of fires are more difficult for firefighters to control and their significant size puts more communities at risk. Large wildfires are mainly the result of fuel accumulations and can be reduced in frequency if fire prone land is treated with prescribed burns that firefighters start on purpose and control, but there are not enough areas being treated with prescribed burns at this point in time. As this chapter delves deeper into prescribed, or controlled, burns, it will become clear why this mitigation strategy is not being implemented at the rate required to reduce large wildfire risk in fire prone areas.

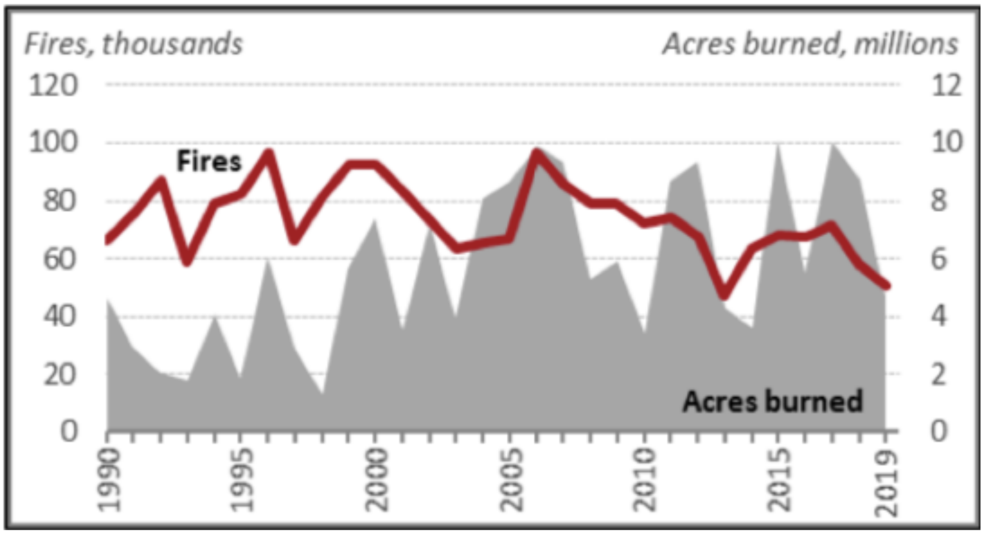

Figure 1. Annual Wildfires and Acres Burned. Source: *Wildfire Statistics*. Congressional Research Service, 4 December 2020, https://fas.org/sgp/crs/misc/IF10244.pdf. Accessed 2 January 2021.

History of Wildfire Management in the U.S.

In order to fully understand today's wildfire problem, it is important to briefly review the history of wildfire management in the United States. The policies and actions of fire management from the past century have fundamentally structured both how we fought wildfires in the past and how we fight wildfires today.

The Bureau of Forestry was established in 1905 and later became the Forest Service with the mission to protect timber resources and watersheds located within National Forests (Reilly 546). While the Forest Service viewed wildfires as a threat to this mission, this opposition was primarily rhetorical until the Great Burn of 1910 (Reilly 547). The Great Burn of 1910 is also known as the Big Burn or the Big Blowup and was a forest fire that occurred in August of 1910 throughout the border regions of eastern Washington, northern Idaho, and western Montana (Krainz 405). After this fire, the Forest Service adopted a policy of total fire suppression where the agency actively fought all wildfires regardless of their source and, more surprisingly, suppressed research efforts that were attempting to examine whether or not fires play a necessary role in the preservation of forest health (Reilly 547). Coert DuBois, a forester from the Forest Service, and H. H. Chapman, a researcher at Yale University, both promoted the benefits of wildland burning in the 1920s and 1930s, but public land management policy addressed wildfires as unwanted for the next four decades, with emphasis on prevention and, if not prevented, then suppressed to the smallest area possible (Cohen 21).

It was not until the late 1960s and early 1970s that policy began to recognize wildfires as a historical, ecological factor (Cohen 21). It was during this time that prescribed burns, which are fires set intentionally for forest management purposes, began to be employed more commonly. Long before the U.S. government recognized the importance of prescribed burns, however, Native Americans were intentionally setting intermittent fires on California's land. Before the arrival of Western settlers in the early eighteen-hundreds, hundreds of indigenous tribes across California renewed food, medicinal and cultural resources, created habitat for animals, and reduced the risk of larger, more destructive wildfires through the use of small intentional burns (Cagle). This was done for thousands of years until the U.S. government banned intentional burning with the Act for the Government and Protection of Indians in 1850, before California was even a state (Cagle). The United States then began a war on fire that has lasted up until fairly recently. Fortunately, federal, state, and local governments are gradually coming to understand the importance of prescribed burns and are turning to indigenous people for help (Sommer). Native tribes are now joining forces with government agencies to fight California's wildfire problem. An example of such a collaboration is the work being done by the Yurok and Karuk tribes in partnership with the environmental not-for-profit Nature Conservancy's Prescribed Fire

Training Exchange, known as TREX, to expose more firefighters to the practice of prescribed burning (Cagle).

While current policy is now more in favor of wildfires and their benefits, and there is greater public understanding of these benefits, wildfires and prescribed burns are still viewed with some hostility. Current policy recognizes the importance of wildfires as an ecological process and this recognition has provided latitude for planned burning and designated unplanned fires as desirable (Cohen 21). Despite this recognition, there are tensions and conflicts among the various parties involved in the wildfire problem that are slowing the process of normalizing controlled burns. Although environmental managers understand the importance of controlled burns in preventing larger wildfires, homes sprinkle the wildland-urban interface, making it difficult for planned burns to be implemented at the frequency needed to mend the wildfire problem in California. Most homeowners are hostile towards controlled burns due to the unwanted smoke they generate and a fear that these burns will accidentally jump fire lines and damage nearby communities. When implemented properly and in the correct conditions, health risks associated with these burns and the chance of a planned burn spreading to nearby communities are both low. Although these risks are low, tensions still exist between environmental managers who need to perform prescribed burns to protect those living in ecologically fragile areas and homeowners who do not want to be inconvenienced. A major conflict also exists between environmental managers and homeowners and real estate developers. While environmental managers advocate for prescribed burns, homeowners and real estate developers are demanding housing in these ecologically fragile areas. To satisfy this demand, local governments allow homes to be constructed in vulnerable areas, but doing so makes controlled burns more difficult and puts homeowners at an increased risk of home damage from large wildfires. The limit on controlled burns due to the presence of housing and people in the WUI is the major reason that wildfires and the WUI are interconnected concepts. The wildfire problem is becoming worse because wildlands are not burning as often as they need to and this is because housing scattered throughout the WUI makes controlled burns difficult to perform. For this reason, we cannot consider just wildfires as a standalone event or the WUI as an area unrelated to wildfires. They are interconnected concepts in which one affects the other and vice versa.

Fire management policies from the past that focused on suppressing all wildfires, in combination with the difficulty of performing controlled burns due to housing, have generated costs for today environmentally. These environmental costs have subsequently resulted in economic, financial, and social costs. The costs of wildfires are most commonly described in terms of damage costs. However, it is important to understand the full scope of costs associated with wildfires besides just the damages to infrastructure and property. This next section will designate which costs should be considered when calculating the total cost of wildfires and the impact of these costs on those living in ecologically fragile areas and those who are directly or indirectly involved in the wildfire problem, such as governments and residential developers.

Environmental Costs

Our history of total fire suppression has resulted in costs and damage for the environment today. One example of this impact is that reductions in fire occurrence have changed species composition in some types of ecosystems, such as the ponderosa pine forests, and increased the amount of both live and dead vegetation (Cohen 21). The intensity of a wildfire is determined by its speed and temperature. While a wildfire’s speed is largely determined by wind, the amount of fuel determines it’s temperature. Fuel accumulation feeds the intensity of a wildfire by making it hotter, which can make wildfires more damaging to forests by burning past a tree's bark and seed barriers. Since fuels are burned in wildfires, there is less fuel to sustain new wildfires and the chance of a new wildfire occurring becomes less likely after the first wildfire. Conversely, fuel accumulations from suppression of wildfires can increase the frequency of wildfires by making the chance of new wildfires more likely. The damages of wildfires to the environment should be considered as a cost because of the losses in natural resources and wildlife. Wildfires can damage timber resources and also force animals to migrate. In some cases, wildfires can also negatively affect grazing animals' winter survival when coupled with drought conditions (National Park Service). The environmental costs of wildfires from our long history of total fire suppression has resulted in larger, more intense fires that play a significant role in the economic, social, and financial costs of wildfires.

Economic Costs

Various economic costs are incurred by communities and individuals from wildfires. Job loss is one of these costs, which can occur when a business has to close due to extreme damage or when an employee loses their home and must move to a different area. Job losses can be either temporary or permanent depending on whether rebuilding efforts are pursued. Seasonal agricultural workers are significantly impacted because their jobs get cancelled when wildfires are in the area. Approximately 71 percent of California's agricultural workers are Latino, which means this population is hardest hit when wildfires affect outdoor work, such as grape picking in California's wine country (NPR). Lost wages, whether it be from business closure, displacement, or hazardous outdoor conditions, can have a significant negative impact on the livelihoods of families and individuals. A reduction in income, even if temporary, can cause difficulties in affording food or paying bills, especially for families and individuals that were already struggling financially pre-disaster. Wildfires can also have some positive impacts on wage and employment growth rates, but these are very dependent on a county's economic reliance and wildfire frequency. For example, a study by Nielsen-Pincus et al. found that government-dependent counties, recreation counties, and counties with frequent wildfires saw the greatest increases in employment and government-dependent counties saw the greatest average wage increases (6). Additionally, local economies can benefit from economic activity generated from suppressing a wildfire, such as building fire lines or providing firefighters with food and ice, but only if spending and contracting are done locally (Diaz 1). If spending and contracting are not done locally, then local economies face an economic loss from wildfires.

Another economic cost of wildfires is structure loss, which, as mentioned before, is one of the most common costs reported when evaluating total costs of wildfires. Despite its commonality of use, it is still a cost that should be used in calculating the total costs of wildfires. Figure 2 below depicts the number of structures damaged or destroyed each year between 2013 and 2020 based on data available from the California Department of Forestry and Fire Protection. Although this timeline only illustrates structure loss from the past eight years, it does show that structure loss is highly variable from year to year. This is due to variations in weather conditions, including snow fall, annual precipitation, wind, and drought conditions. Structures can include residential houses, businesses, and government buildings. Houses are especially vulnerable to structural loss from wildfire depending on the housing arrangement and location. A study that examined the effect of housing arrangement and location on the likelihood of housing loss found that smaller, more isolated housing clusters with fewer roads are the most at risk of property loss (Syphard et al. 2). It is also important to note that besides just structures, other types of property, such as vehicles, can also be damaged or destroyed during a wildfire.

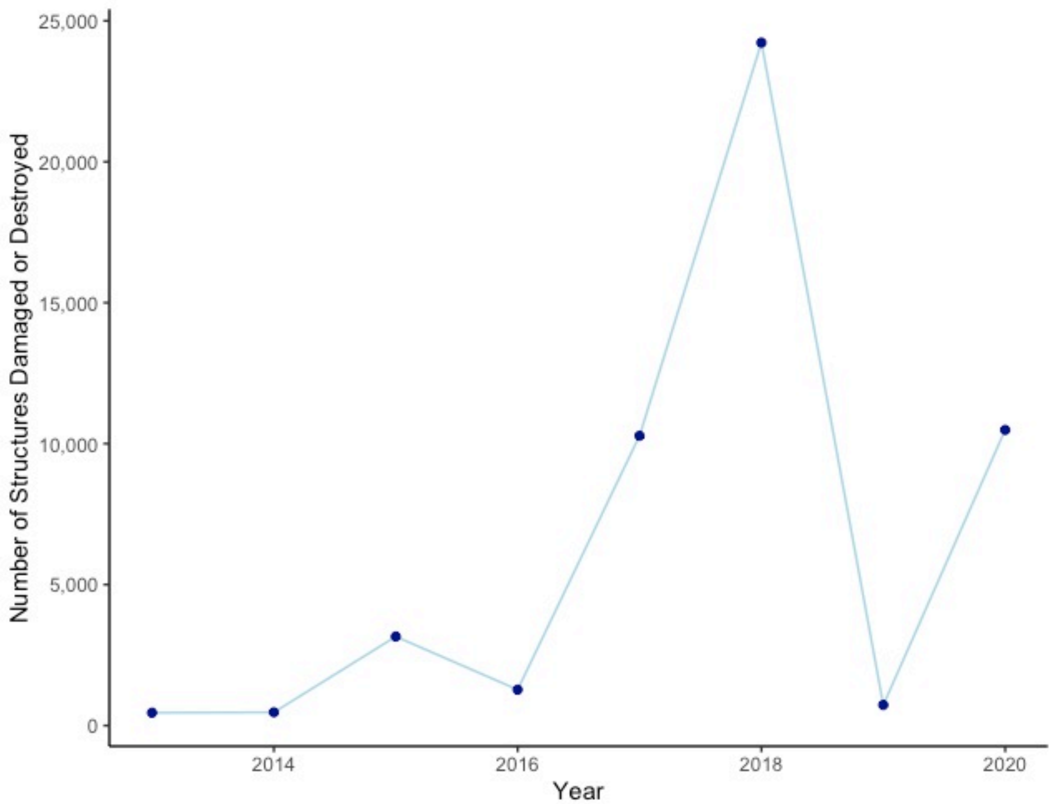

Figure 2. Structure Damage and Loss from Wildfire Between 2013 and 2020. *Source*: Compiled by author based on data from https://www.fire.ca.gov

The tourism industry is a sector of the economy that is negatively affected by wildfires. Some areas are dependent upon the income generated from tourists visiting recreational parks that offer scenic landscapes and outdoor activities. A study on the Sierra de Aracena y Picos de Aroche Natural Park in southern Spain estimated the economic susceptibility of the park from wildfires to be approximately 31,210,807 € using a driving and travel times cost approach or 89,460,204 € for the total cost (Molina et al. 459). Converted to U.S. dollars, this is roughly $38,363,387 and $109,961,798, respectively. These numbers illustrate the potential economic loss of national parks from reduced tourism that results from wildfires in or near a park. The tourism industry is affected both directly and indirectly by wildfires. A direct impact would be physical damages to the landscape or structures within the recreational area. An indirect impact would be people's perception of risk following a wildfire. News and social media networks greatly publicize a wildfire and its impacts, which can increase people's risk perception. This can make people feel that an area is unsafe and at risk of more wildfires, even though the opposite is actually true. The occurrence of a wildfire reduces the chances of another fire occurring since fuels have been burned and the remaining fuels are likely insufficient to sustain a large wildfire.

The insurance industry is another sector of the economy that is negatively affected by wildfires. Insurance companies carry the bulk of costs from wildfire damages on private properties. For example, total claims in California were in excess of $12 billion in insured losses from the 2018 wildfire season (California Department of Insurance). As mentioned previously, the insurance industry is designed to handle idiosyncratic arbitrary risk, not systemic risk. Idiosyncratic arbitrary risk is associated with disasters that affect specific areas randomly, while systemic risk is associated with disasters that broadly affect larger areas. The growing wildfire problem is actually a signal of growing systemic risk. More acres burned means more houses are at risk of being severely damaged or completely destroyed, and this is changing conditions for the insurance industry that treats fire destruction of housing as a one-off idiosyncratic occurrence. Areas that are historically known for having frequent wildfires also contribute to the reshaping of the type of risk insurance companies are exposed to. When the same area keeps experiencing wildfires, the risk is less random. In response to this changing risk composition, insurance companies are refusing to cover certain areas. As previously mentioned, millions of Californians were at risk of losing insurance coverage until the Insurance Commissioner issued a mandatory one-year moratorium. However, many homeowners have still lost their insurance that would cover wildfire losses. More than 340,000 policyholders in fire prone areas are estimated to have been dropped by their insurer in the past four years (Shrimali). Insurance has also become much more expensive in response to growing losses from wildfire with premiums rising by as much as 300 to 500 percent in some cases (Shrimali). Dropped policies and increasing premiums are likely to only get worse if wildfires continue to cover larger areas and put more property at high risk.

Another cost of wildfires is the potential adverse health outcomes associated with smoke inhalation and other non-health related outcomes. Short-lived but very high levels of particulate matter or PM are emitted during wildfires (Kochi et al. 804). Common adverse health outcomes may include hospital admission for respiratory and cardiac symptoms, hospital outpatient visits for respiratory symptoms, work loss days, and restricted-activity days (Kochi et al. 804). In order to better understand the state of research on wildfire smoke and health outcomes, Kochi et al. reviewed the pre-existing literature on the health-related economic costs of wildfire-smoke exposure. Their synthesis found mixed results from the pre-existing literature. For example, some of the relevant studies regarding hospital admissions related to asthma, general respiratory symptoms, and cardiovascular symptoms during wildfire events found significant increases while others did not. Twelve of the thirteen relevant studies for general respiratory symptoms found a significant increase in hospital admissions during a wildfire event, six of the nine relevant studies for asthma found a significant increase, and only one of the six relevant studies for cardiovascular symptoms found a significant increase (Kochi et al. 809). The concluding remark from this review was that “there is still significant uncertainty about the health effects of wildfire smoke” (Kochi et al. 812). In addition to adverse health outcomes, wildfire smoke can also have non-health related adverse outcomes. Depending on wind direction, wildfire smoke can disrupt road and air traffic by making it more difficult for drivers and air pilots to see (Doerr and Stantín 6).

Wildfires can also negatively affect the residential real estate market by reducing property values and demand, although not all communities are equally affected. A hedonic property framework is the most common model used to examine the impact of wildfires on home values. One study found that house prices drop approximately 9.71 percent after one wildfire and 22.7 percent after a second wildfire (Mueller et al. 166). This study also found that demand for houses located near wildfires immediately decreases following each wildfire and decreases more after repeated wildfires (Mueller et al. 169). Another study found that proximity to and view of burned areas has negative effects on property values (Stetler et al. 2241). The impacts of wildfires on home values is also not equal across the income distribution. Poor communities suffer greater declines in property value following fires of similar or greater strength than those in wealthy communities (Balaban and Fu 830). Property values can actually continue to increase in extremely affluent communities, such as Rancho Santa Fe, despite a history of high fire risk (Balaban and Fu 830).

Social Costs

In addition to economic costs, wildfires also impose social costs on society. For the purposes of this thesis, social costs will be considered the costs imposed on consumers as a result of exposure to a transaction. In this case, the transaction is the purchase of a home that was constructed in an ecologically fragile, fire-prone area. Consumers have social costs imposed on them simply from purchasing these houses. While the destruction of a home in an ecologically fragile area, like the WUI, results in some quantifiable monetary costs, such as job loss, structure loss, and home value reduction, the social costs that households face are more difficult to quantify. For example, it is difficult to determine the cost of temporary or permanent displacement on individuals and families following a wildfire. In 2018, it is estimated that at least 22 wildfires created more than 354,000 new displacements, which accounted for almost 30 percent of the total new displacements recorded in the United States in 2018 (Internal Displacement Monitoring Centre). Temporary displacement can cause disruptions in income flows and psychological well-being. Permanent displacement can have larger impacts on the overall livelihoods of those displaced, and in fact, is a sign of the problem of climate or environmental refugees right here in the United States. Each of these negative displacement outcomes have unknown costs. Additionally, not everyone faces the same social costs from wildfires. Disparities in wildfire consequences on those in different income classes is a key area of concern in the context of the wildfire problem that will be discussed more fully in later chapters. While estimating the monetary value of social costs is beyond the scope of this thesis, they are still costs that should not be ignored when considering the costs of wildfires to society.

Financial Costs

Wildfires impose not only economic and social costs on society, but also financial costs in terms of money spent on fighting wildfires. The financial costs of wildfire can be divided into two categories: suppression costs and mitigation costs. Regarding suppression costs, the federal government and individual state governments are each responsible for setting their own budgets for fighting wildfires depending on whether a wildfire starts on federal or non-federal land. Suppression spending includes contracted services (this includes direct suppression, post-fire cleanup, or fire-camp provisioning), federal personnel, flying contracts, agreements with states, and supplies and materials (Davis et al. 2). A significant portion of suppression spending is on contacts with private firms. In a study that examined local contract spending, 39 percent of the total federal suppression spending analyzed was made up of contracts for services with private firms (Nielsen-Pincus et al. 4). Suppression spending has significantly increased over time.

Figure 3 depicts this trend by illustrating total federal firefighting costs for suppression only from the Forest Service and Department of the Interior agencies between 1985 and 2019 (last updated March 11, 2020). The state of California also spends a significant amount of money on fighting wildfires through the California Department of Forestry and Fire Protection, also known as CAL FIRE. According to a Stanford climate policy researcher, approximately $2.5 billion is spent on CAL FIRE firefighting each year (Louie). Figure 4 depicts CAL FIRE's suppression costs for both base fire protection and emergency fire suppression by fiscal year. Both Figure 3 and Figure 4 illustrate an increase in suppression spending over time.

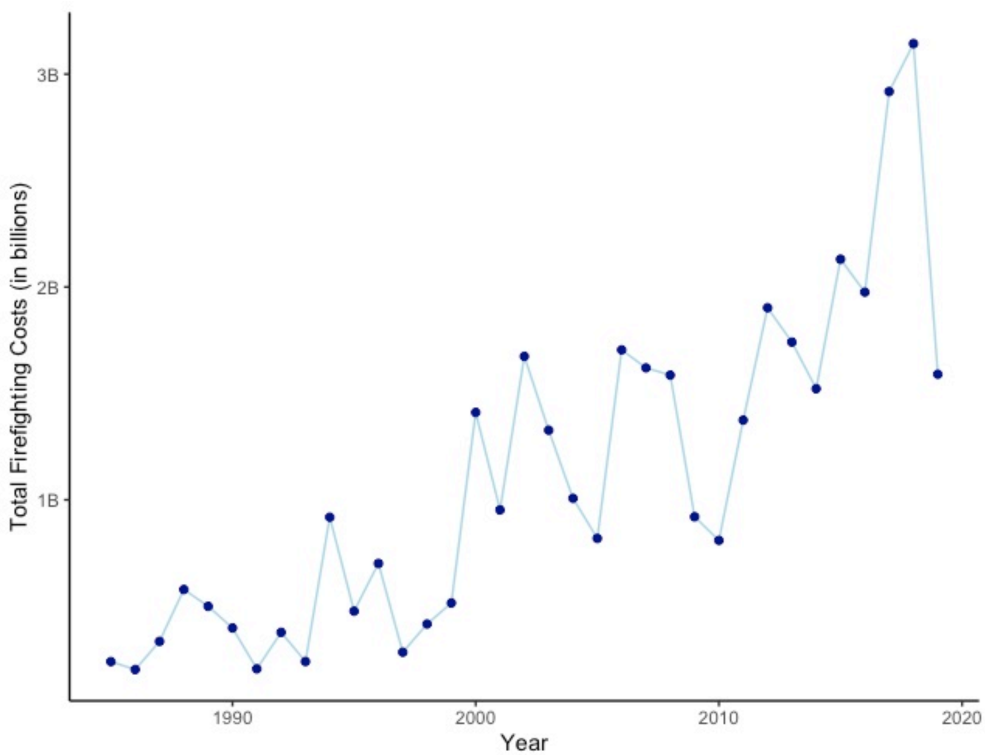

Figure 3. Federal Firefighting Costs Between 1985 and 2019. *Source*: Compiled by author based on data from https://www.nifc.gov

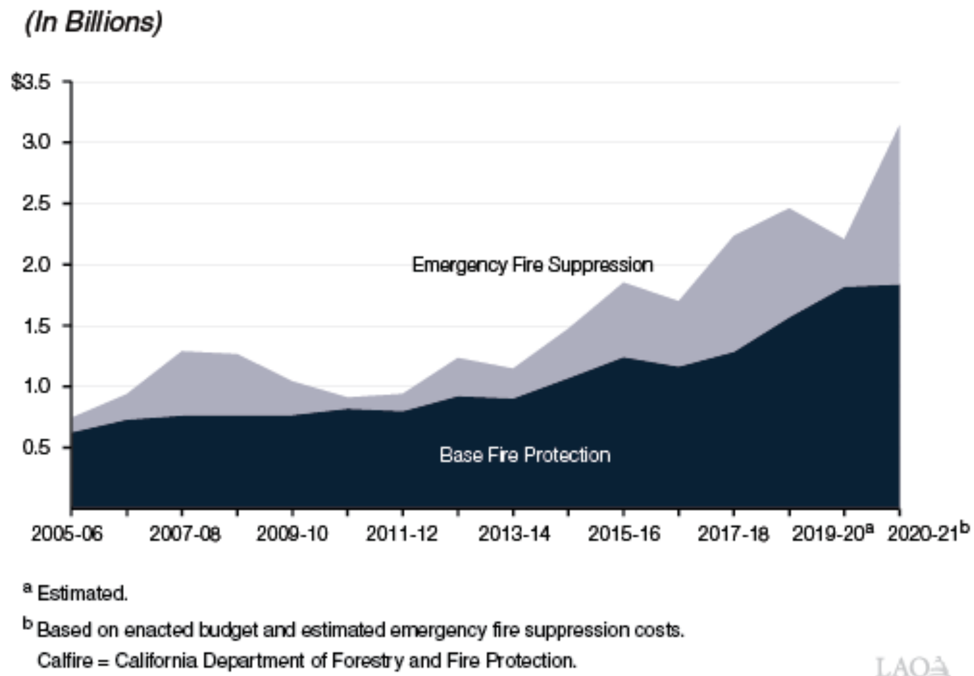

Figure. 4. CalFire Wildfire Suppression Costs Expected to Exceed $3 Billion in 2020-21. Source: Brown, Brian. "State Wildfire Response Costs Estimated to Be Higher Than Budgeted." *Legislative Analyst's Office*, 19 October 2020, https://lao.ca.gov/Publications/Report/4285.

Mitigation is the other way that we fight wildfires, although significantly less money is invested in this strategy in comparison to suppression. Mitigation means the prevention of wildfires, while suppression encompasses the strategies to fight active fires. Mitigation strategies include fire-resistant building materials, defensible space, fuels reduction, education programs, risk maps, and prescribed burns. Fire-resistant building materials can be used either during construction of a new home or renovations of an existing home. Defensible space is the practice of reducing vegetation around the home so that there are less fuels that could put the home at risk of severe damage. Fuels reduction is the process of reducing fuels through a variety of methods, including thinning trees, removing underbrush, and limbing trees (National Park Service). Prescribed burns are a type of fuels reduction process that uses planned and controlled fires to reduce fuel accumulations. The Firewise program is an example of an educational program that provides "a collaborative framework to help neighbors in a geographic area get organized, find direction, and take action to increase the ignition resistance of their homes and community and to reduce wildfire risks at the local level" (NFPA). Risk maps provide wildfire risk information, which gives households the opportunity to engage in mitigation activities, such as defensible space, fire-resistant building materials, and educational programs (Mozumder et al. 1589). In comparison to suppression spending, mitigation receives significantly fewer funds from government budgets to fight wildfires. Figure 5 depicts the stark contrast between suppression spending and mitigation spending in the United States. Suppression spending appears to be increasing over time more quickly than mitigation spending. For example, suppression spending jumped from $2 billion in 2013 to a little under $3.5 billion in 2018, whereas mitigation spending went from approximately $400 million to $500 million across the same time period (see Figure 5).

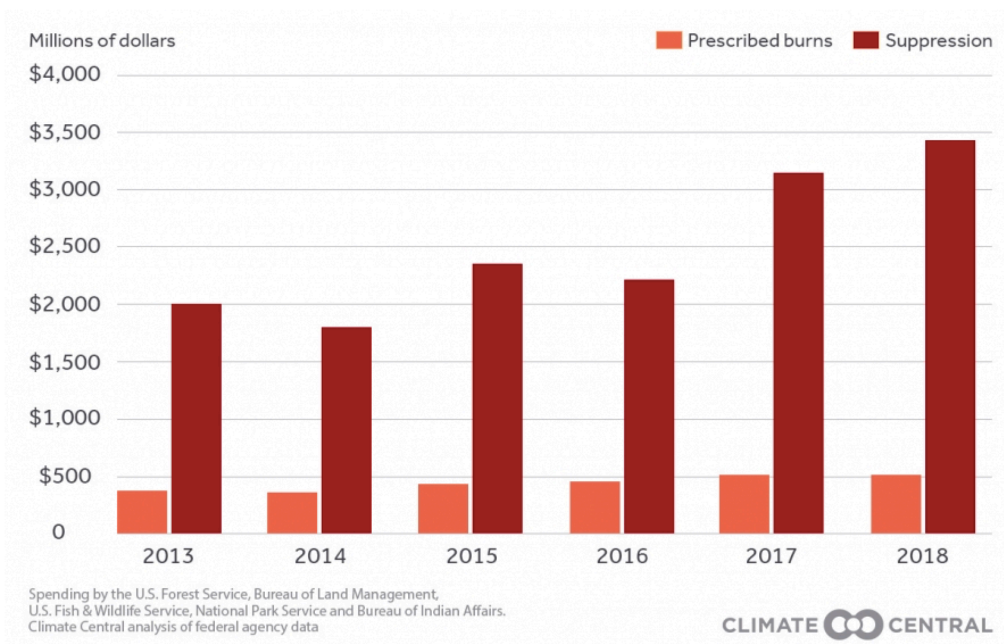

Figure 5. Spending on Fire Suppression vs. Prescribed Burn Treatment. Source: *The Burning Solution: Prescribed Burns Unevenly Applied Across U.S.* Climate Central, 2021, https://www.climatecentral.org/news/report-the-burning-solution-prescribed-burns-unevenly-applied-across-us. Accessed 2 January 2021.

Although fire-resistant building materials, defensible space, fuels reduction, education programs, and risk maps are very important and useful mitigation strategies, prescribed burning is arguably the most important mitigation strategy because it possesses the greatest ability to significantly reduce all other costs associated with the wildfire problem. When prescribed burns are absent from a fire-prone landscape, thick vegetation grows and invasive species that act as a tinderbox for fire, like the scotch broom plant, thrive. Thick vegetation and invasive species are major sources of fuel that can make small wildfires very large very quickly. Alternatively, when prescribed burns are present in a fire-prone landscape, vegetation is thinned out and invasive species are burned before fuel accumulations become too excessive, making room for plant species that are more resistant to wildfire. A lack of excessive fuels and an abundance of fire-resistant plants means that when a wildfire does start, it is more likely to stop on its own rather than spreading to nearby communities at a speed faster than firefighters can handle. With fewer wildfires reaching communities, the economic, social, and financial costs associated with wildfire destruction are significantly reduced. Investing in prescribed burns today can create long-term reductions in costs for the future. However, as mentioned before, prescribed burns are becoming increasingly difficult to perform as more and more housing is constructed in ecologically fragile areas, such as the WUI.

The Wildfire Problem and Contributing Factors

So far it has been established that there are fire-prone areas, these fire-prone areas are generating significant costs economically, socially, and financially, and policies are mostly directed at fire suppression as opposed to mitigation, especially controlled burns. But why are we spending so much more on suppression than we are mitigation? In this thesis, I argue that the two main contributing factors to California's wildfire problem are climate change and construction in the wildland-urban interface (WUI). The climate crisis has changed wildfire dynamics faster than we have come to understand the benefits of controlled burns, so suppression has been given priority over mitigation to keep up with the growing wildfire problem and too much housing in the WUI has made it difficult for controlled burns to be implemented at the speed required to curb the growing wildfire problem.

Climate change is contributing to worsening wildfires by introducing changes in the weather conditions that determine a wildfire's size and severity, along with the length of wildfire seasons. Meteorological variables, including temperature, relative humidity, and precipitation, play a significant role in shaping the climate conditions that influence wildfire activity (Barbero et al. 893). Higher temperatures, lower humidity, and decreased precipitation all create dryer conditions that can fuel a wildfire's rate of spread. These same variables that influence wildfires are also being altered by climate change and subsequently worsening wildfires. For example, droughts in the southwestern United States are projected to become more intense and summer temperatures in the west are projected to continue rising, along with a reduction in soil moisture (NASA). Using a spatially explicit landscape model, Cassell et al. found that wildfires will become more frequent, more extensive, and more severe under the projected climate scenario and there will be an increase in the number of extreme fire years under projected climate change (9). A study predicting very large fires (VLFs) under climate change found projected increases in VLF potential across most of the United States with the largest increases in regions that experienced numerous VLF in recent decades, such as the intermountain West (Barbero et al. 894). Additionally, Westerling et al. found that the average wildfire season length, which is defined as the time between the first reported wildfire discovery date and the last control date, increased by 78 days when comparing 1970 to 1986 with 1987 to 2003 (941). The regional spring and summer temperatures were moderately correlated with the annual fire season length

(941). Earlier snowmelt years were also associated with longer wildfire seasons because they can result in earlier, longer dry seasons that reduce soil moisture and make vegetation drier (942).

The WUI is the second contributing factor to the wildfire problem, and the one that is the focus of this thesis, because the presence of housing in wildland areas makes it more difficult for prescribed burns to be implemented. These planned burns are necessary for preventing the wildfire problem from growing worse because they can reduce the risk of large wildfires by thinning out vegetation and removing invasive species that are prime fire fuel. Our inability to do more controlled burns stems from the tension between environmental managers who want to do planned burns, and homeowners who do not like the smoke generated by these burns and feel fearful about fire being so close to their home. There are also conflicting interests between environmental managers and homeowners and real estate developers, who demand housing in the WUI.

While we know that real estate developers are demanding housing in the WUI purely for profit, it is not known with as much certainty why homeowners are demanding homes in these ecologically fragile areas when it puts them at so much risk. To begin answering this, the next chapter will determine who, in class terms, is moving to the WUI, which is something that no one has yet explored through state-wide empirical analysis. Cost of housing is a big way of understanding the class dynamics of housing, but it is difficult to examine due to variations in housing costs over time and by area. Instead, income will be used as a proxy for class because, generally, poor people tend to live in poor housing and wealthy people tend to live in rich housing. Once it is established *who* is moving to the WUI, the question of *why* can then be answered. In answering *why*, we can then understand what actions need to be taken to reconfigure human relations to the ecologically fragile WUI.

Chapter 3: The Intersection Between Housing, Class, and Wildfires: An Empirical Analysis

Defining the Wildland-Urban Interface

The wildland-urban interface, or WUI, is the area where houses intermingle with or meet undeveloped vegetation. It can be found in the United States and other countries around the world, including Argentina, Australia, France, and South Africa (Radeloff et al. 3314). The primary focus of this thesis is one state in the U.S., California, a particularly important state in the national imagination and economy, and also a particularly important state when it comes to wildfires. There are two types of WUI, which are known as intermix and interface. Intermix WUI is defined as areas with at least 6.18 houses per km^2 and at least 50 percent cover of wildland vegetation (Martinuzzi et al. 8). Interface WUI is defined as areas with at least 6.18 houses per km^2 and less than 50 percent cover of vegetation located less than 2.4 kilometers from an area at least 5 kilometers squared in size that is at least 75 percent vegetated (Martinuzzi et al. 8). In simpler terms, intermix WUI is "the area where houses and wildland vegetation directly intermingle" and interface WUI is "developed areas that have sparse or no wildland vegetation, but are within close proximity of a large patch of wildland" (Kramer et al. 642). Currently, the most up-to-date information and data on the wildland-urban interface is from 2010. There is also information and data available from 1990 and 2000. Since it appears that this data is being updated every ten years, hopefully there will be new data within the next few years, but 2020 data was not yet available for this current thesis.

In 2010, the WUI covered about 771,000 km^2 in the conterminous United States, which is about 9.9 percent of the land area (Martinuzzi et al. 12). The intermix WUI covers more land area than the interface WUI, but the interface WUI contains more houses and a larger population (Martinuzzi et al. 12). The WUI can be found in all of the lower 48 states, which excludes

Hawaii and Alaska but includes the District of Columbia. Although the WUI is present across most of the country, some regions have more WUI area than others. North Carolina, Georgia, Texas, and Pennsylvania have the largest WUI area, which demonstrates that the majority of WUI area is concentrated in the eastern and southern United States (Martinuzzi et al. 12). However, California has the greatest number of houses located in the WUI with a total of 4.46 million houses in these areas (Martinuzzi et al. 14). The United States has approximately 4.6 million seasonal homes and 59 percent of them are located in the WUI with Florida and California hosting the greatest number of seasonal homes (Martinuzzi et al. 16).

WUI Growth Trends

The WUI grew rapidly between 1990 and 2010 in terms of land area, housing units, and population. Land area grew by 33 percent, from 581,000 to 770,000 km^2 (Radeloff et al. 3314). Additionally, there were also 12.7 million more houses and 25 million more people in 2010 when compared to 1990 (Radeloff et al. 3316). While the total WUI in the conterminous United States grew rapidly over the course of twenty years, intermix WUI and interface WUI grew at different rates. Intermix WUI grew from 5.6 percent to 7.5 percent, whereas interface WUI only grew from 1.6 percent to 2.0 percent (Radeloff et al. 3316). However, interface WUI had a housing growth rate of 43 percent between 1990 and 2010 in comparison to 38 percent in intermix WUI (Radeloff et al. 3316). Essentially, more and more natural land in California is characterized as WUI.

Demographic trends and changes have played a significant role in the growth of the WUI in the United States. A study by Hammer et al. examined how demographic changes in the West are influencing WUI growth. They found that a growing population in combination with declining average household sizes and changes in vacancy rates has caused the number of housing units to more than triple between 1940 and 2000 (Hammer et al. 778). However, it is the distribution of this growing population and the resulting housing patterns that are most significantly impacting the WUI and wildfire problem. The population of the West grew 4.5 times larger between 1940 and 2000, in comparison to other contiguous states which grew only 1.7 times larger (779). Although the West does not contain the most WUI area within the country, it is an area where the WUI is at more risk from wildfire events. Approximately 2.2 million housing units were added to the WUI in the West during the 1990s, which accounted for a 25 percent growth rate (779). Interregional migration to the West and population deconcentration are each conditions necessary for continuing WUI expansion (778). Increases in multiple homeownership and seasonal homes have also been contributing to more housing units in the WUI since these types of property are typically sought after for their natural and environmental amenities. There is also one specific demographic group that has been contributing to WUI expansion in recent years and is expected to continue adding people to these areas. The baby boomer generation has now reached retirement age and their migration to amenity-rich nonmetropolitan areas is expected to exacerbate the population growth trends occurring in the West and WUI. Between 1960 and 2000, about 6.7 million people were added to the West from net migration of baby boomers, which is the difference between out-migrants and in-migrants (780).

Making the WUI

There are two main processes that create new WUI land: construction of new houses in pre-existing WUI areas and growth of vegetation into non-WUI areas that then pushes these areas into WUI classification based on the WUI definitions stated above. Construction of new houses has been the dominant WUI creation process as opposed to vegetation growth. A study by

Radeloff et al. that examined WUI growth found that 97 percent of all new WUI areas were the result of housing growth in sparsely settled areas, whereas only 2 percent was caused by vegetation growth and 1 percent was due to a combination of both (3316).

In the case of California, the creation of new WUI areas due to construction of new homes becomes a complicated process because local land use planning is ultimately up to cities and counties, not the state, making it a decentralized system. This means that land use policies may vary significantly in different areas of the state. Therefore, land use policies that influence the creation of more WUI land from residential real estate development may also vary widely from area to area. The real estate development process involves many steps and obstacles that vary by city and county. Generally, zoning regulations are the initial obstacle to development and the approval process is the larger obstacle. Since land use in California is decentralized, private landowners, including farmers, ranchers, and companies, are able to decide whether to open up their land for development and it is up to the local community to manage the growth of these rezoned areas (Balaban and Fu 824). It is possible that many of these private landowners sold property they owned in the WUI, which was then rezoned, thus allowing development to occur in areas where economic or political forces created pressure to do so (Balaban and Fu 824). This agricultural or business property that they sold would not have been considered to be WUI until it was rezoned to be used for residential property, which would then shift it to a WUI area since there would now be houses in the area. There is motivation to expand residential development into WUI areas because of California's shortage of housing. In a survey of planners in California, half of respondents rated land supply as a major or severe constraint to residential development (Mawhorter and Reid 19). This issue is likely most prominent in highly desirable city areas that are the hubs for job growth. Especially in coastal cities, housing growth is unable to keep up with job growth (Reid et al. 245). Affordable housing is a particularly prominent issue in many major cities throughout California. The lack of land supply in California's cities in combination with a lack of affordable housing creates both the motivation to push residential development into WUI areas and the motivation to purchase houses in these areas.

The WUI and Wildfire Risk

Prior research suggests that wildfire destruction, in terms of buildings destroyed, is higher in the WUI than other areas. A study that examined wildfire destruction in the WUI found that 82 percent of destroyed buildings were located in the WUI even though only 32 percent of California's buildings are in the WUI (Kramer et al. 645). There are also differences in the destruction of property between interface and intermix WUI. For example, this study also found that 50 percent of all destroyed buildings were located in the interface WUI (Kramer et al. 645).

Higher rates of destruction from wildfire in the WUI are likely due to several factors, most of which derive from the presence of humans. Sparsely developed WUI areas tend to have fewer roads, which can complicate firefighting efforts by making it more difficult for teams to reach structures. The opposite can also make building destruction worse. If houses are close enough to each other and the flames of a wildfire are large enough, a fire can jump from structure to structure in what is known as urban conflagration (Internal Displacement Monitoring Centre). Humans are also the most common cause of wildfires. More people in the WUI means there is a greater chance of wildfire due to human negligence. It is also of little surprise that there are higher rates of building destruction in the WUI because this is the area where flammable vegetation meets flammable houses. There is minimal chance of a wildfire destroying buildings in a city packed with skyscrapers, apartment buildings, and lots of concrete because there is not enough vegetation to sustain a destructive wildfire. Completely vegetated areas with no housing are also not going to host high rates of building destruction because there are no buildings to be destroyed. A WUI fire disaster only occurs if a house ignites, otherwise it is only an extreme wildfire (Cohen 22). It is possible to allow wildfires to burn past a house with no damage to the structure if the house is properly and sufficiently resistant to ignition. However, this is evidently not the case as illustrated by the high rates of building destruction in the WUI.

The inability of fire managers to perform more controlled burns in the WUI due to large amounts of housing is the most important reason that the WUI has higher rates of housing destruction. These homes are interspersed with or near wildland that needs periodical burning to prevent very large, more destructive wildfires in the future, but the presence of these homes makes the task of using controlled burns to prevent large wildfires very difficult. The insufficient amount of controlled burns occurring in the WUI has resulted in fuel accumulations that are combining with longer wildfire seasons due to climate change. These combined forces are increasing the risk of very large, destructive wildfires and therefore putting homes in the WUI at greater risk of severe fire damage or complete destruction.

Although people and vegetation have likely intersected in ecologically fragile ecosystems throughout history, the WUI and its fire problem were not nationally acknowledged until relatively recently. It was not until 1985 that the home destruction problem related to wildfires became nationally recognized, which is known as the WUI fire problem (Cohen 20). The Wildfire Strikes Home conference of 1986 was the initial response fire management response to the WUI fire problem (Cohen 20). Since then, a plethora of research has been conducted in relation to the WUI and its problems. Past research has ranged from environmental science oriented research, such as examining the geospatial composition of the WUI, to the social dynamics influencing life in the WUI, such as perceptions of risk in relation to mitigation efforts.

While there has been expansive research on the WUI, one area of research that has not yet been investigated is the income distribution of those living in the WUI, which can be used to determine the overall class composition of the WUI.

The WUI and Income

Previous literature has suggested that the WUI consists of a generally wealthy population (Reilly 542). This claim is based on the large amount of second homes in these areas (one in five homes in the WUI is a second home), which is typically a luxury only those with very high incomes or accumulated wealth can obtain (Reilly 553). While the amount of second homes in the WUI can serve as a good indicator of how wealthy WUI residents are, it is based too heavily on the causal assumption that more second homes means the residents are more wealthy. In order to combat this causal assumption and better understand the full range of income across the WUI, I will use geospatial data on the location of the WUI in California to determine the median income of residents in these areas. This will provide numerical quantities on who is living in the WUI, specifically in terms of low-income, middle-income, and high-income residents. These findings on the distribution of income in the WUI will have significant implications for how we design solutions to the growing wildfire problem. In addition to determining the class composition of those living in the WUI, I will also use mapped visualizations with the Camp Fire in Paradise, California as a case study to illustrate the relationship between wildfires, the WUI, and class.

Data and Methods

Data on both the WUI and median household income were obtained and combined into one dataset for the empirical portion of this thesis. The first set of data consists of geospatial data and a geodatabase that plot the WUI across the conterminous United States in 1990, 2000, and

2010. The geodatabase includes information such as housing and population densities in 1990, 2000, and 2010, as well as WUI classes in these same years. The most recent year for which WUI data is available is 2010, which will be used for the income analysis. Data on median household income in 2012 is from the U.S. Census Bureau and is distributed by the National Historic GIS project. 2012 was the closest year to 2010 for which median household income data was available. Census blocks are the unit of analysis for the WUI data and census tracts are the unit of analysis for the median household income data. The combined data set contained data on the entire United States, so another data set was created that is a subset of the larger data set. This smaller data set contains data only on the WUI in the state of California.

The income groups for this analysis were determined by first dividing the median household income variable for all of California in 2012 into quintiles, or fifths. This resulted in the following income groups: less than $38,347, between $38,348 and $49,771, between $49,772 and $62,830, between $62,831 and $83,430, and more than $83,431. The lowest income group was then shifted up to $46,662 and the other income groups were also shifted up by the corresponding difference between the old value and new value. This value was chosen for the lowest income group because the California Department of Housing and Community Development defines “low-income” as up to 80 percent of median family income or local area median income. This also the definition set forth by the Department of Housing and Urban Development and is one of the most common definitions for low-income. Since this thesis is examining the income of residents of the WUI across all of California and the income data used for this analysis was measured at the census tract level and not the household level, I used the median household income for the state of California in 2012 as a replacement for median family income or local area median income. The median household income for the state of California in

2012 was $58,328 and 80 percent of that value is $46,662. The new income groups resulting from this shift of the quintiles to reflect the California Department of Housing and Community Development's definition of "low-income" are as follows: less than $46,662, between $46,663 and $58,086, between $58,087 and $71,145, between $71,146 and $91,746, and more than $91,746. It should be noted that these income groups do not represent median household income at the household level. Instead, these represent median household income at the census tract level. As an example, the lowest income group could be interpreted as the number of people, housing units, or acres in census tracts with a median household income of $46,662 or less. Table 1 summarizes the income groups and indicates their corresponding classification of income classes.

Income Group	Classification
< $46,662	Low-income
$46,663 - $58,086	Lower middle-income
$58,087 - $71,145	Middle-income
$71,146 - $91,745	Upper middle-income
> $91,746	High-income

Table 1. Income Groups and Corresponding Classification of Income Classes

While the first income group represents low-income, the next three income groups collectively represent middle-income, with the second and fourth income groups acting as subdivisions of the middle income that represent lower middle-income and upper-middle income. Middle income is much more difficult to define because there are many different definitions of the middle class. For example, Pew Research Center classifies the middle class as those earning between 67 percent to 200 percent of the median income, Alan Krueger of former President Obama's Council of Economic Advisers uses 50 percent to 150 percent of median income, and Lester C. Thurow used a range of 75 percent to 125 percent of median income (Reeves et al.). Although there is no official government definition of the middle class, the

Census Bureau has displayed income information in the past by dividing the income distribution into quintiles. Using quintiles, the middle class can narrowly be classified as only the middle (third) quintile or more broadly as the middle three quintiles (Elwell 4). The middle three quintiles approach was chosen to define the middle class income for this thesis, with the slight change of an upward shift across all income groups to accommodate the definition of low income. The income range for middle class can also vary greatly by region due to differences in costs of living, so $91,745 was chosen as the cut-off for this group because it was decided that it is better to estimate a higher cut-off rather than a cut-off that may exclude important portions of the middle class. The high-income group was then defined as any income above the cut-off for upper middle class.

In addition to quantifying the presence of the WUI across income groups, I also created a map using ArcGIS software to visualize the relationship between income, wildfires, and the WUI. The insights from this map will serve to supplement the findings from the income analysis of the WUI. The first layer added to the map was the WUI in 2010. A layer containing the most up-to-date American Community Survey (ACS) median household income data was added next. The Camp Fire perimeter layer was then added.

Results from Income Analysis of the WUI

The first set of findings investigate the population size, number of housing units, and acres in both California as a whole and within the WUI. These three variables were selected for the analysis of income and class in the WUI because they serve as excellent indicators of the size of the WUI. I will use the classification of the income groups in terms of the classes they represent (see Table 1) to discuss the results of my analysis.

Population, housing units, and acres in California were summarized first to serve as a comparison to the WUI population, housing units, and acres. The total population, housing units, and acres for all of California are summarized in Table 2. While population and housing units were more equally distributed across income groups, the low-income group accounted for more than half of the acres in California. The large percentage of land in the lowest income group can be explained in part by the large amount of land dedicated to agriculture. Approximately 43 million acres of land are used for agriculture in California (Thompson). Although income in the agricultural industry depends largely on the size of the operation, owners of smaller farms generally have lower incomes. Additionally, census tracts that are mostly agricultural land will have fewer people, which can pull down the median household income of those census tracts.

ALL CALIFORNIA (TOTALS):						
Quintiles for Median Household Income	Population	%	Housing Units	%	Acres	%
< $46,662	10,932,734	29%	3,782,852	28%	55,092,507	54%
$46,663 - $58,086	6,480,933	17%	2,378,473	17%	19,422,114	19%
$58,087 - $71,145	6,260,546	17%	2,365,283	17%	13,654,526	13%
$71,146 - $91,745	6,780,545	18%	2,586,125	19%	8,511,509	8%
> $91,746	6,782,854	18%	2,559,954	19%	4,882,872	5%
Total	37,237,612	100%	13,672,687	100%	101,563,528	100%

Table 2. Population, Housing Units, and Acres by Income Group for all of California

Population, housing units, and acres were then examined by WUI type and income group. Population by WUI type and income group were examined first and the findings are summarized in Table 3. The population variable from the dataset used for this analysis measures the number of people in census tracts that fall into each income group. In comparing this table to the previous table in order to determine the representation of each income group for the WUI, it can be seen that the low-income group is underrepresented and the high-income group is overrepresented, but the middle class income groups are comparable. From Table 3 below it can also be seen that the intermix WUI had a larger population overall than the interface WUI, except for the high-income group. The most important finding from this table is the identification of which socioeconomic class makes up the majority of the WUI population. As mentioned previously, the middle three income groups collectively represent the middle class. When these three groups are combined, it can be seen that 57 percent of the intermix WUI population, 50 percent of the interface WUI population, and 54 percent of the total WUI population is middle class. When the low-income population is added to the middle class, these numbers become 81 percent, 60 percent, and 72 percent, respectively. This shows that the overwhelming majority of WUI residents are lower and middle class people and disputes the suggestions of previous literature that the WUI is primarily inhabited by wealthy Americans.

Population						
Quintiles for Median Household Income	Intermix	Percentage in Intermix	Interface	Percentage in Interface	Total WUI	Percentage in Total WUI
< $46,662	380,002	24%	98,043	10%	478,045	18%
$46,663 - $58,086	317,012	20%	132,098	13%	449,110	17%
$58,087 - $71,145	288,938	18%	130,035	13%	418,973	16%
$71,146 - $91,745	308,337	19%	248,301	24%	556,638	21%
> $91,746	316,524	20%	417,342	41%	733,866	28%
Total	1,610,813	100%	98,043	100%	2,636,632	100%

Table 3. Population by Income Group and WUI Type

Housing units was analyzed next and these findings are summarized in Table 4. The first important component in this table is the total number of housing units in the total WUI. When this number is calculated with the total number of housing units in all of California from Table 2, it can be concluded that approximately 1 in 13 houses in California are located in the WUI. Socioeconomic class representation of housing units in the WUI in comparison to all of California are similar (see Tables 2 and 4). The combined middle class again makes up the largest portion of the WUI across all WUI types. The intermix WUI is 59 percent middle class housing units, the interface WUI is 50 percent, and the total WUI is 56 percent. When housing units from low-income census tracts are also considered, these numbers then become 84 percent, 60 percent, and 75 percent, respectively. Supporting the same finding as in population, the majority of housing units in the WUI are located in lower and middle class census tracts.

Housing Units						
Quintiles for Median Household Income	Intermix	Percentage in Intermix	Interface	Percentage in Interface	Total WUI	Percentage in Total WUI
< $46,662	189,462	25%	38,017	10%	227,479	20%
$46,663 - $58,086	163,352	22%	48,012	13%	211,364	19%
$58,087 - $71,145	138,018	19%	47,108	12%	185,126	17%
$71,146 - $91,745	130,670	18%	96,041	25%	226,711	20%
> $91,746	122,282	16%	148,809	39%	271,091	24%
Total	743,784	100%	377,987	100%	1,121,771	100%

Table 4. Housing Units by Income Group and WUI Type

The findings for acres are summarized in Table 5. Acreage data again confirms that the WUI is made up primarily of lower and middle class constituencies. These income groups combined account for 57 percent of total WUI acres. However, acreage data also shows one slight difference with regard to the poorest where the proportion of acreage is higher than the proportion of housing they occupy in Table 4.

Acres						
Quintiles for Median Household Income	Intermix	Percentage in Intermix	Interface	Percentage in Interface	Total WUI	Percentage in Total WUI
< $46,662	1,304,590	28%	21,385	14%	1,325,975	27%
$46,663 - $58,086	960,913	21%	19,262	13%	980,175	20%
$58,087 - $71,145	912,493	20%	14,462	10%	926,955	19%
$71,146 - $91,745	827,401	18%	31,958	21%	859,358	18%
> $91,746	673,496	14%	62,454	42%	735,950	15%
Total	4,678,893	100%	149,521	100%	4,828,413	100%

Table 5. Acres by Income Group and WUI Type

The above results provide solid, quantifiable evidence regarding who is moving to the WUI, in terms of class, based on the breakdown of population, housing units, and acres by income group. Given that no one has previously examined this breakdown, these results hold significant value for furthering our understanding of the WUI's influence on wildfires and what solutions need to be formulated to reduce the WUI's burden on the wildfire problem. From these results, it can be observed that all income groups can be found in the WUI to some extent. The WUI's coverage is extensive, with approximately 1 in 13 houses in California located in the WUI. Although the WUI encompasses all income groups, the results of this empirical analysis reveal that lower and middle income census tracts make up the greatest percentage of the WUI population, housing units, and acres across all WUI types. In the total WUI, which consists of intermix and interface communities combined, 54 percent of the population, 56 percent of the housing units, and 57 percent of the acres in California are middle class alone. When low-income census tracts are added to this, 72 percent of the population, 75 percent of the housing units, and 84 percent of the total WUI acres are in lower and middle income census tracts.

It is evident from these results that the overwhelming majority of the WUI is constituted by lower and middle income residents, but why does this information matter? Knowing which income classes make up the largest portion of the WUI is the first step in figuring out what to do next to alleviate the pressure that the WUI is putting on the wildfire problem. As this thesis has already established, the WUI is contributing to California's growing wildfire problem by making it more difficult to perform controlled burns. These burns must be carefully planned so that they do not affect nearby housing with smoke or damage. This task becomes trickier as more and more housing is constructed in ecologically fragile zones. The results from this analysis of class dimensions in the WUI can help answer the question, why are so many people moving to the WUI? Knowing that it is lower and middle income households who make up the majority of the WUI, it can be speculated that the expensive price of housing in California may be one strong factor that is at play here. The median sale price of homes in California reached a peak in September of 2020 at approximately $712,430 (Kamin). Additionally, the average cost of rent can range from $1,061 for a studio to $2,437 four-bedroom home, but these costs can be much higher depending on the city (RentData.org). For example, average rent for a two-bedroom home in the San Francisco area is approximately $3,553 (RentData.org). The rise in expensively priced homes and high rents in California's most desired areas in addition to a shortage of affordable housing may be pushing financially constrained households to the WUI, where houses are further away from the expensive cities and subsequently cheaper too.

The Camp Fire in Paradise, CA as a Case Study

Now that it has been discovered who, in class terms, is moving to the WUI in the greatest numbers, mapping fire perimeters against WUI and median household income layers can help supplement these findings by highlighting the relationship between wildfires, the WUI, and class. Since it would be too much to look at all wildfires that have occurred in the state of California, I selected the Camp Fire as a case study to illustrate these relationships and to see if any interesting patterns exist. In the following map visualizations, orange areas are the intermix WUI and yellow areas are the interface WUI (see Table 6). Additionally, the median household income of the census tracts in the last 12 months is scaled by a color range from purple to green, with lower incomes being depicted by increasingly darker purple and higher incomes being depicted by increasingly darker green (see Table 6).

Wildland-Urban Interface	Interface Intermix
Non-WUI Vegetated	No housing Very low housing density
Non-vegetated or Agriculture	Uninhabited Low and very low housing density Medium and high housing density Water
Median Household Income in past 12 months (inflation-adjusted dollars to last year of 5-year range)	> 90,000 60,300 < 30,600
Camp Fire Perimeter	

Table 6. Legend for GIS maps in Figures 6a and 6b

The Camp Fire started in November of 2018 as a result of faulty powerlines and affected Butte county (CAL FIRE). This was the deadliest and most destructive wildfire in California's history, with 85 deaths and 18,804 structures destroyed (CAL FIRE). The town of Paradise was the worst affected area, with 95 percent of the town burned by the wildfire (Ailworth). News stories about the tragedy in Paradise swamped newspapers, magazines, television, radio, and the internet for months. The stories about the town's recovery continue today. Many of these stories documenting the Camp Fire are anecdotes of the people who survived and their stories of escaping Paradise. For example, a New York Times Magazine article from August 4th, 2019 tells the gripping story of how one woman narrowly escaped the fire, going into fine detail on not just how she escaped, but also her life story and background. These anecdotal stories do an excellent job of putting readers in the mindset of the Camp Fire survivors and also give some indication of Paradise residents' socioeconomic status. However, anecdotes are only focused on a few select individuals and may not necessarily be indicative of the whole population. My geographical analysis of the Camp Fire in Paradise is able to showcase the general socioeconomic status of the whole town's population by determining the class status of those residing in Paradise using income as a proxy for class. Examining the class status of Paradise residents, in combination with the Camp Fire perimeter and presence of WUI, can aid in better understanding the role of the WUI in the Paradise, California tragedy.

Figure 6a depicts the fire perimeter as a dotted line against the WUI and income layers. Examining the Camp Fire perimeter in its entirety, affected census tracts ranged in median household income from $40,071 to $109,444. As illustrated in Figure 6a, lower middle-income census tracts were primarily affected by the Camp Fire with the fire perimeter encompassing the entirety of these census tracts. Portions of some low-income and high-income census tracts were also within the fire perimeter. Intermix and interface WUI areas were present across all census tracts impacted by the Camp Fire, but the lower middle-income census tracts appear to have the greatest proportion of WUI relative to the size of the census tract.

Figure 6b depicts the outline for the town of Paradise, California. From this map, two critical aspects of Paradise are evident. First, the median household income of the census tracts that make up Paradise range between $44,500 and $57,330. In class terms, the town of Paradise is home to primarily low and lower-middle income residents. Secondly, Paradise appears to be almost entirely WUI area with a mixture of both intermix and interface areas. While it was somewhat known from anecdotal news articles that Paradise was home to primarily low and middle-income households, it was not known that the town was essentially all WUI. It is important to note, however, that those living in Paradise knew they lived in an at-risk area. The town had evacuation plans already in place and regularly performed emergency drills (Monroe). The problem Paradise faced when the Camp Fire struck was that the town never anticipated they would need to evacuate the entire town in a very short time period (Monroe). The fire moved too quickly and too many people were trying to flee all at once (Monroe). The anecdotal account of one woman's survival story from the New York Times Magazine article previously mentioned is a testament to the chaos that ensued when no one could actually leave Paradise because of the road traffic (Mooallem). It was these traffic jams that cost numerous people their lives (Mooallem). Paradise's problem wasn't lack of preparation, it was instead the fire itself. The problem with the fire itself is where the role of the WUI comes in. As established earlier in this thesis, fires increase in severity from a variety of factors, including temperature, humidity, wind, and fuel accumulations. While all these factors had important roles in the severity of the Camp Fire, the WUI is entirely responsible for the fuel accumulations factor. The more houses there are interspersed with or near wildland areas, the more difficult it is to do controlled burns. Without concrete evidence on how often controlled burns were implemented prior to the Camp Fire, it can only be speculated that there were not enough. Given the evidence that Paradise is almost entirely WUI area, it can be further assumed that there were not enough controlled burns occurring around Paradise given both the severity of the fire and the vast amounts of housing interspersed with and near wildland areas.

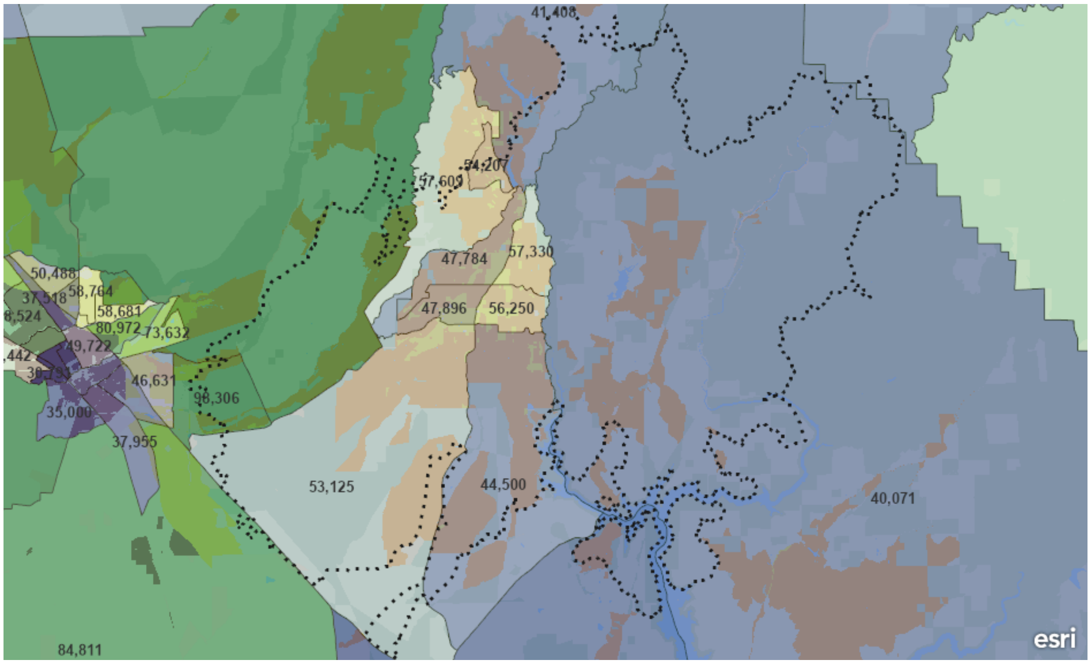

Figure 6a. Camp Fire perimeter mapped in comparison to the WUI (intermix and interface) in 2010 and median household income by census tract

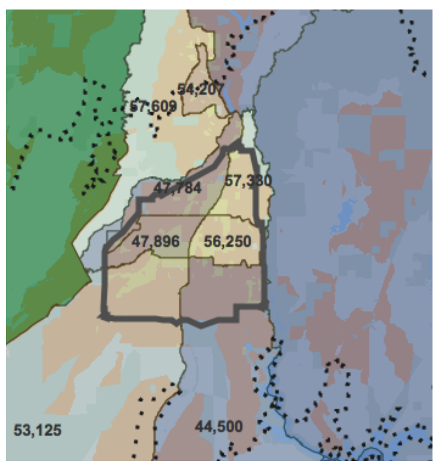

Figure 6b. Paradise, CA perimeter in comparison to Camp Fire perimeter, the WUI, and median household income by census tract

In the first part of the empirical analysis, it was revealed that the majority of the WUI is low and middle income people, houses, and acres. These maps of Paradise support this finding by showcasing the large presence of low and lower-middle income residents in a town made almost entirely of WUI. Anecdotal news articles have noted that many residents of Paradise moved there for its affordability and the town attracted primarily working-class retirees and younger families (Mooallem). Lower and middle income people moving to the WUI for its affordability creates more WUI when new houses are built to accommodate this demand. More housing in the WUI makes controlled burns more difficult to perform, which then increases fuel accumulations and the risk of very large wildfires. It is in these ways that the WUI, class, and wildfires are interconnected. Knowing that WUI areas are especially attractive to low and middle income households for their affordability, as evidenced by anecdotal news stories and this thesis' income analysis and geographic maps of Paradise, provides clarity that the shortage of affordable housing in California is a problem that needs to be addressed in order to fully address California's wildfire problem. The next chapter will discuss the implications of these findings in finer detail, along with the limitations of this analysis, and what needs to be addressed next moving forward.

Chapter 4: Implications and Discussion of Results

Implications of Empirical Work

While the results of the income analysis from the previous chapter show that the WUI encompasses the entire income distribution in California, the most important finding is that lower and middle class households make up the majority of these ecologically fragile areas. The devastating consequences that can arise when the WUI and wildfire meet is evidenced by the case study of the Camp Fire in Paradise. The mapped visualizations revealed that the town was primarily low and lower-middle income households and almost entirely WUI area. Based on this new understanding of the WUI's class composition that resulted from the empirical work of this thesis, it can be speculated that the affordable housing crisis in California is one major factor pushing lower and middle class people to the ecologically vulnerable WUI.

The affordable housing crisis in California is a complex issue that has been studied by scholars since the mid-1970s (Dougherty). To briefly delve into this issue and how it relates to the wildfire problem, it should be emphasized that this is a three-fold issue. There are three different kinds of housing crises currently and each one is relevant to the wildfire problem.

The first one involves California's homeless population, which was around 150,000 as of January 2021 and is the crisis that California's governor has devoted the most attention to (Levin). When wildfires destroy houses, those people become homeless temporarily. This was an especially big issue for Butte county after the Camp Fire in 2018, which already had 2,000 homeless people before the fire (Levine). After the fire, around 52,000 people had been evacuated and were looking for a place to stay overnight (Levine). The influx of new homeless people created tensions with the old homeless people because resources were so constrained that very difficult decisions had to start being made regarding who was given a place in shelters and who was turned away (Levine). Addressing the homelessness problem in California means increasing the availability and stock of affordable rental housing, which can in turn make more temporary housing available to wildfire evacuees.

The second housing crisis involves the 7.1 million people living in poverty in California, of whom 56 percent see more than half their paycheck go to rising rents (Levin). Due to displacement and gentrification pressures, along with overcrowding and unsafe housing conditions, these renters are increasingly fleeing urban areas to the cheaper exurbs (Levin). Not only can these renters not afford the rents in cities, they also cannot afford the suburbs, which is the next outer ring of a city. Even further than the suburbs is the exurbs, which are typically rural areas right outside suburban areas. These exurban areas may actually be the wildland-urban interface in many cases. Addressing high rental costs in California's cities and suburbs can improve the wildfire problem by reducing the need for people to live in the fire-prone WUI simply because it is cheaper to do so.

The third and final housing crisis in California affects the younger middle-class and higher-income population through the rising cost of homes (Levin). The average home in California cost approximately three times the average household income in the late 1960s, but today costs more than seven times the average household income (Levin). Additionally, high rents are making it more difficult for young people to save up for the down payment needed to purchase a house (Levin). High-income households are also being squeezed by the high costs of housing in California and many have been leaving the state in flocks to go to more affordable areas like Austin and Portland (Levin). This has especially been an issue for Idaho, which has seen rapid growth in its economy due to Californians moving there for the more affordable housing (Dougherty). While this can be considered good for Idaho's economy, it is bad for the people already living in Idaho because the influx of Californians, with budgets up to fifty percent higher than locals, is pushing the cost of housing in Idaho higher and higher (Dougherty). This last housing crisis is the most complex because resolving it means not just improving rental costs, but also keeping the overall housing stock growing at a rate that can keep up with the amount of people moving to California for jobs. However, meeting this demand does not mean constructing more houses in the WUI. It instead means constructing more houses in ecologically sustainable ways that will allow for controlled burns to be implemented as needed so that people and wildfire can safely coexist.

The empirical work of this thesis demonstrated that all income groups are present in the WUI. Similarly, the housing crisis in California is also impacting all income groups, ranging from the homeless to higher-income Californians. The results of the income analysis in the previous chapter also demonstrated, however, that lower and middle class households make up the majority of the WUI and it was speculated that the lack of affordable housing may be a driving force behind this finding. For this reason, all three aspects of the housing crisis can be considered relevant in the context of the wildfire problem for two reasons. First, each housing crisis involves one of the groups that makes up the largest portion of the WUI. The first two aspects of the crisis involve low-income people and the third aspect of the crisis involves middle-income people. The second reason is that the solution for each component of the housing crisis heavily resides in making rental and housing costs more affordable. With more affordable rental and housing costs, the demand for houses in cheaper but more ecologically vulnerable areas can be reduced. Steps can then be taken to construct houses in more sustainable ways that will enable controlled burns to occur at the frequency needed to keep forests healthy and prevent more very large wildfires in the future. While it was not the goal of this thesis to solve California's housing problem, the work of this thesis has shown how the housing problem is interrelated with the wildfire problem and highlighted the need to address these two problems in conjunction.

It should also be noted that not everyone living in the WUI moved there because the housing is more affordable. While some people moved there for this reason, others may have moved to the WUI for its natural amenities. These amenities can include forests, lakes, streams, hillsides, coasts, and wildlife (Balaban and Fu 824; Stetler et al. 2233). Since the WUI is the area where housing and vegetation meet or intermingle, it is likely that many WUI areas are rich in natural amenities. However, it is also likely that the majority of those moving to the WUI for its natural amenities are higher-income households because studies have proven that property values increase with proximity to natural amenities (Stetler et al. 2239; Kim and Johnson 896). Understanding the relation of natural amenities to the WUI serves to partially explain why higher-income households may be moving to the WUI, but this is less relevant to the work of this thesis, which has established that the greatest portion of the WUI is made up of lower and middle class households, not higher-income households.

The implications of the empirical work from the previous chapter for both the affordable housing crisis and wildfire problem are especially important in how they relate to the difficulty of performing controlled burns in the WUI. As already discussed earlier in this thesis, insufficient implementation of controlled burns is one of the primary contributors to California's wildfire problem. These burns are needed to reduce fuel accumulations, keep forests healthy, and reduce the risk of very large wildfires in the future. Controlled burns are becoming increasingly difficult to perform in the WUI for two main reasons. The first is that they are technically difficult since it is a tricky task to burn areas when there is a lot of housing near or interspersed with the vegetation. The mapped visualizations of Paradise illustrate this difficulty. The town of

Paradise was found to be almost entirely WUI and therefore brings up the question, how can controlled burns be implemented in this area without smoke affecting nearby communities and at the same time maximizing community protection by treating the areas that need controlled burns most? If burns are performed at a far distance from WUI areas to avoid smoke entering the communities within the WUI, then fire managers risk not burning the areas that need controlled burns the most. The second reason controlled burns are difficult to perform in the WUI is that people are afraid of them. As mentioned in the second chapter of this thesis, hostility of the general public towards controlled burns is due not only to unwanted smoke, but also the fear that these burns might jump fire lines and damage nearby communities. This fear has been a big setback for indigenous communities who are trying to bring back the culture of controlled burns. The growing number of houses in the WUI is driven largely by a need for more affordable housing, as can be speculated from the large portion of lower and middle class households living in the WUI. Alleviating the wildfire problem by performing more controlled burns relies heavily on reducing the demand for houses in the WUI, which can be done by creating affordable housing solutions in other areas of California.

In addition to analyzing the class breakdown of the WUI, this thesis is also the first to use the concept of ecological distribution conflicts through a political ecological framework in the context of wildfires. This concept is substantially applicable in understanding the conflicts that arise between parties of varying interests in the prevention and mitigation of wildfires, fighting fires, and in post-fire consequences. One of the biggest conflicts found was between insurance companies and homeowners in terms of who pays for wildfire damages. As more and more large, intense wildfires destroy increasing numbers of homes, the risk to insurance companies becomes increasingly systemic and has resulted in some insurance companies refusing to cover homes in high-risk areas. This refusal of insurance companies clashes with the homeowners in these areas, who believe that they have a right to be covered because many of them do not possess the financial means to cover wildfire damages entirely on their own. The conflict between the insurance companies and homeowners is yet another example of how addressing the affordable housing issue can help further address the wildfire issue. Finding affordable housing solutions can reduce the demand for houses in the cheaper, but more ecologically vulnerable WUI.

Limitations and Directions for Future Research

The work of this thesis did face some limitations due to restraints on time and breadth of analysis. First and foremost, this thesis encountered two major crises that are both significantly contributing to the wildfire problem. The first is the climate crisis that is causing changes in temperatures, humidity, and precipitation and subsequently lengthening wildfire seasons. The second is the affordable housing crisis, which is pushing lower and middle class households into the WUI where housing is more affordable. These are two very large issues that go beyond the scope of this thesis, but further research on each is necessary in mitigating the wildfire problem. Another limitation this thesis faced was the complexity and complications around city and urban planning. These decisions regarding where affordable housing is built and where housing can be constructing in the WUI are both made at the county level as opposed to the state level. California has 58 counties in total, making it very difficult to understand how planning decisions are made. Future research could investigate these decisions and how they vary from county to county. Exploring this component of the wildfire problem can provide insight into how homes can be safely constructed in the WUI and how more affordable housing can be constructed in non-WUI areas. This thesis also faced limitations in exploring the full complexity of fighting wildfires. Besides the complication of housing in WUI areas, many other factors are involved in fighting wildfires, including the terrain, roads, and windspeed. It was beyond the scope of this thesis to explore all the factors that come into play when suppressing wildfires. Future research could possibly include an analysis of interviews with firefighters on the unique complexities of fighting wildfire in WUI areas. The field of research surrounding wildfires has many subcomponents and is continuously expanding. These future areas of research have the potential to continue developing the research on wildfires and further our understanding of the wildfire problem.

Conclusion

To end this thesis, I would like to share a quote from a survivor of the Camp Fire in Paradise. Rex Stewart is a 66 year-old carpenter who had lived in Paradise for more than 40 years when the Camp Fire started. Mr. Stewart was fortunate to escape the fire, but had nothing left except his coat and hat. Standing outside an evacuation shelter, he told a New York Times journalist, “Paradise is gone. There’s nothing to go back to” (Johnson and Del Real). It’s true. The Camp Fire destroyed 95 percent of the town’s buildings and drove out 90 percent of its population (Kamin; Ailworth). Besides physical loss, the town of Paradise lost everything that it used to be. The identity of a town and all the memories of tranquility made there were lost and replaced by the words “gone” and “nothing”. Figures 7 and 8 below are images obtained from Google Earth of one Paradise neighborhood in May and December of 2018. These images encompass the meanings of “gone” and “nothing”. Not one house present in the first image is present in the second image.

Figure 7. A Neighborhood in Paradise, CA in May of 2018. *Source*: Compiled by author using Google Earth.

Figure 8. A Neighborhood in Paradise, CA in December of 2018. *Source*: Compiled by author using Google Earth.

As wildfires increase in severity and number of acres burned across California, the risk of wildfire and its devastating destruction looms over many neighborhoods. This is a problem that we will keep facing and is the reason that both the climate crisis and affordable housing crisis need to be addressed. We often hear of climate refugees in other countries, particularly in regions like Latin America, sub-Saharan Africa, and Southeast Asia, but less attention is given to the climate refugees right in our own country. For the victims of Paradise and other wildfires throughout California that have nothing to go back to, the climate crisis and impact of housing in fire-prone areas on this crisis is their reality.

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