**Eco-cultural Management Implications of California Hazelnut Treatment with Wild and Prescribed Fire: A Case Study in Northern California**

By

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**Abstract**

The tribal nations of northwest California are restoring their practice of cultural prescribed burning to facilitate the regeneration of basket-making materials, medicines, and food. Among the cultural foods are California hazelnut nuts (*corylus cornuta* var. *californica*). California hazelnut nut production was hypothesized to improve through the application of fire at certain points in the development of hazelnut stands and the biological communities surrounding them. In order to investigate the effect of fire on California hazelnut nut productivity, multiple 100 m2 sampling plots were created within areas where wildfires or prescribed burns had occurred, and areas where they have not occurred in >13 years. In those plots, precipitation, nuts per shrub, solar access of individual shrubs, stem diameter, number of stems, among other relevant factors in nut production were measured. Time since last fire (TSLF) was later calculated based upon CalFire fire perimeter maps. Monitoring areas were identified through the local knowledge of Tribal and United States Forest Service staff. Generalized linear mixed models (GLMMs) indicate that the number of nuts produced by individual hazelnuts varied based on interactions between solar access and TSLF. Based on the results of this study, there are multiple ways to manage hazelnut shrubs in order to optimize nut production for cultural food usage. Future studies need to focus on the correlation between fire regime factors and the prevalence of other cultural resources in order to determine the most economically efficient way of applying fire to tribal and public lands.

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**Introduction**

Along the Klamath River in the northernmost part of California, the Yurok, Karuk, and Hupa tribal nations are attempting to restore cultural burning practices to their ancestral territories (Karuk Tribe, 2010, Yurok Tribe, 2012, Hoopa Valley Indian Reservation, 2015). These practices are in line with state and local non-indigenous governmental goals of decreasing wildfire hazards, as prescribed burns decrease wildfire fuel loads and reduce the chance of catastrophic wildfires (Kalies & Kent, 2016). However, tribes view the burns not only as a practice of hazard reduction, but also as a way to increase the abundance of natural resources important to their culture (Lake et al., 2017). One such cultural resource is California hazelnut, corylus cornuta var. californica, an understory shrub that contemporarily produces important basket weaving material from its stems (Zobel, 2002). Another historical use for California hazelnut was as a food resource (Boyd, 1999). Due to the nutrition the nuts can provide and the importance of cultural foods to indigenous communities (Kuhnlein & Receveur, 1996), understanding the relationship of California hazelnut nut production and wildland fire can be useful to land managers interested in utilizing fire not only to decrease hazards, but also to improve cultural resource abundance.

**Background**

1. Social History of Fire and Fire Suppression in Northern California Coastal Forests

Intentional and complex human utilization of fire has been present in the America’s for thousands of years (Kimmerer and Lake, 2001). In northern California coastal forests, American Indian communities along the Klamath River utilized fire in a way that created a mosaic of different vegetation types across landscapes (Lightfoot & Parrish, 2009) (Kimmerer and Lake, 2001). These patches would be created in order to maintain paths, facilitate the gathering of basketry materials, aid in creating attractive browse for game, and increase the abundance of important plant food and medicinal resources (Lightfoot and Parrish, 2009). Fire also served a variety of aesthetic and religious purposes. For example, the Karuk tribe historically conducted ritual burns in ceremonies related to the new year (Kimmerer and Lake, 2001). Indigenous burning practices were extremely sophisticated, the result of knowledge being transmitted and refined intergenerationally (Kimmerer and Lake, 2001).

Fire suppression in California began immediately with the onset of United States’ colonization (van Wagtendonk, 2008). Upon their arrival, anglo-american settlers began the California Genocide, the state sanctioned mass murder of American Indians in areas considered valuable to miners and ranchers (Madley, 2016). Dehumanization of American Indians as a result of racism and settler propaganda to justify the genocide consequently led to a belief that the general nature of their lives was poor (Madley, 2016), despite the fact that the societies of the indigenous people of Northern California coastal forests were socially stratified as a result of wealth accumulation (Thompson, 1991) (Lesure, 1998). This dehumanization led many American foresters to see use of fire, by American Indians and non-American Indians alike, as something that was harmful to the overall utility of territory sought by European settlers and industrial timber interests (Pyne, 1982). Therefore, the institutions created and developed by the United States to manage settler land and water use advocated for the exclusion indigenous or indigenous inspired knowledge of fire, a key component of ecosystems they managed (Pyne, 1982). The exclusion of fire from the California landscape, rather than being a cost-effective way to manage timber, was the result of colonial ideologies held by land manager who believed they were superior to indigenous people.

Many tribes in the Northern California coastal forests were able to persevere through the genocidal period of California history, and thus had to contend with the newly created colonial institutions of the United States Forest Service (USFS) and the California Department of Forestry and Fire Protection (Cal Fire). Fire, being a central component of the lifestyle of tribes like the Yurok, Karuk, and Hupa, continued to be used by indigenous people well into the 20th century (Anderson, 2005). However, in Northern California, the USFS soon began to prohibit indigenous fire and become an agent of wildfire suppression. The USFS was officially established in its contemporary sense starting in 1905 (Pyne, 1982). This placed it in direct conflict with tribes who were burning in order to manage the environment for culturally important resources (Pyne, 1982). Fire suppression on the scale subsequently enforced until the 1970’s was unprecedented prior to the United States occupation of Northern California coastal forests, causing prairie loss, encroachment on hardwood dominated forest by pseudotsuga menziesii, and decreasing the prevalence of fire enhanced cultural resources utilized by local tribes (Kimmerer and Lake, 2001) (Biswell, 1989) (Figure 1). Colonial management of resources, therefore, had a profoundly negative effect on the ability of tribes to practice their culture by altering the environment in a way that it had not been altered in thousands of years.

1. Contemporary Fire Policy, Social Aversion to Fire, and Indigenous Resurgence

Since the 1970s the official position of the USFS has *not* been one unequivocally committed to fire suppression. Research in the 1960s supported the role of fire in forest ecosystems throughout the continental United States (van Wagtendonk, 2008). This led to broader institutional support within the USFS of policies that allowed wildfires to burn freely if they did not pose a risk to private or governmental property (van Wagtendonk, 2008). However, obstacles to broader use and tolerance of fire continued to present themselves.

In northern California coastal forests, the reimplementation of fire regimes was complicated by the growth of communities in the WUI (Hammer, 2007). Popular fear of fire or prescribed fires as a danger to life, property, and forest ecosystems had already been stoked by the USFS through mascots like Smoky the Bear (Kosek, 2006). Aesthetic preferences of landowners who moved into the WUI often favored, and in many cases continue to favor, the exclusion of fire in favor of mechanical thinning (Fischer & Charnley, 2012). Additional obstacles to the use of burning include burning restrictions in the interest of protecting endangered species, lack of funding to pay for qualified people to burn, and air quality restrictions (Quinn-Davidson & Varner, 2011) All of these factors contribute to a lack of institutional commitment by both the USFS and CalFire to use fire as a land management tool. While there are organizations that recognize the importance of fire being present in the Northern California coastal forests’ various habitats (Northern California Prescribed Fire Council, etc.) they are small compared to state agencies.

Contemporarily, the Hupa, Karuk, and Yurok tribes have become established to the point that they are important political actors in decision making processes regarding large scale land management (Diver, 2016). They are often the strongest advocates of more aggressive fire use and the re-establishment of cultural fire as well. The Yurok Tribe now actively burns on their reservation (Yurok Tribe, 2012). The Karuk Tribe has a large vested interest in USFS public land management practices in the Six Rivers National Forest and the Klamath National Forest, as they lack a formal reservation in which to conduct broadcast burns, and much of their ancestral territory is within the confines of these national forests (Diver, 2016). However, state regulations place limits on all tribe’s ability to conduct controlled burns due to the costly organizational requirements for being able to conduct the burns, air quality regulations, and lack of state funding for preventative fire measures.

1. Tribal Governance as a Pathway Towards Improved Fire Utilization in NCCF

Tribal governments are often overlooked as important agents of change within the human-environmental systems they exist in. However, collaboration with indigenous people has often led to improved outcomes for nations when it comes to natural resource management (Diver, 2018) (Mistri et al, 2016). For example, in Mexico, Indigenous forms of agriculture and the allowance of this agriculture have been seen as a way to prevent deforestation (Toledo, Ortiz-Espejel, Cortés, Moguel, & Ordoñez, 2003). In addition, tribes in the United States can sub-contract with various state and federal agencies in order to carry out land management objectives, monitor environmental conditions, and provide health services to American Indian community members (Wagner, 2008). Oftentimes, tribes can be some of the largest employers within rural areas, for both tribal members and people unaffiliated with the tribe. (Wagner, 2008). The large role tribal governments may play in communities within the wildland urban interface, also makes them excellent sources of information for non-tribal stakeholders in terms of education about local history and ecology. Thus, tribes stand poised to become some of the most essential collaborators in developing pathways for federal and state managers to introduce prescribed fire and limited wildfire fire tolerance into areas where fire suppression has been occurring for the past century. Additionally, regardless of their utility in allowing federal agencies to achieve their objective, the federal government also holds a responsibility to help improve the capacity of tribes to exercise sovereignty and achieve self-determination (Indian Self-Determination and Education Assistance Act of 1975).

In order to assess the impact of allowing indigenous people to collaboratively and independently manage natural resources adjacent to federal or state agency authority, there are many political, economic, and ecological factors to consider. Among these is increasing the ability for indigenous knowledge and western scientific knowledge to exist contemporaneously and equally in decision-making processes (Diver, 2018), allowing for government organizations sharing management power and responsibility with indigenous institutions to justify their decisions within the context of achieving optimal social and ecological outcomes. Therefore, a more robust understanding of indigenous knowledge of fire within a Western scientific framework would lead to more collaboration. In the context of the Karuk Tribe and the United States Forest Service, this means not only that the current research behind the beneficial effects of controlled or managed fire on preventing catastrophic wildfires, but also the effect these fires have on culturally important natural resources. One such resource is the Calfornia hazelnut.

1. The California Beaked Hazelnut

The California hazelnut is a species of shrub that extends from southwestern British Columbia to the central coast of California (Fryer, 2007). Hazelnut most commonly occurs within Douglas Fir dominated mixed-evergreen forests (Fryer, 2007). The shrub itself grows in thickets, with multiple stems shot out of a single plant’s rhizome. The physical characteristics of the plant vary depending on a multitude of factors. High fire frequency (3-7 year fire return interval) in areas where hazelnut is present tends to keep the shrubs at one to 1-3 meters height. At very high fire frequencies (2-5 year fire return interval), shrubs will have more and physical characteristics that favor their use in basketry materials based on ethnographic knowledge (Marks-Block et al 2019). Low fire frequencies (>20 year fire return intervals) tend to allow hazelnut shrubs to gain more stems with diameters around 3-6 cm and reach heights of 4-10 m (Fryer, 2019). Nuts grow individually or in clusters of up to 4, surrounded by bracts that extend at least twice as long as the nut itself (Fryer, 2019). Controlled burning at specific intervals along with pruning were likely precolonial management practices to achieve desirable characteristics of hazelnuts (Lightfoot and Parrish, 2009). Hazelnut fire management strategies for optimal nut production were never described in depth by ethnographers. Currently, hazelnuts are commonly described as a minor species throughout the NCCS ecoregion, however it is acknowledged that they may become frequent or dominant in areas where burning occurs regularly (Fryer, 2019).

Hazelnut thickets in areas that no longer have fire frequencies beyond 20 years tend to occur in the understory of mixed hardwood-evergreen forests, where nut production tends to be quite low (Fryer, 2019). Most studies of hazelnut trees report that nut productivity declines as the amount of time that has passed since the last fire has occurred. Maximum nut production is speculated to occur at around 11 years after the last fire (Fryer, 2019).

California hazelnuts tend to begin producing nuts in June and typically will be fully matured by late July to mid-August (Fryer, 2019). Seeds suffer from high predation by rodents and weevils (Fryer, 2019). This tends to make it very hard for humans to gather hazelnuts except during a specific interval wherein the nut meat is developed to a point where it is nutritious but not ripe enough to be targeted by seed predators. The factors that determine the spread of hazelnut plants within ecosystems vary depending on the age of the stand and how frequently it is affected by fire. Seed dispersal occurs in older stands when a chipmunk or other seed predator stores a seed in a cache (Fryer, 2019). Only when the seed is buried will germination occur. In younger stands more frequently burned in low-intensity fires, rhizomatous reproduction may occur leading to high abundance or stand dominance. Although fire is not a necessary aspect of California hazelnut reproduction or occurrence, California hazelnut is highly adapted to fire and benefits from increased use of fire (Fryer, 2019). Historically, burning hazelnut would have served the dual purpose of facilitating new shoot development and easing the process of harvesting the nuts, rather than simply new shoot development as it does now.

As hazelnuts are non-timber forest products, renewed harvesting by indigenous and non-indigenous people alike could be considered a good way to increase the prevalence of traditional foods into tribal citizens’ diets, at least marginally increase local food consumption, and increase the perceived value of controlled burning to all community members. Although there may be limited potential for hazelnuts to become a main income source in the same way basketry material harvesting can be when the material is woven into traditional baskets, it may be a useful supplemental resource. Investigating the effect of fire on hazelnuts would allow for important aspects of indigenous knowledge of how fire effects the land to be tested in ecological communities that have changed over the past 100 years of fire suppression. In addition, these relationships need to be understood in terms of their impact upon humans, especially the indigenous people whose cultures greatly benefit from these resources. In order to understand the economic effect of fire management on WUI communities that contain tribal governments, models need to be created that consider the contemporary livelihoods of tribal citizens and treat tribal governments as sovereign nations. We approached this need by investigating how the culturally important plant species of California Hazelnut would respond to reintroduced burning regimes and how fire management practices associated with greatest California Hazelnut nut productivity would could be judged in the context of promoting tribal sovereignty and self-determination, accommodating human use and occupancy, and promoting biodiversity.

**Methods**

In order to determine the sampling procedure and find sampling locations for this research, areas of interest in terms of hazelnut production known to USFS employees, areas targeted by tribal land management entities for burning, and locations known to tribal harvesters where California hazelnuts grew or were managed for their stems were identified and marked by GPS. Locations were also explored that were not previously identified but where burns created by wildfires were known to have occurred or had the potential to occur. Once a range of investigative locations had been identified, 100 m2 sampling units were established by randomly marking 10m by 10m square plots occupied by hazelnuts covering over 30% of the ground. This was done because in order for the research to be of interest to tribal harvesters, nut productivity needed to be analyzed within a context of reasonable stand density, as harvesters would probably not seek out an individual California hazelnut shrub in a wildland area. The plots were always established at least 5-10 meters away from the road to prevent roadside canopy characteristics from unduly affecting the sampled solar access measurement.

Biophysical characteristics of the sites were described from existing soil maps, fire maps from the Cal Fire database, USFS forest management logging records, and general location near roads or other features. Slope was measured using a clinometer and aspect using a compass. Percent solar access over a year was measured at each shrub within a plot using a SunEye-2010. The stem diameter of the largest stem within each plant was measured using a digital caliper. The number of stems and nuts on each plant were individually counted by the researchers. Precipitation data was gathered from Remote Automated Weather Stations monitoring areas closest to sampling plots. Elevation and GPS location were found using Garmin eTrex 30 devices. The fire effect data we chose to gather was time since last fire (TSLF), found by locating our GPS points within CalFire wildfire or CalFire controlled burn maps in ArcGIS. TSLF is the only variable used to understanding fire effects within the project.

TSLF and fire severity are main drivers of disturbance characteristics of sites. Fire severity was excluded due to the difficult nature of measuring it accurately and because controlled fires and wildfires were grouped together. Controlled fires are typically less intense than wildfires. Fire return intervals (FRI) are another important fire metric that was excluded from this study. FRIs can be important factors in determining plant species abundance in the successional periods following a fire. Future studies need to be conducted with these variables accounted for, but in the context of a landscape that had been highly fire excluded for the better part of a century it was the best estimation procedure possible at the time.

The variables we measured were chosen along with TSLF due to their hypothesized correlation with nut production. Based on the biology of nut producing plants in general, the number of nuts produced by a hazelnut would depend on the amount of nutrients transferred to the branches growing the nuts. The action of transferring the nutrients would be done by the stems, and the volume of nutrients able to be transferred would be determined by stem thickness. Sunlight and soil nutrient composition would then determine the availability of nutrients for the stems to distribute, thus allowing the California hazelnut shrub to generate the energy and biomass stored within the nuts. In addition, each California hazelnut shrub is affected by a surrounding biological community characterized by surrounding pests and plant competitors. All these factors are in some way effected by the disturbance regime the California hazelnut experiences. Various interactive variables were included in tested regression models.

A negative-binomial generalized linear mixed model (GLMM) was created utilizing R statistical software in order to determine the effect of TSLF has on California hazelnut nut production. This model was chosen in order to account for the random effect plots in which the individual California hazelnut shrubs were sampled could have on nut productivity. Aspect, precipitation, slope, elevation, solar access, stem diameter, and total stems were included in models as covariate fixed effects due to their hypothesized effect in nut production. TSLF was separated into categories to analyze differences in nut production patterns across different levels of these explanatory variables in the GLMM. TSLF was treated as a categorical variable because TSLF is a proxy for different periods of succession the California hazelnuts are experiencing in response to a specific disturbance event. Combined categories for TSLF were generated from general age groups ranging from 3-7 years since last fire, 8-12 years since last fire, and 13 or more years since last fire to adjust for study design imbalances (e.g., 6 observations in some high TSLF categories but more than 50 observations in 4 and 10-year TSLF categories).

**Results**

In order to determine the model most relevant for a multiple regression analysis of the data, Wald Type 3 Chi Square tests were run on multiple GLMM models that incorporated variables hypothesized to have an effect on nut production. Based on the Wald Type 3 Chi Square tests, the model of best fit incorporated the number of stems on individual California hazelnut shrubs (p < 0.001), the diameter of the basal stems on the shrubs (p < 0.001), the amount of sunlight each shrub had access to (solar access) (p < 0.001), TSLF (p < 0.001), and the interactive variable TSLF\*solar access (p < 0.01) (Table 1). The amount of precipitation over the area in which samples were taken, the elevation of the sampling plots, the slope on which the samples were taken, and the aspect of the samples were all found to have an insignificant relationships (p > 0.05) with the nut production of individual California hazelnut shrubs.

In the negative-binomial GLMM model of best fit, the number of stems an individual California hazelnut shrub had and its basal stem diameter were positively correlated to nut production and were highly significant (Table 2). Solar access likewise had a large positive effect on nut production, but its effect on nut production was highly dependent on the TSLF category individual California hazelnut shrubs were grouped in (Figure 2). Younger California hazelnut shrubs from more recent burns were less influenced in nut production by solar access than older California hazelnuts shrubs from older burns.

On average hazelnut shrubs from relatively younger burns had more nuts per shrub than hazelnut shrubs from older burns, with the highest number of hazelnuts produced within the 3-7 years since last fire category (Figure 3). However, when accounting for the interactive effect of solar access and TSLF, shrubs that were in areas that had burned 13 or more years ago produced more nuts if they had solar access above 80% (Figure 4) (Figure 5). However, there was a very high variance in nut production at higher levels of sunlight, especially in plots that hadn’t been burned in more than 13 years. Nut production exhibited considerable heteroskedasticity when plotted against numerous variables including solar access (Figure 6).

Based on simple regression models, solar access of individual shrubs and basal stem diameter were both very highly correlated to TSLF. Solar access was positively correlated to TSLF (p < 0.001) and stem diameter (p<0.001) was negatively correlated to TSLF.

**Discussion**

On average, more California hazelnut nuts were produced by California hazelnut shrubs in areas that had burned within the past 12 years than in areas that had been burned 13 or more years ago. However, this difference in hazelnut production between different categories of TSLF was not significant on its own, and hazelnut production by individual shrubs was determined by multiple factors that covaried to a significant extent. If California hazelnuts lack access to a completely open canopy, younger more recently burned shrubs produce more nuts than older shrubs that have not experienced fire in a long time. If California hazelnuts have access to a completely open canopy, older California hazelnut shrubs will produce on average a larger amount of nuts than younger shrubs. Fire most likely amends the soil, decreases insect nut predators, and clears vegetation that competes for resources with California hazelnuts. This allows younger California hazelnut shrubs to produce more nuts in otherwise similar conditions to older shrubs. Based on the relationship a California hazelnut’s nut production has with its basal stem diameter and its total number of stems, more sunlight may give older shrubs the ability to take advantage of their physiological traits.

Based on these findings, there may be more than one way to manage California hazelnut shrubs for nut productivity. One way of managing California hazelnuts for nut production may be to take advantage of California hazelnut plots managed for basketry stems in the terminal year of their use. Another may be to identify areas with high California hazelnut density and intentionally burn them every decade, give or take a few years, in order to take advantage of the increased nut productivity without wasting too many resources in more frequent burning. The last way would be to transplant or maintain California hazelnut shrubs alongside roads, trails, or in gardens in order to allow the shrubs to reach an advanced age and take advantage of the increased solar access these locations would impart upon them.

Controlled burns have great importance to the culture and well-being of native people. As wildfires become more frequent and severe in California due to climate change and fire suppression (Calkin & Finney, 2015) (Abatzoglou, 2016) (Westerling 2016), it is becoming more important that controlled burns play a role in catastrophic wildfire mitigation. By framing controlled burns as both fuel reduction and eco-cultural restoration, collaborative efforts between indigenous and non-indigenous government entities can benefit. In addition, social acceptance of fire is an important part of increasing its use in mitigating wildfires (Ryan et al, 2013). Framing fire as a way of improving cultural resources for indigenous people in California could help communicate the role of fire in ecosystem restorations in way that makes fire seem less destructive.

Future research will need to analyze more broadly the relationship between eco-cultural resources and fire regimes, along with an assessment of the effect any controlled burns have on protecting property. Controlled burns, in order to be economically efficient in terms of generating value equal to the cost of conducting them need to affect multiple eco-cultural resources. The relationship between TSLF and solar access of individual shrubs demonstrates that burning creates more open canopy which would benefits understory shrubs other than California hazelnuts. Future studies should also address the relationship between TSLF and associated ecological community structure, especially those community structures that both serve the forest conservation purpose wanted by the USFS and the cultural resource dense community structures wanted by indigenous people, such as California black oak woodlands.

Much of the research done on the relationship between indigenous people and their environment is conducted with the goal of determining how indigenous and non-indigenous governance structures can coequally manage resources in order to achieve shared goals. Based on analyses of attempts to include indigenous people in natural resource management projects, the most effective way to encourage indigenous participation is to empower their communities to be able to act in a co-equal manner to the nation states they exist within (Mistry, 2019). Empowerment consists of supporting the social cohesion, cultural continuity, and traditional lifeways of indigenous people. One component of empowerment is to conduct research with the intent of delivering information pertinent to the objectives of indigenous people rather than the objectives of the overarching nation-state (Mistry et al., 2016). To this end all future research will need to be conducted with respect for Indigenous knowledges, Indigenous control of knowledge mobilization, intergenerational involvement of the Indigenous community at hand, respect for self-determination of Indigenous people, continuous cross-cultural education, and early involvement of the Indigenous community in the research, as these components of mutually beneficial research are identified as being extremely important when working with Indigenous communities (Reo, 2017).

**Figures**

|  |  |  |  |
| --- | --- | --- | --- |
| Table 1 | | | |
| Variables | χ2 | Df | P(>|χ2|) |
| Stems | 77.171 | 1 | 0.000 |
| Stem Diameter | 85.464 | 1 | 0.000 |
| Solar Access | 45.476 | 1 | 0.000 |
| TSLF | 18.273 | 3 | 0.000 |
| TSLF\*Solar Access | 14.983 | 3 | 0.002 |
| Results of a Wald Type III Chi Square test on the significance of variables affecting nut production. Precipitation, elevation, and slope were all found to have a non-significant effect (p > 0.05) on nut production. | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table 2 | | | | |
| Variables | Coefficient | Standard Error | Z-Value | P(>|z|) |
| Stems | 0.028413 | 0.003312 | 8.580 | 0.000 |
| Stem Diameter | 0.095901 | 0.010734 | 8.935 | 0.000 |
| Solar Access (%) | 6.4538 | 0.9720 | 6.640 | 0.000 |
| TSLF Category:  3-7 Years | 2.688393 | 0.704722 | 3.815 | 0.000 |
| TSLF Category:  8-12 Years | 2.069929 | 0.793454 | 2.609 | 0.009 |
| TSLF Category:  3-7 Years  \*  Solar Access | -0.035624 | 0.011628 | -3.064 | 0.002 |
| TSLF Category:  8-12 Years  \*  Solar Access | -0.024878 | 0.013038 | -1.908 | 0.056 |
| The effects of explanatory variables on nut production based on GLMM negative binomial regression model. | | | | |

A picture containing photo, covered, white, snow

Description automatically generated

Figure 1: Aerial photographs of Weitchpec, California Demonstrating Encroachment of Pseudotsuga Menziesii on Shortgrass Prairies.

A close up of a logo

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Figure 2: The Effect of Solar Access on Nut Production within TSLF groups

A screenshot of a cell phone

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Figure 3: Box plot demonstrating higher average nut production in younger burns.

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Figure 4: Comparison of the predicted nuts per shrub from solar access across three TSLF categories

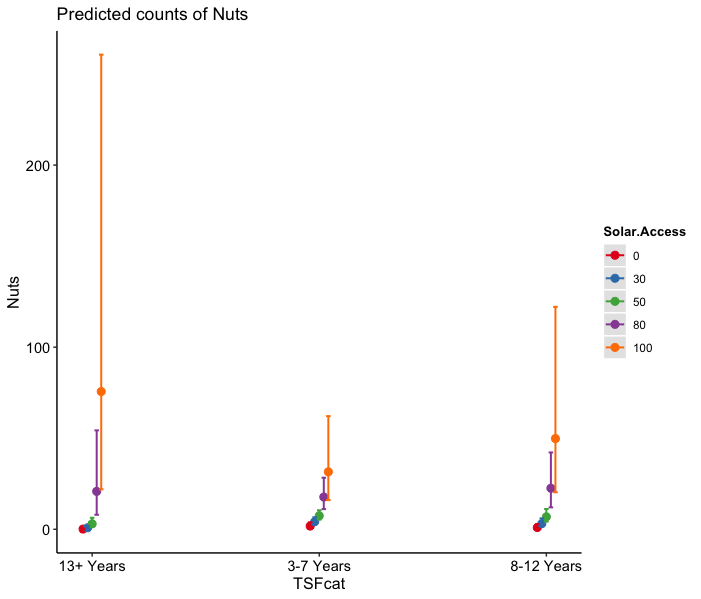


Figure 5: Count of California hazelnut nuts predicted based on various levels of solar access across TSLF categories.

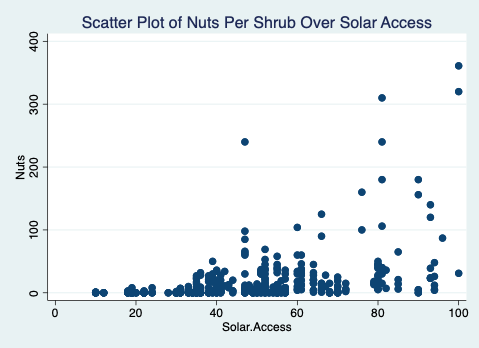


Figure 6: Scatter plot demonstrating heteroskedasticity in Nut data over Solar Access

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