Bulletin of the Southern California Academy of Sciences

Volume 119 | Issue 1 Article 4

2020

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Jon E. Keeley
U.S. Geological Survey, jon_keeley@usgs.gov

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Cover Page Footnote

*Corresponding author: jon_keeley@usgs.gov

Bull. Southern California Acad. Sci.
119(1), 2020, pp. 35–47

Protecting the Wildland-Urban Interface in California: Greenbelts vs Thinning for Wildfire Threats to Homes

Jon E. Keeley,[1,2]* Greg Rubin,[3] Teressa Brennan,[1] and Bernadette Piffard[3]

[1] *U.S. Geological Survey, Western Ecological Research Center, Sequoia-Kings Canyon Field Station, 47050 General's Highway, Three Rivers, CA 93271*
[2] *Department of Ecology and Evolutionary Biology, University of California, 612 Charles E. Young Drive, South Los Angeles, CA 90095*
[3] *California's Own Native Landscape Design, Inc., 25950 Los Arboles Ranch Rd., Escondido, CA 92026*

Abstract.—This study utilized native chaparral and sage scrub shrubs planted in lightly irrigated greenbelts around homes to evaluate the impact on live fuel moisture content (LFMC) and predicted fire behavior. As to be expected LFMC varied markedly throughout the year being over 100% in winter in all species and treatments that included adjacent thinned native shrublands and untreated control shrublands. However, in the summer and fall there were marked differences between treatments. For most species lightly irrigated plants had the highest LFMC in the summer and fall, followed by thinned treatments and controls. These differences in moisture content coupled with structural differences in the vegetation contributed to expected differences in flame length and rate of spread. Lightly irrigated native shrubs planted around homes can reduce fire hazard while possessing other desirable features of utilizing native vegetation.

Losses of lives and property from wildfires have spiraled out of control in recent years and we need to address potential strategies for reducing the impact of fires that spread into urban communities (Keeley and Syphard 2019). Key to saving homes and lives is the 'defensible space' around homes (Syphard et al. 2014; Penman et al. 2019). Ordinances are largely focused on reducing wildland fuels adjacent to homes. However, widespread clearing of native vegetation near homes (Fig. 1) impacts aesthetics, privacy, biodiversity, faunal attractiveness, and property values (Gibbons et al. 2018).

Hazard reduction strategies involving options other than clearance, such as creation of 'greenbelts' (Gardner et al. 1987; Kent 2005), are solutions not yet fully explored; greenbelts of vegetation (i.e., widely space irrigated shrubs and trees) were applied in numerous sites and seemed to be effective at reducing fire hazard. Other studies have shown that the 'greenness' (measured by the Normalized Vegetation Difference Index) near homes had the same effect as removing woody vegetation (Gibbons et al. 2018). This is effective primarily because fire behavior is markedly influenced by live fuel moisture content (LFMC), a measure of the water content of vegetation (Dennison et al. 2008). For chaparral shrublands of southern California, when LFMC of shrubs is 60 - 80%, fire risk is considered to be high because the heat energy generated by a burning plant exceeds the energy needed to eliminate plant moisture, leaving excess energy to pre-heat adjacent plants and propagate a wildfire (Weise et al. 1998, Stow et al. 2005, Dennison et al. 2010). There is empirical

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* Corresponding author: jon_keeley@usgs.gov

Fig. 1. Example of an increasingly common type of fuel clearance around homes near Ramona in San Diego County (Photo Jon Keeley, USGS).

evidence that LFMC will affect rate of fire spread in both laboratory and field studies (Rossa and Fernandes 2018).

Greenbelts have often been favored because esthetically they are more pleasing than heavy clearance that removes much of the vegetation in belts around properties (e.g., Fig. 1). One of the downsides of greenbelts as often applied is that they commonly involve non-native species, and homeowners often move to the wildland-urban interface in order to experience natural settings. An alternative is to use native shrubs in landscapes around homes and maintain them with light watering during the summer. This allows yards with native flora but kept lightly irrigated during the fire season to potentially inhibit fire spread. This approach has been utilized in a number of landscaping projects in southern California (Rubin and Warren 2013). It has advantages over many standard greenbelt designs in that it uses native shrubs, which are most attractive to native fauna (Jeschke et al. 2014), adding to the wildland-urban experience.

While there is anecdotal evidence of the effectiveness of such light irrigation of native plantings at reducing fire hazard (e.g., Pellizzoro et al. 2007), there is little in the way of experimental evidence. The purpose of this project was to test the efficacy of this technique at altering fire behavior in comparison with more commonly used shrub ‘clearance’ or ‘thinning’ or with untreated native shrublands.

Materials and Methods

We utilized three home landscaping projects installed by California’s Own Native Landscape Design Inc. (Escondido, CA) that had been installed at least 5 yrs prior to the experiment comprising shrub species native to the site and lightly irrigated (see below) throughout the dry season. Just beyond the property line were native shrublands that had been thinned in the years immediately before our experiment. Just beyond the thinned vegetation was untreated native shrublands. Based largely on differences in live fuel moisture

Fig. 2. Aerial view of Ramona showing location of the three residences used for this study (Google Earth^{TM} image). These sites were on High Country Rd. (HCGY), Oak Grove Rd. (OKGR), and Rangland Rd. (RGLD) in the community of Ramona, San Diego County, CA.

during the fire season we hypothesized that the lightly irrigated treatments would generate lower flame lengths and slower rates of fire spread than either unirrigated thinned treatments or untreated controls.

Our experimental design was to monitor live foliage fuel moisture approximately every 2 wks for 2.5 yrs on irrigated, thinned and untreated chaparral and sage scrub species at three sites. In addition, we quantified the extent of thinning by measuring areal coverage of thinned and untreated vegetation. Using these data, we modeled fire behavior with Fuel and Fire Tools software[1] for the two treatments and untreated controls. These modeling results were used to evaluate our hypothesis.

The overall experimental design was to compare the predicted fire behavior in three locations in San Diego county's wildland-urban interface in order to evaluate the effectiveness of different approaches in creating defensible space at the WUI. The criteria for site selection was a wildland-urban interface that included a residence adjacent to wildland open space. Three homes in northeastern San Diego County near Ramona California were selected for study (see Fig. 2).

At each site, three study areas were established surrounding the house to include 1) native plants indigenous to the site were planted in an area 10 m from the home, 5-10 m wide and at least 30 m long (e.g., Fig. 3), 2) at least 30 m from the home a native natural sage scrub or chaparral shrubland area that had been thinned according to prescriptions commonly used for creating defensible space around homes, and 3) further from the home a control area of natural shrubland vegetation. All sites were more or less on level ground with slopes $< 10\%$.

[1] https://www.fs.fed.us/pnw/fera/fft/index.shtml

Fig. 3. Example of summer lightly irrigated native vegetation (photo by Jon Keeley, USGS).

The prescription for the lightly irrigated plantings was: Native shrubs indigenous to the site were planted roughly 10 m from the homes in a belt of approximately 5 m width surrounding the home extending 30-50 m. These were lightly irrigated during the summer months June to October, once every 10-14 days with a MP-Rotator^{TM} stream nozzles with rate of 9.75 mm equivalent precipitation per hour; this equated to 12.5 to 18.8 mm per month during the summer.

The native shrubland vegetation outside the lightly irrigated vegetation were areas dominated by lower stature sage scrub and others with higher stature chaparral species. These areas were matched in the thinned and untreated areas and comprised the same sage scrub species, *Eriogonum fasciculatum* (California buckwheat) and dependent on the site the same chaparral component; *Arctostaphylos glauca, Quercus berberidifolia* and *Malosma laurina*.

Data were collected on fuel structure within the three locations in order to select the appropriate fuel model for the fire behavior part of this study. Species composition varied between the three sites and although this adds to the variance in data, it provides a better picture of a range of responses in different settings. In general, each site comprised species characteristic of both sage scrub and chaparral. Structural characteristics were determined with a single 20 m line transect through each treatment in each vegetation type at each site, recording area of live and dead foliage and height for each species using the line-intercept method (Cox 1990).

Species were selected for live fuel moisture content based on availability. At all three sites we sampled the semi-deciduous sage scrub *Eriogonum fasciculatum.* An evergreen chaparral shrub was also included but varied between sites: *Arctostaphylous glauca* at Site HCGY, *Malosma laurina* at Site OKGR, and *Quercus berberidifolia* at Site RGLD (See Fig. 2).

LFMC was determined approximately every 2 wks for 2 yrs according to established procedures (Countryman and Dean 1979; Pollet and Brown 2007; Haase et al. 2016). Briefly, three terminal foliage samples were collected from each of the target species in each

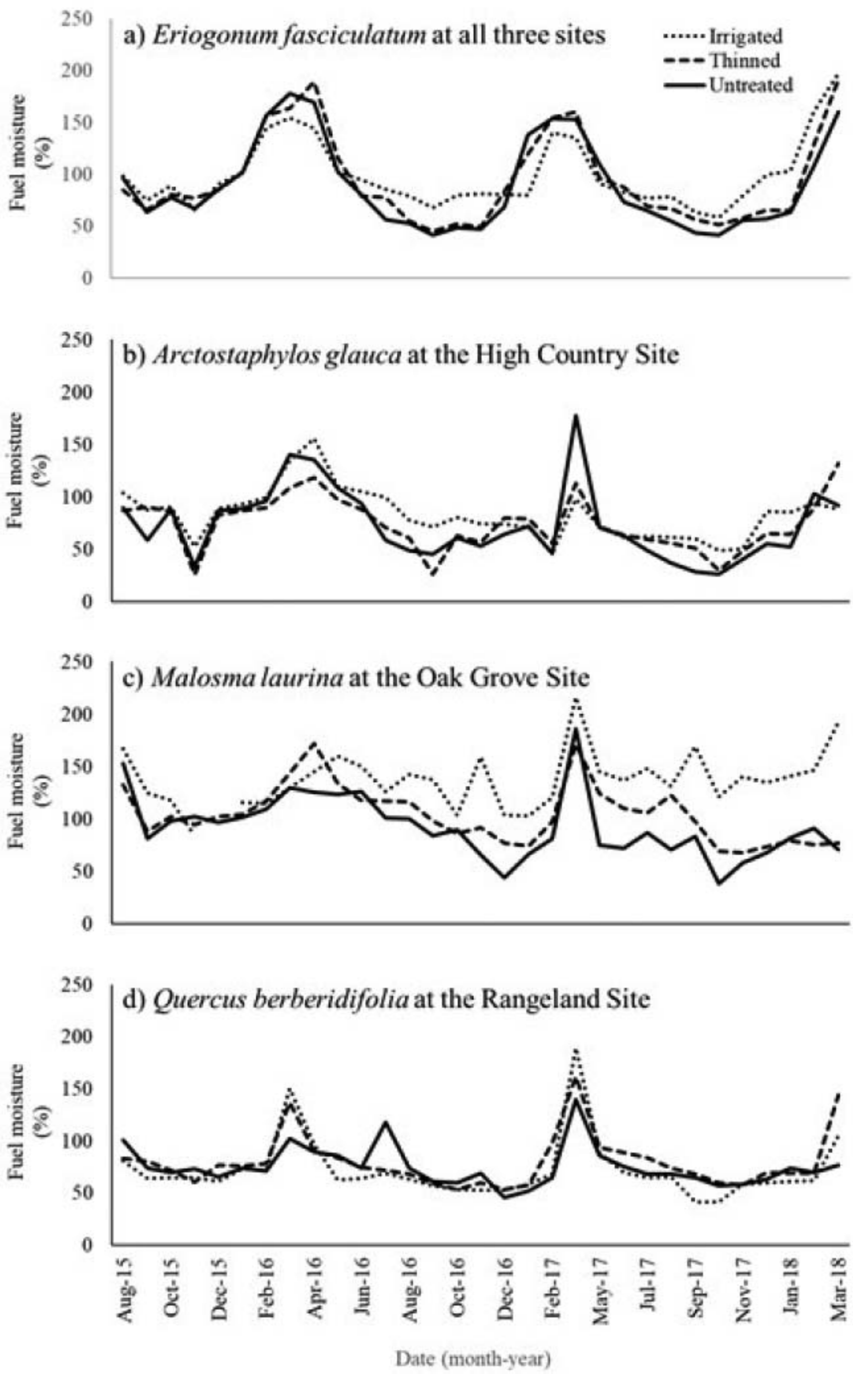

Fig. 4. Two and a half years of live fuel moisture content (LFMC) for the four species used in this study presented by treatment.

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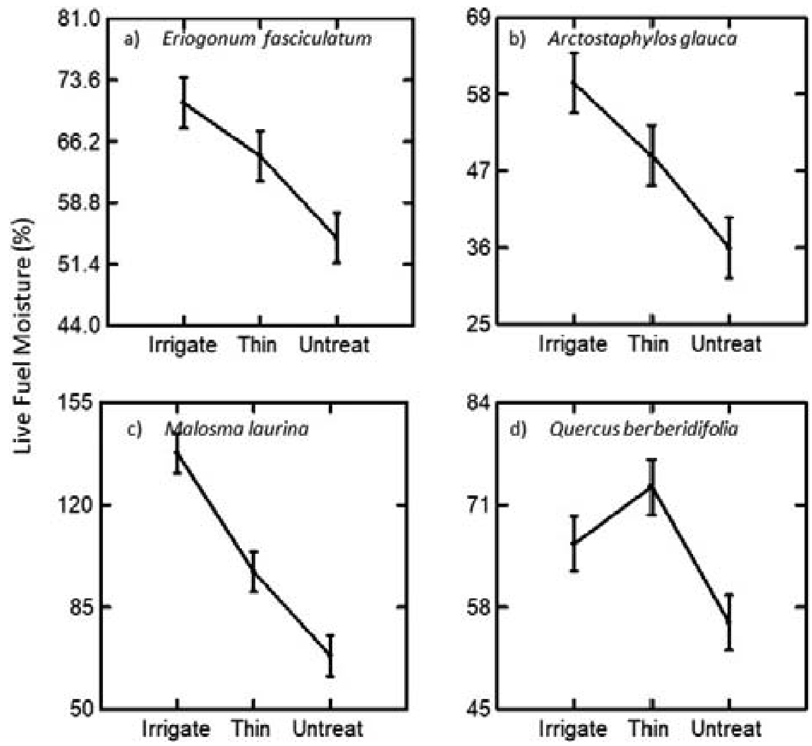

Fig. 5. Average LFMC for all collections from June - October 2017 for the four species. Error bars are the standard error of the mean and ANOVA gave a significant difference between treatments for all species, though the Bonferroni test showed: a) *Eriogonum fasciculatum*: $P < 0.001$, Irrigated = Thinned > Untreated, b) *Arctostaphylos glauca*: $P = 0.004$, *Irrigated* > Thinned > Untreated, c) *Malosma laurina*: $P < 0.001$, Irrigated > Thinned > Untreated, and d) *Quercus berberidifolia*: $P = 0.04$, Irrigated = Thinned > Untreated.

treatment at each of the three sites. These samples were stored in pre-weighed airtight tins and returned to the lab and weighed. The lids were removed and dried to constant weight in a forced convection oven and reweighed. Samples were collected at the same time each day after morning dew had dissipated (between 11AM and 2 PM). Live fuel moisture was calculated as a percentage of dry weight, as follows:

$$Live\ fuel\ moisture\ (\%) =$$
$$\left(\left(\,(wet\ wt - tin\ weight) - (dry\ wt - tin\ wt)\,\right)\ /\ (dry\ wt - tin\ wt)^{*}\ 100\right)$$

Summer and fall data were compared across treatments with ANOVA and the Bonferroni test for separating treatments.

Expected fire behavior was modeled for each of our treatments using the Fuel and Fire Tools software application that allows the input of site specific vegetation and fuels data as well as various environmental characteristics including fuel moisture, slope, and wind speed. The vegetation data from our treatments that we incorporated into the model (Appendix I) included the overall average height and percentage live and dead cover of vegetation in each treatment as well as the relative cover of each species present based on the line-transect data. We did not collect data on fuel moisture of downed woody fuels and

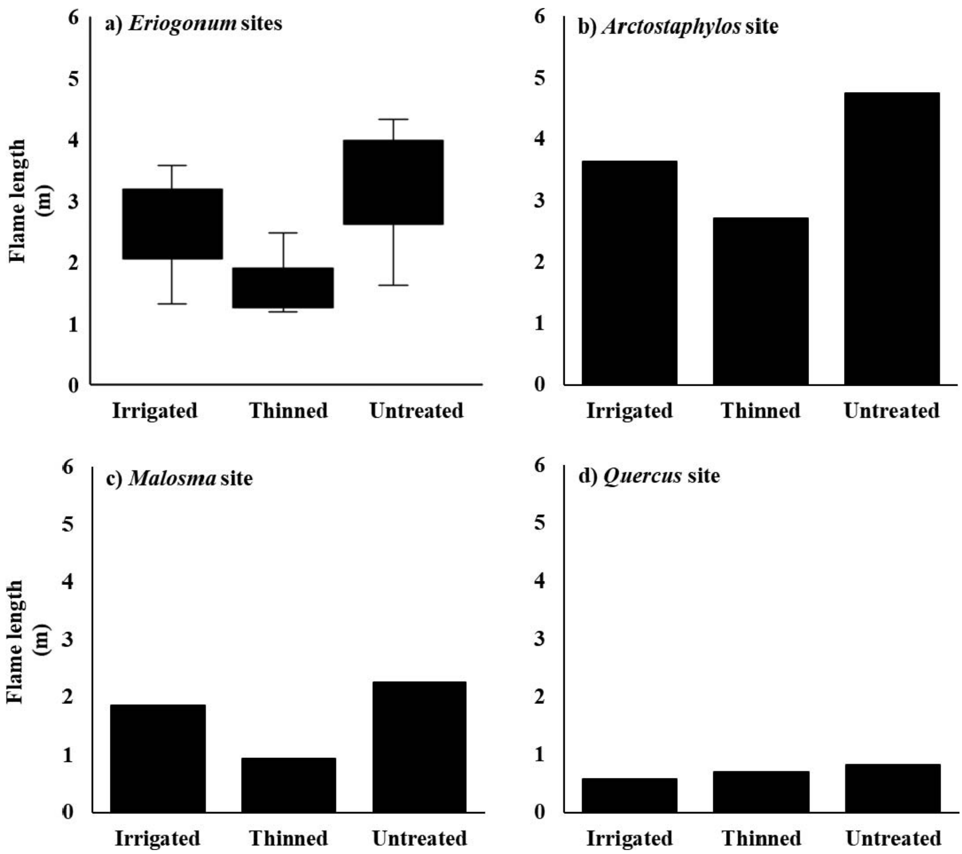

Fig. 6. Predicted flame length for the dry season for a) *Eriogonum*, error bars are the standard error of the mean across the three sites, b) *Arctostaphylos*, c) *Malosma*, and d) *Quercus* sites for the three treatments.

therefore accepted the default values associated with these specific vegetation types that are included in the model.

Results

As to be expected LFMC varied markedly throughout the year nearly always over 100% in winter in all species and treatments (Fig. 4). Summer and fall patterns were of particular interest as this is the time of most wildfires in the region. These warm season LFMC varied between treatments and species (Fig. 5). For the sage scrub species *Eriogonum fasciculatum* it was not significantly different between irrigated and thinned treatments but these were higher than untreated controls (Fig. 5a). Evergreen species had the highest LFMC in irrigated plants, followed by thinned and then controls for *Arctostaphylos glauca* and *Malosma laurina* (Fig. 5b, c). These species, however, differed significantly in LFMC, with irrigated *M. laurina* having over double that of irrigated *A. glauca*. *Quercus berberidifolia* showed no difference between irrigated and thinned shrubs but they were slightly higher than controls (Fig. 5d). In short, during the warm season untreated controls had lower LFMC than treated plants for all for target species. Only the two evergreen shrubs *A. glauca* and

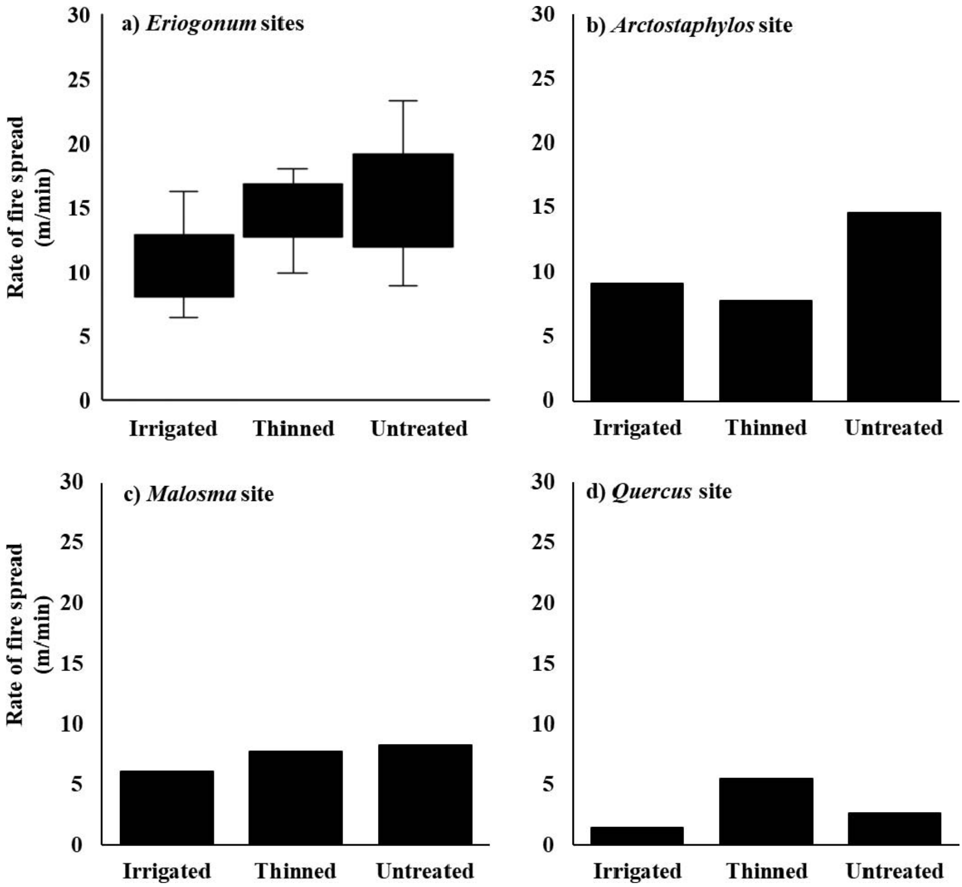

Fig. 7. Predicted rate of fire spread for the dry season for a) *Eriogonum*, error bars are the standard error of the mean across the three sites, b) *Arctostaphylos*, c) *Malosma*, and d) *Quercus* sites for the three treatments.

M. laurina had higher fuel moisture in irrigated over thinned plants; for *E. fasciculatum* and *Q. berberidifolia* there was no difference between irrigated and thinned plants.

At all sites chaparral was markedly taller than the sage scrub but within a site for chaparral and sage scrub, heights were roughly similar across treatments (Appendix I). Vegetative cover was similar between controls and irrigated plantings and markedly lower in thinned treatments.

Our fire behavior models were run for each site separately but the general patterns of treatments were similar for *Eriogonum fasciculatum* and these results were combined for all sites (Fig. 6a) and compared with the evergreen species at their single sites (Fig. 6b-d). Untreated controls would be expected to have higher flame lengths and this was true for all species (Fig. 6). However, thinned plots with their much lower biomass were predicted to have the lowest flame lengths. Irrigated treatments, however, seemed to stand out most in the lower rates of fire spread (Fig. 7). Fuel structure played an important role in that the fine fuels in *Eriogonum* (Fig. 7a) contributed to the fast rate of spread.

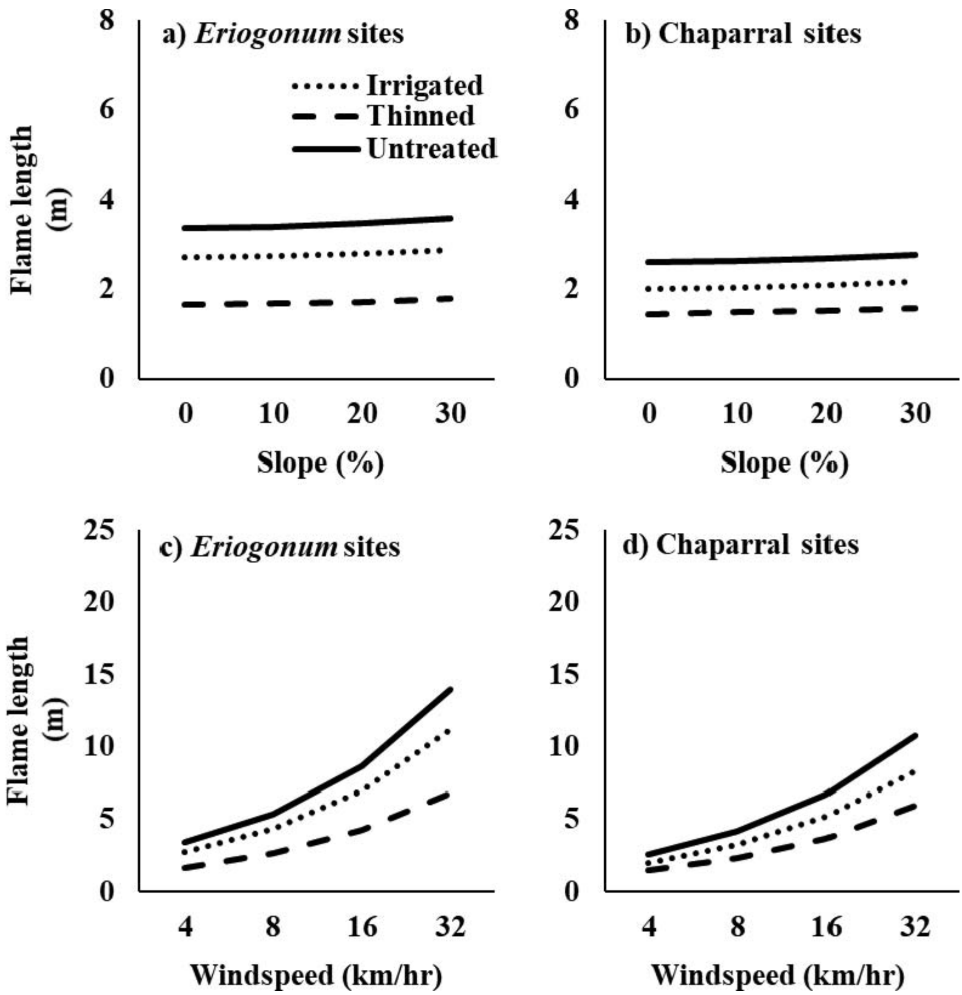

Fig. 8. Predicted flame lengths for changes in slope given the conditions present at the a) *Eriogonum* and b) chaparral sites, and for changes in wind speed at the c) *Eriogonum* and d) chaparral sites.

Using these scenarios, we asked the question how changes in slope and wind speed would alter these patterns. For *Eriogonum* sites and chaparral sites under these conditions, it is apparent that slope had only a minimal impact on flame length (Fig. 8a & b). Windspeed on the other hand had a much greater impact on flame length and this was most pronounced in the finer fuels of the sage scrub *Eriogonum* (Fig. 8c). Rate of fire spread followed a similar pattern (Fig. 9) with slope playing far less of a role than wind speed.

Discussion and Conclusions

Reducing housing losses at the wildland-urban interface often requires clearance of vegetation around the structures, however, there is growing evidence that maintaining natural landscapes of green woody shrubs and trees can be compatible with reducing fire hazard (Gibbons et al. 2018). This is important because it provides homeowners options of

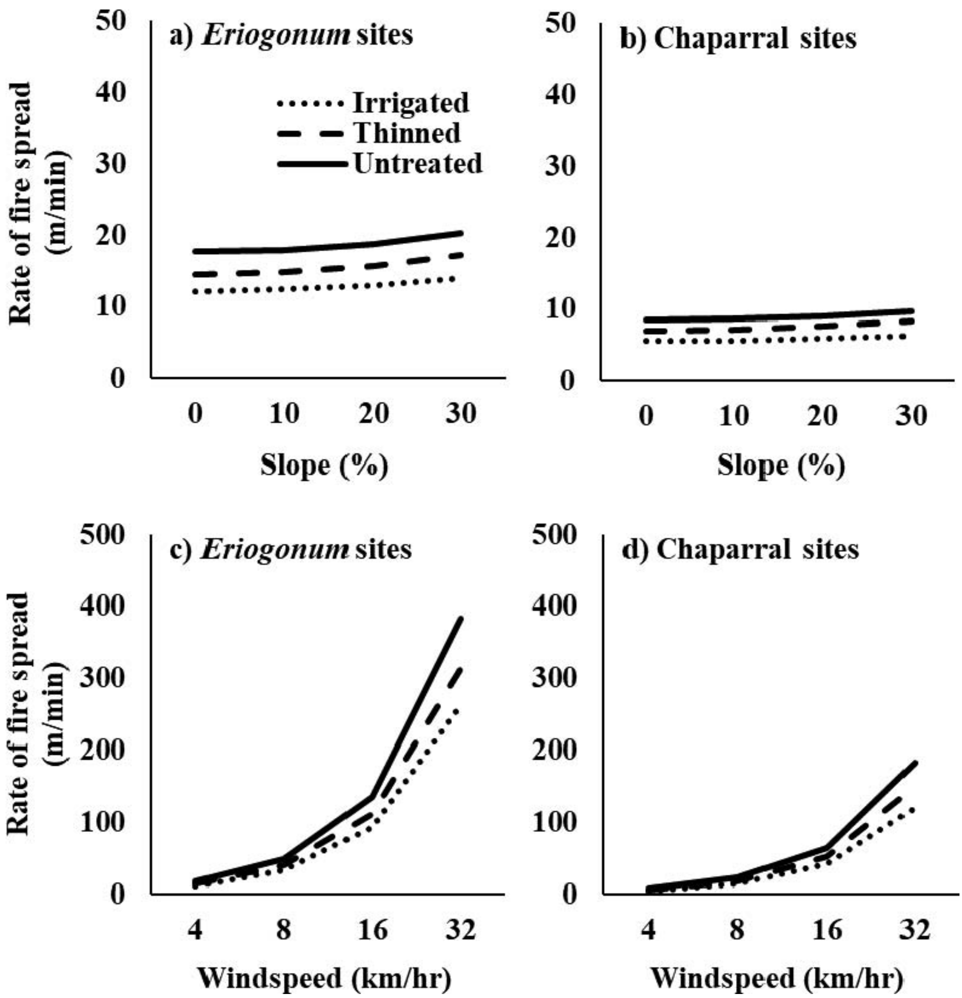

Fig. 9. Predicted rate of fire spread for changes in slope given the conditions present at the a) *Eriogonum* and b) chaparral sites, and for changes in wind speed at the c) *Eriogonum* and d) chaparral sites.

how they can produce esthetically pleasing landscapes around homes and yet still provide some level of fire protection. Greenness of vegetation around homes has been shown to be associated with a reduced loss from wildfires (Gibbons et al. 2018), and there are several possible explanations for this pattern. Greenbelts around home often have reduced levels of flammability but other possibilities include a potential role for green trees acting as 'ember-catchers' particularly in wind-driven fires (Keeley and Syphard 2019).

The present study examined greenbelts that utilized native shrubs that were the same species as surrounding wildland vegetation but were lightly irrigated during the summer drought. We showed that live fuel moisture during summer and fall were typically higher in these irrigated shrubs than in adjacent unirrigated shrubs of the same species and using these data fire behavior models suggested these native shrub landscapes provided a level of fire protection.

For all species, both sage scrub *Eriogonum fasciculatum*, and chaparral species, flame length and rate of spread were lower than untreated adjacent chaparral. When this vegetation was thinned rate of fire spread was still higher than the irrigated treatment in three of the four species. However, there was no improvement in flame lengths by irrigating these species. Thus, thinning natural vegetation has variable benefits in terms of reducing fire hazard and in some respects may be no different than lightly irrigated treatments. However, one important distinction is that homeowner preference of lightly irrigated green native vegetation during the summer over the dried thinned native vegetation.

There are clearly species differences in the role of irrigation in affecting summer-fall LFMC and these have impacts on fire behavior. Indeed, this study contributes to a need for studies that link LFMC to fire behavior (Weise et al. 1998; Pimont et al. 2019). Species differences observed in this study follow patterns observed by Pivovaroff et al. (2019). Both studies showed that during the dry season *Malosma laurina* had the highest LFMC of all species tested and Pivovaroff et al. (2019) showed this was linked to the least negative foliage water potentials. These patterns potentially are tied to the very deep root systems of this species that allows access to deep underground water during the dry season.

In summary, there is evidence that lightly irrigated native shrub landscaping can meet many desirable outcomes. Using native vegetation that has a long legacy on this landscape is potentially more compatible with the native fauna in the region (Jeschke et al. 2014, Tallamy and Shropshire 2009). For example, native plants can maintain greater diversity of insects that have direct and indirect benefits and can affect populations at other trophic levels (Narengo et al. 2018). Pollination webs are potentially greater as well as diversity of dispersers, both of which play important ecosystem processes. These lightly irrigated native landscapes consume far less water than more traditional landscaping (Rubin and Warren 2013) and these plants maintain higher LFMC during the dry season, contributing to reduced fire risk.

Acknowledgments

Support was provided by Department of Defense, NAVFAC SW and Naval Base San Diego Contract No. N62473-14-2-0006. We thank Anne Pfaff for assistance with figures, and Taylor Johnson and Lisa Markovchick with fuel moisture sampling. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Appendix I. Structural data for fire modeling for the three treatments at the three sites for both chaparral and sage scrub species.

Site	Treatment	Vegetation type	% veg. cover	Average height (m)	% of veg. live in primary layer	Live fuel moisture (species)	Dead fuel moisture
Highcountry	Control	Chaparral	90	1.8	75	Arcgla	1, 10, 100 hr fuels - 9%, 10%, 11%
Highcountry	Thinned	Chaparral	28	1.5	94	Arcgla	1, 10, 100 hr fuels - 9%, 10%, 11%
Highcountry	Planted & irrigated	Chaparral	90	1.8	75	Arcgla	1, 10, 100 hr fuels - 9%, 10%, 11%
Highcountry	Control	Sage scrub	98	1.4	90	Erofas	1, 10, 100 hr fuels - 9%, 10%, 11%
Highcountry	Thinned	Sage scrub	41	1	100	Erofas	1, 10, 100 hr fuels - 9%, 10%, 11%
Highcountry	Planted & irrigated	Sage scrub	98	1.4	90	Erofas	1, 10, 100 hr fuels - 9%, 10%, 11%
Oak Grove	Control	Chaparral	88	1.5	94	Mallau	1, 10, 100 hr fuels - 9%, 10%, 11%
Oat Grove	Thinned	Chaparral	50	1.5	95	Mallau	1, 10, 100 hr fuels - 9%, 10%, 11%
Oak Grove	Planted & irrigated	Chaparral	88	1.4	94	Mallau	1, 10, 100 hr fuels - 9%, 10%, 11%
Oak Grove	Control	Sage scrub	91	1.1	100	Erofas	1, 10, 100 hr fuels - 9%, 10%, 11%
Oak Grove	Thinned	Sage scrub	29	1	65	Erofas	1, 10, 100 hr fuels - 9%, 10%, 11%
Oak Grove	Planted & irrigated	Sage scrub	91	1.1	100	Erofas	1, 10, 100 hr fuels - 9%, 10%, 11%
Rangeland	Control	Chaparral	97	2.5	91	Queber	1, 10, 100 hr fuels - 9%, 10%, 11%
Rangeland	Thinned	Chaparral	58	1.9	75	Queber	1, 10, 100 hr fuels - 9%, 10%, 11%
Rangeland	Planted & irrigated	Chaparral	97	2.4	91	Queber	1, 10, 100 hr fuels - 9%, 10%, 11%
Rangeland	Control	Sage scrub	95	0.8	65	Erofas	1, 10, 100 hr fuels - 9%, 10%, 11%
Rangeland	Thinned	Sage scrub	75	0.8	66	Erofas	1, 10, 100 hr fuels - 9%, 10%, 11%
Rangeland	Planted & irrigated	Sage scrub	95	0.7	65	Erofas	1, 10, 100 hr fuels - 9%, 10%, 11%