

## **Fire Modeling and Risk Prevention**

Evora, Portugal

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## Abstract

With the highest incidence of fire ignitions in Europe, Portugal serves as a potential catalyst for the development of more effective fire management plans in fire prone regions.<sup>1</sup> The number of farmers in Portugal has decreased over the decades leading to large, unmanaged tracts of land that often interface with populated areas. Abandoned areas that were previously grazed by livestock are experiencing a shift from grassland to shrubland.<sup>2</sup> The aim of this study is to assess the impact of fire risk from grassland succession to more mature shrub and tree species if management efforts to thin grassland vegetation are not pursued. This study explores the effect of fire management efforts in Evora, Portugal by modeling and comparing two scenarios: existing conditions of shrub encroachment and conversion to managed grassland. Fuel models of each scenario were digitized in ArcGIS using a combination of satellite imagery and 90 GPS ground control points of land cover. Additional ground control points were collected using FireSphere— an interactive mobile application— to add geocoded field notes and cross reference GPS points. Fire behavior was simulated over a 1.5-square mile study site within the wildland-urban interface using FlamMap and spatial comparisons were evaluated in ArcGIS. Variables measured include flame length, crown fire activity, heat per unit area, and rate of spread. Results indicate an increased fire risk due to shrubland encroachment. Methodology used in this report can be adapted to evaluate and identify high priority sites near populated areas in need of improved fire management.

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<sup>1</sup> Paton, Douglas, and Fantina Tedim. "Enhancing Forest Fires Preparedness in Portugal: Integrating Community Engagement and Risk Management." *Planet @ Risk* 1.1 (2013): 44-52. Print.

<sup>2</sup> Correia, P. T. (1993). Land abandonment: Changes in the land use patterns around the Mediterranean basin. *CIHEAM*, 1(2), 97 – 112.

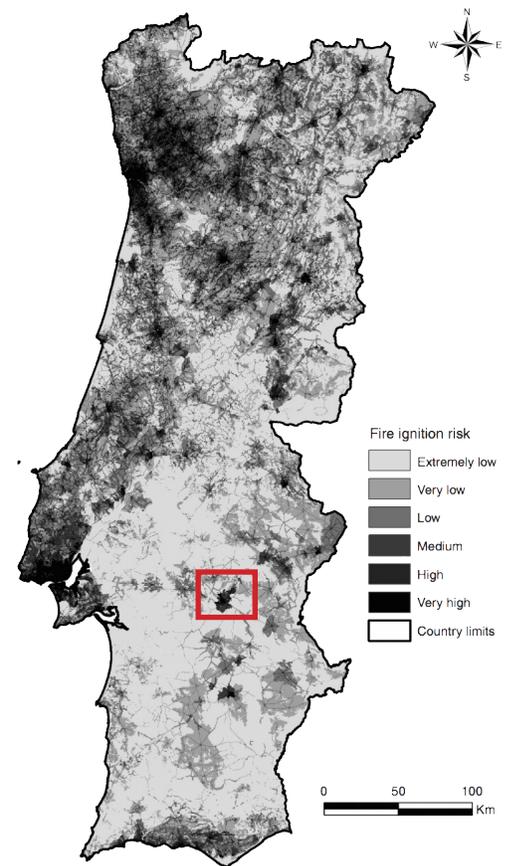
## Table of Contents

I. Introduction.....	4
II. Objectives.....	5
III. Description of Study Site.....	5
IV. Methodology.....	6
V. Assumptions and Limitations.....	8
VI. Data Analysis & Results.....	9
A. Crown Fire Activity.....	9
B. Heat Per Unit Area.....	9
C. Rate of Spread.....	9
D. Flame Length.....	9
VII. Discussion & Recommendations.....	14
VIII. Works Cited.....	15

## I. Introduction

With the highest incidence of fire ignitions in Europe, Portugal serves as a potential catalyst for the development of more effective fire management plans in Europe. Fire modeling is necessary in order to accurately identify hotspots and landscape mosaics that increase fire risk. Fire modeling in Portugal has been the subject of studies by Botequim (2010), Moreira et al. (2009), and Peterson et al. (2008). Botequim performed a fire simulation using FARSITE and FlamMap on sites in Northern and Central Portugal to examine how landscape structure, weather, and fire-ignition locations influenced fire spread (2010). Moreira et al. found regional variations in land-type vulnerability to wildfire, categorizing Portugal into three different fire dynamic zones (2009). One potential reason for regional variation is climatic differences, which poses the question of how projected changes in climate regimes will impact fire risk. The Alentejo region of southern Portugal has historically had low occurrence and smaller-scale wildfires compared to other nearby regions; however, climate change projections outline a 4 degree Celsius increase in mean temperatures in the Alentejo region over the next 50-80 years.<sup>3</sup>

Furthermore, rural areas are undergoing a net loss of residents as more people relocate to city centers.<sup>4</sup> This phenomenon is known as “social desertification” and has resulted in land conversion of managed Montado landscape to cliffrose and scrubland. Climate change combined with social desertification will result in shifting fire risk dynamics within Alentejo. Such changes will require environmental foresight to anticipate and mitigate risk but previous research concentrates on mitigation strategies for northern and central regions. The goal of this study is to propose a methodology that offers a fine-scale simulation and explores mitigation measures specific to the



**Figure 1.** An existing fire ignition risk map highlights Evora (identified with a red box) as a very high fire ignition risk zone.<sup>5</sup>

<sup>3</sup>“Projected Changes in Annual Mean Temperature and Annual Precipitation— European Environment Agency.” <http://www.eea.europa.eu/data-and-maps/figures/projected-change-in-annual-mean>

<sup>4</sup>Peterson, S.H., M.E. Morais, J.M. Carlson, P.E. Dennison, D.A. Roberts, M.A. Moritz, and D.R. Weise. 2008. Spatial Modeling of Fire in Shrublands Using HFire. Res. Pap. PSW-RP-259. Department of Agriculture, Forest Service, PacificSouthwest Research Station: Albany, CA. <http://www.treesearch.fs.fed.us/pubs/31914>

<sup>5</sup>Catry, F. X., F. C. Rego, F. L. Bação, and F. Moreira. “Modeling and Mapping Wildfire Ignition Risk in Portugal.” *International Journal of Wildland Fire* 18, no. 8 (2009): 921–31.

southern region of Portugal. Fuel models were used to compare intensities and spread rates under different conditions. Results can be used to inform land use management plans and fire mitigation programs in anticipation of shifting climate dynamics.

## II. Objectives

This study explores the effect of fire management efforts by modeling and comparing two scenarios: (1) existing conditions of shrub encroachment and (2) grassland conversion. The aim of this study is to assess the impact of grassland succession to more mature shrub and tree species if management efforts to thin grassland vegetation are not continuously pursued. Results can be used to support incentives to manage grassland cover which will likely be key in addressing increased fire frequency exacerbated by

climate change near populated areas.



**Figure 2.** The selected study area in Evora is approximately 1.5 square miles.



**Figures 3 and 4.** Site photos reveal dry grassland between 2-3 feet in height (top and bottom).

## III. Description of Study Site

The selected study site is located approximately 1 mile northwest of the city center of Evora, Portugal (Figure 1). Site selection was based on the existence of typical wildland urban interface elements of both developed and undeveloped land. High density housing, open grasslands, and orchards are the main elements found within the study boundary. Diverse land use types such as the ones observed reflect realistic conditions of wildland urban interfaces. The area of the study site is approximately 1.5 square miles. The site also includes a number of community buildings such as schools, a

recreation center, gardens, and government institutions.

#### IV. Methodology

Classification of vegetative groups was undertaken prior to fieldwork to provide a basis for groundtruthed observations (Figures 3 - 18). The initial fuel model was developed and subsequently rectified based on field surveys that were performed in June and July 2015 in order to improve spatial resolution and fuel model accuracy. Roughly 90 ground control points were collected with a Global Positioning System (GPS) to serve as accuracy assessments for the fuel model. The FireSphere mobile application provided a secondary groundtruthing database in which georeferenced photos and fuel details could be recorded for future analysis.

FlamMap was used to analyze fire behavior between two scenarios: (1) existing conditions and (2) maintained grassland (Figure 19). Present conditions at the study site indicate areas of thick shrub encroachment - posing a higher fire risk than maintained grassland. Digitization of non-burnable surfaces versus burnable surfaces rendered a high-resolution fuel model. Fuel types were determined by the Anderson Fuel Model which defines grassland, shrubs, tree cover, houses, pools, and pavement as a fuel class of 1, 4, 10, 13, 97 and 99, respectively (1982).<sup>6</sup> The change between fuel models is primarily a transition from a continuous secondary overstory to herbaceous fuels, entailing a decrease in fuel class, where appropriate, from 4 to 1, respectively.

Next, the fuel model for the shrubland mitigation scenario was created by selecting shrubland zones (class 4) and converting to grassland areas (class 1) to simulate the removal of overgrown



**Figure 5.** Dock plant was observed in many fields.



**Figure 6.** Firesphere, an interactive mobile application, was used to track and record field observations.

<sup>6</sup> Hal E. Anderson, "Aids to Determining Fuel Models for Estimating Fire Behavior," *The Bark Beetles, Fuels, and Fire Bibliography*, 1982, 143.



**Figure 7.** A grove of managed cork trees sits on private property behind a wall.



**Figure 8.** A managed olive orchard is situated on the site's northern boundary.



**Figure 9.** Four foot mounds with small to medium rocks shapes a nearby field.



**Figure 10.** A vacant lot with four foot tall grass cover is situated between two houses.



**Figure 11.** Some grasses were recently cut.



**Figure 13.** Most grasses were between 1-4 feet tall.



**Figure 15.** Animals graze this small orchard nestled inbetween a housing complex.



**Figure 16.** A grassy field was found nestled between swaths of urban housing.



**Figure 17.** An irrigated field sits adjacent to an urban garden.



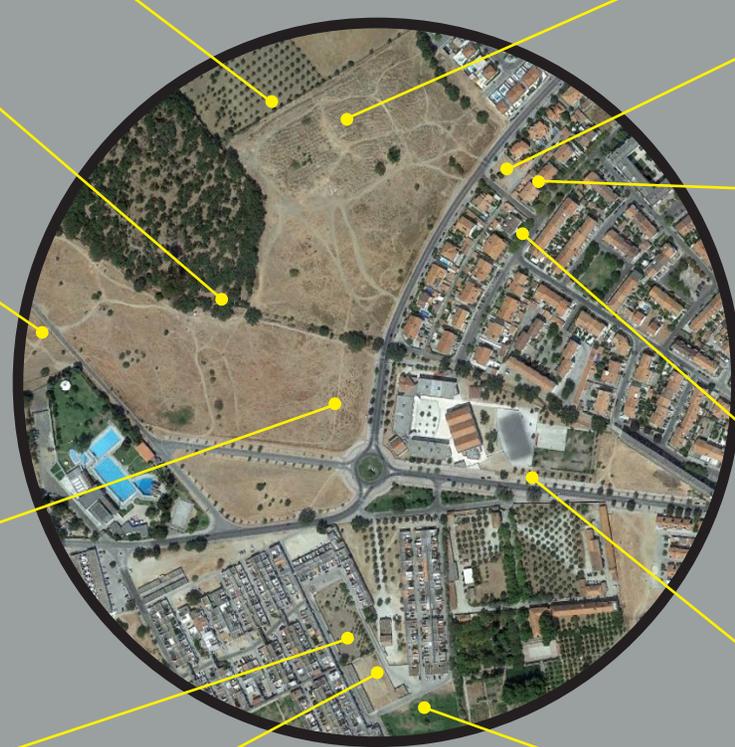
**Figure 12.** Many homes had clay tile roofs.



**Figure 14.** Many streets were lined with trees.



**Figure 18.** Most street trees grew into one another, creating a continuous path if fire were to occur.





**Figure 19.** Fuel models used in FlamMap reflect two different scenarios: shrub encroachment versus managed conditions. The two fuel models show differences in digitizing between current open space as shrub cover (class 4) compared to grass cover (class 1).

shrubbery. Each fuel model was analyzed using FlamMap with all other parameterized inputs remaining constant. Variables measured included flame length (feet), crown fire activity (class), heat per unit area ( $\text{kJ}/\text{m}^2$ ), and rate of spread (chains/hr). Spatial comparisons were evaluated in ArcGIS to determine the extent of spatial changes on fire behavior. Histogram comparisons between both scenarios were created and graphed using Excel to better understand overall changes in intensities for each variable modeled. Results were used to measure effectiveness of shrubland mitigation in regards to fire risk within the study site.

## V. Assumptions and Limitations

Due to limited data— likely from the language barrier— this study adapted wind conditions from the Claremont Canyon region within Northern California. This area experiences a similar Mediterranean climate as the examined site. Wind conditions were set to 35 MPH at 20 feet above the surface for each variable analyzed. Fuel moisture characteristics were also adapted from a Claremont Canyon dataset for the same reason. Aspect, elevation and slope were created using a digital elevation model of 30-meter resolution acquired from the European Environment Agency. Land cover was digitized using high-resolution imagery from Google Earth Pro and verified through fieldwork using a GPS locator and Firesphere. Imagery was acquired in January 2015 while fieldwork

was conducted in June 2015, thus slight variations may exist within the boundaries of existing land cover types.

## **VI. Data Analysis & Results**

### **A. Crown Fire Activity**

No significant shift in crown fire activity occurred between existing conditions of shrub encroachment and managed conditions (Figure 20). A direct comparison of crown fire activity levels between existing and managed conditions reveals minimal reduction of 0.3% from class 2 (moderate intensity) to class 1 (low intensity) (Figure 21). This is likely because shrubland and grassland exhibit similar crown fire characteristics since both are generally less than 3-inches in diameter and burn relatively quickly, falling under low-intensity surface fires.<sup>7</sup>

### **B. Heat Per Unit Area**

The highest heat intensities produced in the simulation were eliminated under managed conditions. The most significant change in heat per unit area was seen through a reduction in extreme HUAs (between 50,000 to 150,000 kJ/m<sup>2</sup>). A reduction in heat per unit area occurred in high interval categories (60,000 - 70,000 kJ/m<sup>2</sup>), which shifted to an increase in occurrence at lower interval categories (0 - 5,000 kJ/m<sup>2</sup>). This is a desirable change, as fires at lower heat levels are easier to control and manage (Figure 22). The largest reductions occurred as a 50% decrease in HUA between 25,000-35,000 kJ/m<sup>2</sup>, reflecting again the simulated conversion from shrubland to grasses (Figure 23).

### **C. Rate of Spread**

The rate of spread slowed significantly between shrub encroachment to managed conditions, with 20% of the study site shifting from 1,250 to 4,000 chains per hour to 0 to 250 chains per hour (Figures 24 and 25). This change likely reflects the higher heat intensities of burning shrubs compared to grasses, causing the rate of spread of shrubs to be more rapid. Therefore, shrub mitigation leads to more manageable spread rates.

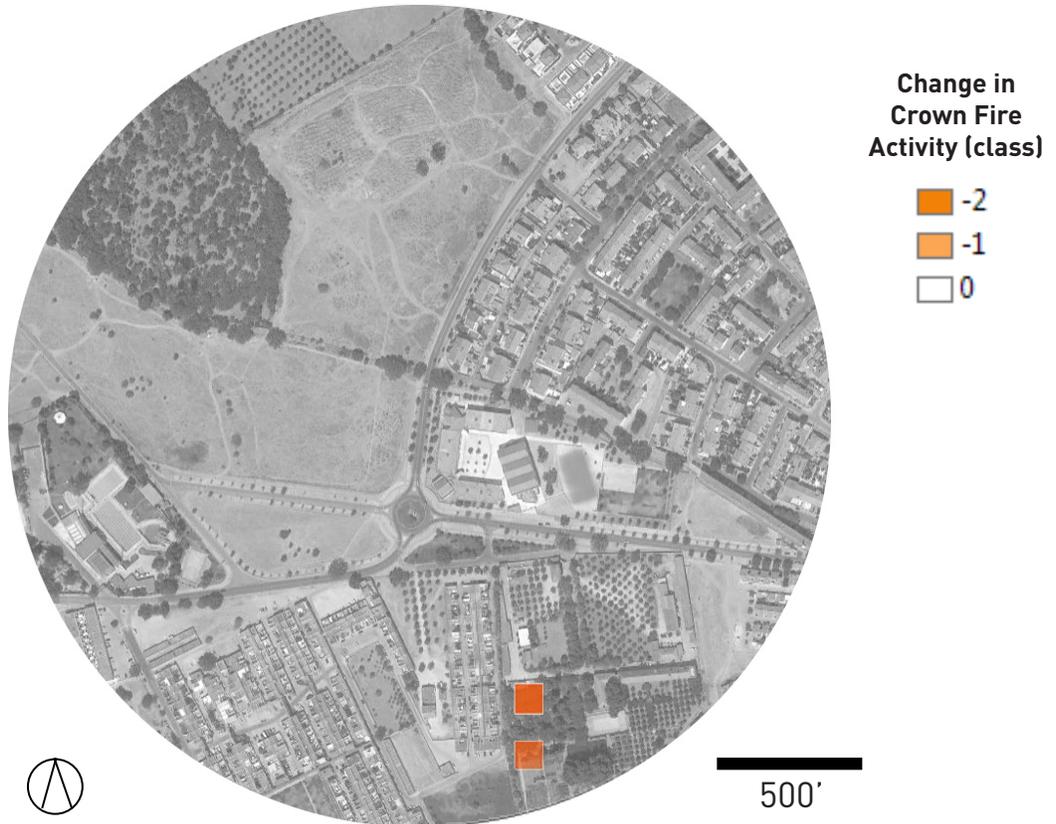
### **D. Flame Length**

A spatial comparison of scenarios shows about a 25% reduction from very large flames (60 to 130 feet) to significantly smaller flames (0 to 10 feet) (Figures 26 and 27). Additionally, about 25% of moderate flame lengths (10 to 20 feet) also shifted to a more manageable range (0 to 10 feet) between modeled scenarios of shrub encroachment to managed conditions respectively. The reduction of extreme flame lengths likely reflects the interconnections between small and large fuel types, such as fuel ladders that emerge between land use types, that trigger dynamic responses.

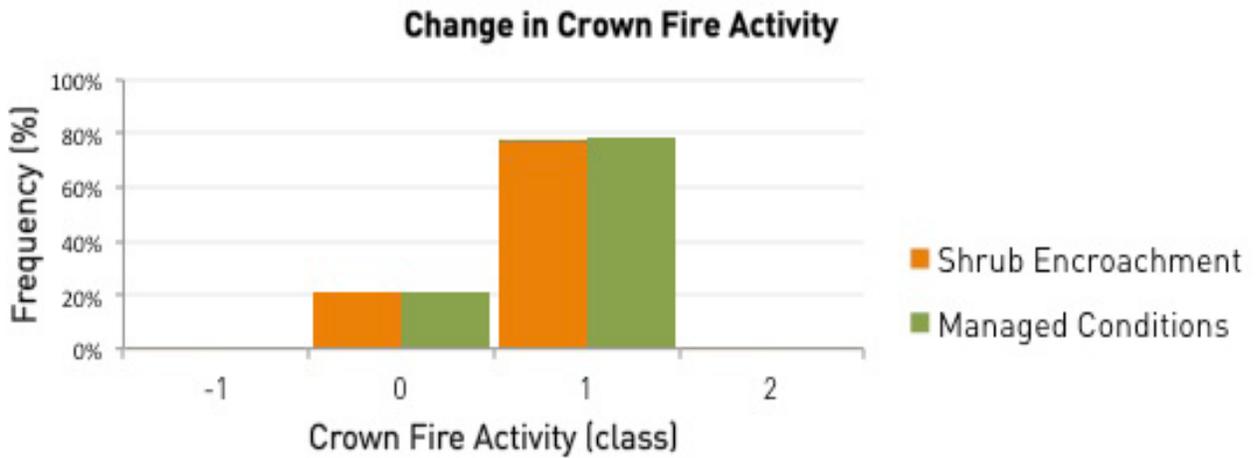
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<sup>7</sup> Linton, Jeremy V. *Wildfires: Issues and Consequences*. Nova Publishers, 2004.

### Change in Crown Fire Activity from Shrubland Encroachment to Managed Conditions

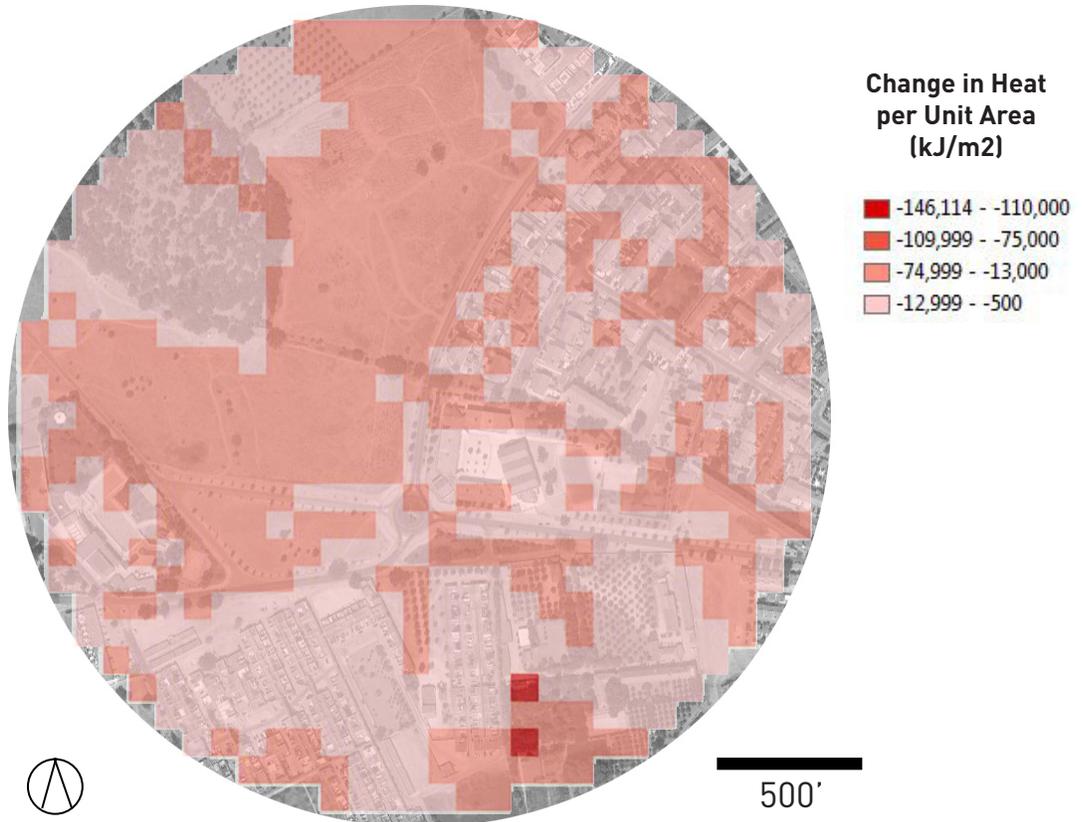


**Figure 20.** Very little change in crown fire activity occurred between scenarios. Only two small regions experienced a change of -2 near the southern portion of the site.

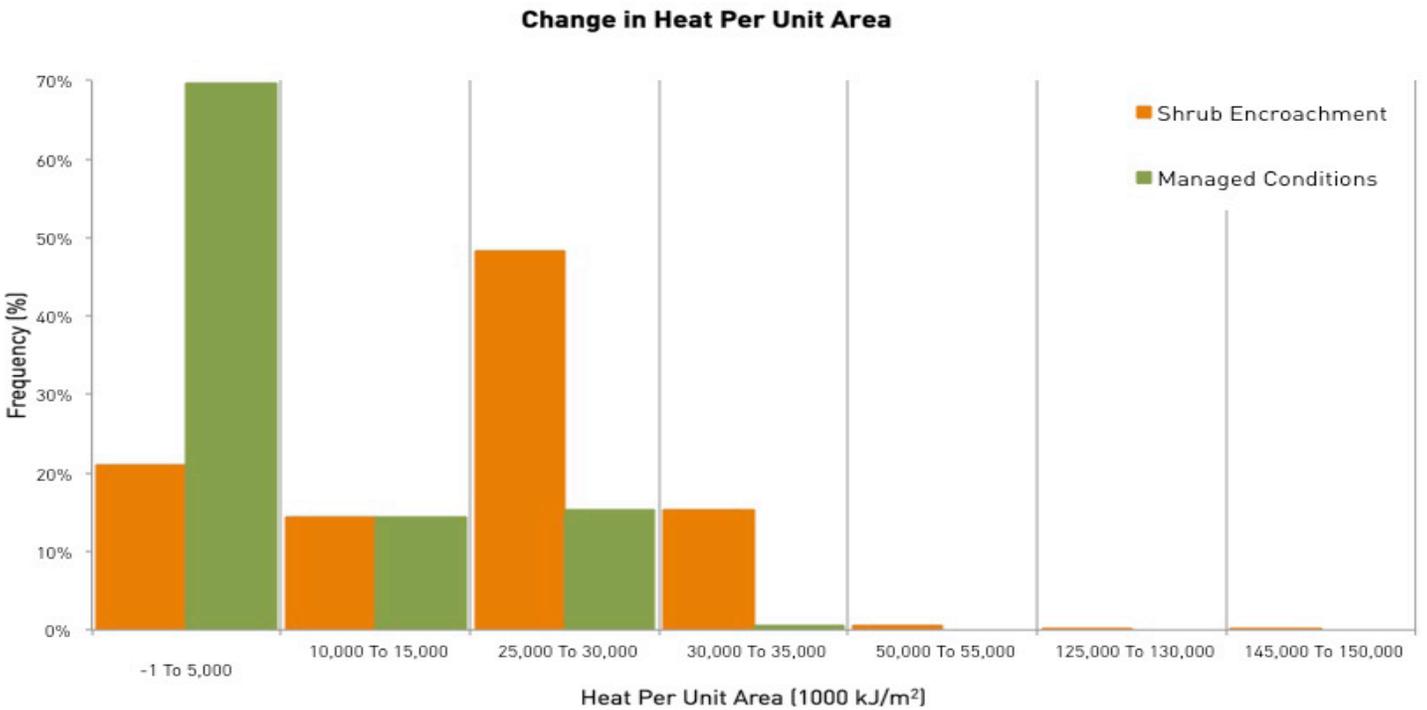


**Figure 21.** A comparison of crown fire activity between existing conditions and managed conditions resulted in minimal changes to overall fire behavior.

### Change in Heat Per Unit Area from Shrubland Encroachment to Managed Conditions

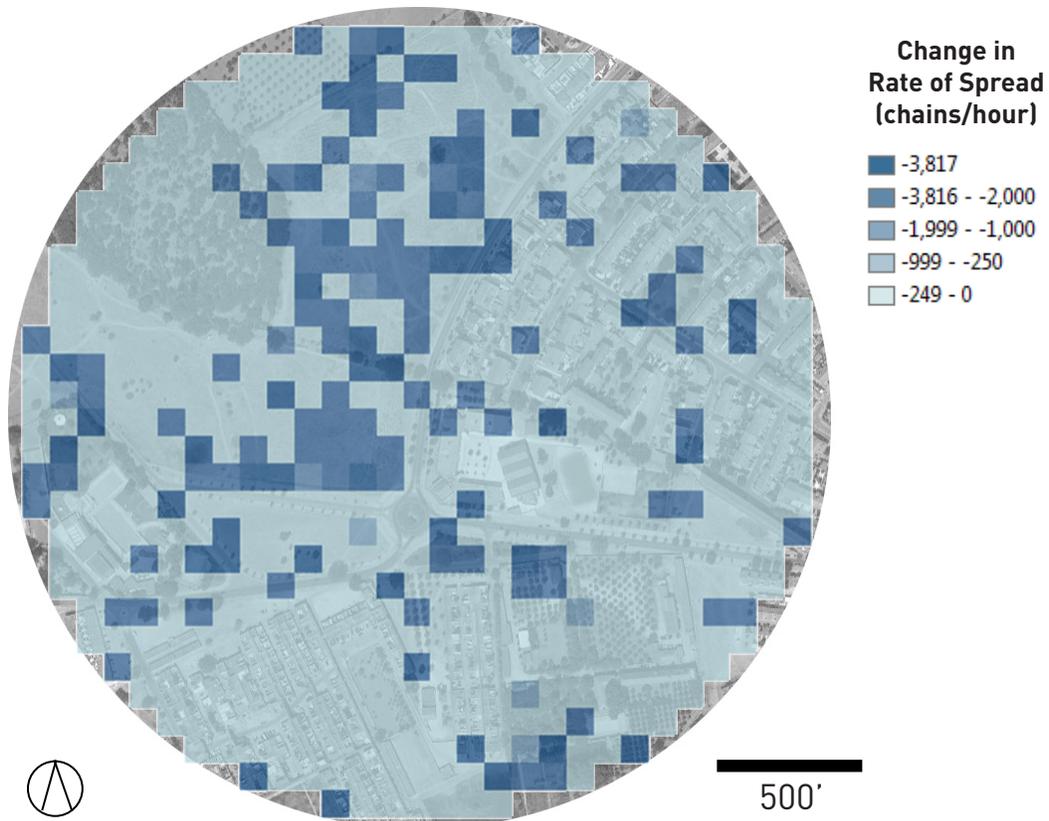


**Figure 22.** By prioritizing efforts to reduce shrub encroachment near the southern boundary of the site, a large amount of heat per unit area - between 110,000 to 150,000 kJ/m<sup>2</sup> - could be avoided in the event of a wildfire



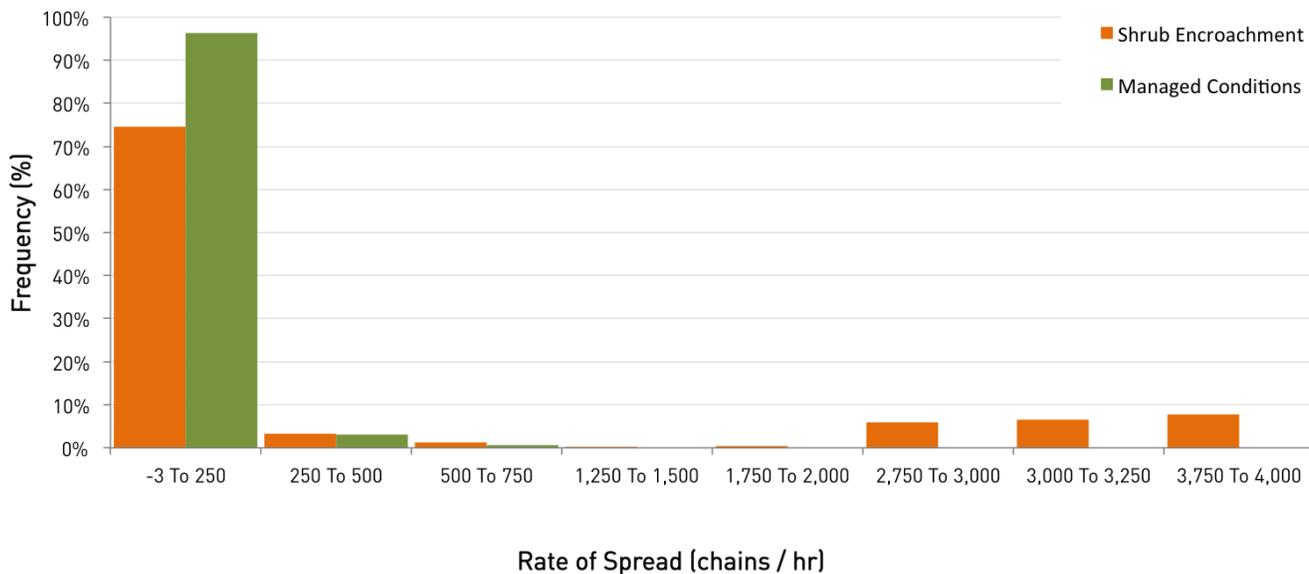
**Figure 23.** A reduction in heat per unit area occurred in high interval categories (60,000 - 70,000 kJ/m<sup>2</sup>), which shifted to an increase in occurrence at lower interval categories (0 - 5,000 kJ/m<sup>2</sup>).

### Change in Rate of Spread from Shrubland Encroachment to Managed Conditions



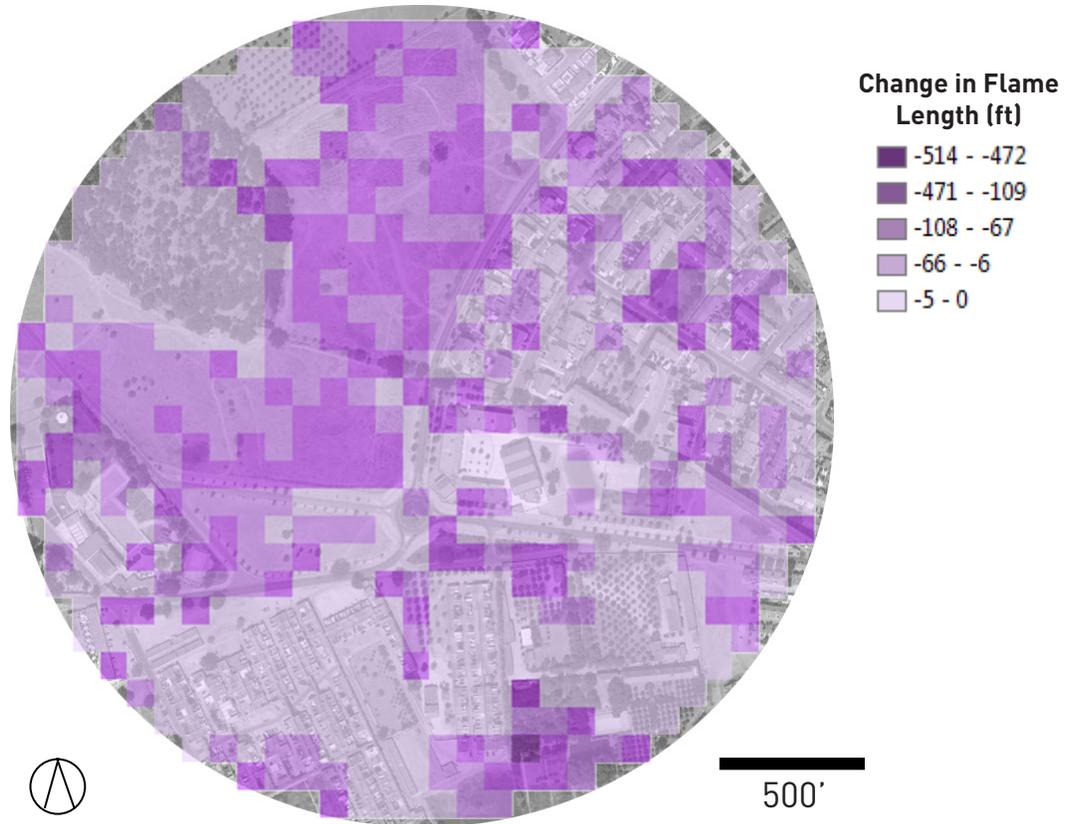
**Figure 24.** Very quick rates of spread— between 2,000 to 3,800 chains per hour— are reduced throughout the site under managed conditions. This will likely have a significant effect on resulting fire intensities felt throughout the site and beyond.

### Change in Rate of Spread

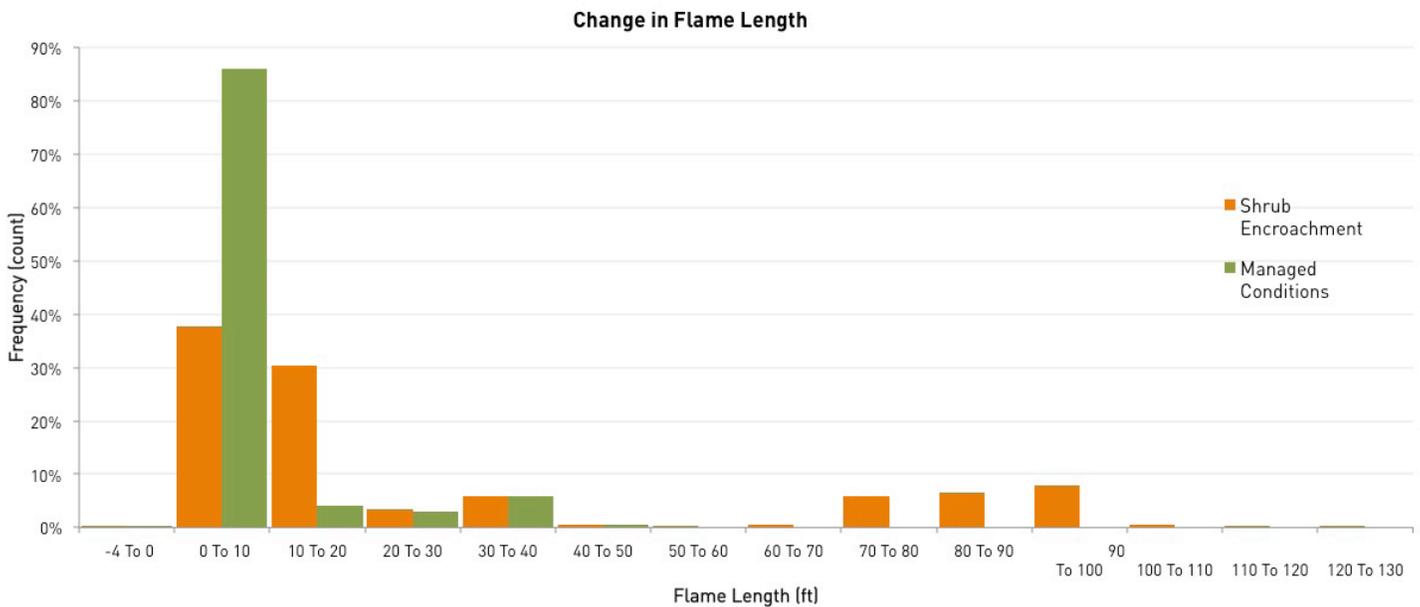


**Figure 25.** Shrub mitigation resulted in noticeable reductions in rate of spread, with shifts from 2,750 - 4,000 chains per hour to 0 - 250 chains per hour.

### Change in Flame Length from Shrubland Encroachment to Managed Conditions



**Figure 26.** A spatial comparison of rate of spread reflects change from shrub encroachment to grasslands through active land management. The most intensive flame length changes are seen near the southern edge of the study sites, with reductions between 470 to 515 foot flames.



**Figure 27.** Flame lengths shifted from very large in length (60 to 100 feet) to much smaller lengths (0 to 10 feet).

## VII. Recommendations

Minimizing shrub encroachment can greatly reduce flame length, rate of spread, heat per burned area, and crown fire activity. A summary of total effects of shrub removal include: minimal to no effect on crown fire activity; significant decreases in heat per unit area from extreme rates (between 50,000 to 150,000 kJ/m<sup>2</sup>) to more manageable levels (0 - 5,000 kJ/m<sup>2</sup>); an overall decrease in high rates of spread at dangerous intervals (1,250 to 2,000 chains per hour) to more manageable intervals (0 to 250 chains per hour); and a reduction from very large flame length (between 60 – 130 feet) to moderate lengths (0 to 10 feet).

Modeling the extent and behavior of two fire scenarios in Evora has proven the effectiveness of land management practices that foster minimization of shrub encroachment. Following the current demographic trends in Portugal, shrub encroachment may continue to accelerate in this landscape and thus exacerbate fuel conditions and potential ignitions.

These findings can be used to inform recommendations for community actions, therefore reducing overall fire hazards and risks. Community outreach to educate homeowners and local residents on fire risk indicators and mitigation measures can help increase awareness of potential vulnerabilities within the community. Additionally, a crowd-sourcing application to monitor affected areas as well as a more robust land management plan with fire mitigation methods would help to better equip this community. Such practices as goat grazing or manual management would also help to curb potential fire risks as climate change continues to influence unprecedented and unpredictable climatic conditions in central Portugal.

The methodology of this study can be scaled-up to better understand land management practices for the entirety of the Alentejo region. Furthermore, this type of analysis could be replicated for other land cover types with varying height and density ranges to simulate a range of mitigation scenarios. Spotting behavior exacerbates fire risk with given shrub types, so further research should also account for ember size variation and therefore transport differences between modeled land cover types. Such analyses could then be modeled in FARSITE, a fire modeling program that shows fire behavior over time, to simulate fires with different wind directions and parameter intensities. Resulting data could inform long-term mitigation strategies involving shrub management for Evora and other Portuguese towns situated within the wildland urban interface.

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