College of Tropical Agriculture and Human Resources
University of Hawai‘i at Mānoa

Forest and Natural Resource Management
September 2016
RM-21

Wildfire Ignition Density Maps for Hawai‘i

Clay Trauernicht and Matthew P. Lucas
Department of Natural Resources and Environmental Management

Introduction

Ignition density mapping provides a basic but key resource for assessing wildfire risk, planning to reduce that risk, and prioritizing areas for wildfire preparedness and prevention education (Catry et al. 2010, Koutsias et al. 2014, Chas-Amil et al. 2015). In Hawai‘i, the area burned by wildfires has increased fourfold within the past century and affects a proportion of state land area each year that is comparable to the Western US (Trauernicht et al. 2015). This increase is tied to the expansion of nonnative grasslands and shrublands across the state that provide ample fuels, in addition to episodic drought and frequent high winds. Wildfire occurrence is also obviously a consequence of available ignition sources, which, in Hawai‘i, are primarily caused by human activities.

The only natural ignition sources in Hawai‘i are volcanic events, which are restricted to active eruptions, and lightning strikes, which are rare because cool ocean temperatures buffer the land surface heating required for thunderstorm formation. More than 99% of known wildfire causes were attributable to human activities, for example, sparks from machinery, cars, and downed electrical lines; campfires; fireworks; and arson. Wildfire ignitions are very frequent in Hawai‘i, with the annual

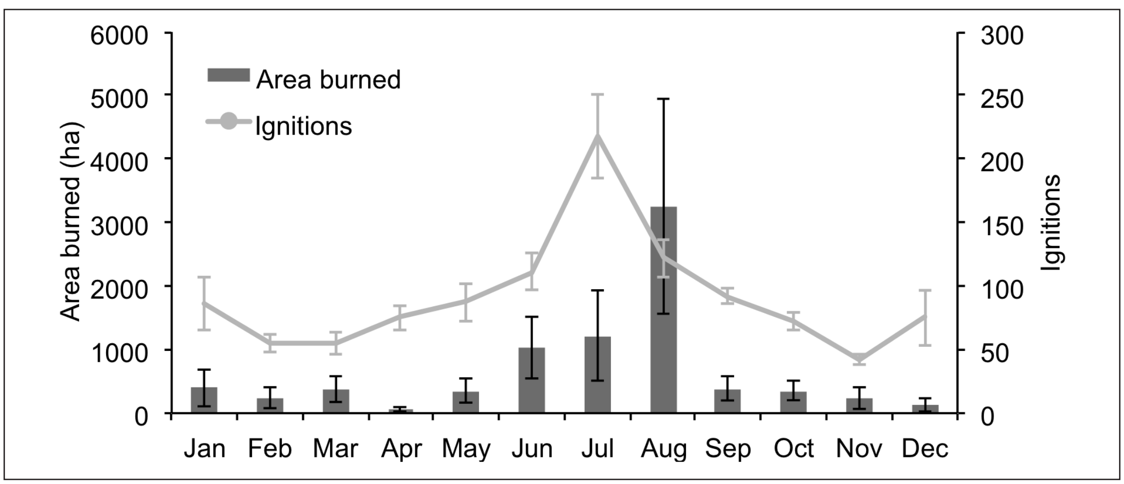


Figure 1. The average number of ignitions per year in Hawai‘i (light grey line) peak near holidays in July and December. The average area burned per year in Hawai‘i (dark grey bars) peaks during the drier summer months. Data is from statewide wildfire records 2005–2011. Error bars illustrate standard error.

In collaboration with the Pacific Fire Exchange (PFX), a Joint Fire Science Knowledge Exchange Consortium committed to reducing threat to ecosystems and communities in Hawai‘i and the U.S.-Affiliated Pacific from wildfire. http://www.pacificfireexchange.org/

number ranging from 600 to 1300 over the last 10 years. Peaks in ignition numbers around the Fourth of July and New Year's holidays also point clearly to people as the main cause (Figure 1). Although predicting the exact timing of these events is difficult, ignition density maps based on the spatial patterns of prior wildfires can illustrate where ignitions are most likely to occur.

This guide is designed as a reference source for ignition density maps created for the state of Hawai‘i by the University of Hawai‘i Cooperative Extension Service. As opposed to complex fire-growth and behavior models that incorporate numerous input parameters, fire ignition density maps are simply derived from location data of past wildfires. The wildfire-incident records maintained by fire response agencies typically contain data on fire location, size, time, and date of occurrence, as well as other information. Although the perimeters of larger fires are often mapped, most wildfire records contain a single point for the incident location (e.g., latitude and longitude). Further, representing wildfires incidents as points on a map makes it difficult to distinguish "clusters" of high ignitions because points overlap.

An approach that addresses this limitation is to calculate ignition density (e.g., the number of ignitions per unit area) from point-based wildfire location data using mathematical smoothing functions. The variation in ignition density over a landscape can then be plotted as a heat map or contour map (see Detailed Methods below). This provides a much clearer illustration of where ignitions are most frequent using a straightforward, quantitative value (e.g., number of ignitions per square mile per year). The Hawai‘i ignition density maps presented here were created using adaptive kernel density estimation (KDE). This technique is a type of mathematical smoothing function that has been used to map and manage disease outbreaks, crime events, traffic incidents, and similar incident-based data sets. It has also been proven useful by fire scientists to produce regional fire occurrence maps when information on the actual areas burned (i.e., fire perimeters) is limited or unavailable (de la Riva 2004, Amatulli 2007).

Hawai‘i Ignition Density Maps

The Hawai‘i ignition density maps presented here are based on an ignition density "surface" that indicates the number of ignitions per square mile per year across Hawai‘i state. (See Detailed Methods below.) Ignition points came from the Hawaii State Wildfire History, a data set compiled and quality controlled by the Hawaii Wildfire Management Organization (HawaiiWildfire.org). This data set provides the location, date of occurrence, and area burned for over 11,000 wildfire incidents reported by the National Park Service, the Hawai‘i Division of Forestry and Wildlife, and all four County Fire Departments from 2000 through 2012.

The ignition density maps incorporate wildfire incidents over the greatest time spans for which complete county, state, and federal (excluding Department of Defense) wildfire records were available for each county. This time span ranged from 2000 to 2012 and was different for each county (see Detailed Methods). The maps cover the six main islands in the state: Kaua‘i, O‘ahu, Moloka‘i, Lana‘i, Maui, and Hawai‘i Island, as both a statewide product and per county. Importantly, for the county-level products, the map color scale for ignition density is based on the maximum and minimum values within each county. This information is available on the Pacific Fire Exchange website (www.PacificFireExchange.org/new-maps- tools/) as image files and as 250m-resolution raster data files to be used with geographic information system (GIS) software.

Applications

Table 1 shows how patterns of fire occurrence can inform multiple aspects of wildfire preparedness, planning, and

Table 1. Applications of ignition density information

- **Assessing relative risk of wildfire ignitions**
- **Communicating wildfire risk to policy- and decision-makers**
- **Communicating wildfire risk to the public**
- **Land-use and development planning**
- **Prioritizing areas for fuels reduction**
- **Designing fuel breaks to maximize effectiveness**
- **Strategic placement of firefighting resources**
- **Prioritizing communities for wildfire outreach and education**
- **Prioritizing areas for preparedness planning and resource mapping**
- **Integration into quantitative fire occurrence models**
- **Providing baseline data for evaluating outreach programs**

risk reduction. For instance, maps of ignition points already indicate that wildfire ignitions happen primarily along roadsides and occur on both leeward and windward sides of the islands. Ignition density maps, however, reveal well-defined “hot spots” of greater wildfire ignitions in more populated areas. Given the predominance of human-caused wildfires in Hawai‘i, these patterns indicate where investments in public outreach and education are most needed (e.g., Chas-Amil et al. 2015).

Identifying areas of greater ignition risk can help justify or establish the need for proactive wildfire risk reduction such as fuel breaks and fuel-reduction treatments. Knowing where wildfires are most likely to start, when combined with local knowledge of fuels, topography, and valued resources (see Trauernicht and Pickett 2015), allows landowners and land managers to maximize the effectiveness of investments in fuel breaks, road maintenance, and other fuel-reduction measures. For instance, there may be scenarios in which fuels reductions can be designed to help fire responders contain wildfires in the areas where they are most likely to start versus designing fuels reductions around valued resources (i.e., homes, crops, plantations, endangered species). In addition, ignition density information provides a key component of more sophisticated analyses of fire risk that integrate ignition probabilities with models of potential fire spread (e.g., FARSITE; http://www.firelab.org/project/farsite).

Ignition density maps also allow for wildfire frequency to be compared among islands and elsewhere. Leeward O‘ahu has the highest ignition densities in the state, with the number of ignitions per year many times greater than the highest ignition densities on other islands. This is due to much greater population densities combined with episodic dry conditions on the leeward side of the island. But these maps also highlight just how significant wildfire issues are in Hawai‘i relative to other parts of the country. Recent work by the US Forest Service has found that small-fire ignition densities in the continental US range from 0 to 4 ignitions per square mile over the entire period from 1992 to 2012 (Dillon et al. 2015). Ignition densities in the more populated areas of Hawai‘i greatly exceed these values and further highlight the need to address the social drivers of wildfire occurrence.

Detailed Methods

Kernel Density Estimation (KDE) works by placing an assigned area buffer around each spatial point of interest, thus creating a normal distribution of probability, or “kernel,” over each point location. This surface effectively creates a buffer of probability that the ignition oc-

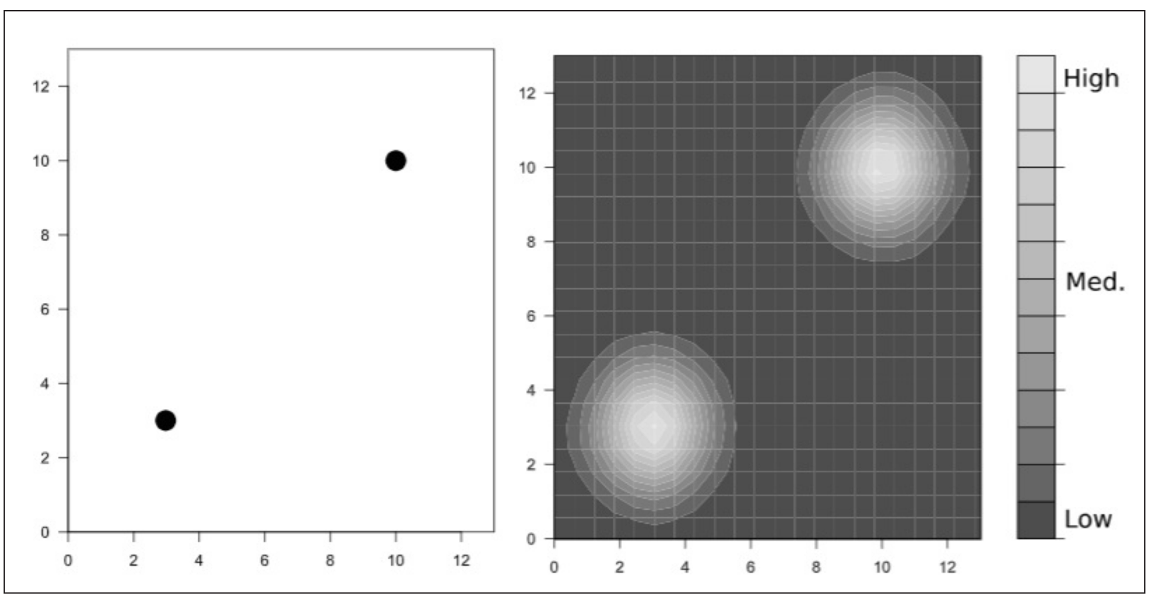


Figure 2

curred within a given space, spread around the original point location. Converting a single point to a probability helps to account for uncertainty regarding the accuracy of the ignition location in the original wildfire record (de la Riva 2004, Amatulli et al. 2007). Smoothing across multiple points also allows for the calculation of density values per unit area. In Figure 2 on the previous page, the two points in the left panel represent the locations for two wildfire incidents plotted on a map. In the right panel, KDE has been used to derive kernels (showing estimated ignition density) centered on each point and with normal distribution from high to low probability of occurrence.

KDE is also useful for indicating clusters of wildfire incidents that may not be apparent from plotting point data alone. When multiple points overlap, the kernel density values, or probabilities, are summed to derive the ignition density surface. In Figure 3 below, the left panel shows a map with point locations for seven wildfire incidents and the right panel illustrates the resulting fire occurrence map from the sums of kernels produced by the KDE function. The clustering of points in the lower left corner of the map is indicated by higher values on the ignition density map.

Different techniques can be used to determine the spread of probability, or kernel width, around each point. In the examples above, the spread of probability was fixed at an arbitrary distance. The Hawai‘i Ignition Density Maps presented used a technique called adaptive kernel density estimation in which the spread of the kernel probability at each point is adjusted according to the distance to a given nearest neighbor (i.e., the first, second, third, etc. closest point). This technique performs better for occurrence data, such as wildfire ignitions, where points tend to be spread unevenly across a landscape (Amatulli et al. 2007). Amatulli et al. (2007) also provide a goodness-of-fit test to determine the optimal nearest neighbor to be used in the density estimation.

For the Hawai‘i ignition density maps, given differences in the number and spatial spread of ignition points, multiple adaptive kernels were tested and the optimal kernel setting was identified separately for each county (Amatulli et al. 2007). This also made it possible to use all the years for each county for which complete agency records were available (Honolulu City/County (O‘ahu): 2001–2012; Maui County: 2000–2012; Kaua‘i County: 2005–2012; Hawai‘i County: 2004–2011). Despite the variable width of the kernels drawn over each point, the output of the adaptive KDE attributes equal weight to each incident point location and represents true ignition density; in the case of these maps, the number of fires per square mile per year.

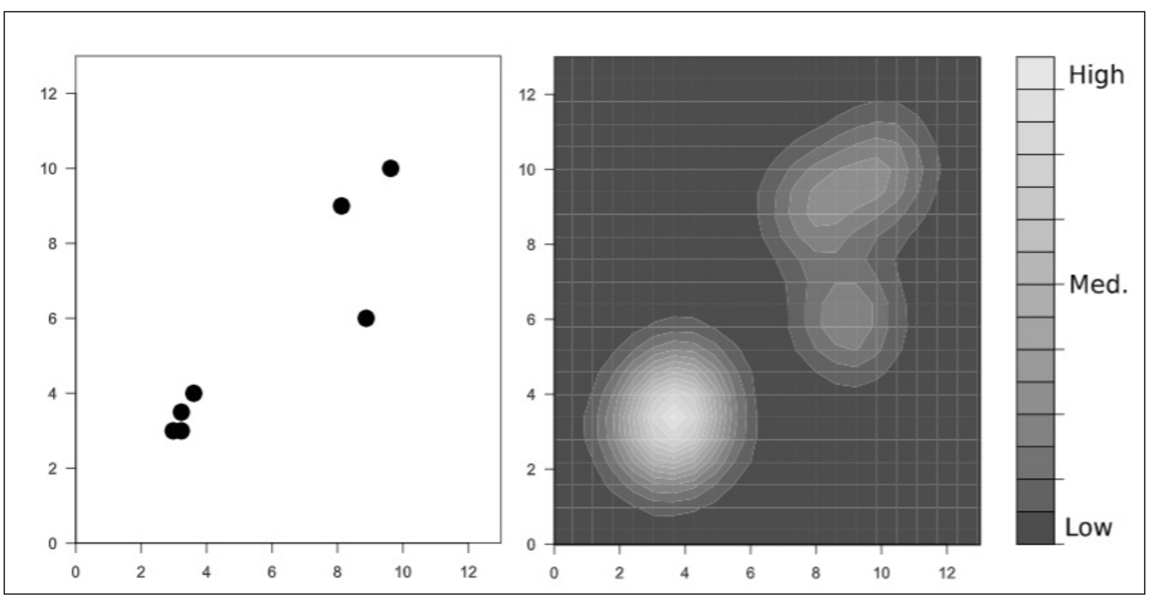


Figure 3

References

Amatulli, G., Peréz-Cabello, F., and de la Riva, J. 2007. Mapping lightning/human-caused wildfires occurrence under ignition point location uncertainty. *Ecological Modelling* 200(3): 321–333.

Catry, F.X., Rego, F.C., Bação, F.L., and Moreira, F. 2010. Modeling and mapping wildfire ignition risk in Portugal. *International Journal of Wildland Fire* 18(8): 921–931.

Chas-Amil, M.L., Prestemon, J.P., McClean, C.J., and Touza, J. 2015. Human-ignited wildfire patterns and responses to policy shifts. *Applied Geography*, 56: 164–176.

De la Riva, J., Pérez-Cabello, F., Lana-Renault, N., and Koutsias, N., 2004. Mapping wildfire occurrence at regional scale. *Remote Sensing of Environment* 92(3): 363–369.

Dillon, G.K., Menakis, J., and Fay, F. 2015. Wildland Fire Potential: A Tool for Assessing Wildfire Risk and Fuels Management Needs.(link is external) pp 60–76. *In* Keane, R.E., Jolly, M., Parsons, R., and Riley, K. Proceedings of the Large Wildland Fires Conference, May 19–23, 2014; Missoula, MT. Proc. RMRS-P- 73. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 345 p.

Koutsias, N., Balatsos, P., and Kalabokidis, K. Fire occurrence zones: kernel density estimation of historical wildfire ignitions at the national level, Greece. *Journal of Maps* 10.4 (2014): 630–639.

Trauernicht, C., Pickett, E., Giardina, C.P., Litton, C.M., Cordell, S., and Beavers, A. 2015. The contemporary scale and context of wildfire in Hawai‘i *Pacific Science*, 69(4): 427–444.

Additional Resources

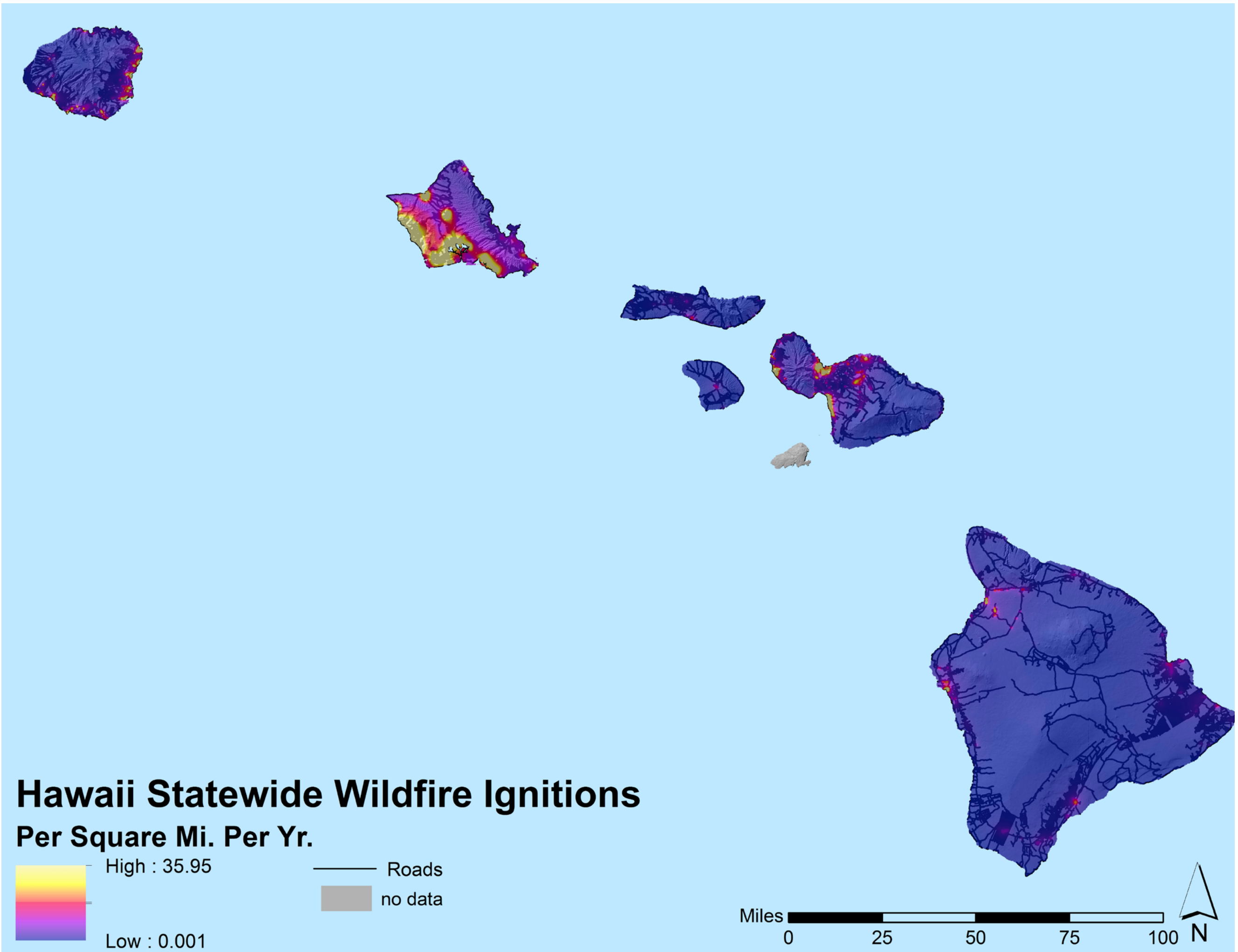
Trauernicht, C., and Pickett, E. 2015. Pre-fire planning guide for land managers in Hawai‘i and Pacific Islands. University of Hawai‘i Cooperative Extension Service publication.

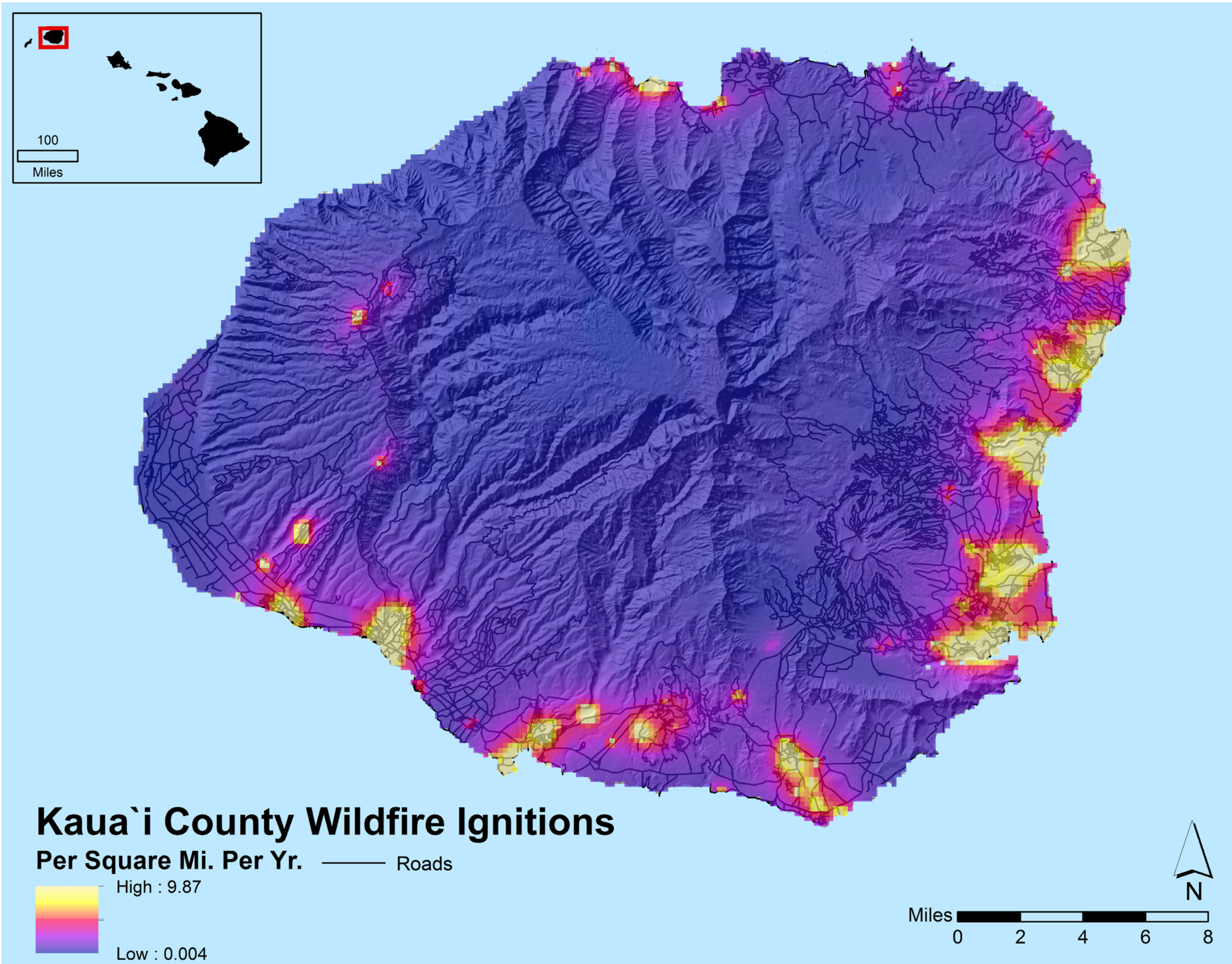
Truaernicht, C. 2014. Wildfire in Hawaii. Pacific Fire Exchange fact sheet. www.pacificfireexchange.org/research-publications/wildfire-in-hawaii-fact-sheet

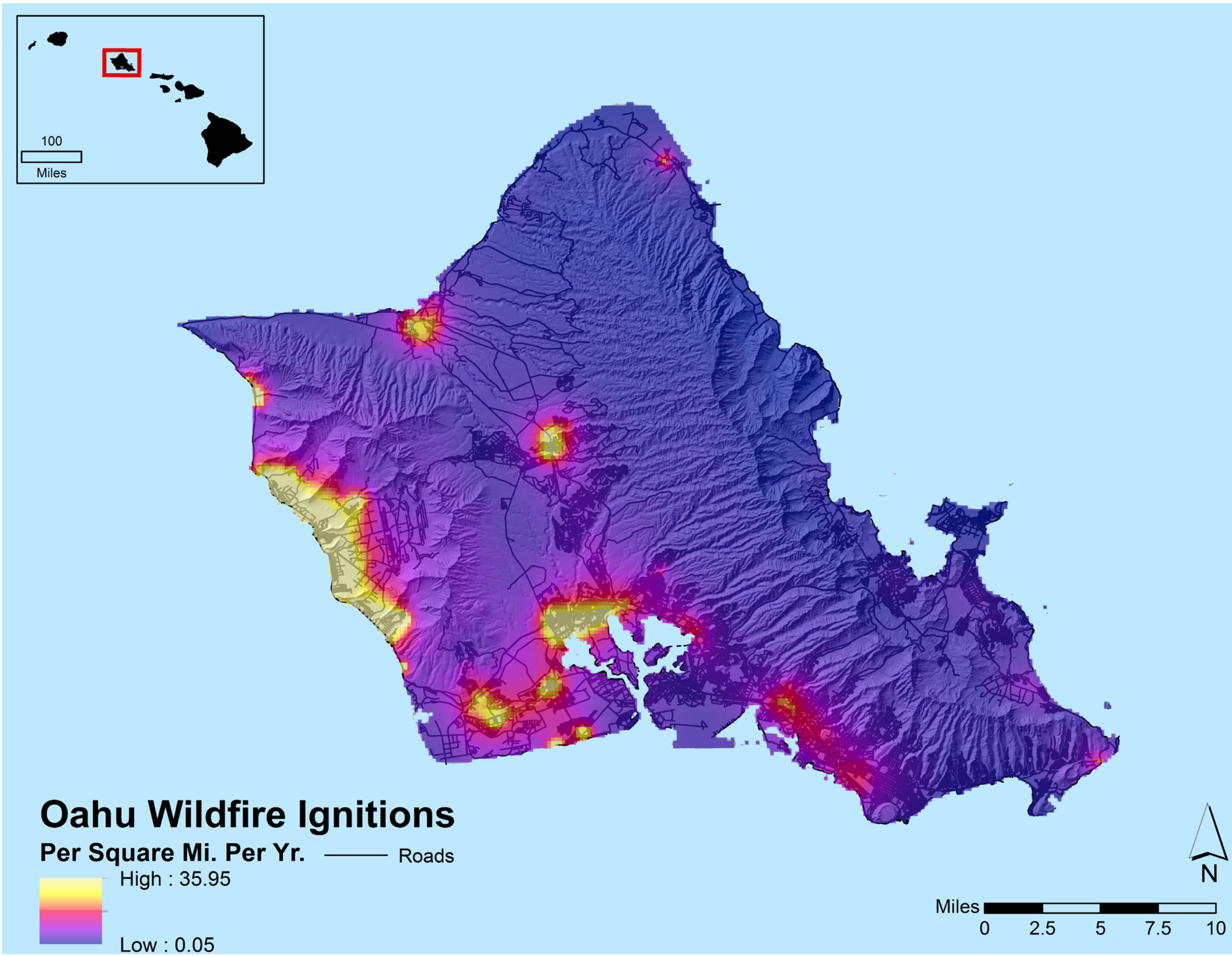
Acknowledgements

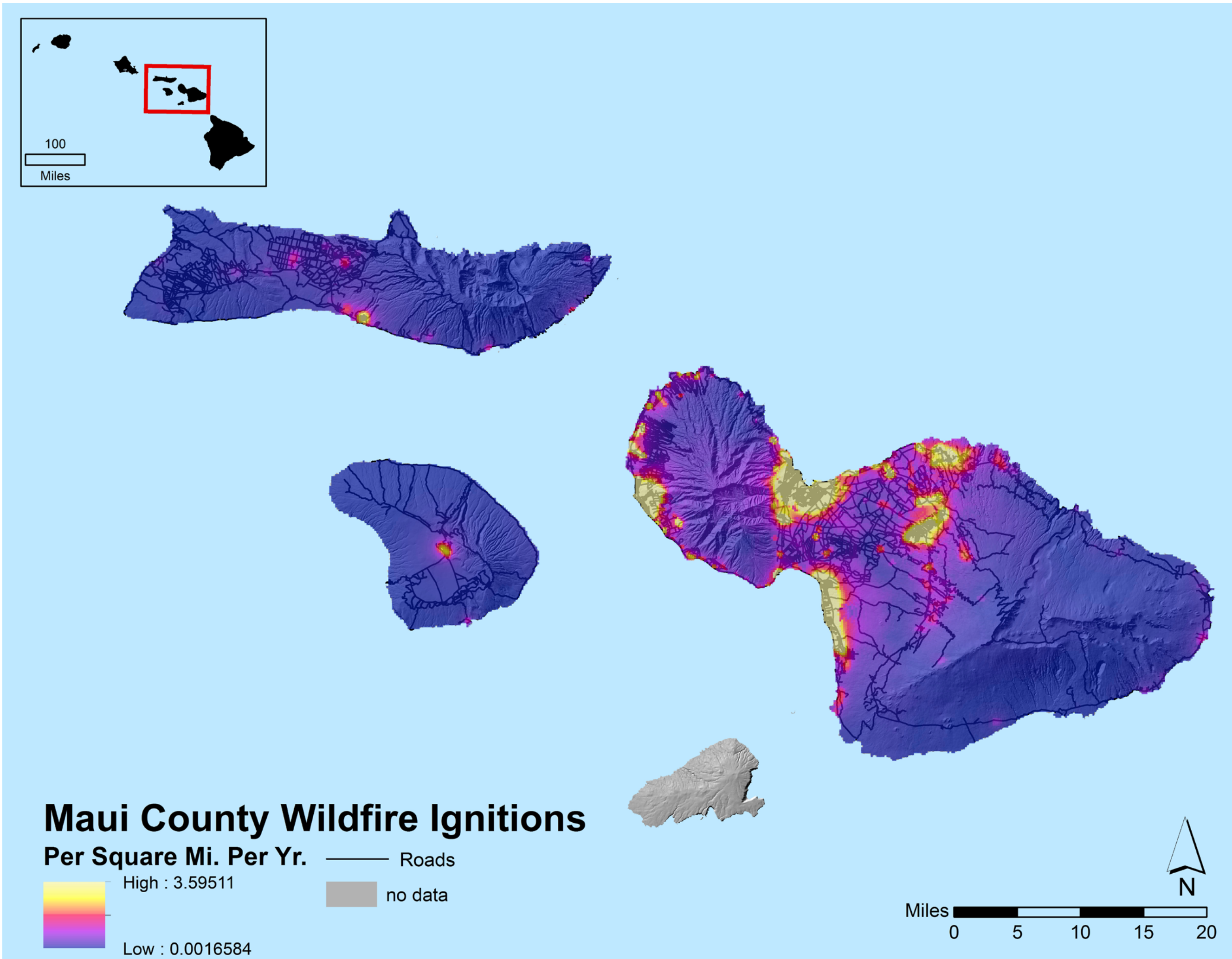
This document was made possible by funding from the Joint Fire Science Program and the College of Tropical Agriculture and Human Resources at the University of Hawai‘i at Mānoa.

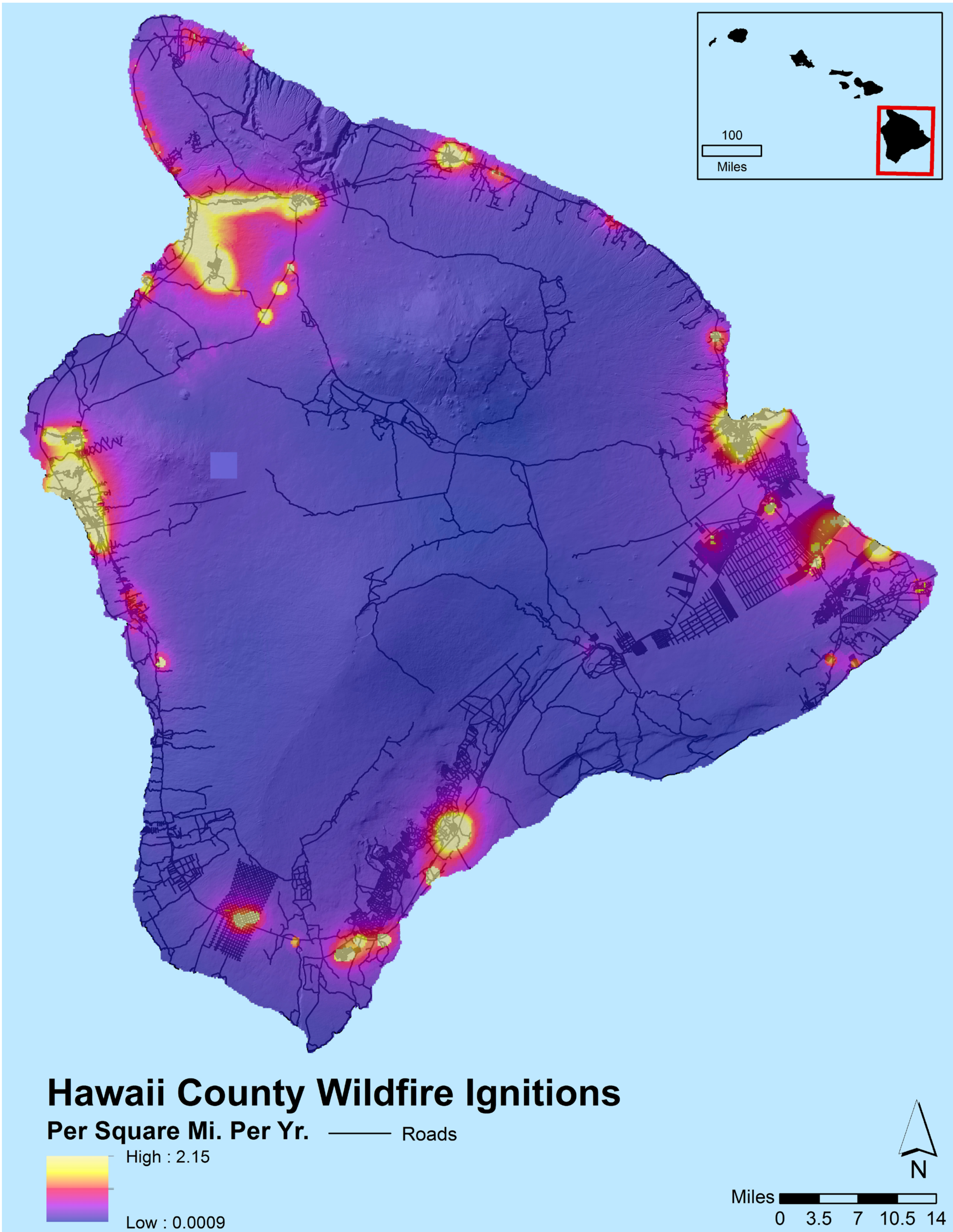
Maps


Hawaii Statewide Wildfire Ignitions
Per Square Mi. Per Yr.
High : 35.95
Low : 0.001
Roads
no data
Miles
0
25
50
75
100
N


100
Miles
Kaua`i County Wildfire Ignitions
Per Square Mi. Per Yr.
Roads
High : 9.87
Low : 0.004
N
Miles
0
2
4
6
8


100
Miles
Oahu Wildfire Ignitions
Per Square Mi. Per Yr.
Roads
High : 35.95
Low : 0.05
N
Miles
0
2.5
5
7.5
10


100
Miles
Maui County Wildfire Ignitions
Per Square Mi. Per Yr.
High : 3.59511
Low : 0.0016584
Roads
no data
N
Miles
0
5
10
15
20


100
Miles
Hawaii County Wildfire Ignitions
Per Square Mi. Per Yr.
Roads
High : 2.15
Low : 0.0009
N
Miles
0 3.5 7 10.5 14