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Wildland-Urban Interface Maps Vary with Purpose and Context

Susan I. Stewart[1]
Bo Wilmer[2]
Roger B. Hammer[3]
Gregory H. Aplet[2]
Todd J. Hawbaker[4]
Carol Miller[1]
Volker C. Radeloff[4]

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Rural Studies Program
Oregon State University
213 Ballard Extension Hall
Corvallis, OR 97331
(541) 737-1442
rsp@oregonstate.edu

[1] USDA Forest Service
[2] The Wilderness Society
[3] Oregon State University
[4] University of Wisconsin

Abstract

Maps of the Wildland-Urban Interface (WUI) are both pragmatic policy tools and powerful visual images with broad appeal. While the growing number of WUI maps serve the same general purpose, this paper demonstrates that WUI maps based on the same data can differ in ways related to their purpose, and discusses the use of ancillary data in modifying census data. A comparison of two methods suggests GIS methods used for mapping the WUI be tailored to specific questions. Dasymetric mapping to improve census data precision is useful but dependent on data quality, and land ownership datasets suffer problems that argue for caution in their use. No single mapping approach is "best," and analysts must be clear about the problem addressed, the methods used, and data quality. These considerations should apply to any analysis, but are especially important to analyses of the WUI upon which public-sector decisions will be made.

Introduction

The dramatic losses and costs associated with recent wildland fires in the U.S. have captured widespread media coverage and subsequent public attention. Recent in-depth newspaper stories have singled out housing growth in high fire risk areas as a major problem (Heath 2007, Johnson 2007), drawing new attention to what resource managers, scientists and policy makers have long known: that housing growth in the wildland urban interface (WUI) is a serious concern in the U.S. Both the National Fire Plan (NFP) and the Healthy Forest Restoration Act (HFRA) have provided incentives for focusing wildland fire risk mitigation in this zone. In this context, WUI maps are both pragmatic policy tools and powerful visual images with broad appeal, which may explain their recent proliferation (Radeloff et al. 2005, Theobald and Romme 2007, Wilmer and Aplet 2005).

While the various WUI maps serve the same general purpose, differences in the methods used to produce them can result in very different maps. Platt (this issue) discusses and demonstrates variations in three WUI mapping methods, and illustrates these differences for Boulder County, CO. Building on previous analysis (Radeloff et al. 2005, Wilmer and Aplet 2005, Hammer et al. 2007) we extend his comparison to consider two additional issues and illustrate these in California. This paper demonstrates that WUI maps based on the same data can differ in ways that reflect the purpose for which the map was developed. We also discuss the use of ancillary data in modifying census data for resource management planning and raise questions about its possible outcomes depending on the extent and location being mapped.

Comparing Methods and Maps

Two independently generated methods for mapping the wildland urban interface were published in 2005 (Wilmer and Aplet 2005; Radeloff et al., 2005). The Wilmer and Aplet method (WA), and the Radeloff, Hammer and Stewart method (RHS) were both designed to help prioritize fuels management and wildland fire risk mitigation efforts. Each method involved two analyses, one to determine where housing and vegetation coincide, and another to determine where houses and vegetation are in close proximity. To determine where housing and vegetation coincide, areas were identified where both housing criteria (housing density and/or pattern) and vegetative land cover criteria (type and density) are met. To determine where houses and vegetation are in close proximity, a GIS buffer analysis specified some distance for "close proximity" and indicated the areas within that distance. Both methods use the U.S. census data on housing (U.S. Census Bureau 2002) and National Land Cover Data (Vogelmann et al. 2001) to characterize vegetation. However, the order for applying criteria and the units of analysis used for including and excluding areas differs, yielding markedly different results (fig. 1a-f).

Here, we illustrate these differences, using California as an example. To compare the methods, we first intersected census block boundaries with public lands boundaries and moved housing units in census blocks that are partially in public ownership onto the privately-owned portion of the census block. The land ownership data available for California is accurate and complete, facilitating this modification without the loss of accuracy. Starting from this common base, both methods identify census blocks where housing density exceeds one housing unit per 40 acres (fig. 1a and 1d). Then the methods diverge; the RHS method selects those census blocks that also have more than 50 percent wildland vegetation, and designates these as intermix WUI (fig. 1b), and finally uses a buffering process to identify interface WUI, where housing is in close proximity (1.5 mi) to a large, contiguous area of wildland vegetation (fig. 1c). Starting with the same initial set of census blocks that meet the housing density minimum, the WA method uses a buffering process to add areas in the vicinity (0.5 mi) of housing (fig. 1e), and then removes pixels (30 m cells) where the vegetation does not meet criteria as wildland fuel (fig. 1f).

Combining the WA and RHS maps shows three different categories of WUI area (fig. 2, 3). Those identified by both methods (yellow) have housing units and wildland vegetation; those in orange identified only by RHS have housing adjacent to wildland vegetation, but do not locate or measure the extent of that adjacent vegetation. Areas in purple identified only by WA consists of wildland vegetation within a half-mile of communities, but do not identify the location of housing. Statewide (figure 3), the two methods identify over 5 million acres in common, but each identifies unique areas as well. The WA method uniquely identifies an additional 9.5 million acres, and the RHS method, 1.8 million acres. Statewide,

There are two major reasons for the differences in the maps. The first is in buffering for proximity analysis. The WA method buffers 0.5 mi around all blocks that meet the housing criteria, in keeping with the HFRA language including a half-mile zone around communities as part of the WUI (U.S. Congress 2003). The RHS method is based on the older National Fire Plan (NFP) WUI definition, which does not specify a community buffer but does discuss interface-type WUI where homes are near wildland vegetation (USDI and USDA 2000, 2001). A wider buffer is used (1.5 mi) to identify interface areas, but is extended only from areas with dense wildland vegetation, and only those blocks or portions of blocks with adequate housing density are retained. Where the HFRA intent was to identify communities and establish a buffer around them to be treated as mitigation zones in the creation of Community Wildfire Protection Plans, the NFP interface definition was based on the notion that wildland fire is carried into communities when fire brands emanate from wildland fires, creating an area of potential risk.

The second major difference is in the way areas without wildland vegetation are identified and included or excluded. The RHS method excludes whole census blocks where less than 50 percent of the 30m NLCD pixels within the block are wildland vegetation. The WA method removes just the individual 30m NLCD pixels that lack wildland vegetation cover types; and they do so after buffering, so that non-vegetated areas are removed from the WUI community buffer zones as well. The pixel-by-pixel retention of wildland vegetation gives the WA map its speckled appearance.

The details of an analysis process such as this can easily obscure the larger differences in methods and motivations. The main goal of the Wilmer and Aplet approach is to identify areas of treatable wildland fuels near communities. In contrast, the goal of Radeloff, Hammer and Stewart is to identify housing growth near forests and other wildland vegetation and its consequences for wildland fire. Although both methods start by identifying communities and adjust based on the vegetative characteristics within or near the blocks, the WA method is focused on vegetation, while RHS is focused on housing. The maps and statistics that result from the two methods convey somewhat different information that is consistent with the focus of each approach. Wilmer and Aplet provide detailed information about wildland vegetation in and near communities. Radeloff, Hammer and Stewart identify housing intermingled with or near wildland vegetation.

There are advantages to each approach, and both are relevant to current debates on wildfire policies. Using the RHS data provides specific, high-confidence counts of housing units. Census blocks are broken only where the 1.5 mile buffer bisects them, and no block is intersected more than once. Hence the extent of interpolation needed to provide a count of housing units is minimal. In contrast, counting the housing units in the mapped WUI is not feasible using the WA method because areas as small as $30m^2$ are eliminated from census blocks. However, the WA map clearly shows the extent of wildland vegetation across an entire area, including more densely-settled urban areas, identifying what the *Federal Register* classifies as “occluded” WUI communities, islands of vegetation surrounded by development (USDI and USDA 2001). In landscapes such as southern California, these occluded areas may be at risk under severe wildfire conditions.

What all these maps taken together illustrate most clearly is the elusiveness of a single or "actual" WUI zone. Whether one focuses on the houses or the vegetation depends on the management goal, or the policy question: treating wildland fuels, preparing a community wildfire protection plan, or identifying areas where houses and forests affect one another. There is growing recognition that wildland fire is a "wicked" problem, one where simple solutions are elusive and efforts to define a problem reveal a new set of problems (Carroll et al. 2007). As such, making progress requires precision in the description of the problem and letting the situation dictate which facts (and a map is nothing more than a representation of facts) are best suited to addressing the problem.

Improving WUI Maps

Regardless of the problem to be addressed, every effort should be made to represent accurately the concept being mapped. Most WUI maps use either human population or housing data from the U.S. Census Bureau to measure human presence. Unfortunately, the size of census units (e.g. blocks, block groups, tracts) varies with settlement density. The result can be a large block with a small cluster of homes in one area but large uninhabited spaces in the rest, and an average density too low to meet the WUI criteria despite the presence of a community. To improve the spatial resolution of housing data, ancillary data sources can be used to modify the boundaries of a unit such as a census block, employing a technique called "dasymetric mapping" (Mennis, 2003). Public lands boundaries are commonly used for this purpose because houses generally do not occur on public lands. An original census block can be split into two modified blocks, one being the part of the block that is in public ownership and can be assumed to have no housing units, and the other – the area outside the public land boundary – which is assumed to be the correct location of all of the block's housing units. We used this approach to generate the starting data for our analysis (Figs. 1a and 1d). The same technique has also been used in WUI mapping by Wilmer and Aplet (2005); by Hammer et al. (2007) in a WUI analysis of Washington State, Oregon, and California; and by Theobald and Romme (2007) in creation of a national WUI map.

Dasymetric mapping is quite useful but highly dependent on the quality of the ancillary data used, and current land ownership data in the U.S. suffers from a number of problems. Omissions and inaccuracies are common. For example, the widely-used Protected Areas Database (PAD) (DellaSala et al. 2001) is compiled from land ownership information attainable in each state, so data quality and errors vary by state depending on the data available and the extent of participation and assistance provided by state officials. Differences in ownership patterns across the U.S. introduce further questions about data quality and consistency. In the West, large blocks of land exist in public ownership, and because their designation as public lands pre-dates widespread settlement of the region, there are relatively few private inholdings within the national forests. The situation is different in the East, where most forests have extensive inholdings which are often attractive building sites. However, inholdings may not be mapped if their size is below the minimum mapping unit size of the land ownership map, which can lead to erroneous changes to housing data. Furthermore, the East also has extensive non-Federal public forest land. The majority of state public land is represented in the PAD, but the large expanse of county forests in some eastern states (e.g., Wisconsin) are not included. Hence land ownership data varies from east to west, as it does from state to state.

The current problems with land ownership data argue for caution in its use. Using this data to produce a national WUI map can result in uneven accuracy from state to state and from east to west, making it impossible to derive meaningful conclusions in nationwide comparisons.

Conclusions and Implications

The more closely one looks at the details of data sources and processing behind WUI maps, the more questions arise about any one map. Due to the characteristics of currently available data, maps that provide the consistency necessary for state-by-state comparison will lack spatial precision where census units are large. Improving precision via dasymetric mapping is not currently feasible without sacrificing data quality, unless the map is limited in its extent (i.e., to a state or sub-state region where high-quality ownership or other ancillary data are available). Sensitivity analyses, which test how much the WUI changes when the parameters used to map the WUI are altered, can provide information to address some of these questions but unfortunately is not commonly conducted (Stewart et al. 2007). Maps of any description require much more documentation, verification and testing than is now customary. Full documentation of data and disclosure of its errors become especially important for any data intended for use in further analysis because errors are multiplicative when combining data sets, but these disclosures are not yet common in the GIS academic community due in part to the extensive detail involved.

In conclusion, GIS analysis and mapping are a powerful tools in representing the extent of the wildland-urban interface fire problem, but the specific methods used must be tailored to the specific question being asked. The WUI can take many forms, from the homes adjacent to wildland fuels to the wildland fuels adjacent to homes. No single approach is “best,” and each must be clear about the problem being addressed, the methods used, and the effect of data quality on the results. These considerations should apply to any analysis, but they are especially important to analyses such as the location and extent of the WUI, upon which public-sector decisions will be made. We must all do better.

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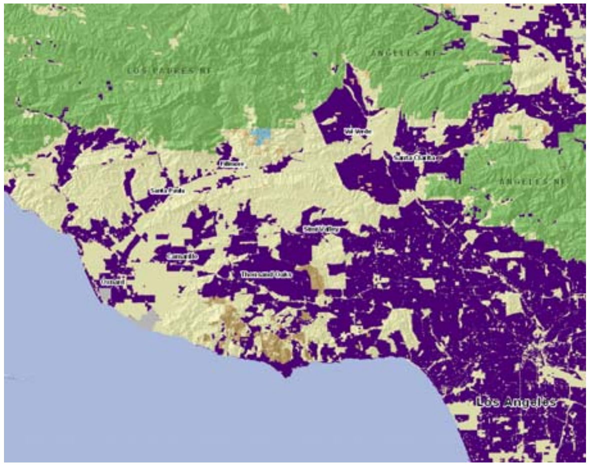


Figure 1a. RHS Method
Housing Density > 1 housing units per 40 ac

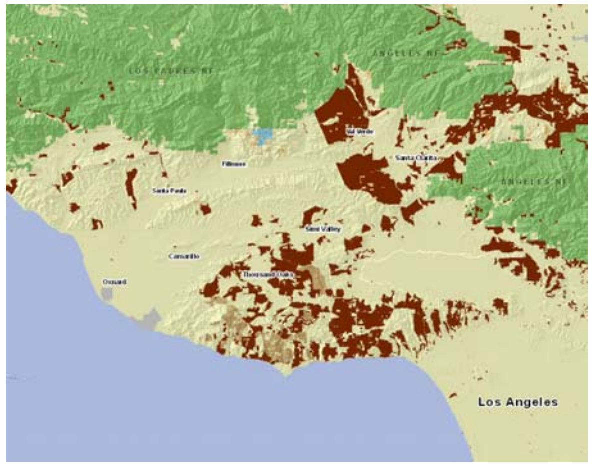


Figure 1b. RHS Method
Removal of blocks < 50% vegetated

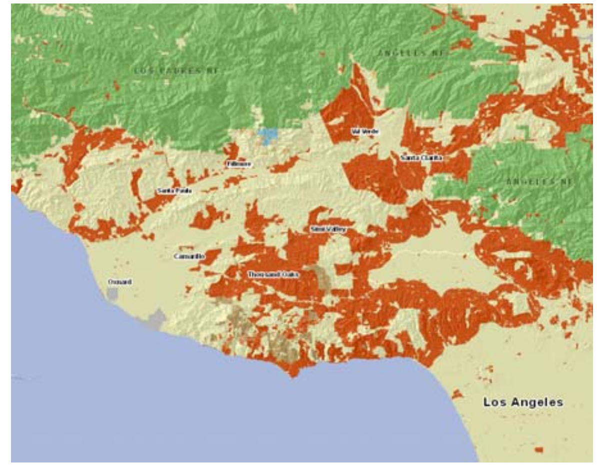


Figure 1c. RHS Method
Addition of area within 1.5 mi of blocks > 75% vegetation

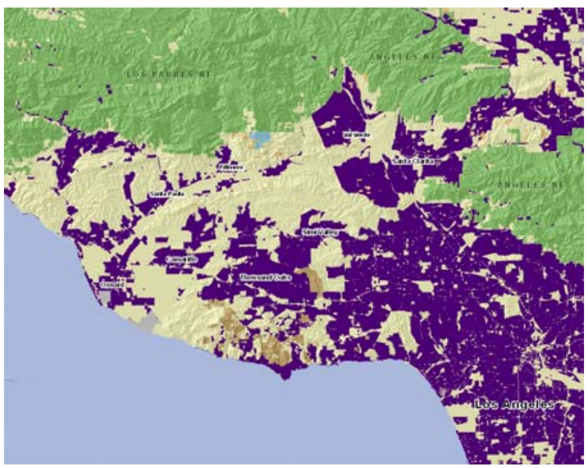


Figure 1d. WA Method
Housing Density > 1 housing unit per 40 ac

Figure 1e. WA Method
Addition of area within 0.5 mi of WUI blocks

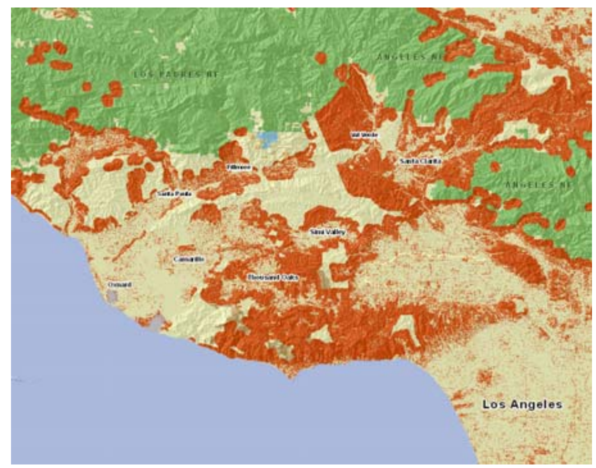
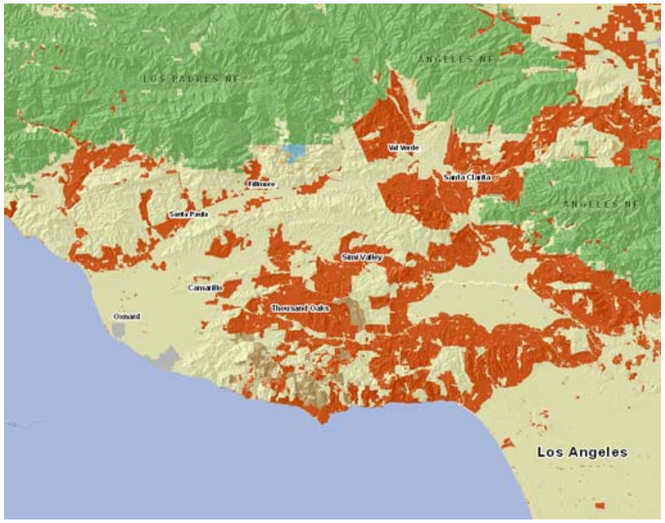


Figure 1f. WA Method
Removal of pixels with non-wildland fuels



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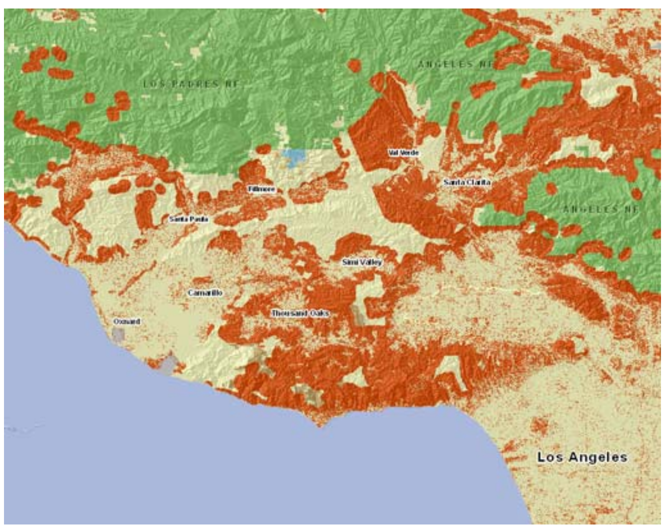

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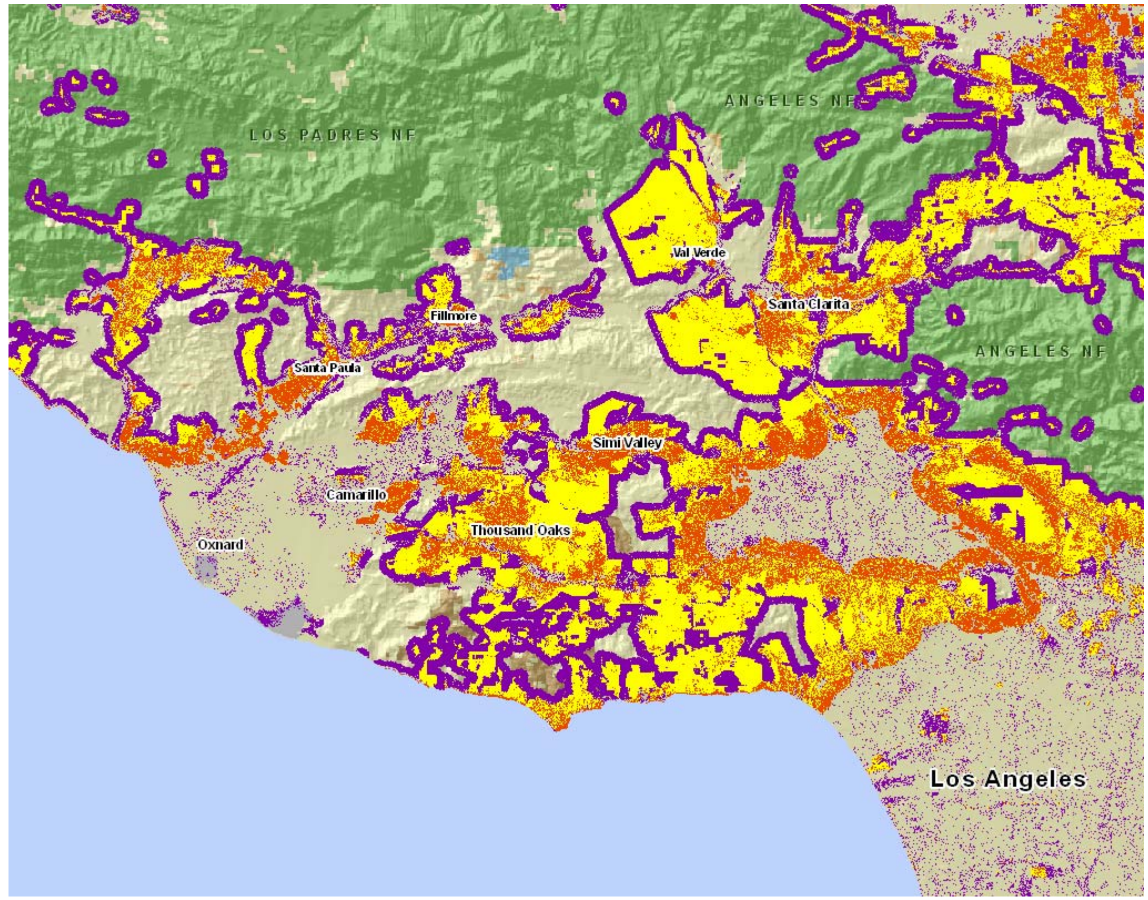
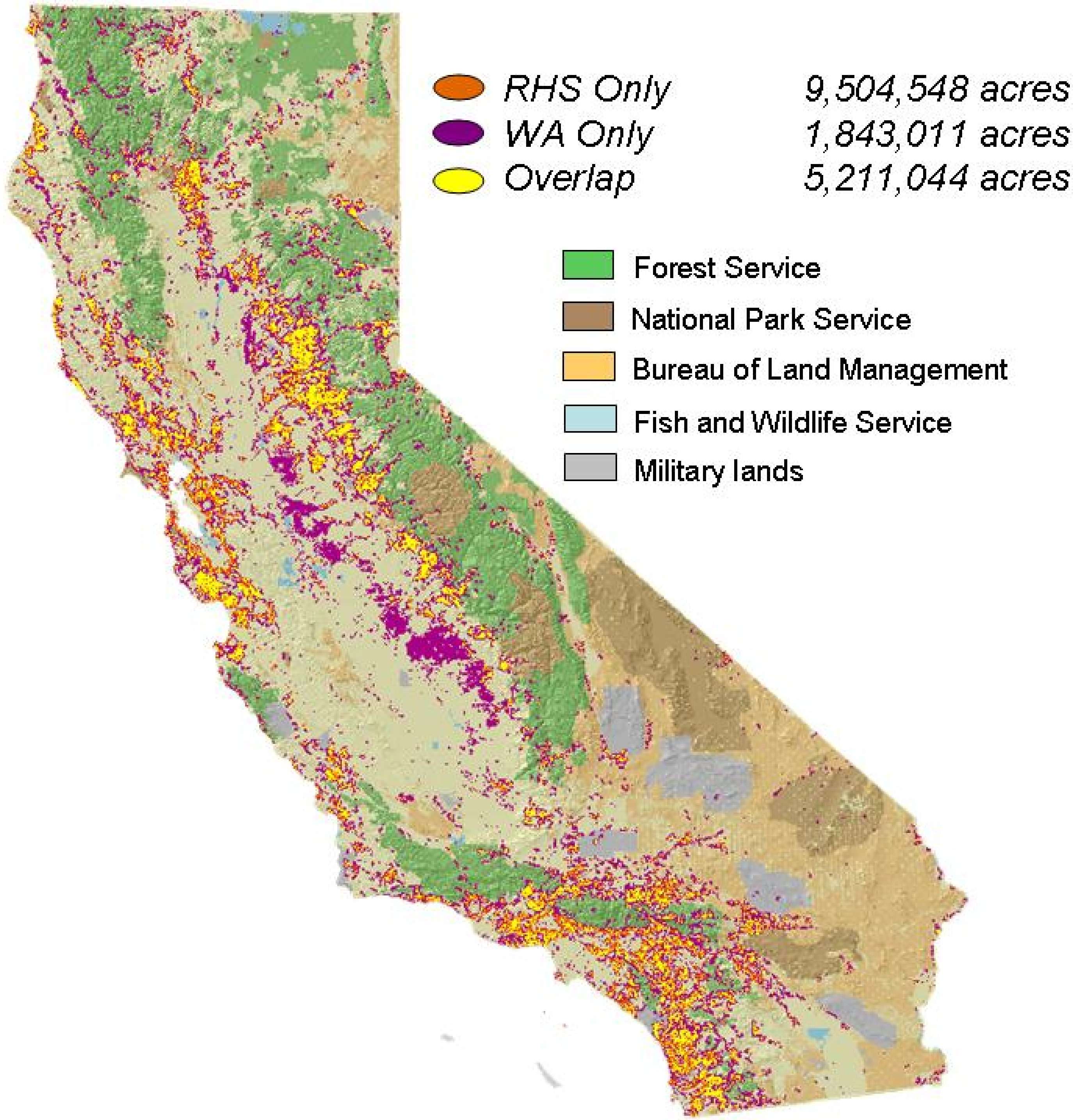


RHS only WA only Overlap Forest Service


RHS Only 9,504,548 acres
WA Only 1,843,011 acres
Overlap 5,211,044 acres
Forest Service
National Park Service
Bureau of Land Management
Fish and Wildlife Service
Military lands