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# Wildland–Urban Interface Maps Vary with Purpose and Context

Susan I. Stewart, Bo Wilmer, Roger B. Hammer, Gregory H. Aplet, Todd J. Hawbaker, Carol Miller, and Volker C. Radeloff

## ABSTRACT

Maps of the wildland–urban interface (WUI) are both policy tools and powerful visual images. Although the growing number of WUI maps serve similar purposes, this article indicates that WUI maps derived from the same data sets can differ in important ways related to their original intended application. We discuss the use of ancillary data in modifying census data to improve WUI maps and offer a cautionary note about this practice. A comparison of two WUI mapping approaches suggests that no single map is “best” because users’ needs vary. The analysts who create maps are responsible for ensuring that users understand their purpose, data, and methods; map users are responsible for paying attention to these features and using each map accordingly. These considerations should apply to any analysis but are especially important to analyses of the WUI on which policy decisions will be made.

**Keywords:** wildland–urban interface, fire policy, GIS, Healthy Forest Restoration Act, National Fire Plan

The dramatic losses and costs associated with recent wildland fires in the United States 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, Boxall 2008), drawing new attention to what resource managers, scientists, and policymakers have long known: that housing growth in the wildland–urban interface (WUI) is a serious concern in the United States. Both the National Fire Plan (NFP) and the Healthy For-

est 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, and both roles contribute to their recent proliferation (Radeloff et al. 2005, Wilmer and Aplet 2005, Theobald and Romme 2007).

Most WUI maps that cover a broad extent (such as the whole United States) are based on the definitions used in either the NFP or the HFRA and use population or housing data from the US Census and veg-

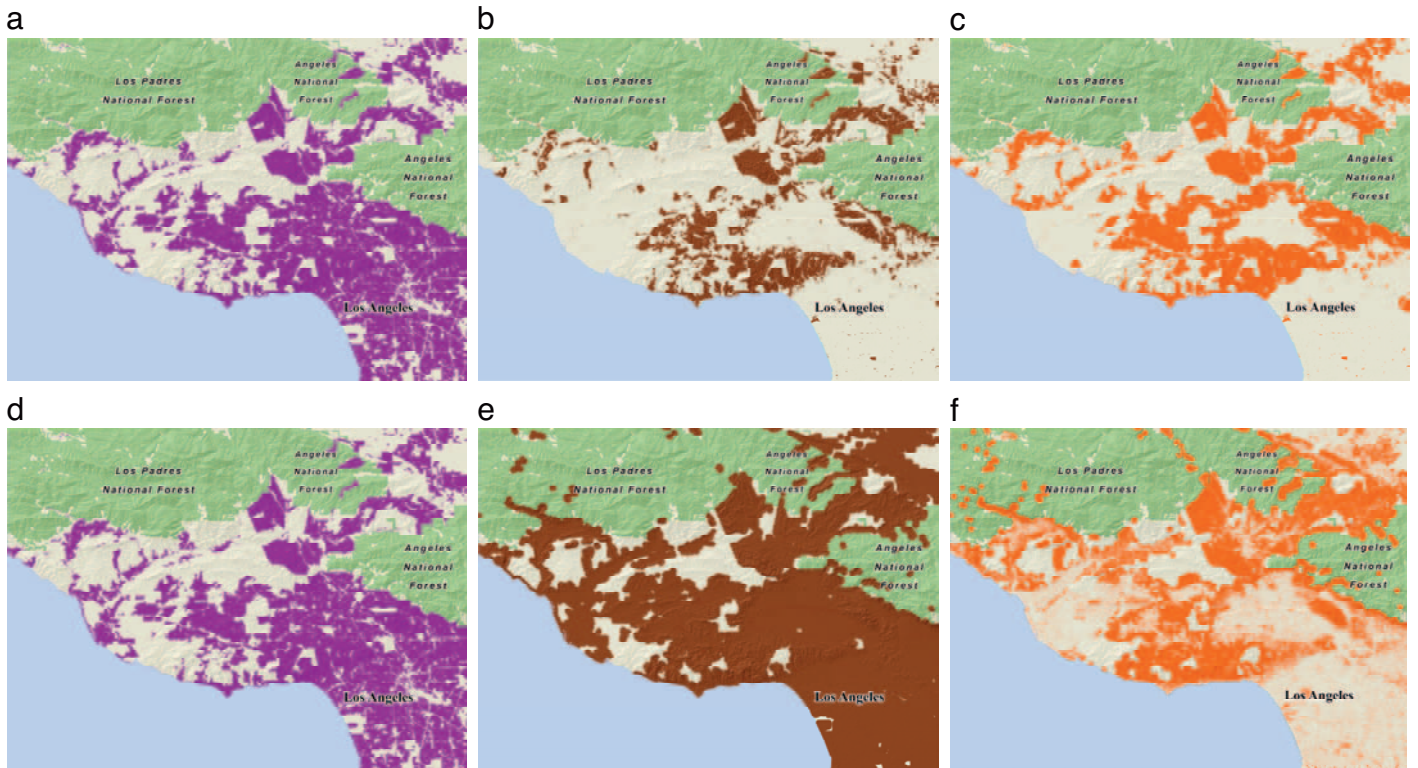
etation data from satellite image classifications such as the National Land Cover Dataset (NLCD). However, although they often rely on the same general definitions and data, differences in the analytical methods used to produce them can result in very different WUI classifications. We show that WUI maps derived from the same standard data sets can differ in important ways that reflect the purpose or application for which the map originally was developed. We also discuss the practice of using ancillary data and dasymetric mapping to modify census housing data for use in WUI mapping and other resource management tools and recommend caution with this practice.

## Comparing Methods and Maps

The two WUI mapping methods compared here were generated independently and were published in 2005, by Wilmer and Aplet (2005) (WA) and by Radeloff, Hammer, and Stewart (2005) (RHS). Both methods use the same data: the US Census data to measure housing (US Census Bureau 2002) and the National Land Cover Data to characterize vegetation (Vogelmann et al. 2001). Each method involved two analyses, one to

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**Figure 1.** Major steps in the delineation of the wildland–urban interface (WUI) in the Los Angeles area using the approach by (a–c) Radeloff, Hammer, and Stewart (2005) and (d–f) Wilmer and Aplet 2005. (a) Housing density >1 housing unit per 40 acres. (b) Removal of blocks <50% vegetated. (c) Addition of area within 1.5 mi of blocks >75% vegetation. (d) Housing density >1 housing unit per 40 acres. (e) Addition of area within 0.5 mi of WUI blocks. (f) Removal of pixels with non-wildland fuels. (c and f) Representation of the final outcome of each approach.

determine where housing and vegetation coincide, designated as intermix WUI, and another to determine where houses and vegetation are in *close proximity*, designated interface WUI. 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) were met. To determine where houses and vegetation were in close proximity, a geographic information system (GIS) buffer analysis specified some distance for “close proximity” and indicated the areas within that distance. However, the order in which the criteria were applied and the units of analysis used for including and excluding potential WUI areas differed, yielding markedly different maps (Figure 1, a–f).

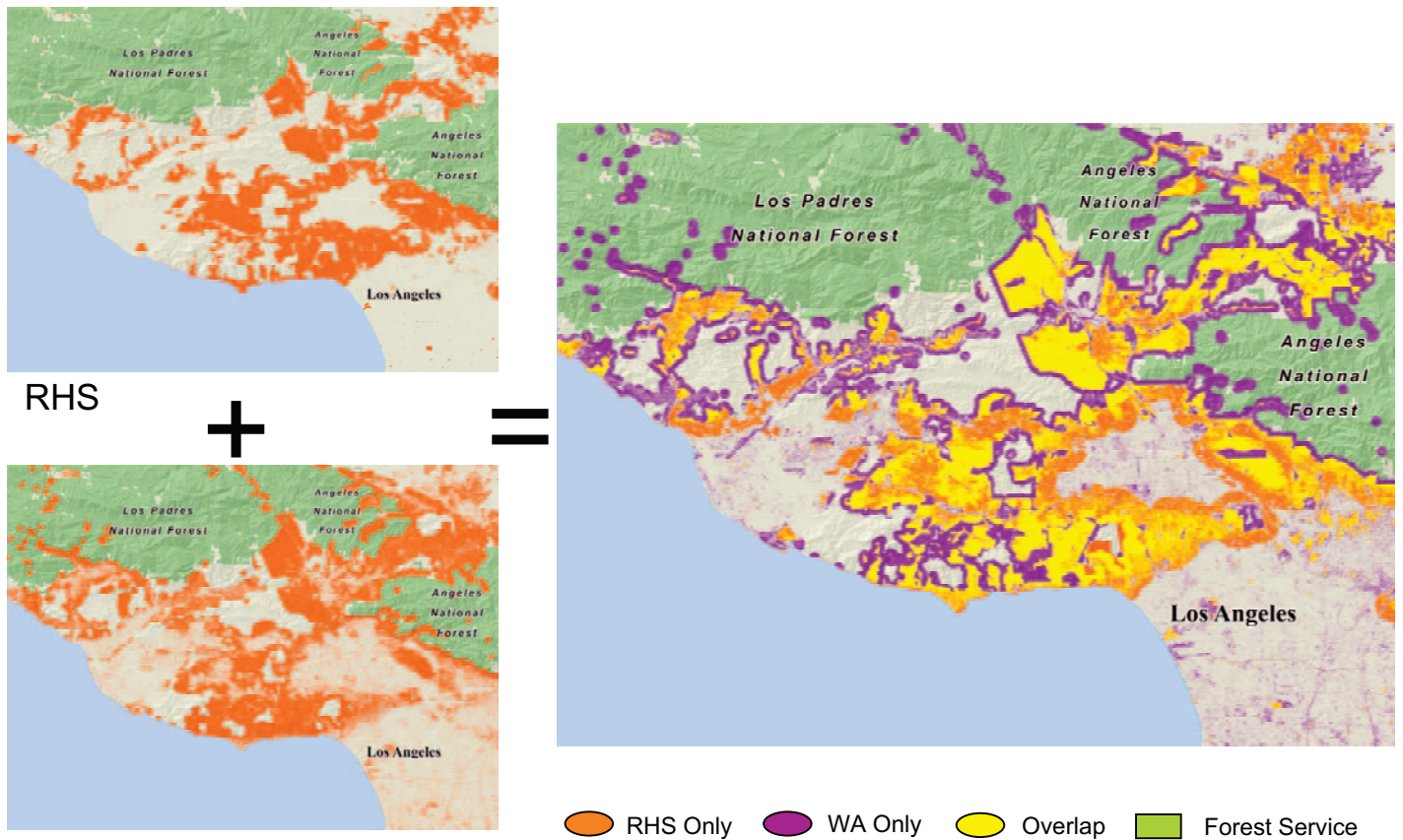
Using California as an example, we illustrate these differences. Both of the analyses start by intersecting census block boundaries with public lands boundaries and assigning housing units in census blocks that are partially in public ownership to the privately owned portion of the census block. The landownership data available for Cali-

fornia are accurate and complete (California Spatial Information Library [CalSIL] 1997), facilitating this dasymetric modification without the loss of accuracy [1]. Working from this same modified housing density data, the WUI analysis in both methods started by identifying census blocks where housing density exceeded one housing unit per 40 ac (Figure 1, a and d). Then, the analyses diverged. The RHS method selected those census blocks that also have more than 50% wildland vegetation and designated these as intermix WUI (Figure 1b) and then used a buffering process to identify interface WUI, where housing was in close proximity (within 1.5 mi) of a large (more than 1,325 ac) contiguous area of wildland vegetation (Figure 1c). The WA analysis used a buffering process to add all areas in the vicinity (within 0.5 mi) of housing (Figure 1e), and, finally, removed pixels (30-m cells) in which the land cover was not considered wildland fuel, such as urban, agricultural, or barren (Figure 1f).

A geographic comparison quantifies the proportion and extent of the areas classified as WUI by each, by both, and by neither

method (Figures 2 and 3; Table 1). Those areas identified as WUI by both methods (yellow in Figures 2 and 3; upper left cell of Table 1) contain more than one house per 40 ac and wildland vegetation. Areas identified only by RHS (orange, upper right cell) contain housing adjacent to wildland vegetation, but do not identify or measure the extent of that adjacent vegetation. Areas identified only by WA (purple, lower left cell) consist of wildland vegetation within 0.5 mi of houses but do not identify or measure the extent of that housing. Statewide (Figure 3), the two methods identified over 5 million ac in common, but the WA method classified twice as much WUI area as the RHS method (Table 1).

Differences between the two WUI maps stem from variations in the analysis methods that reflect the purpose and definition underlying the maps. The first difference is in buffering for proximity analysis, which stems from the way in which proximity is treated in the NFP and HFRA WUI definitions. The WA method buffers 0.5 mi around all blocks that meet the housing criteria, in keeping with the HFRA’s specifica-



## WA

**Figure 2.** The combined area identified as wildland–urban interface in the Los Angeles area by both approaches. The Radeloff, Hammer, and Stewart (2005) (RHS) method focuses on identifying housing near wildlands; the Wilmer and Aplet 2005 (WA) method focuses on identifying treatable wildland fuels near housing.

tion that a 0.5-mi zone around communities is part of the WUI (US Congress 2003). The RHS method is based on the older NFP WUI definition, which does not specify a buffer for each community but does include interface WUI where homes are near wildland vegetation (US Department of the Interior [USDI] and USDA 2000, 2001). The wider buffer (1.5 mi) used by RHS identifies interface areas but extends only from areas with dense wildland vegetation and retains only those blocks or portions of blocks with adequate housing density. Proximity is captured differently in the two definitions: 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, whereas the NFP interface definition was based on the notion that fire brands carry wildland fire into communities, creating an area of potential risk. Thus, one major source of difference in the two maps is the HFRA-based definition used by WA and the NFP-based definition used by RHS.

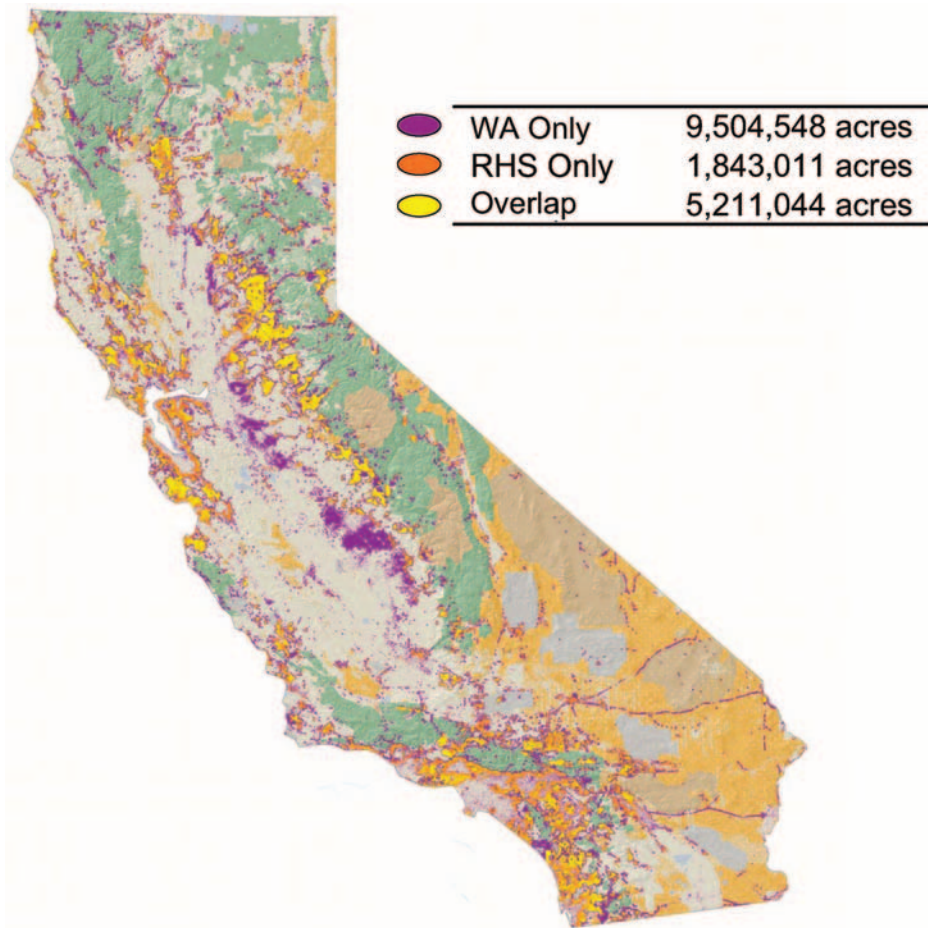
The second major distinction between WA and RHS is in the way areas without wildland vegetation were treated. The RHS method excludes entire census blocks where fewer than 50% of the 30-m NLCD pixels within the block are wildland vegetation. The WA method removes only the individual 30-m NLCD pixels that lack wildland vegetation cover types; and they do so after buffering, so that nonvegetated areas are removed from the WUI community buffer zones as well. The pixel-by-pixel retention of wildland vegetation in the WA map shows precisely where wildland vegetation is present near housing.

### Maps Vary Depending on Their Purpose

The differences between these analyses highlight the underlying differences in the motivations for mapping the WUI. The goal of the WA approach was to identify vegetated areas near housing to prioritize treatment of wildland fuels. In contrast, the goal

of the RHS approach was to identify housing near forests and other wildland vegetation and its consequences for wildland fire. Although both methods start by identifying areas with housing and adjust based on the vegetative characteristics within or near the blocks, the WA method is primarily focused on vegetation, whereas RHS is primarily focused on housing. The maps and statistics that result from the two methods convey somewhat different information that is consistent with the motivation for each approach. Both specify where the WUI is located, but the WA method provides additional detailed information about wildland vegetation in and near communities, information that is useful for managers focused on reducing hazardous fuels. The RHS method quantifies the housing units in or near wildland vegetation, additional details that allow policymakers to assess the scope of human settlement in areas affected by wildland fire management.

There are advantages to each approach, and both are relevant to current



**Figure 3.** The combined area identified as wildland–urban interface across California. RHS is the approach by Radeloff, Hammer and Stewart 2005; WA is the approach by Wilmer and Aplet 2005).

**Table 1.** A Comparison of the Radeloff, Hammer, and Stewart 2005 (RHS) and Wilmer and Aplet 2005 (WA) wildland–urban interface (WUI) classifications for the state of California.

	WA classification			
	WUI		Non-WUI	
	Acres	%	Acres	%
RHS Classification				
WUI	5,211.044	5	1,843.011	2
Non-WUI	9,504.548	10	83,255.375	83

debates on wildfire policies. The RHS data provide specific, high-confidence counts of housing units. Census blocks are broken only where the 1.5-mi 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. Counting the housing units in the WUI is less feasible using the WA method because areas as small as 30 m<sup>2</sup> may be eliminated from census blocks

and it is not possible to determine how many of the housing units in a census block were contained in the eliminated areas versus the remaining areas. However, the WA map clearly shows the location and extent of wildland vegetation across the landscape, including the vegetation in more densely settled areas, identifying what the NFP *Federal Register* notice classified as “occluded” WUI areas, islands of wildland 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.

Taken together, what these maps illustrate most clearly is the elusiveness of a single or “actual” WUI zone; different ideas and maps of the WUI may be more or less relevant to the user, depending on their needs. There is growing recognition that wildland fire is a “wicked” problem, where simple solutions are elusive and any effort to define a problem reveals a new set

of problems (Carroll et al. 2007, Hammer et al. in press). As such, map users should let the situation dictate which facts (and a map is nothing more than a representation of facts) are best suited to addressing their particular problem. Whether one should focus on the housing or on the vegetation will depend on whether one is treating wildland fuels, preparing a community wildfire protection plan, or identifying areas where housing growth affects forest management.

### More Transparency Is Needed

We can not expect map users to choose the right map unless analysts make their purpose, data, and analysis methods transparent. Like many GIS products, WUI maps often lack the full documentation needed for transparency. For example, while the general analytical approach is usually explained in the metadata, manipulation of input data is also common and is not always fully explained.

Dasymetric mapping (Mennis 2003) of housing data is a prime example. Most WUI maps use housing data from the US Census to measure human presence, because structure protection is important in wildland fire-fighting and because housing counts include all residences, while population counts exclude seasonal residents. Unfortunately, the spatial extent of a census unit (e.g., block, block group, and tract) varies with housing density, tending toward larger units where housing is more sparse. The result can be a large census 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. To work around this problem, ancillary data can be used in dasymetric mapping to modify the boundaries of census blocks. Public land boundaries are the ancillary data most commonly used for this purpose. Where public lands are included in a census block, the result is often a large, sparsely settled block. However, public lands generally do not contain houses, so by intersecting public land boundaries and census block boundaries, 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.

In both WUI mapping methods shown here, this dasymetric method was used to modify the housing data before the analysis. The same technique has also been used by Wilmer and Aplet (2005) in their analysis of WUI areas in Idaho, California, and Colorado; by Hammer et al. (2007) in a fire risk analysis of Washington, Oregon, and California; and by Theobald and Romme (2007) in creation of a national WUI map.

The quality of dasymetric mapping results is highly dependent on the quality of the ancillary data used, and current landownership data suffers from uneven quality. Omissions and inaccuracies are common. Although the California data used in this analysis are accurate and complete, the Protected Areas Database (PAD; DellaSala et al. 2001) for the entire United States is more variable. It is compiled from whatever landownership information can be attained 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. Complicated ownership patterns in some areas of the United States introduce additional problems with data quality and consistency. In the West, where designation as public land predates widespread settlement of the region, there are relatively few private inholdings within the national forests. The situation is different in the East, where forests may have extensive inholdings that are also attractive building sites and small inholdings are not represented in the public land boundaries. Under these circumstances—which are not uncommon—assuming houses occur only outside public land boundaries is not correct, and dasymetric mapping introduces errors into the housing data. Furthermore, the East also has extensive non-federal public forestland. The majority of state public land is represented in the PAD, but the large expanses of county forests in some eastern states (e.g., Wisconsin) still have not been included. Hence, the quality of landownership data varies from East to West, as it does from state to state. These current problems argue for caution in the use of landownership data, particularly for national-level mapping where the regional variations in data quality complicate interpretation of the results. When the landownership data itself are supplemented or modified before use

in dasymetric mapping, this too should be transparent to any data user, so that the quality of the methods and the end product can be understood and judged.

Data set improvement is an ongoing process, and some shortcomings we note with the PAD are likely to be remedied in subsequent versions of the data. Beyond these particular issues, though, the general point is that dasymetric mapping, like overlay analyses, converting GIS data from vector to raster (“gridding”), and other common GIS operations all have the potential to introduce error. But errors are hidden from the map users by map appearance that does not vary with data quality and even from other analysts when the operations and adjustments used are not fully documented in the metadata. Work must continue to develop better data, minimize errors introduced through analysis, and better communicate and document the characteristics of the data on which a map is built.

## Conclusions and Implications

WUI maps have proliferated in recent years, and different WUI patterns on these maps have caused confusion among land managers. The underlying cause for these differences, though, are the different purposes for which the maps were developed; such as focusing on vegetation versus focusing on housing or mapping for local planning purposes versus national policymaking.

The solution is not to declare a single map best or, conversely, to tell managers not to use a given map because it is wrong, but rather to consider the purpose for which each map was developed and critically evaluate the quality of the data and analysis on which it is based. Most people who use WUI maps, including scientists, land managers, planners, and wildland fire policymakers, could benefit from reviewing different WUI maps. These users often have a sophisticated understanding of the WUI and recognize it as a complex place. Building on that understanding, we suggest that because it is complex, we can represent the WUI in different ways, depending on what information is needed for the task at hand. As research adds to our knowledge about how people, ecosystems, and fire interact in the WUI, the variety of maps needed to convey this information will also expand.

Each mapping approach 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, on which policy decisions will be made.

## Endnote

- [1] Because public land boundary data are not accurate and complete for the whole conterminous United States, Radeloff (Radeloff et al. 2005) and others did not use this method in their 2005 analysis; but in Hammer et al. 2007, the multistate study area was one that did permit use of this method.

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