

The Wildland–Urban Interface: Evaluating the Definition Effect

Rutherford V. Platt

ABSTRACT

The wildland–urban interface (WUI) is the area where human-built structures and infrastructure abut or mix with naturally occurring vegetation types. Wildfires are of particular concern in the WUI because these areas comprise extensive flammable vegetation, numerous structures, and ample ignition sources. A priority of federal wildland fire policy in the United States is to help protect communities threatened by wildfire, creating a demand for maps of the WUI. In this study, five models of the WUI are compared for four counties in the United States. The models are all based on the widely cited characteristics of the WUI published in the *Federal Register*, although they differ slightly in their focus (vegetation or housing) and implementation (the details of the WUI definition). For models that differ in focus, I describe how the purpose of the map led to different results. For conceptually similar models, I assess how different effects—the “dasymetric effect,” the “settlement representation effect,” and the “merging buffer effect”—influence the extent of the WUI in different counties. The differences between the WUI maps can be more or less pronounced depending on the spatial distribution of housing, vegetation, and public land. No single mapping approach is unequivocally superior, and each has tradeoffs that need to be fully understood for use in management.

Keywords: wildland–urban interface, GIS, wildfire

The wildland–urban interface (WUI), the area where human-built structures and infrastructure abut or mix with naturally occurring vegetation types, is a nexus of conflict between people and the environment. The WUI is associated with the vexing problems of structure loss caused by wildfire, habitat fragmentation, spread of invasive species, and human–wildlife conflict. Of these, however, the wildfire issue has attracted the most attention. Wildfires occur in the WUI because it holds extensive flammable vegetation, numerous structures, and ample ignition sources. In dry years, these conditions

can lead to high-profile events such as the Hayman Fire of Colorado, which in 2002 burned over 130,000 ac, destroyed 600 structures, and cost over \$39 million to fight (Graham 2003). In response to such conflagrations, the federal government has spent large sums on fire suppression—\$746 million in 2007 alone (US Forest Service 2007). Nevertheless, in each year from 2002 to 2007 an average of 63,161 fires burned 6.4 million ac (National Interagency Fire Center 2007).

The WUI in the United States is extensive and growing rapidly in many places. According to one estimate, the WUI covered

9% of all land area in the United States and 39% of all structures as of the year 2000 (Radeloff et al. 2005), although as I will show that this number is dependent on the definition of the WUI. The counties of the Front Range of Colorado, which contain areas of extensive wildland vegetation, grew by 250,000 people or 53% from 1990 to 2000 according to the 2000 census. Many WUI environments in Arizona, California, Oregon, and elsewhere have experienced comparable population growth. Much of this growth has taken place in exurban areas removed from urban centers (Theobald 2005). The rapid expansion of the WUI has led to a number of changes in exposure to hazard, fuel composition and structure, and ignition sources (Cardille et al. 2001).

A major priority of federal fire policy is to provide support to communities in fire-prone areas. For example, the National Fire Plan of 2000 aims to “provide assistance to communities that have been or may be threatened by wildfire” (US Department of Interior [USDI] and USDA 2000). Similarly, the Healthy Forests Restoration Act (HFRA) seeks to reduce severe wildfires and to assist communities in developing strategies that reduce risk to people and property in the WUI. HFRA states that priority should be given to hazardous fuel reduction projects that provide for the protection of communities and watersheds. The act au-

Received September 18, 2007; accepted April 15, 2009.

Rutherford V. Platt (rplatt@gettysburg.edu) is assistant professor, Gettysburg College, Department of Environmental Studies, Gettysburg, PA 17325. Financial support was provided by the National Science Foundation (award GRS-0541594). The author thanks Matthew Shank, Gettysburg College class of 2008, for his help as a research assistant.

Copyright © 2010 by the Society of American Foresters.

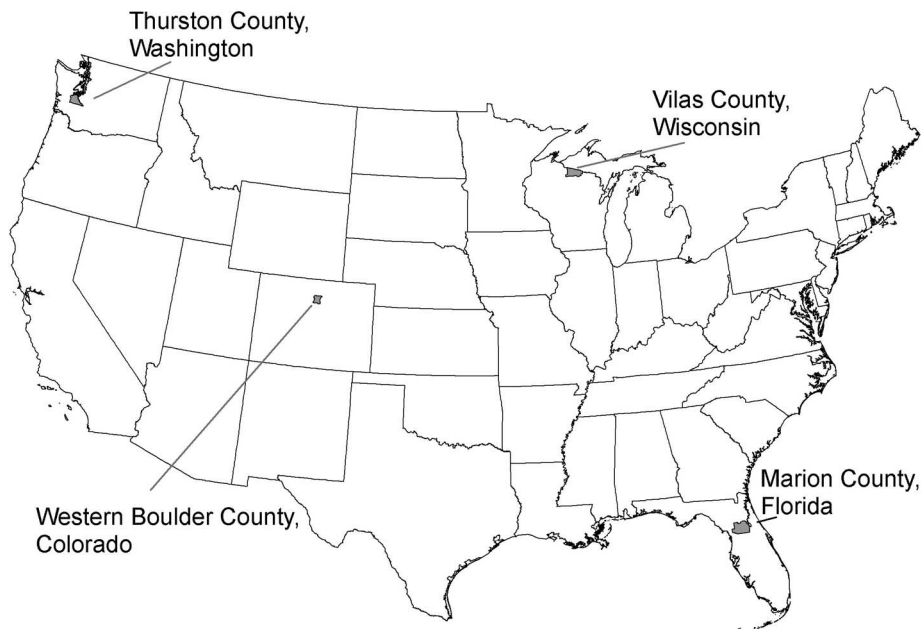


Figure 1. Study areas.

thorized specific fuel reduction projects within areas extending from 0.5 to 1.5 mi from the boundary of an at-risk community or within an area defined by the community itself.

Although the spatial extent WUI is clearly important to fire policy, there is no commonly accepted definition of the WUI. Originally, the WUI was defined as “any point where fuel feeding a wildfire changes from natural [wildland] fuel to man-made [urban] fuel” (Butler 1974, p. 3). Because the term was coined, there has been a proliferation of related concepts, including “exurban fire,” “residential wildland interface,” “mixed urban/rural fires,” “I-zone,” and “urban/rural interface,” all with slightly different meanings. Today, perhaps the most commonly cited definition of the WUI is an area “where humans and their development meet or intermix with wildland fuel” (USDI and USDA 2001, p. 753). The WUI has been further subdivided into three types of communities: the interface community, intermix community, and occluded community (Davis 1990). The interface community refers to an area where urban land directly abuts wildland fuels. The “intermix” is an area where there is no clear boundary between urban and wild areas. The “occluded interface” comprises patches of wildland vegetation that lie in an urban matrix.

These definitions have three typical components: housing or settlements, a buffer around the settlements, and wildland vegetation. Federal policy, such as HFRA, is vague about what constitutes the WUI (Hill

2001), allowing local communities to use their own definitions for Community Wildfire Protection Plans. Thus, exactly what constitutes an “at-risk” settlement or an appropriate area surrounding a settlement is not standardized (Wilmer and Aplet 2005, Platt 2006). For example, the Southwest Region (Region 3) of the US Forest Service defines the WUI as not only areas surrounding structures, “but also the continuous slopes and fuels that lead directly to the sites, regardless of the distance involved” (US Forest Service Manual 2000). The local government of Flagstaff, Arizona includes social values into its definition of the WUI: “An area in-and-around a neighborhood or community where the immediate or secondary effects of a wildfire threaten values-at-risk and will be a serious detriment to the area’s overall health and sustainability” (Summerfelt 2003, p. 6). Given these varied definitions, it is no surprise that one early attempt to map “communities at risk” in the vicinity of federal land yielded a scattershot map of 11,376 WUI communities that was visibly inconsistent across state lines (USDI and USDA 2001). To compare the spatial extent of the WUI across locations and time periods, however, standardization of definitions is important.

In an attempt to standardize the WUI concept, a set of characteristics were published in the *Federal Register* in conjunction with the National Fire Plan (USDI and USDA 2001). These characteristics have been frequently used to map the extent of

the WUI. The resulting maps of the WUI have been used for many purposes, including evaluating the potential for home construction next to public forests (Gude et al. 2008), estimating the area and number of housing units within fire regime condition classes (Hammer et al. 2007), estimating the extent of the WUI within fire hazard classes (Theobald and Romme 2007), and developing scenarios for future expansion of the WUI (Platt 2006). Although the WUI map in these studies used the *Federal Register* characteristics as a starting point, the specific implementation differed. Thus, the critical variables (the areal extent of the WUI and the number of structures within the WUI) may be subject to a “definition effect” that could affect the results of these studies. The degree to which there is a definition effect is not obvious; a sensitivity analysis of one method indicated that WUI maps were fairly robust to changes in housing density, intermix vegetation, and interface vegetation (Radeloff et al. 2005).

In this study, I map the WUI in four US counties using five methods: two variations on the Radeloff, Hammer, and Stewart (RHS) method (Radeloff et al. 2005, Stewart et al. 2007), the Wilmer and Aplet (WA) method proposed by the Wilderness Society (Wilmer and Aplet 2005), and two variations on the buffer from structures (BFS) method described in this article. The methods differ subtly in focus (vegetation or housing) or implementation (the details of the WUI definition), but all apply the general criteria published in the *Federal Register* (USDI and USDA 2001). The primary research questions are, first, how do the methods differ in terms of the area of the WUI, the percentage of all structures in the county that fall within the WUI (excluding structures with less than 50% wildland vegetation within a 0.5-mi buffer), and the percentage of the WUI comprising public land? Second, how do these differences relate to the focus of the models, and to the distribution of structures, vegetation, and public land within the four counties? These differences were evaluated in terms of the “dasymetric effect,” the “settlement representation effect,” and the “merging buffer effect,” described later.

Methods

Study Areas

The WUI mapping methods were applied to four counties: Marion County,

Table 1. Characteristics of study areas.

	Marion, FL	Vilas, WI	Thurston, WA	Boulder, CO
Area (square miles)	1,064,013	651,356	495,188	304,180
Population	316,183	22,379	234,670	28,022
Number of developed parcels	144,277	20,331	83,370	24,211
Percentage of county area that is public land	34%	38%	25%	73%
Public land patch size in acres: mean (standard deviation)	3,440 (2,689)	9,516 (94,810)	9,523 (51,790)	221,1000 (33,780)
Percentage of county area comprising hazardous fuel	67%	78%	80%	87%
Hazardous fuel patch size in acres: mean (standard deviation)	198 (7,991)	1,223 (14,450)	96 (4621)	1,275 (34,360)

Table 2. Summary of WUI models.

Model	RHS	RHS-2	WA	BFS-1	BFS-2
Source	Radeloff et al. 2005	Stewart et al. 2007	Wilmer and Aplet 2005	This article	This article
Settlement definition	Census blocks of density more than one structure per 40 ac	Census blocks of density more than one structure per 40 ac after public land is removed	Census blocks of density more than one structure per 40 ac after public land is removed	Points representing structures mapped from parcel centroids, excluding remote structures farther than 569 m from another structure	Points representing structures mapped from parcel centroids, excluding remote structures farther than 569 m from another structure
Buffer	None	None	0.5 mi	0.5 mi	0–0.37 mi depending on tree height
Wildland vegetation	Blocks with 50% or less wildland vegetation removed unless within 1.5 mi of an area that is more than 1,325 ac and more than 75% vegetated	Blocks with 50% or less wildland vegetation removed unless within 1.5 mi of an area that is more than 1,325 ac and more than 75% vegetated	Nonwildland vegetation removed from WUI	Nonwildland vegetation removed from WUI	Nonwildland vegetation removed from WUI

Florida; Vilas County, Wisconsin; Thurston County, Washington; and the mountainous western portion of Boulder County, Colorado (henceforth, Boulder County). The counties (Figure 1) were selected to represent prototypical WUI environments in different parts of the country. All are fire prone and feature a mixture of settlements and wildland vegetation but in other ways they differ (Table 1). Marion County, Florida, is the largest (1,064,013 mi²), most populated (316,183 people in 2006) and, because of its extensive farmland and urbanized land, has the lowest proportion of hazardous fuel (67%). Boulder County has the highest proportion of both public land (73%) and hazardous fuel (87%), both of which are concentrated in large contiguous patches. Topographically, it is rough and steep. Vilas County has a relatively small population (22,379 people) dispersed throughout a landscape of extensive hazardous fuel (78%) and lakes. Thurston County has the lowest proportion of public land (25%), a large population (234,670 people), and though it has a high proportion of hazardous fuel (80%); the fuel occurs in small discontinuous patches (mean, 96 ac). In sum, the four counties represent a range of environments

and development patterns across the country.

WUI Definitions

The methods for mapping the WUI, although they start from a similar general definition, differ subtly in their focus. The focus of the two RHS methods is to accurately delineate the housing near wildland vegetation (although it has been applied to fuel treatment; see Hammer et al. 2007). The focus of the WA method is to delineate areas of treatable wildland fuels near housing (Stewart et al. 2009). These are not mutually exclusive objectives, so the focus of the BFS methods is to do both: conservatively and accurately delineate housing and nearby areas of treatable wildland fuels. The three methods differ in terms of how the three components of the WUI—the settlements, buffer, and wildland vegetation—are defined and implemented.

The first component of the WUI definition is the “settlements.” All five WUI models use the density threshold that was published in the *Federal Register*: one or more structures per 40 ac. However, the implementation of this definition differs from model to model (Table 2). The RHS-1

method calculates the density of structures within census blocks, the smallest unit in which census data is tabulated and reported. Census blocks follow streets, streams, legal boundaries, and other features. They have a minimum size of 0.69 ac but no maximum size.

In contrast, The RHS-2 and WA methods use a simple dasymetric mapping technique to refine estimates of housing density. Dasymetric mapping refers to techniques that use ancillary data to disaggregate coarse data to a finer resolution (Eicher and Brewer 2001). In this case, estimates of housing density are refined by removing public land from the census block area calculation (public land is assumed not to contain houses). If the landownership data are inaccurate or incomplete, this dasymetric mapping process may actually reduce the accuracy of housing unit counts (Stewart et al. 2009).

For the BFS method, I define “settlements” as a set of points representing structures that are within 1,890 ft of another structure. At this distance threshold, a set of 40-ac square parcels with structures at the center would count as a settlement, but a more dispersed set of structures would not. This is consistent with the widely used den-

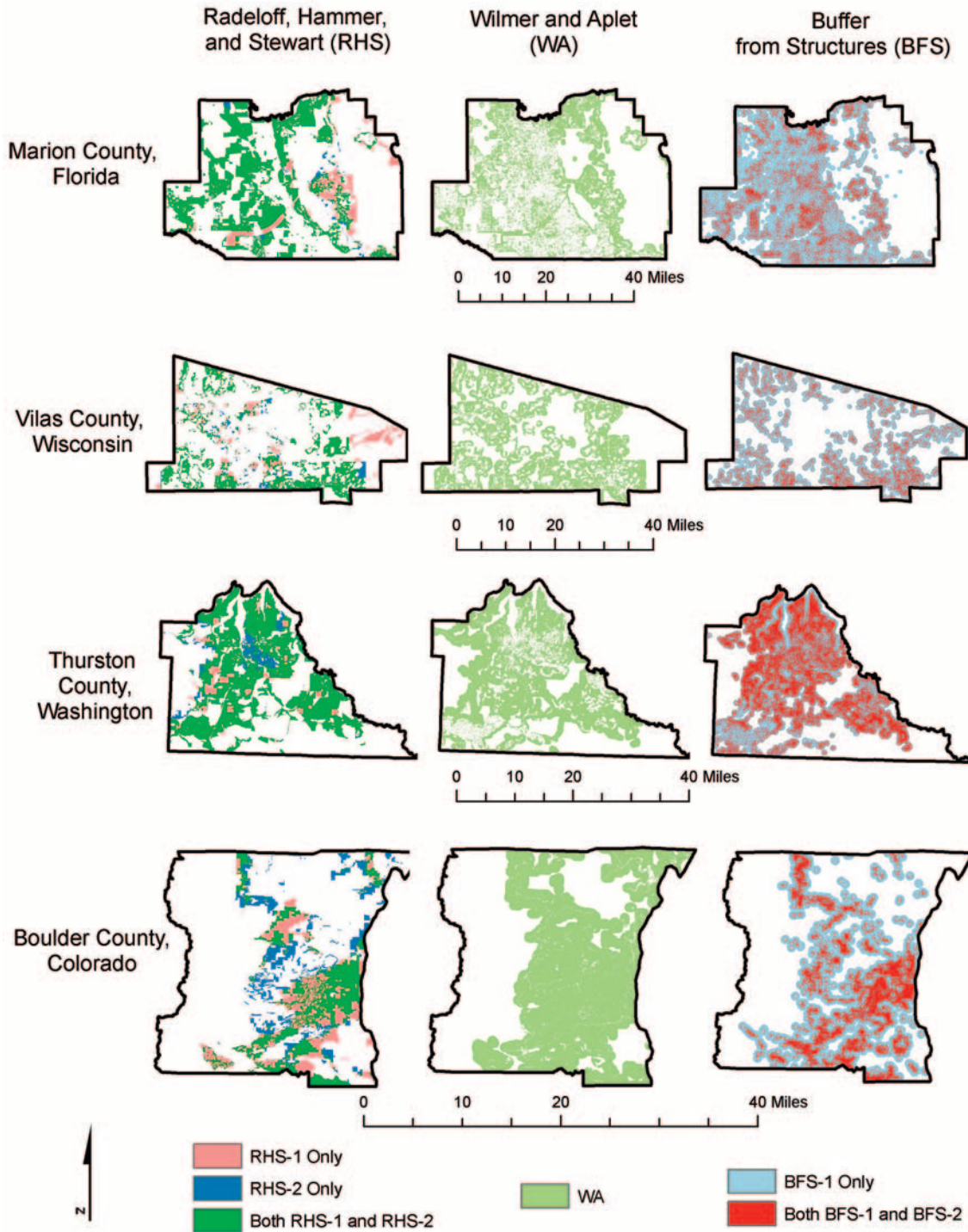


Figure 2. WUI maps under different definitions.

sity threshold of one structure per 40 ac published in the *Federal Register*. I estimate location of structures with the centroid (geometric center) of each developed parcel within the county. In our experience, it is far faster to calculate parcel centroids than to digitize hundreds of thousands of structures (many of which are obscured by trees) and keep the digitized layer up-to-date. Digi-

tized parcel data is up-to-date and publically available for all four counties, but digitized structure locations were only available for Boulder County (digitized in 2003 on 1-m digital ortho quarter quadrangles and on-the-ground global positioning systems readings). In Boulder County, a 0.5-mi buffer of parcel centroids contains 100% of the digitized structures, and a variable buffer rang-

ing from 0 to 0.38 mi (described later) contains 96% of the digitized structures. This suggests that the parcel centroids provide a good estimate of the location of structures.

The second component of the WUI is the buffer around settlements that extends into wildland vegetation or represents a distance from wildland vegetation. Buffers represent an area where managers should look

Table 3. Comparison of wildland–urban interface (WUI) models.

	Area of WUI (ac)	Percent of county in WUI	Percent of structures in WUI ^a	Percent of WUI that is public
Marion County, Florida				
RHS-1	352,612	33	61	1
RHS-2	309,122	29	62	0
WA	375,840	35	90	26
BFS-1	395,228	37	100	17
BFS-2	130,149	12	93	7
Vilas County, Wisconsin				
RHS-1	155,179	24	80	22
RHS-2	132,199	20	76	0
WA	294,049	45	89	28
BFS-1	251,054	39	99	27
BFS-2	66,470	10	85	15
Thurston County, Washington				
RHS-1	211,023	20	82	8
RHS-2	201,634	19	81	0
WA	262,109	25	99	16
BFS-1	236,969	22	100	19
BFS-2	155,179	15	97	7
Boulder County, Colorado				
RHS-1	61,952	20	75	45
RHS-2	113,521	37	93	0
WA	120,593	40	92	55
BFS-1	126,762	42	99	32
BFS-2	39,536	13	96	18

^a Percentage of all structures in the county that fall within the WUI, excluding structures with less than 50% wildland vegetation within a 0.5-mi radius.

for wildfire mitigation opportunities. Ideally, buffer distances are selected based on management objectives such as structures protection, firefighting objectives, or protection from flying embers (Theobald and Romme 2007). Fuel treatments in the home ignition zone (100–150 ft beyond structures) will reduce the possibility of radiant heat igniting a home (Cohen and Butler 1998, Cohen 2001). Beyond the home ignition zone, forest treatments may help firefighters work more safely or reduce the potential for crown fires. This area is sometimes called the “Community Fire Protection Zone” (Wilmer and Aplet 2005), or the Community Protection Zone” (CPZ; Theobald and Romme 2007). The HFRA (2003) recommends that wildfire mitigation should generally take place within 0.5 mi of communities (although up to 1.5 mi in particularly hazardous areas) and can also extend to values identified by the community (e.g., a reservoir). Wilmer and Aplet (2005) also suggest a 0.5-mi buffer, which provides flexibility to adapt treatments to natural fuel breaks in the terrain. Several sources recommend a 1.5-mi buffer distance in certain circumstances (California Fire Alliance 2001, HFRA 2003, Stewart et al. 2007), a distance that represents an estimate of how far an average firebrand can fly. With the exception of the “home ignition zone” buffer, how-

ever, I was not able to find a scientific rationale or peer-reviewed study to justify the buffer width.

In the RHS methods there is no buffer outside of settlements that is included in the WUI (although a buffer is used to identify the interface WUI, see later). This is because the RHS methods are based on the National Fire Plan WUI definition, which does not specify a buffer but does distinguish interface WUI (Stewart et al. 2009). The WA and BFS-1 methods are based on the HFRA, and use a 0.5-mi buffer. The BFS-2 method uses a conservative buffer that varies by canopy height. Experimental research has indicated that the width of this buffer should ideally depend on the sustained flame length of the forest fire (Cohen and Butler 1998). As an approximation, I estimate the potential sustained flame length as two times the average overstory canopy height and the appropriate buffer as four times the sustained flame length (Nowicki 2002). For example, a fire in a forest canopy 100 ft high has an estimated sustained flame length of 200 ft. To create a CPZ for such a fire, a settlement would need an approximate buffer of 800 ft. In the BFS-2 method, buffers were derived from the canopy height layer in the Landfire data product (The National Map Landfire 2006), which classifies canopy height into five classes (0, 0.1–16, 16.1–49, 49.1–115,

and 115.1–246 ft) based on predictive models calibrated with Landsat imagery and biophysical characteristics. Thus, the variable buffer ranges from 0 to 0.38 mi depending on estimated canopy height.

The third component of any WUI definition is wildland vegetation, which typically includes trees, shrubs, and grasses but not developed land, agricultural land, or urban/recreational grasses. These land cover classes are delineated in several national data sets including the 1990 and 2000 National Land Cover Data Set (NLCD; Vogelmann et al. 2001) and the Landfire existing vegetation data set (The National Map LANDFIRE 2006). The WA and BFS methods simply remove nonwildland fuel cover types, which are excluded from area calculations. In contrast, The RHS methods use a different strategy to deal with wildland vegetation (Radeloff et al. 2005). To be included in the WUI, census blocks (of one or more structures per 40 ac) must either be more than 50% vegetated (WUI intermix) or 50% or less vegetated and within 1.5 mi of a large area (more than 1,325 ac) with more than 75% wildland vegetation (WUI interface). With the RHS methods, a census block may contain locally dense vegetation and dense settlements and still not be considered part of the WUI if the housing and vegetation thresholds are not met. Conversely, nonwildland vegetation areas within census blocks are considered part of the WUI if housing and vegetation thresholds are met.

Comparison of WUI Models

When managers or stakeholders map the WUI they are often interested in how big it is, how many structures are in it, and whether it comprises public or private land. Thus, I compared the WUI models based on several metrics that address these common inquiries: WUI area, percentage of the county in the WUI, percentage of all structures in the county that are located in the WUI (excluding structures with less than 50% wildland vegetation within a 0.5-mi buffer), and percentage of the WUI that is public land (federal, state, or county).

We compared models that have a different focus (e.g., RHS versus WA) and models that are conceptually similar but differ in terms of the specific implementation (e.g., RHS-1 versus RHS-2, WA versus BFS-1, and BFS-1 versus BFS-2). For models that differ in focus, I described how the purpose led to different results. For conceptually

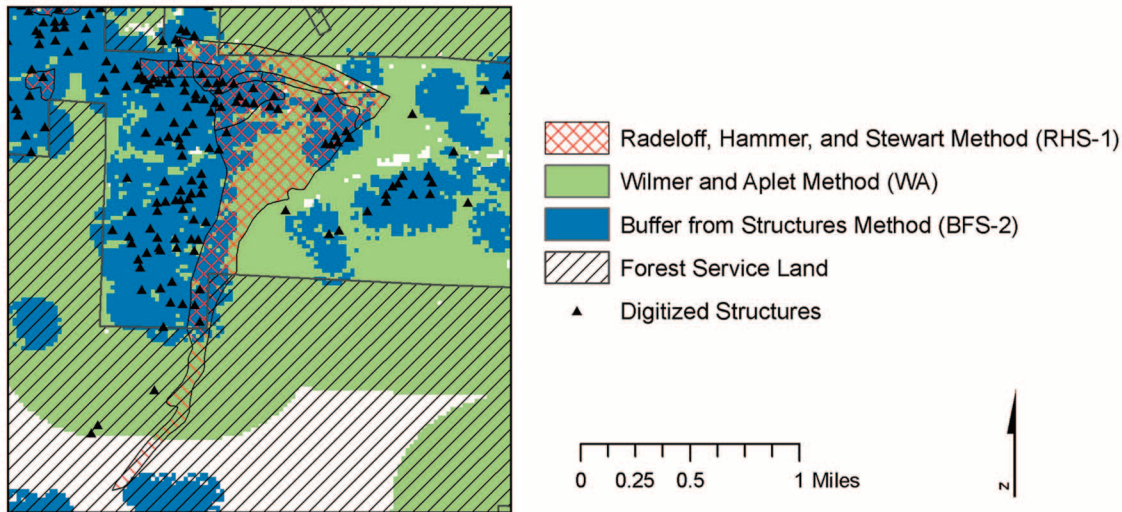


Figure 3. Detail of Boulder County, Colorado.

similar models, I assessed how the distribution of structures, vegetation, and public land affect the mapped outcome in terms of the dasymetric effect, the settlement representation effect, and the merging buffer effect. The dasymetric effect is the influence of dasymetric mapping on the results, in this case removing public land before calculating housing density. The settlement representation effect reflects the fact that the choice of the spatial representation of settlements (points or polygons) may affect the overall size of the WUI. The merging buffer effect depends on the spatial representation of the settlements (the starting point of the buffer) and also the buffer size.

Results

I first compared the two models that are conceptually the most dissimilar. Comparing the RHS-2 approaches to WA illustrates the difference between a housing-focused approach and a vegetation-focused approach. Consistent with Stewart et al. (2009), WA has a larger spatial extent than RHS-2 (Figure 2; Table 3). The difference in spatial extent is caused by differences in the buffer and treatment of wildland vegetation (Table 2). The purpose of the WA method is to identify an area where vegetation could potentially be treated, while the purpose of the RHS method is to identify an area where structures intermix or are adjacent to wildland vegetation. By definition, RHS-2 does not contain any public land, while the WA buffer can extend into public land; thus, 16–55% of the WUI is public with the WA method.

Next, I made a series of comparisons

between models that are conceptually similar but differ in the details of implementation. To evaluate the dasymetric effect, I compared RHS-1 and RHS-2, which differ only in that public land is removed before the density calculation in RHS-2. I found that the strength of the dasymetric effect varies from county to county. In Marion, Vilas, and Thurston counties the size of RHS-2 is smaller than RHS-1 by only 1–4%. In Boulder County, however, RHS-2 represents 37% of the county while RHS-1 represents 20%—a difference of 17% (Table 3). Boulder County has far more public land adjacent to private land than do the other counties. When this land is removed from density calculations, a high percentage of the remaining census blocks surpass the density threshold (one or more structures per 40 ac). In areas with less public land or concentrated public land, such as Thurston County, RHS-1 and RHS-2 have much closer values.

The dasymetric effect is also reflected in the percentage of structures in the WUI. Illustrating this issue, Figure 3 shows that to the west of the areas classified as WUI using the RHS-1 method, there is an area of high housing density. These structures are within a single large census block, most of which is uninhabited and extends far beyond the map detail. Thus, the overall density is below one building per 40 ac even though locally the housing density is very high.

To evaluate the merging buffer effect, I compared BFS-1 and BFS-2, which differ only in terms of buffer size. Clearly, the 0.5-mi buffer creates a larger WUI than the

more conservative variable buffer. However, the spread between the two differs by county. In Boulder County, BFS-1 covers 42% of the county where BFS-2 covers only 13%, a difference of 29% (Table 3). In Thurston County, however, BFS-1 covers 22% of the county, where BFS-2 covers 15%, a difference of 7%. The development in Thurston County is highly clustered, leading to a high merging buffer effect. Buffers tend to merge together when the spatial representation of settlements is large, when settlements are clustered, and when the buffer is large.

To evaluate the settlement representation effect, I compared WA to BFS-1, which differ in the representation of a settlement (census blocks of a threshold density with public land removed versus points derived from parcels). It becomes clear that the settlement representation effect is modest. The settlement representation effect is most visible in Vilas County, where there are many large census blocks that only just meet the one structure per 40-ac threshold, and are spatially dispersed. Buffering from large dispersed census blocks (as opposed to point locations or smaller polygon geographies) yields a large WUI. In Boulder County and Marion County, BFS-1 method actually has a greater extent than the WA method because settlements as represented by parcel centroids are more dispersed than settlements represented by census blocks (Table 3).

Discussion

Even when models are similar conceptually, use the same density thresholds (e.g.,

one or more structures per 40 ac) and data sources (e.g., NLCD land cover data), the details of the implementation can lead to different estimates of the extent of the WUI and the percentage of structures in the WUI. The results show that the mapped output of the WUI shows a definition effect that is subtle in some counties (e.g., Marion and Thurston counties) and more pronounced in others (e.g., Boulder and Vilas counties). The dasy-metric, merging buffer, and settlement representation effects can make an important difference in the size of the WUI, but the magnitude depends on the amount and distribution of development and public land.

I believe that all five methods can be appropriate for mapping the WUI across large areas as long as the assumptions and limitations are made explicit. Although I can not consider any single model of the WUI to be the “true” or “correct” model, this analysis does illuminate tradeoffs between the different models. The RHS-1 method can miss structures because large parcels with extensive public land are often classified as “non-WUI,” even when they contain pockets of dense development. The WA and RHS-2 methods address this issue, although they may be prone to inaccurate housing counts because of poor quality of public land data in some areas. The WA method captures more structures than the other models by “casting a wide net.” If the goal is to include all structures in the WUI and to give managers latitude for fire management within a wide area, the WA method is an easily implemented approach. The BFS methods sacrifice little in terms of the percentage of wildland structures included in the WUI (as evidenced by Boulder County, where 96% of digitized structures lie within a 0- to 0.38-mi buffer of parcel centroids) and still are generally smaller than the WA method. In particular, the BFS-2 method is useful for identifying the highest priority areas for mitigation near housing because of the conservative buffer size. Another benefit of the BFS methods is that they use parcel data, the most spatially detailed and frequently updated data source for housing.

Defining the WUI consistently and clearly is an important task. Given that federal programs target treatments within the WUI, any differences could affect the areas prioritized for treatment and how funds are allocated. Without a full understanding of the tradeoffs between methods and potential

definition effects, maps of the WUI can potentially mislead. This study is not the final say on how the WUI should be mapped, but it is a testament that data sources and definitions are important.

Literature Cited

- BUTLER, C.P. 1974. The urban/wildland fire interface. P. 1–17 in *Proc. of Western States Section/Combustion Institute Pap.*, Vol. 75, No. 15, Spokane, WA, May 6–7, 1974. Washington State Univ., Pullman, WA.
- CALIFORNIA FIRE ALLIANCE. 2001. *Characterizing the fire threat to wildland-urban interface*. California Fire Alliance, Sacramento, CA. 75 p.
- CARDILLE, J.A., S.V. VENTURA, AND M.G. TURNER. 2001. Environmental and social factors influencing wildfires in the Upper Midwest, United States. *Ecol. Applic.* 11(1):111–127.
- COHEN, J.D. 2001. Saving homes from wildfires: Regulating the home ignition zone. *Zoning News* May 2001, 1–5.
- COHEN, J.D., AND B.W. BUTLER. 1998. Modeling potential ignitions from flame radiation exposure with implications for wildland/urban interface fire management. P. 81–86 in *Proc. of the 13th conf. on fire and forest meteorology*, Vol. 1, Lorne, Victoria, Australia, October 27–31, 1996. International Association of Wildland Fire, Fairfield, WA.
- DAVIS, J. 1990. The wildland–urban interface. Paradise or battleground? *J. For.* 95(10):18–22.
- EICHER, C.L., AND C.A. BREWER. 2001. Dasy-metric mapping and areal interpolation: Implementation and evaluation. *Cartogr. Geogr. Inform.* 28(2):125–138.
- GRAHAM, R.T. (TECH. ED.). 2003. *Hayman fire case study*. US For. Serv. Rocky Mtn. Res. Stn. Gen. Tech. Rep. RMRS-GTR-114. 396 p.
- GUDE, P., R. RASKER, AND J. VAN DEN NOORT. 2008. Potential for future development on fire-prone lands. *J. For.* 106(4):198–205.
- HAMMER, R.B., V.C. RADELOFF, J.S. FRIED, AND S.I. STEWART. 2007. Wildland–urban interface housing growth during the 1990s in California, Oregon, and Washington. *Int. J. Wildl. Fire* 16:255–265.
- HEALTHY FORESTS RESTORATION ACT (HFRA) H.R. 1904. 2003. *An initiative for wildfire prevention and stronger communities*. Available online at www.frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=108_cong_bills&docid=f:h1904enr.txt.pdf; last accessed Dec. 27, 2008.
- HILL, B.A. 2001. *The National fire plan: Federal agencies are not organized to effectively and efficiently implement the plan*. Testimony before the Subcommittee on Forests and Forest Health, Committee on Resources, House of Representatives, US General Accounting Office, GAO-10-1022T. 14 p.
- NATIONAL INTERAGENCY FIRE CENTER 2007. *Fire statistics*. Available online at www.nifc.gov/fire_info/nfn.htm; last accessed Dec. 27, 2008.
- NOWICKI, B. 2002. *The community protection zone: Defending homes and communities from the threat of forest fire*. Center for Biological Diversity. Available online at www.biologicaldiversity.org/swcbd/programs/fire/wui1.pdf; last accessed Dec. 27, 2008.
- PLATT, R.V. A model of exurban land-use change and wildfire mitigation. *Environ. Plan. B Plan. Design* 33:749–765.
- RADELOFF, V.C., R.B. HAMMER, S.I. STEWART, J.S. FRIED, S.S. HOLCOMB, AND J.F. MCKEEFRY. 2005. The wildland–urban interface in the United States. *Ecol. Applic.* 15(3):799–805.
- STEWART, S.I., V.C. RADELOFF, R.B. HAMMER, AND T.J. HAWBACKER. 2007. Defining the wildland–urban interface. *J. For.* 105:201–207.
- STEWART, S.I., B. WILMER, R.B. HAMMER, G.H. APLET, T.J. HAWBACKER, C. MILLER, AND V.C. RADELOFF. 2009. Wildland–urban interface maps vary with purpose and context. *J. For.* (107): 78–83.
- SUMMERFELT, P. 2003. The wildland urban interface: What’s really at risk? *Fire Manag. Today* 63(1):4–7.
- THE NATIONAL MAP LANDFIRE. 2006. *LAND-FIRE canopy height layer*. US Department of Interior, Geol. Surv. Available online at www.gisdata.usgs.net/website/landfire/; last accessed Dec. 27, 2008.
- THEOBALD, D.M. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. *Ecol. Soc.* 10(1):32.
- THEOBALD, D.M., AND W. ROMME. 2007. Expansion of the US wildland–urban interface. *Landscape Urban Plan.* 83:340–354.
- US DEPARTMENT OF INTERIOR (USDI) AND USDA. 2000. *The National Fire Plan: Managing the impact of wildfires on communities and the environment*. Available online at www.forestsandrangelands.gov/NFP/overview.shtml; last accessed Dec. 27, 2008.
- US DEPARTMENT OF INTERIOR (USDI) AND USDA. 2001. Urban wildland interface communities within vicinity of federal lands that are at high risk from wildfire. *Fed. Regist.* 66(3): 751–777. Available online at www.frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2001_register&docid=01-52-filed.pdf; last accessed Dec. 27, 2008.
- US FOREST SERVICE MANUAL. 2000. *FSM 5100*, Chap. 5140, R3 Supplement No. 5100-2000–2. Available online at www.fs.fed.us/im/directives/dughtml/fsm.html; last accessed Apr. 1, 2009.
- US FOREST SERVICE. 2007. *Fiscal Year 2007 Budget Justification*. Available online at www.fs.fed.us/publications/budget-2007/fy2007-forest-service-budget-justification.pdf; last accessed Dec. 27, 2008.
- WILMER, B., AND G. APLET. 2005. *Targeting the community fire planning zone: Mapping matters*. The Wilderness Society, Washington, DC. Available online at www.wilderness.org/Library/Documents/upload/TargetingCFPZ.pdf; last accessed Dec. 27, 2008.
- VOGELMANN, J.E., S.M. HOWARD, L. YANG, C.R. LARSON, B.K. WYLIE, AND N. VAN. DRIEL. 2001. Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper Data and Ancillary Data Sources. *Photogramm. Eng. Rem. Sens.* 67:650–652.