# Using GIS to identify potential wildland-urban interface areas based on population density.

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## Abstract

*The risks associated with managing areas within the wildland-urban interface (WUI ) are of increasing concern in natural resource management. One of the particular problems is the increased threat to life and property from catastrophic wildfires. The purpose of this analysis is to aid federal priority-setting within the National Fire Plan to help address WUI issues. In this analysis, we attempt to identify potential WUI areas based on population density using the aid of a Geographic Information System (GIS). Populations were classified into 5 population density categories at the national and state levels as well as within and surrounding federal lands.*

## Introduction

The risks associated with managing areas within the wildland-urban interface (WUI ) are of increasing concern in natural resource management. These areas exist where wildland vegetation and urban encroachment co-exist, but neither dominates. The migration of Americans from crowded urban environments to rural areas has brought people, homes and other developments into low population-density areas "with little knowledge of or concern for potential interactions and impacts" (Plevel 1997). This migration has tripled the amount of land devoted to suburbia since 1950 (Ball 1997). Rural encroachment of this magnitude sets the stage for land-use conflicts, property rights concerns, and forest health issues. One particular problem is the increased threat to life and property from catastrophic wildfires.

Wildfires are destroying more homes every year (Plevel 1997). This situation is providing land managers with expensive management problems that need to be addressed. More attention needs to be paid to the issues associated with WUI areas across the country. These areas are a key factor in wildland fire prevention and suppression (Keeley *et. al.* 1999). The following section, outlines possible solutions to the WUI problem a discussed in recent publications on the topic.

## Literature Review

Possible solutions to wildfire threats within the WUI has been described as a function of home ignitability, fuel management, and public policy. Homeowners have a responsibility to safeguard their homes within the WUI. Cohen (2000) found that a homes' exterior and its surrounding 40 meters determine the likelihood of it being

destroyed in a wildfire (i.e, home ignitability). This includes building homes with less-combustible materials and clearing vegetation or other debris at least 40 meters away from a home's exterior. The removal of fuel immediately surrounding a home creates a fire-resistant barrier that reduces the likelihood of a home being destroyed by wildfire.

Winter and others (2002) suggest that reducing the amount of fuel within WUI areas is the best prevention from destructive wildfires. Kalabokidis and Omi (1998) reported similar findings: "management of fuels [such as thinnings and slash treatments] and prevention of human-caused ignitions are most promising for controlling wildfires and damage in the urban interface."

Government-owned land has been subject to fire suppression for a century. However, in many cases these efforts have allowed fuel loads to build and larger, catastrophic fires are the result. In these areas, fire prevention treatments should be considered. Hesseln (2001) suggests that due to fuel accumulations and increasing populations within WUI areas, federal fire organizations should be more attentive to fuel treatments, prevention and detection tactics, rather then just focusing on suppression. Proactive fire prevention treatments such as timber harvests, prescribed fire, regular thinnings and/or other fuel reduction methods may prove to be more effective means to prevent a WUI disaster than reactive fire suppression tactics.

Public policy is also suggested as a way to help control the WUI problem. In areas like Southern California, where recent catastrophic fires have destroyed homes and threatened lives, some public policies pertaining to WUI areas have been established. However, few state and local governments have yet to recognize the wildland-urban interface threat as a matter of public policy (Plevel 1997). For now, the responsibility has been placed upon the federal government to address the issue. At the national level, WUI fire has been recognized as a natural hazard and public policy problem (Plevel 1997).

Geographic Information Systems (GIS) have been used to perform spatial analyses to predict fire behavior (Green *et al.* 1995) and to identify potential wildland urban interface areas using remotely sensed vegetative cover data (Sampson *et al.* 2000**,** Greenberg and Bradley 1997). Information generated through GIS analyses is becoming indispensable tools for land-use planning and policymaking (Greenberg and Bradley 1997).

## Scope of the analysis

The USDA Forest Service has designated funds to map potential wildland-urban interface areas as part of their resource mapping efforts. The purpose of this particular study is to use GIS to further identify potential wildland-urban interface areas as a function of population density. The resulting data will be used for federal priority-setting within the National Fire Plan. The goals of this study are:

1. To produce a national map of potential wildland-urban interface areas based on population density,
2. To gain an understanding of the potential number of people affected in wildland-urban interface areas at the state-level for the lower 48 states,
3. To produce state-level population density maps to identify potential wildland-urban interface areas, and

4. To map the presence of potential wildland-urban interface areas within and adjacent to federal lands.

The objective of this study is not a stand-alone final identification of WUI areas. The products of this project will provide national and state-level population data indicating potential WUI areas based on population density. This data should be used in further analyses with other WUI data created based on vegetation or other considerations. The ultimate goal of this project is to a more accurately identify WUI areas across the United States.

## Project Definition

In this project, WUI areas were defined on the basis of population densitiy. The WUI is defined as the zone that is less populated than an urban or suburban area, but more populated than a rural, agricultural, or wildland setting. This area was named a "mixed" population area, because it contains higher population densities than rural areas mixed with a greater likelihood of wildland vegetation being present than suburban settings.

### LandScan 2000 Global Population Data

To attempt a coarse-scale geographic analysis of this question, the development of a population density map of the 48 contiguous States was necessary. Population data was obtained from LandScan 2000, an international population data set prepared by Oak Ridge National Laboratory for the Department of Defense. Discussion of the development of the original LandScan data set can be found in Dobson et al. (2000). For this project, the LandScan 2000 data set was utilized; this data set is a significant improvement over the original 1998 product, according to its developers (Personal communication with Jerry Dobson).

LandScan is a 30-arc second grid coverage, with estimated ambient population for each pixel. Since 30-arc second coverage generates pixels that grow narrower as they proceed northward, an average pixel size was calculated in order to estimate the acres represented per pixel. At the center of the analysis area, the pixel size was estimated in the 1998 data to be about 163 acres. For the current exercise, the average pixel size worked out to be about 160-165 acres across the lower 48 states. For expansion to persons per square mile, it appears adequate to use an expansion factor of 4, indicating 4 pixels per square mile. Further analysis conducted at a finer resolution may use a different average pixel size for each state to obtain slightly more accurate estimates.

**Table 1-** Human population density categories used in identification of potential wildland-urban interface areas in the U.S. lower 48 states.

| | People Per | |
|---|---|---|
| Classification | Pixil | Sq. Mile |
| Wildland | 1 or less | 4 or less |
| Rural | 2-10 | 8-40 |
| Mixed or WUI | 11-100 | 40-400 |
| Suburban | 101-400 | 400-1,600 |
| Urban | 401 + | 1,600+ |

### Population Density Categories

Population density categories were developed to identify potential

WUI areas (Table 1). The least populated group (wildland) had estimated populations of 1 person or less per pixel. This translates to a population density of up to 4 people per square mile. Much of the federal land in the West falls into this category. The area labeled "rural" had LandScan population densities of 2-10 people per pixel, or about 8-40 per square mile. This appears, from visual examination, to cover many agricultural areas.

At the other end of the population density scale, we defined "urban" as areas containing 401 or more people per pixel. The data set contained pixels that indicated almost 65,000 people per pixel in some cities. At a somewhat lower density, we defined "suburban" as areas containing 101 to 400 people per pixel or about 400 to 1,600 per square mile. The "urban" category indicates population densities above 1,600 per square mile. The map illustrating these areas was compared in several test locations to the maps of urban areas generated by the U.S. Census Bureau, and the map fit was excellent, indicating that these classifications were consistent with other data definitions in common usage.

The area of "mixed" population density left in the middle of the density spectrum is defined as the potential WUI area. This area contains 11 to 100 people per pixel, or about 40 to 400 per square mile. It includes small towns, isolated subdivisions, and areas where scattered growth is being experienced. While these areas are highly diverse, and can only be accurately mapped with very local and high-resolution data, we feel that this provides the most useful definition available for the national strategic purposes of this risk mapping exercise.

## GIS Procedures

The GIS analysis was conducted in two distinct phases. In the first phase, population data at the national and state levels were generated from the global LandScan 2000 data set. These data were analyzed to quantify potential WUI areas across the nation. The second phase of the GIS analysis identified WUI areas within and adjacent to land managed by five major federal landholding agencies. This phase quantified WUI areas within and adjacent to USDA Forest Service (USFS), the Bureau of Land Management (BLM), the Fish and Wildlife Service (FWS), the National Park Service (NPS) and the Bureau of Indian Affairs (BIA) landholdings seperately.

*National and State analysis*

To begin the first GIS analytical phase, the global LandScan 2000 population data layer was clipped to include only the lower U.S. 48 contiguous states. During this procedure, a wide buffer was maintained around the U.S. border to include any islands off the coast. The resulting U.S.-based LandScan population data was then categorized into the five population density classifications described earlier. The resulting data provided a map of the potential WUI areas across the county (Figure1).

The U.S. LandScan 2000 population data was further clipped into 48 individual layers, one for each of the 48 lower contiguous states. The result provided state-level population density data for the lower 48 states. The state level population data was categorized into the five population density classifications. Population counts were summarized within each density category for each state. The resulting LandScan 2000

state-level population totals were compared to 2000 U.S. Census state population data as an independent check of reliability. The quality check indicated no consequential differences.

*Federal land Analysis*

To convert this analysis to a more useful tool for federal priority-setting within the National Fire Plan, federal land boundary layers were overlain on the population density map. The most recent data on U.S. federal landholdings was downloaded in shape file format from the National Atlas website (http://www.nationalatlas.gov) . This data layer was used to locate federal land boundaries for the USFS, the BLM, the FWS, the NPS and the BIA. The polygons representing each agency's land boundaries were buffered by one mile to include the area directly adjacent to these lands and to account for any inaccuracies within the data layer itself. The resulting buffered federal boundaries data layers were used to clip the LandScan 2000 population data. The resulting federal land population data were categorized into the five population classes and population counts summarized.

**Results**

*Phase 1*- The results of phase one was a national-level population density map to be used to identify potential WUI areas (Figure 1). This product should be used in further analyses in conjunction with other data layers including vegetation data and possible fuel-load data. Also, WUI population estimates by state were produced in this phase. The

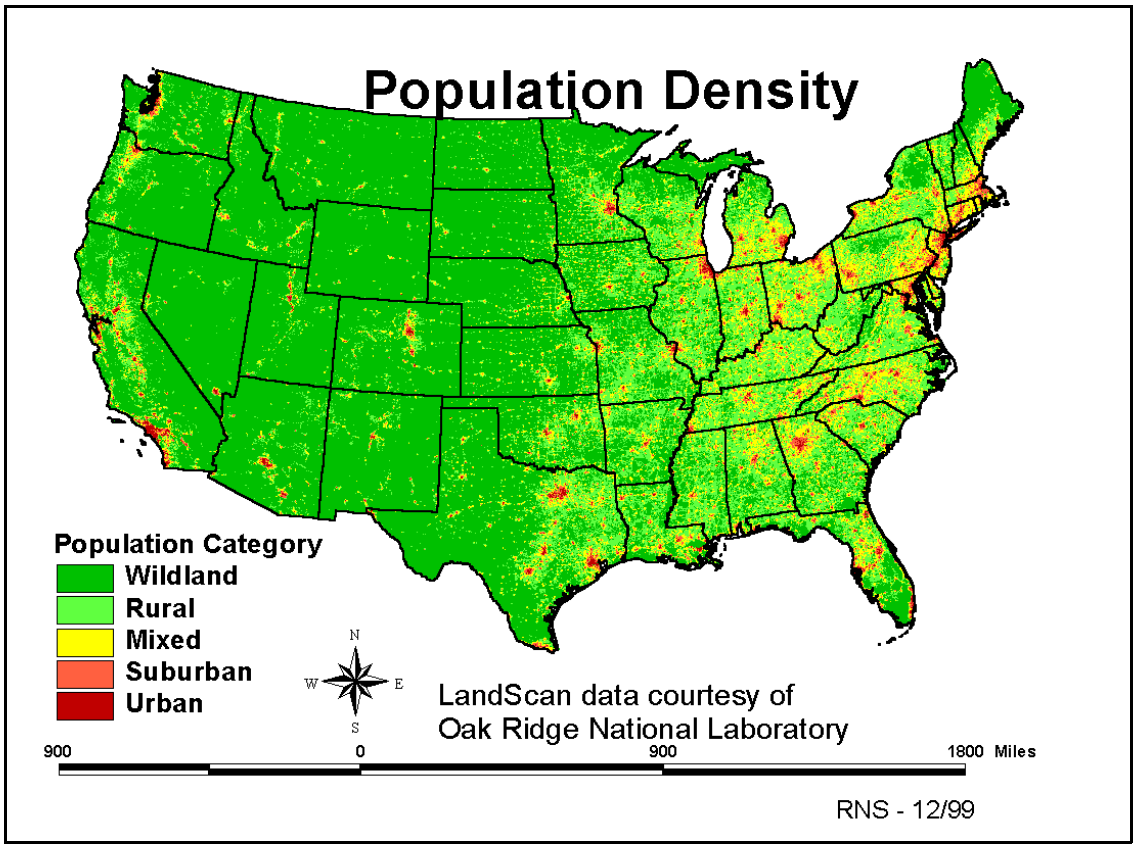


**Figure 1**- National population density map. Potential WUI areas (or the mixed category) are indicated in yellow.

states that contained the highest population totals within the WUI (or mixed) population category are a good places to focus fuel and fire management, education programs and public policy pertaining to WUI fire. Sixteen states showed greater than a million people living within the potential WUI areas with a total of 34 million people in the lower 48 states (Table 2).

Since the population inside the wildland-urban interface area is likely to be a function of the state's total population, then the more populated states would have higher WUI population totals. Further analysis should be done in conjunction with wildland vegetation maps and on-the-ground studies to establish findings of increased reliability.

*Phase 2*- During phase two, potential WUI areas were located within and adjacent to federal lands. In addition, a table was produced summarizing population totals by agency and population density category (Table 3). These results should contribute to the priority-setting of the national fuels management program. These data are at a coarse scale and should interpreted with an understanding of their uncertainty. While the population data are in grid cells that are fairly small, the vector data currently available for the federal land holdings is fairly coarse (1:2,000,000 scale). A 160 acre LandScan cell would be 0.015 inches wide on a map produced at a 1:2,000,000 scale. If this project proceeds to be examined at smaller scales, it may be useful to obtain federal land boundary

data produced at regional or state-levels.

**Table 2-** State wildland-urban interface* population** totals, excluding AK and HI.

| State | WUI Pop. | State | WUI Pop. | State | WUI Pop. | State | WUI Pop. | State | WUI Pop. |
|---|---|---|---|---|---|---|---|---|---|
| TX | 2,097,084 | WI | 1,084,936 | MS | 614,224 | KS | 341,726 | VT | 171,814 |
| PA | 1,962,253 | AL | 1,084,614 | WA | 602,381 | CO | 341,577 | MT | 156,471 |
| OH | 1,947,352 | IL | 1,068,807 | MD | 558,436 | AZ | 323,655 | SD | 119,782 |
| MI | 1,688,435 | VA | 1,052,566 | AR | 538,692 | CT | 316,382 | DE | 109,637 |
| NC | 1,626,456 | KY | 1,022,524 | OK | 531,807 | ME | 309,238 | NV | 101,033 |
| CA | 1,475,472 | FL | 1,020,082 | IA | 486,823 | NH | 254,589 | ND | 94,617 |
| NY | 1,423,943 | MO | 802,912 | WV | 457,889 | ID | 253,179 | WY | 75,449 |
| IN | 1,321,818 | SC | 763,045 | OR | 449,501 | NM | 199,714 | RI | 62,425 |
| GA | 1,312,135 | LA | 711,234 | MA | 415,858 | NE | 198,841 | 48 STATE TOTAL | |
| TN | 1,260,824 | MN | 697,815 | NJ | 400,546 | UT | 174,513 | **34,085,106** | |

* The wildland-urban interface was defined on the basis of population density. This area contains 11 to 100 people per LandScan 2000 pixel, or about 40 to 400 people per square mile.

**Population estimates taken from LandScan 2000 data set.

**Table 3-** George Washington & Jefferson National Forest human population totals, by population density, fine vs coarse scale analysis.

| | Population Density Group | | | | Total |
|---|---|---|---|---|---|
| Data Scale | Rural | Mixed | Suburban | Urban | Population |
| Coarse (1:2,000K) | 43,127 | 58,765 | 42,727 | 47,034 | 191,653 |
| Fine (1:24K) | 34,073 | 32,354 | 23,922 | 32,181 | 123,368 |
| Actual Diff. | 9,054 | 26,411 | 18,805 | 14,853 | 68,285 |

*Sensitivity Analysis*

The raster (or GRID) based LandScan 2000 global population data was produced with a 30 arc second (1 km. or finer) resolution for the entire world . The average grid cell of the clipped LandScan layer used in this analysis represented 160-165 acres (or about a 1/4-mile square). The federal land vector layer used to identify the position of in WUI areas within and surrounding agency land was produced at a scale of 1:2,000,000. Due to file size and memory limitations of computers, using coarse data is necessary to perform spatial analyses at a national scale. Results from this analysis are accurate at a national scale. However, estimates from this analysis examined at smaller scales may contain unacceptable error levels.

In an attempt to quantify the sensitivity of the results to scale, a finer-scale analysis

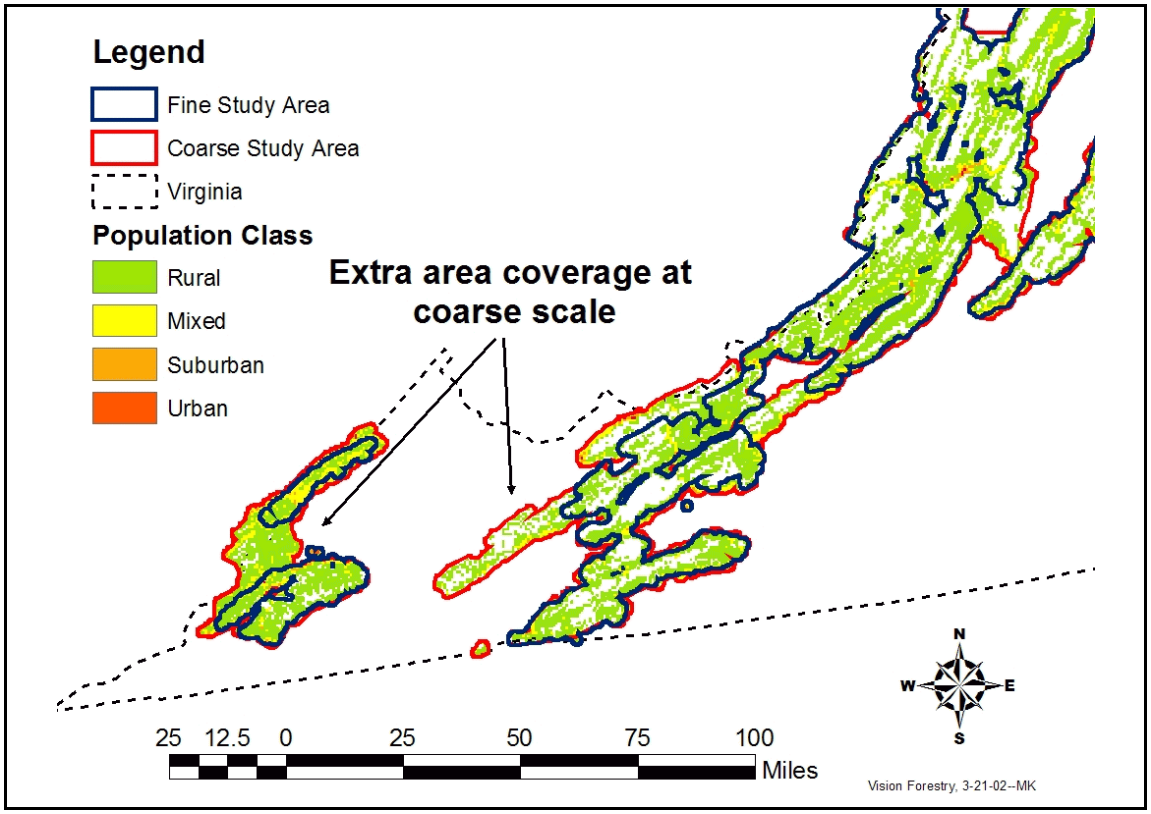


**Figure 2**- Boundary comparison of the fine vs course scale vector layers of the GW&Jeff NF

was performed. The George Washington and Jefferson National Forests (GWJNF), located along Virginia's southwestern border and in parts of West Virginia, were selected for the finer scale analysis. A 1:24,000-scale vector layer of the GWJNF boundary was obtained from the forest's website (http://www.fs.fed.us/gwjnf/gisdatadictionary.html). This layer was then buffered and used to clip the LandScan 2000 population data, using the same procedure applied to the coarser file used in the national-scale WUI analysis**.** The area and population totals of the fine and coarse vectors files for the GWJNF were compared (Table 3). The resulting population totals from coarse boundary data were 35.6% higher than population totals derived from the finer scale boundary layer. The difference in area between the fine and coarse vector files critically influenced the population estimations. The coarse vector file is more generalized than the finer scale file. Consequently it encompassed 27% more area than the finer-scale vector file (Figure 2). The overestimate of the population totals due to greater area encompassed with coarser scale data used for the national analysis was not unexpected. When using coarse national-level data at smaller scales, 35% + or - the actual value may be as good as one should hope to achieve. If accuracy at the state or national forest level is desirable, analysis should be conducted with finer scaled data.

**Discussion**

Using GIS to locate potential WUI areas based on population density at the national and state levels was a helpful exercise to further understand the magnitude and geographic distribution of the WUI issue. In addition, quantifying population densities within and adjacent to federal lands could to contribute to the priority-setting of the national fuels management program across the country. Locating WUI areas across the country allows federal agencies to become more proactive in addressing the WUI isssue. The allocation of funds, educational programs and fire prevention/suppression efforts can be better focused to areas of need. Through this process, hopefully the risks associated with wildland fire to lives and property can ultimately be reduced.

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