Chapter 6: Incorporating Rural Community Characteristics Into Forest Management Decisions

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Chapter Summary

As part of the Integrated Landscape Assessment Project, we developed a methodology for managers to include potential community benefits when considering forest management treatments. To do this, we created a watershed impact score that scores each watershed (potential source of wood material) with respect to the communities that are likely to benefit from increased wood supply. The communities we consider are census county subdivisions that correspond to all rural places in four states (Arizona, New Mexico, Oregon, and Washington). Incorporated into the watershed impact score are indices of community characteristics that may be of concern (indicators of socioeconomic well-being, business capacity, and effects of forest policies) and potential biomass supply. A gravity index combined the watershed-level biomass supply with the community-level information and weighted it by the distance between watershed and community, producing an impact score that indicated the potential of each watershed to supply material to communities. Our process allows managers to consider the potential for community benefits when choosing where on the landscape to act.

Introduction

United States federal forest fire policy during the last century has been to aggressively suppress wildfires as rapidly as possible. Consequently, forest conditions are well outside the natural range of variation in many of the forest types of the Western United States (Agee 1993, Franklin and Agee 2003). According to the U.S. Department of Agriculture Forest Service (USDA FS) and the Department of the Interior, about 263 million ha are susceptible to wildland fire (U.S. General Accounting Office 2003). Massive accumulation of forest fuels and changes in the species composition and structure of forests that historically experienced frequent,

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low-intensity fires create conditions in which wildfire, when it does occur, is far more likely than in the past to be catastrophic and expensive, and if not impossible, to contain. Average annual USDA FS expenditures on fire suppression in the 2000s was three times what it was in the previous three decades (Abt et al. 2009). Forest ecologists have become increasingly aware in recent decades, however, that wildfire plays an important role in maintaining healthy forests in fire-adapted forest ecosystems

Recognition of the effects of fire suppression on future fire risk led to the passage of the Healthy Forest Restoration Act (HFRA) in 2003, which was designed to expedite hazardous fuel reduction and forest restoration projects on federal lands. Mechanical fuel removal and restoration thinning have been proposed as potential remedies to this forest health crisis. But because these treatments are costly, resource constraints prevent managers from treating as many hectares as need treating. For example, even after the passage of the HFRA, only 8 million of the 263 million ha at risk were planned for treatment to reduce hazardous fuels between 2000 and 2007 (Rey 2006). Prioritizing the placement of fuel treatments in order to use limited resources efficiently is critically important.

Limited funding means that managers must pick and choose where across the landscape to place treatments. The human benefits of these treatments—the possible increases in mill processing activity, jobs, and other economic activities that may arise from an increase in wood material harvested—will also be located in specific places across the landscape.

The Integrated Landscape Assessment Project (ILAP) was a watershed-level prioritization of land management actions based on vegetation and fuel conditions, wildlife and aquatic habitats, and economic values across all lands in Arizona, New Mexico, Oregon, and Washington. One of the goals of ILAP was to provide land managers, policy analysts, and others with tools to enable them to determine how to place fuel treatments across the landscape in a way that maximizes diverse benefits—such as wildfire risk reduction and wildlife habitat improvements—while still ensuring the treatments are as financially feasible as possible. Limited funding means that managers must pick and choose where across the landscape to place treatments. The human benefits of these treatments—the possible increases in mill processing activity, jobs, and other economic activities that may arise from an increase in wood material harvested—will also be located in specific places across the landscape. That means that managers and others may also have a very real opportunity to consider which communities may benefit from harvest action.

Why Should We Care About Rural Communities When Considering Fuel Treatment Location Decisions?

Throughout the United States, timber harvests from federal lands have declined dramatically since the 1980s. Harvest declines on federal lands, as well as greater domestic and international competition and technological advances, have contributed to fewer employment opportunities in the timber industry. Mechanization, consolidation, and closures of mills continue to concern rural forest communities. Harvest decline was exacerbated in Oregon and Washington with injunctions prohibiting logging on USDA FS and U.S. Department of the Interior Bureau of Land Management (USDI BLM) lands within the range of the northern spotted owl, which was listed as threatened under the Endangered Species Act in 1990. By the late 2000s, national forest harvests in Oregon and Washington declined to about 10 percent of what they were in the late 1980s (USDA FS 2010). The listing of the Mexican spotted owl in 1993, and the subsequent temporary injunction against logging on national forests in 1995, had a similar effect in the southwest. By the late 1990s, national forest harvests had declined to about 19 percent and 13 percent of late 1980s levels in Arizona and New Mexico, respectively (Keegan et al. 2001a, 2001b). These harvest figures include fuelwood harvest, still a significant proportion of use in the southwest, so the decline in useable material for mills was even more pronounced; in 1998, less than half of the cut from national forests in Arizona was available for processing in local community mills.

Federal timber harvests have also contributed directly to county revenues in all four states, through a revenue sharing program from timber sales designed to compensate counties for the loss of tax revenue associated with federal ownership status (Gorte 2010). Beginning in the early 20th century, the USDA FS paid 25 percent of gross timber receipts to the states where the timber was harvested to provide and maintain roads and schools in those counties where national forests are located, while the USDI BLM shared 50 percent of revenues from harvests on the Oregon and California revested grantlands. These lands cover 970 000 ha of forest land, originally granted to railroads, in 18 western Oregon counties (Corn and Alexander 2012). In counties with considerable public lands, these receipts contributed substantially to county budgets after World War II, when harvest activity on public lands accelerated substantially (Corn and Alexander 2012). Although the initial goal of the revenue-sharing was compensation for foregone tax revenue, concern over effects on county budgets of declines in timber harvest resulting from the spotted owl listing led to the appropriation of payments to Oregon, Washington, and California in the early 1990s, and to an adjustment of the revenue-sharing program through the Secure Rural Schools and Community Self-Determination Act of 2000 (USDA FS 2011). Still, adjusted for inflation, Oregon county payments declined by 32 percent on average from the late 1980s to the late 2000s, while Washington county payments declined by 23 percent (USDA FS 2011). Payments from the Secure Rural Schools ended in 2011, which created further uncertainty for rural communities.

Changing public forest values mean that communities near public forest lands can no longer depend on federal agencies to promote rural economic growth and provide sustained-yield employment through timber harvest. Kennedy et al. (2001) suggested that federal agencies have shifted their rural development roles to help facilitate effective rural community adaptation to broader socioeconomic change. The USDA FS has maintained the goal to, “help states and communities to wisely use the forests to promote rural economic development and a quality rural environment” (USDA FS 1994). The USDI BLM maintains that the “most effective, realistic role for public forest resource agencies is to assist rural economies and communities in adapting to changing regional and global forces” (USDI BLM 1994).

Vegetation management (which can include the removal of small trees, excessive brush, and larger trees on overstocked sites to reduce fuels) has the potential to meet the diverse goals of these federal agencies. Treatments can mitigate future wildfire damage, restore forest ecosystem health, and provide many benefits to rural communities, including local employment opportunities, wood supply for mills, and biomass supply for emerging energy markets.

For this study, we have compiled information to be included in a decision support system that allows managers who are considering fire-hazard reducing treatments to include potential community benefits in their considerations. The decision support system consists of layers provided by ILAP teams that address future effects on wildlife, wildfire hazard, and economic feasibility of fuel treatments at the watershed level in the four states. The support system uses Ecosystem Management Decision Support (EMDS; Reynolds 1999, Reynolds and Hessburg 2005), an application framework that runs within a geographic information system, allowing for spatially explicit information on multiple topics to be analyzed simultaneously to aid decisionmaking. The goal of the community economics team was to provide information that enables land managers to consider the current and historical state of communities that may be affected by increased harvest activity. We did this by creating a watershed impact score (WIS) that rates each watershed (potential source of wood material) with respect to the communities that are likely to benefit from an increase in locally delivered wood supply resulting from forest health treatments.

Methods and Data

To give land managers the ability to consider potential effects on communities when choosing where to place fuel treatments, we sought a method to combine disparate information into a single, easy-to-interpret index. Input data included indicators of community conditions, estimates of potential biomass that each watershed could produce, and the distance between sources of material and potential places that can utilize material. The WIS is based on the idea of a gravity index: that the transfer or flow of products is related to both the characteristics of the origin (the push factors) as well as the destination (the pull factors). Although distance is clearly important in determining where material goes, it is not the only consideration. To calculate the WIS, we needed to establish the following:

- Criteria for an origin location
- Criteria for a destination location
- Community characteristics that may be of importance to decisionmakers
- Estimates of potential biomass supply
- Weights and structure of the gravity index

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Gravity index models are a widely used spatial interaction model; they have applications in market analysis (e.g., placing and optimizing shopping center size), predicting migration patterns, or even analyzing university enrollment (Haynes and Fotheringham 1984). For example, shoppers from a rural area faced with two cities to shop in will take many things into consideration when deciding which city to go to, not just the distance involved. Certain mixes of shops or amenities may be more attractive to consumers. Destinations that offer more or have more weight can attract input from a wider radius than destinations that have less weight. Gravity indices have also been used in landscape-level assessments to model the urbanization potential of undeveloped land as a function of population and proximity (Kline et al. 2001). The WIS in the ILAP project built directly on this use of a gravity index in service of both ecological and social issues, but represented, to our knowledge, the first use of a gravity index to include community concerns in planning land management activities.

Following Haynes and Fotheringham (1984), we considered a single sending center gravity index:

$$\mathrm{WIS} = \sum_i \frac{(\mathrm{v}_i \mathrm{w}_j)}{\mathrm{d}_{ij}},$$

where

WIS_j = watershed impact score assigned to j^{th} watershed,

v_i = drawing attribute of i^{th} community (the “pull” factors, e.g., mill presence or poverty, of each destination),

w_j = sending attribute of j^{th} watershed (the “push” factors, e.g., biomass potential, of each origin), and

d_{ij} = travel time between i^{th} community and j^{th} watershed.

Criteria for an Origin Location

The base layer for origins was all watersheds (5th field hydrologic units; USGS and USDA NRCS 2011) in USDA FS Pacific Northwest Region 6 (Oregon and Washington; OR/WA hereafter) and USDA FS Southwestern Region 3 (Arizona and New Mexico; AZ/NM hereafter). Watersheds average about 44 000 to 56 000 ha. We created a centroid point for each watershed—a geographically-weighted center latitude and longitude point for each unique watershed in the four states, excluding masked urban areas (masked areas represented nonmodeled areas for the purposes of determining future potential vegetation, wildlife habitat potential, fire hazard, and economic feasibility of fuel treatments). The result was 945 unique potential origin points in OR/WA and 1,015 in AZ/NM. In the end, many of these watersheds had no biomass that could potentially be supplied to local communities and were not given scores (the process for determining biomass potential is discussed below).

Criteria for a Destination Location

Potential destinations for material removed in fuel treatments are likely to be existing mills but may also include future processing development in places currently without facilities. Thus, we included both those places that are currently processing wood products and those that may potentially be a site for future capital investment as destination locations. Capital investment (both past and future) is likely to be concentrated in existing communities and places with infrastructure and population. In addition, any discrete place also draws workers in from a surrounding area that may be much larger than one physical town or city. Both of these levels of geography are accounted for in our destinations.

For places with infrastructure and population (potential destinations for material), we used the census designated place (CDP) geography from 2000. Places included designated places, consolidated cities, and incorporated places. Designated places are the census-defined counterparts of incorporated places. They are delineated to provide data for settled concentrations of population that are identifiable by name but are not legally incorporated. Boundaries usually coincide with visible features of the boundary of an adjacent incorporated place or other legal entity boundary and are defined in cooperation with local or tribal officials. To focus on rural places, we omitted urban places (those with populations over 50,000) and urban-linked places (those with populations from 10,000 to 50,000 and that are within 32 km of an urban place). Recognizing that both material and people may cross state borders for work, we included those rural places within a 96-straight-line-km distance of the border in each two-state region.

These rural places, along with census county divisions (CCDs), defined community in our study. Census county divisions are delineated by the U.S. Census Bureau to follow visible features, have a community orientation, and coincide with census tracts where applicable. Defining communities as subcounty units helps to mitigate concerns over the use of larger geographies, which may not reflect local peoples' sense of community boundaries. Production, marketing, consumption, and local institutions factored into the delineation of CCDs by the census. The locality on which a CCD is centered usually is an incorporated place or an unincorporated community, which might be identified as a census designated place. In some cases, the CCD may center on a major area of significantly different topography, land use, or ownership, such as a large military installation or American Indian reservation. The name of each CCD is based on a place, county, or well-known local name that identifies its location (USDC Bureau of the Census 1998). We considered CCDs that contain a rural place, as defined above, to be **rural communities**.

To our knowledge, this is the first use of combined census CDP and CCD geographies to delineate communities. More often, single geographic layers are used that are either smaller or larger, such as census tracts or block groups for the former, and counties for the latter. Although geographies smaller than CCDs may better represent a person's sense of place, the use of census tracts or block groups is problematic. Both census tracts and block groups are based on population and neighborhoods, but do not necessarily correspond to recognizable communities. In addition, both block groups and tracts change boundaries between censuses. In more densely populated areas, aggregation is necessary to represent communities using these geographies. This type of aggregation is a time-consuming process, which requires key informants from all regions to determine the appropriate aggregation (Donoghue 2003). Counties are frequently used for ease of data gathering from multiple sources, availability of historical data, and ease of recognition. However, counties are large, heterogeneous areas with multiple recognizable communities contained within. We defined communities in terms of the CCDs that contain rural CDPs in order to maximize the strengths and minimize the individual weaknesses of these geographical definitions as units of analysis, recognizing that this limited the community-level data available to that produced by the U.S. Census Bureau.

The distance between each watershed centroid point and place centroid point was calculated by creating an origin-destination matrix in ArcGIS. This matrix contained distance and travel time estimates for all community-watershed pairs. We added 5 minutes to each distance to account for startup time.

Community Characteristics That May Be of Importance to Decisionmakers

To calculate v_i, the drawing attributes of the i^{th} community, we considered indicators of (1) community distress, (2) business capacity, and (3) USDA FS policy impacts (table 6.1). Our gravity index can, thus, prioritize communities experiencing distress, those with business capacity ready to utilize new supply, those that have been adversely affected by USDA FS policy, or those that share combinations of characteristics. All drawing attributes and their data sources are defined in table 6.1. The rationale for inclusion of each drawing attribute follows.

Indicators of communities in distress (SES)—

The fates of rural communities highly dependent on natural resources has been a concern of land managers for decades. The Sustained Yield Forest Management Act of 1944, for example, had as part of its stated purpose to promote the stability of communities (Hibbard 1999). It is possible that managers may want to target areas of high distress as potential recipients of forest material. Inputs of supply may be able to help stimulate positive economic activity within the community. Although

Table 6.1—Drawing attributes for communities

Indicators	Description	Data source
Communities in distress:		
Poverty	Percentage of population at 185 percent poverty level or below	Census 2000
Income inequality	Gini index: measures inequality of household income distribution	Census 2000
Unemployment	Percentage of labor force unemployed	Census 2000
Unattached youth	Percentage of youth (16 to 19 years old) not in school and unemployed	Census 2000
Population decline	Percentage of decline in population from 1990 to 2000	Census 2000
Business capacity:		
Education	Percentage of population 25 years and over with associates degree or higher	Census 2000
Labor force	Percentage of population in labor force	Census 2000
Mill capacity	Presence of a mill in a census county division since 2000	Various sources (see text)
Specialization	Percentage of employment in forestry, wood products, or paper	Bureau of Land Management 2000
Federal forest policy impact:		
Forest Service impacts	Percentage change in U.S. Department of Agriculture, Forest Service county payments from 1986–90 to 2003–07 average	USDA FS 2010

increasing levels of community distress act as an increasing draw within the WIS, it is worth noting that higher values of these indicators correspond to lower socio-economic status, and overall, more negative conditions within the communities. Community distress indicators used in the WIS include poverty, income inequality, unemployment, unattached youth, and population decline. A measure of overall economic diversity was considered, but rejected owing to lack of variability in the calculated data.

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***Poverty*—**Poverty is a ubiquitous measure that indicates community distress (Charnley et al. 2008, Donoghue and Haynes 2002, Isserman et al. 2009, Kusel and Fortmann 1991, Overdevest and Green 1995, Reeder and Brown 2005, Stedman et al. 2004, 2005). The most widely used definition of poverty is the U.S. Census definition, in which a family is considered poor if its annual pretax money income is less than the poverty threshold for a family of that composition and size. Although the official definition of poverty generally considers only those below the threshold as poor, agencies that provide housing subsidies, food assistance, and low-income health insurance often use income thresholds of 185 percent of poverty or greater. These families may be working enough to keep them above the threshold, but are at great risk of slipping into poverty should their job be lost or work hours reduced. Additionally, studies exploring alternative measures of poverty have generally concluded that a threshold of 150 to 200 percent of the current poverty threshold would be a better measure to adequately capture the modern costs of living (Boushey et al. 2001). For poverty, we used the percentage of households at 185 percent of the poverty level or below, a measure reported in the Decennial Census.

***Income inequality*—**Timberlands have rapidly changed hands in the last decade with millions of hectares of forested land being acquired by real estate investment companies and timber investment management organizations. Many of these parcels of land have been developed into high-end residential properties, which have attracted wealthy retirees and newcomers to forest communities (Bliss et al. 2008). Inmigration of wealthy suburbanites searching for recreation and retirement has greatly altered the socioeconomic structure of amenity-rich communities in the west. While the new residents bring skills, experience, and extra-local connections to these communities, they tend to support low-paying menial jobs instead of employment opportunities with large multiplier effects like wood processing. Nelson (1997) and Brown (1995) found socioeconomic differences between long-time (less wealthy) and newer (more wealthy) residents in rural counties in the Pacific Northwest. Wilkinson (1991) found that income inequality is often a source of social tension.

We measured income inequality using the Gini index, a standard measure of inequality (Allison 1978). To calculate the Gini index for inequality of household income, households are ranked by income, and the aggregate share of income held by each group of households is divided by the total aggregate income. For example, the bottom 10 percent of households may hold 1 percent of the total household wealth, and the next 10 percent of households may hold 5 percent of the total household wealth, and so on until all households are included. The Gini index compares this distribution to a perfectly proportional distribution and incorporates all of this information into a single measure with a value of [0, 1] (DeNavas-Walt et al. 2009). A zero Gini index expresses total equality, where all households receive the same income, while a value of 1 expresses complete inequality (one household receives all income, the others receive none). The Gini index was calculated using household income data from the U.S. Decennial Census.

Unemployment—Unemployment is a common metric in calculating socioeconomic well-being (Ashton and Pickens 1995, Charnley et al. 2008, Feser and Sweeney 2003, Isserman et al. 2009, Stedman et al. 2004, 2005). At an individual level, access to work is a basic economic need and is typically a necessary, though not sufficient, condition for generating a livable income. At a regional level, a high level of unemployment constitutes wasted economic potential, a drain on public resources, and a limitation on public service capacity. The U.S. Census Bureau defines civilians as unemployed if they (1) were neither "at work" nor "with a job but not at work" during the reference week, (2) were looking for work during the last 4 weeks, and (3) were available to start a job. The percentage of the population unemployed was taken directly from this Decennial Census information.

Unattached youth—young adults not working or in school represent both the lack of opportunity in an area, as well as the potential for greater social disruption. This cohort tends to contribute to community distress, as youth who move away from the school and work trajectory are associated with lower lifetime earnings, increased poverty, homelessness, and criminal activity (Montalvo and O'Hara 2008). Such youth are often found in black and Hispanic populations, among teen mothers, in rural areas, and in the youth criminal justice system (Snyder and McLaughlin 2008). To calculate the percentage of unattached youth in a community, we used the population of people ages 16 to 19 not in school, not in the armed forces, nor currently employed from the U.S. Decennial Census data.

Population decline—Dramatic changes in population demographics likely decrease the level of social capital in a community and contribute to community distress, at least in the short term. Measuring population turnover is problematic, though, in that a stable population does not necessarily imply a stable community. Inmigration and outmigration occurring in tandem may result in a stable population, but a very different demographic.

We used percentage of decline in population from the 1990 to 2000 Decennial Censuses as one indicator of community distress. Communities that remained stable or increased in population were given a value of zero. Although increases in population may indicate both positive and negative impacts on community well-being, population decline is less ambiguous. Population adjustment in areas of high unemployment or low income could be considered a positive shift in labor resources regionally, but most certainly indicate negative conditions in the community experiencing this loss (Feser and Sweeney 2003). At a minimum, an absolute loss of population can result in a shrinking work force, lower tax revenues, and smaller school enrollments. When we consider that migration tends to be a highly selective process, with younger, better educated, and higher skilled workers moving first in response to economic decline, the negative effects of population change become more pronounced (Bronars and Trejo 1992, Kwok and Leland 1982, Sjaastad 1962).

Indicators of business capacity (BC)—

Harvest activities may also be focused with a goal of helping communities that are positioned for success, but lacking only in timber supply. In contrast to the idea of assisting communities that are struggling, managers under this scenario would want to target fuels reduction treatments in watersheds that may benefit communities with high business capacity, where small increases in supply may have the potential to secure mill longevity and wage income for the immediate future. In all cases, higher values of each indicator used represent positive factors of the community that contribute to higher business capacity. Business capacity indicators for the WIS include education, the size of the labor force, presence of a mill, and employment specialization in forestry, wood products, or paper.

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Educational attainment—Education is a common proxy for human capital, another variable that contributes to socioeconomic well-being and community resilience (Donoghue and Haynes 2002, Reeder and Brown 2005, Stedman et al. 2004). In the past, family-wage jobs in forest communities traditionally did not require much education past high school. However, the decline of the forest products industry requires new skills on the part of community residents if they are to adapt successfully to this change. We calculated the percentage of population with an associate's degree or higher to represent educational attainment, one indicator of business capacity. These data are available through the U.S. Decennial Census.

Labor force size—The percentage of the population in the labor force, also calculated from Decennial Census data, indicates the relative number of people available for employment. Communities with large proportions of youth or older residents are unlikely to take advantage of new business and employment opportunities. Retirement income and transfer payments account for one quarter or more of economic activity in some rural areas (Rasker 1994). Although some retirees may possess financial capital to invest in new enterprises, a robust labor force is needed to attract new investment and take advantage of new jobs.

Recent mill presence—The presence of a mill indicates whether the physical infrastructure is available to process new supplies of wood. A community with a mill currently operating has the most capacity to easily utilize raw materials supplied as a result of forest treatments, but mills that have recently closed may also be reopened with capital investment. We drew on several sources to obtain data on current mill locations in the four states. The methodology and specific sources used are described below.

Random Lengths publishes a buyers' and sellers' directory of the forest products industry annually (Random Lengths 2010, 2000). This publication, titled "The Big Book," is compiled from information voluntarily provided by mills and secondary processers across the country. Mills listed in the 2000 or 2010 editions of The Big Book were considered as open in those years. The USDA FS periodically publishes profiles of softwood sawmills by state, along with recent capacity data (Spelter and Alderman 2005, Spelter et al. 2009); these reports were used to add to or verify open mills listed in the Big Book. In addition, data from industry consultants of open mills in OR/WA in 2011 (Ehinger 2011) were used to further verify currently open mills.

A community with evidence of a mill open in 2011 or 2010 was given a mill capacity value of 1. If a mill was present prior to or in 2005, the mill capacity was 0.5; if there was a mill present prior to or in 2000, the mill capacity was 0.25. In all cases, all reported mills were counted, regardless of processing capacity or size of logs used in the mill. Communities with no evidence of a mill since 2000 were given a capacity of zero.

Specialization—We used the percentage of the labor force currently employed in forestry, wood products, or the paper industry to indicate whether the labor force in a given community has the appropriate skills and experience to take advantage of employment and business opportunities from fuel treatments. Percentage of specialization in relevant industries was calculated as the number of employees in three industries (three-digit North American Industry Classification System Codes): forestry and logging (113), wood product manufacturing (321), and paper manufacturing (322), as a proportion of all employees. County-level percentage of specialization was calculated in this way from U.S. Bureau of Labor Statistics employment data and applied to all CCDs in that county.

Indicators of federal forest policy impact (FP)—
In addition to focusing on communities with high distress or those with high business capacity to target through fuels reduction treatments, an additional motivation for public land managers may be to assist communities that have experienced changes in fortune as a result of shifting federal forest management policies. If federal land management policies have affected some communities more than others, these communities may have more weight for managers hoping to impact specific places through harvest activities. Forest Service policy impacts are represented by the percentage of decline in county payments from the late-1980s to the mid-2000s.

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Decline in county payments—It is difficult to quantify the effect of changes in public forest management on rural communities. One very real effect, however, of declines in public timber harvest has been the decline in contributions to county budgets related to the revenue-sharing agreements that date back to the early 1900s. Although initially payments were small (along with public timber harvest), payments to counties were still linked to harvest receipts in the late-1980s and peaked at that time in terms of the amount of money distributed to rural counties. Legislation that replaced the timber harvest county payments in the 1990s altered the relative payment amounts to each county and increased some counties' payments, while decreasing others. The large declines in public timber harvest in the late 1990s led to alternative payments designed to ease the strain on county budgets. USDA FS Policy impacts of the USDA FS were indicated by the percentage of decline in county payments from the late-1980s to the mid-2000s. These two time points represent recent overall highs and lows, respectively, in payments to counties from all sources, and were used to proxy negative effects of changes in land management policy. Communities in counties that experienced a decline in county payments were represented by their percentage of decline, whereas communities in counties that experienced no change or an increase in county payments were given a value of 0.

We originally included harvest decline as a USDA FS policy impact variable, but discarded it because of lack of variation between communities. Because all national forests in OR/WA witnessed a comparable decline in harvest rates, inclusion of this variable did not add to our analysis. Although the cut and sold reports were not as easily available at the level needed to check similar trends for AZ/NM, evidence of the decline in overall harvest in AZ/NM indicated that the same was likely true for each national forest there (Keegan et al. 2001a, 2001b). Another indicator considered but not included owing to data gathering difficulties was the change in USDA FS employment.

Estimates of Potential Biomass Supply

Biomass supply is a key component of the possible benefits of fuel treatments for rural communities. Through the use of secondary data, primarily from the U.S. Census Bureau, the WIS captures the need (the Socioeconomic Status, Business Capacity, and Forest Policy indices) at the community level, but also must incorporate the potential for each watershed to actually supply material to nearby places. To quantify the potential biomass, we relied on two different methods: one for OR/WA and one for AZ/NM (where a lack of data precluded utilization of the method used for OR/WA). Both methods are detailed below.

Potential biomass in the Pacific Northwest (OR/WA)—

In OR/WA, potential biomass estimates for each watershed began with maps of current vegetation and vegetation models created for ILAP. Current vegetation conditions were imputed using a nearest neighbor modeling method to match USDA FS Forest Inventory and Analysis plot-level data to remotely sensed imagery (chapter 2). Vegetation state classes were defined using state-and-transition models (STMs). The STMs are used to represent alternative vegetation state classes (combinations of vegetation cover and structure) within potential vegetation types (chapter 2). Transitions link state classes and represent processes such as succession, disturbance, and management activities. The current vegetation condition map was classified into STM state classes, which were used to calculate potential biomass (this analysis is described in detail in chapter 4).

For the eastern forests in OR/WA and the southwestern forests in Oregon,[4] ecologists from the USDA FS identified the desired ending state classes for each current state class and the transition required to get there given a goal of forest restoration. For example, within the dry mixed-conifer potential vegetation type

[4] West-side forests in OR/WA have a very infrequent fire regime and forest conditions are generally not out of historical range (Agee 1993), so these regions are unlikely to be targeted for large-scale vegetation management or restoration treatments and were omitted from the analysis.

in the Oregon East Cascades modeling zone, there is a state class characterized by Douglas-fir/white fir trees of medium size and medium canopy cover. A restoration target state class in this vegetation type and region is Douglas-fir/white fir trees of medium size with open canopy. To move from the former state class to the latter, a partial harvest of small- to medium-sized trees at a medium density was selected as the transition.

An estimate of standing biomass was assigned to each state class using methodology documented in Zhou and Hemstrom (2010) and chapter 4. To obtain an estimate of potential biomass removal for each state class that was a candidate for treatment, we subtracted the standing biomass estimate for the ideal ending state class from the standing biomass estimate for the current state class. Using the example above, the total nonleaf biomass for the more dense state class is estimated at 73.9 oven-dry metric tons (odt) per hectare, while the total non-leaf biomass of the more open state class is an estimated 42.9 oven-dry metric tons per hectare. The difference between these two values (73.9 – 42.9 = 31 odt of material removed per hectare of land in that initial state class) represents the maximum amount of biomass material that could be removed under a restoration scenario, where all areas that are currently in a more dense condition are harvested to create more open, fire-resistant conditions. To calculate total potential removals per watershed, we simply multiplied the per-hectare amount of potential biomass removed under resilience goals by the amount of that state class currently in each watershed.

Because we calculated biomass based on the potential removed from each and every hectare of land, this estimate represented an upper bound on the quantity of biomass that might be removed and supplied to communities for processing from each watershed as a result of resilience activities.

Because we calculated biomass based on the potential removed from each and every hectare of land, this estimate represented an upper bound on the quantity of biomass that might be removed and supplied to communities for processing from each watershed as a result of resilience activities. These estimates included removal of all available biomass, whether stems, branches, or leaves, without leaving any material behind for wildlife or nutrient concerns. Byproducts of current management (logging slash or mill residues) are not included. In addition, different types of biomass destined for specific forest products (e.g., sawtimber, hog fuel chips) were not identified. This estimate was intended only to indicate maximum potential supply relative to other watersheds and was not meant to represent a likely management scenario. It also did not assess financial feasibility.

Given the total biomass potential in each watershed, all watersheds in OR/WA were then ranked by their contribution to total potential biomass supply in the region. The biomass supply variable, as incorporated into the WIS, weighted each watershed relative to all others in the region in terms of its potential biomass supply on a scale of zero to one.

Potential biomass in the Southwest—

Biomass estimates in AZ/NM, where the more detailed resilience strategies and biomass amounts by state class information was not available, were calculated differently from OR/WA. For AZ/NM, biomass estimates were based on the Forest Biomass Resources Supply Study (Cook and O'Laughlin 2011a, 2011c). Researchers at the University of Idaho provided county-level estimates of biomass that might be available at different roadside prices (from $10 to $40 an odt) for all Western States for the Western Governors' Association, following a method established in an earlier, state-level analysis of biomass supply potential. These biomass estimates incorporated several potential sources: forest thinning to reduce fuel loads or improve forest health, logging slash, and mill residues (Cook and O'Laughlin 2011b). Most of this material is, by definition, unmerchantable poles, small and low-value sawtimber, and chip material. As such, it represents opportunities for either use in energy production, or in sawmills with small-diameter stem processing capability.

To portion out the county-level biomass estimates to the watershed level necessary for the WIS, we used the current vegetation map (chapter 2) to identify areas of each watershed with at least 20 percent forest canopy cover. County and watershed layers were combined to create modified counties that coincided with watershed boundaries. County-level biomass total estimates were portioned out to each watershed, with forest canopy cover based on the watershed's contribution to the total county area. For example, if a county had a potential biomass of 25,000 odts per year, and a watershed with complete forest cover comprised 20 percent of the modified county's forested area, then the watershed would be allocated a proportional amount of biomass (20 percent of 25,000 = 5,000 odt/yr). At the modified county level, the total estimates of the biomass for all watersheds in a given county equal the totals given in the Forest Biomass Supply Analysis at a roadside price of $40 per dry ton.

Similar to the process used following the calculations of actual biomass estimates in OR/WA, watersheds were ranked by their contribution to total regional biomass that might be provided. The variable used in the WIS represented the potential contribution of each watershed relative to other watersheds in the region that have forest cover. However, the different methodology used in the two regions, along with the use of a regional baseline in ranking the watersheds, means that the resulting WIS indices are not directly comparable between OR/WA and AZ/NM. For example, a watershed with a high ranking of biomass potential in OR/WA is not the same as a watershed with a high ranking in AZ/NM. Each considered different pools of material as potential biomass, was developed with different motivations, and each was ranked against a different regional total potential supply.

Weights and Structure of the Gravity Index

The component data for each of the community-level indices—the socioeconomic status variables, the business capacity variables, and forest policy variable in OR/WA—were all scaled to lie in the interval [0, 1], inverted when necessary, and truncated in cases when only some of the data values were of interest (e.g., we were only interested in communities with population decline). Adding the component data together resulted in a range of values for the two regions and three indices (table 6.2). Higher values of the SES and FP indices indicate greater distress, a negative measure, while higher values of the BC index indicate greater capacity, a positive measure. High values for all three increase the priority ranking of the watershed.

The indices were inversely weighted by travel time between each watershed-community pair. We constructed the WIS for each watershed by summing the weighted indices for the five nearest communities. This resulted in a score for each watershed consisting of the attributes of the communities most likely to receive biomass supply from that watershed. By limiting the analysis to include only the nearest five communities, we avoided creating a WIS that is dominated by population; it is more responsive to the attributes of the communities. For inclusion in the final calculations, the biomass rankings in tenths based on each watershed's contribution to the total regional biomass potential were scaled to lie in the interval [0, 1].

The resulting comprehensive WIS for watershed j was calculated as:

$$\mathrm{WIS}_j = \sum_{i=1}^{n} \frac{\mathrm{BS}_j\,(\mathrm{SES}_i+\mathrm{BC}_i+\mathrm{FP}_i)}{\mathrm{d}_{ij}},$$

where

WIS_j = watershed impact score for the j^{th} watershed,

BS_j = relative biomass supply for the j^{th} watershed (a push factor),

SES_i = socioeconomic status index for the ith community (a pull factor),

BC_i = business capacity index for the i^{th} community (a pull factor),

FP_i = forest policy impact index for the i^{th} community (a pull factor), and

d_{ij} = travel time between the j^{th} watershed and the i^{th} community.

Table 6.2—Ranges of nonstandardized community indices for Oregon and Washington (OR/WA), and Arizona and New Mexico (AZ/NM)

Region	Range of values of socioeconomic status index	Range of values of business capacity index	Range of values of forest policy impacts Index
OR/WA	0 to 2.82	0.30 to 2.58	0 to 1
AZ/NM	0 to 3.00	0.04 to 2.54	NA

NA = not applicable.

The implicit weights on the indices are 5, 4, and 1 for SES, BC, and FP, respectively, based on the number of variables they each contain. These weights can be adjusted to reflect the values of the policymaker.

Resulting Datasets

We produced nine gravity indices. Each gravity index represented a different combination of data on the numerator; all summed up the values at the watershed level for the nearest five communities and inversely weighted the total by the travel time between watershed and community. Our nine gravity indices included:

- Three simple WIS that incorporated only the standardized community condition variables (SES, BC, and FP indices).
- A WIS that summed these three variables together.
- A WIS that comprised only the relative biomass supply ranking.
- Three WIS that combined each of the community characteristics with the biomass supply ranking (e.g., SES weighted by biomass ranking).
- A comprehensive WIS that combined all information.

We created maps to illustrate how current community conditions translate into WIS, shown in figures 6.1, 6.2, and 6.3. While the WIS is designed for use in a geographic information system-based decision support system for full flexibility, static maps allow the resulting data sets to be displayed in multiple media. In addition, maps allow any stakeholder to visually identify areas where treatments may be able to have the largest positive impact on communities. A full set of maps will be presented in subsequent reports that will describe and interpret our results for both regions.

Current conditions at the community level (the nonstandardized SES, BC, and FP index values) are shown for OR/WA (fig. 6.1). Values are grouped into quintiles, where each quintile represents one-fifth of the observations. In all cases, the first quintile (shown in yellow) are the communities making up the lowest fifth of all the possible values. The dark blues (4^{th} and 5^{th} quintiles) are communities with characteristics that may be targeted by land managers as places to benefit from increases in supply.

We also mapped the relative potential biomass supply for OR/WA (fig. 6.2). The figure shows the volume removed for each watershed per treated acre, relative to the mean amount removed, and the contribution of each watershed to the total potential biomass (the value used in the WIS). The map displays the relative rankings in fifths, so the lowest group (watersheds in yellow) contributes the lowest amounts per acre or the last 20 percent of the total potential biomass supplied in the region. The watersheds in blue contribute either a high amount of biomass per treated acre

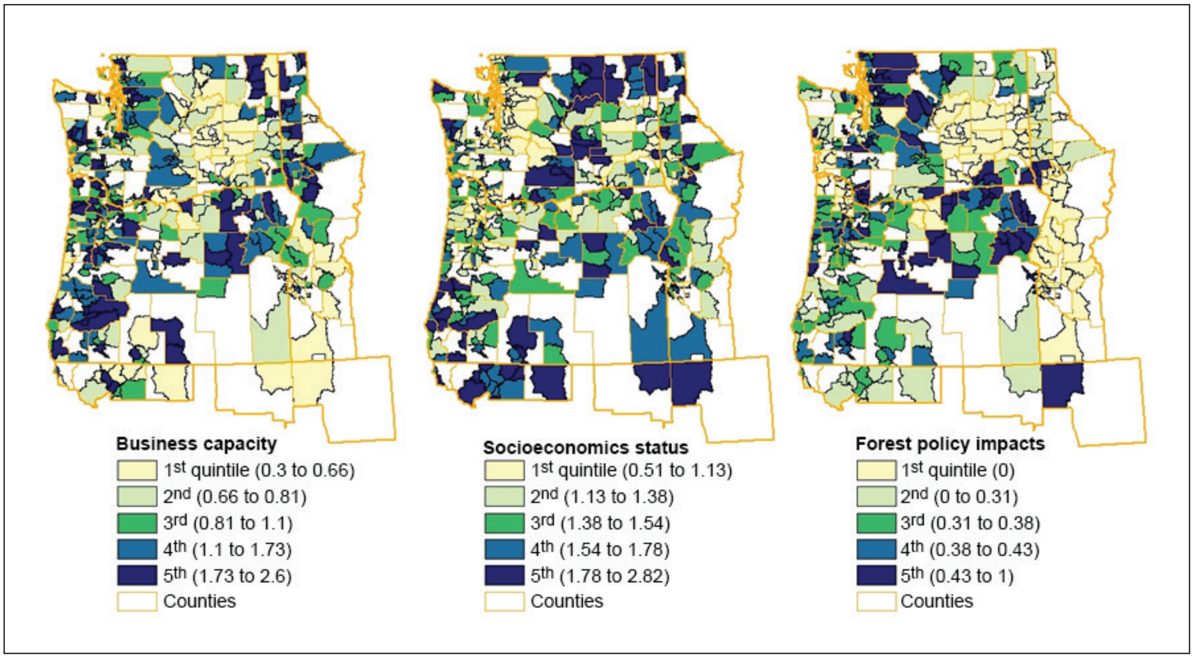

Figure 6.1—Community characteristics in the Pacific Northwest (Oregon and Washington). Data are grouped by quintile. Yellow indicates the lowest values of the indices. Communities in shades of blue are areas where managers may want to prioritize action, either because they have a high business capacity to utilize material, have low socioeconomic status and may benefit from stimulus, or because they have been impacted by changes in federal forest policy.

or a high amount of the total regional biomass potential. These watersheds have the potential to supply a large amount of material relative to other watersheds in the region.

Because the biomass calculation methodology was quite different between the OR/WA and AZ/NM, and the rankings were of each watershed relative to others in the region, maps and values are not comparable between regions in the same way as community conditions. In OR/WA, there was wide variation in potential biomass supply estimated between the heavily stocked east side of the Cascades in both states to the minimally forested Columbia Basin and southeastern Oregon. In AZ/NM, conditions are much less variable across the landscape, but OR/WA has the potential to produce far more overall biomass.

One possible configuration of the gravity index for OR/WA is shown in figure 6.3. In this case, the scores for each community index and the biomass ranking are added together and weighted by the distance between the watershed and the nearest five communities, as given in the formula above. The data are, however, flexible enough that a manager could compute a different gravity index by combining all community characteristics together or incorporating more nearby communities in the score.

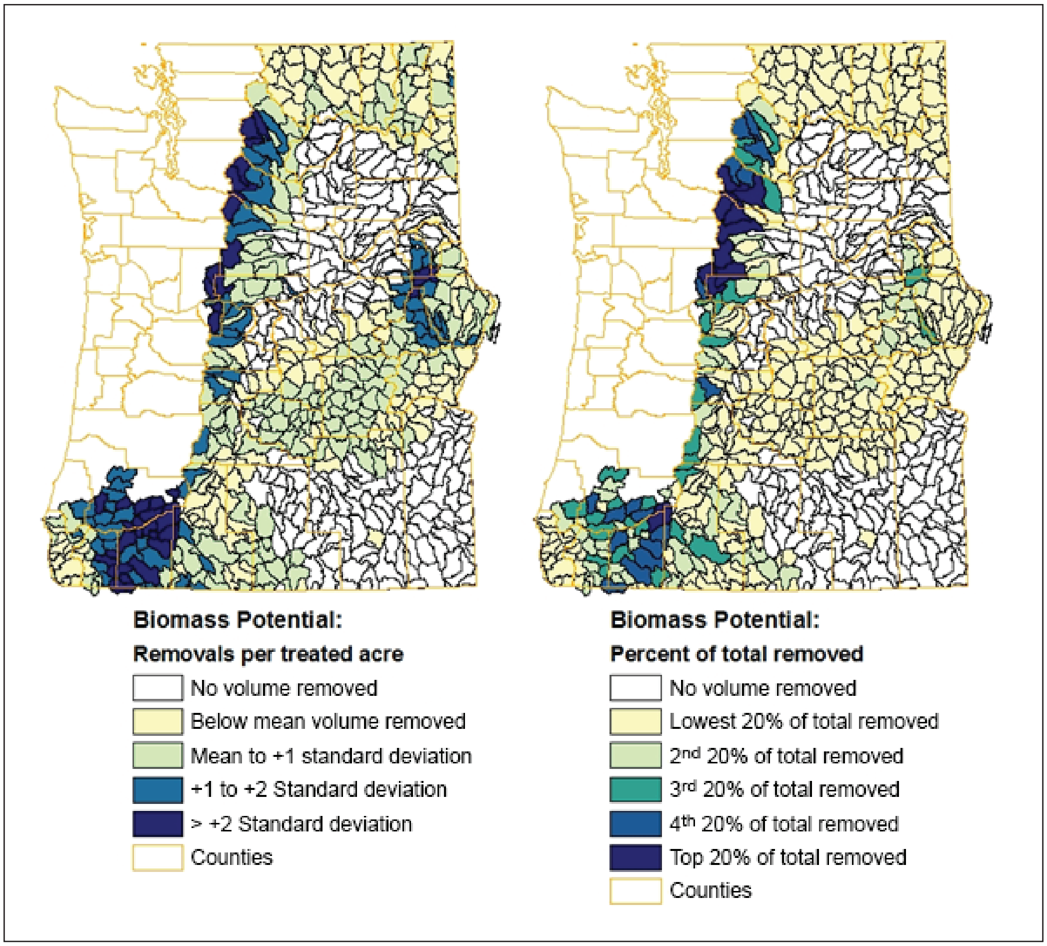

Figure 6.2—Biomass potential in the Pacific Northwest (Oregon and Washington). The map on the left shows the volume removed for each watershed per treated acre, relative to the mean amount removed. Watersheds in blues have a high amount of biomass potential per treated acre. The map on the right shows the contribution of each watershed to the total potential biomass. The watersheds in blue, again, contribute a high amount of the total regional biomass potential, and these watersheds have the potential to supply a large amount of material relative to other watersheds in the region.

Conclusions

Our goal was to provide a spatial data layer for inclusion in an EMDS system, similar to those provided by other teams of ILAP (see chapter 1). This knowledge-based system operates within ArcGIS and allows land managers or policy analysts to incorporate disparate information across landscapes and prioritize activities to meet management goals easily and flexibly. For example, layers showing the future condition of the forest in terms of wildlife habitat, fire hazard, and financial feasibility of treatments can allow managers to highlight watersheds for treatment that can meet all goals of reducing hazard, improving habitat, and having treatments pay for themselves.

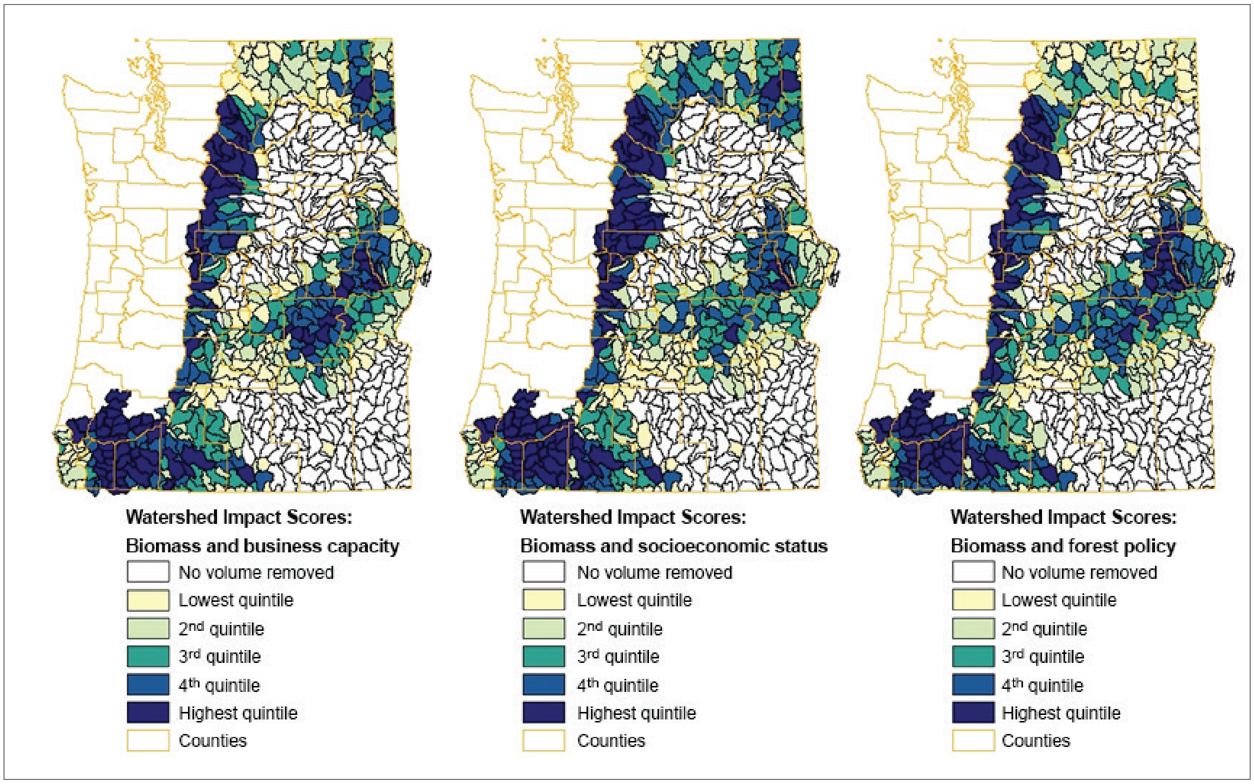

Figure 6.3—Watershed Impact Scores (WIS) for the Pacific Northwest (Oregon and Washington). These maps combine biomass potential with business capacity (left), socioeconomic status (center), and forest policy effects (right). Watersheds in yellow offer the lowest values for each combination, while watersheds in blues offer the highest potential in terms of both biomass and potential to contribute to communities with each of the characteristics. In all cases, the east side of the Cascades in both states along with southwestern Oregon consistently combine high biomass potential in watersheds near to communities who are in socioeconomic distress, have high business capacity, and have been affected by U.S. Forest Service policy. Areas of central Oregon (Grant and Union Counties) and northeastern Washington (Stevens, Pend Oreille, and Spokane Counties) show mixed potential, depending on which community characteristic is of importance.

The community economics information produced in this study allows managers or analysts to add an additional criterion that reflects potential effects of treatments on rural communities in the two regions. The data layer we provided for the EMDS system included nine gravity indices that can be mapped at the watershed level, along with other watershed-level information. Gravity indices are a useful tool for weighting conflicting factors that are spatially related. Distance matters to managers when considering where to place fuel treatments, as they must weigh the costs of removing the material against the benefits created by removing it. The material removed has an opportunity to benefit nearby communities, and the gravity index allows us to incorporate possible community weighing factors into the decision-making process. The compilation of already-existing data in this way allows managers to consider communities when choosing where to place fuel treatments on the landscape.

Distance matters to managers when considering where to place fuel treatments, as they must weigh the costs of removing the material against the benefits created by removing it.

However, there are limitations to this work. Because we want this tool to be replicated and updated in the future, we chose to use census data in many cases. This also allowed the use of a smaller level of geographic aggregation than counties. However, the use of census data resulted in a tradeoff between timeliness of the information for more geographically specific and readily available information. Most of the data were obtained from the 2000 Census, and yet we can expect that the fortunes of many communities, particularly rural, timber-reliant ones, have changed since then, as the United States entered a prolonged recession, and the reduction in demand for wood products was particularly felt in rural OR/WA. In addition, our WIS provides only a snapshot view of community conditions. With the release of the 2010 census data at the subcounty level (assuming no major changes in CCD boundaries occur), both updating and incorporating trend information into the community characteristic indices would increase the relevance of the WIS.

Although we tried to balance considerations of simplicity and accuracy when determining what to use as a community in this study, our boundaries and definitions are clearly somewhat subjective. Reliance on preexisting data limits the true accuracy with which researchers can define communities.

For this study, we made every effort to keep the methodology simple enough to be easily updated and expanded (updated when the new census information is released or expanded to other states). Nonetheless, there were more steps and complicating factors than we had anticipated, particularly in incorporating biomass estimates for watersheds. Still, it is our hope that versions of this work can be adapted to other locations with modifications as needed.

Across the dry forest regions of the west, forest health has declined and the risk for catastrophic wildfire has increased. At the same time, rural communities in the region have struggled in the face of declining harvests from public lands and losses in employment in traditional industries. Fuel treatments have been widely promoted as a way to improve forest health while providing jobs for rural residents skilled in forestry, but the fact that budget limitations will force managers to choose priority forest areas to treat is sometimes neglected. The ILAP project was developed to provide land managers with a way to account for multiple goals by creating a decision support system capable of combining disparate information about wildlife habitat, wildfire hazard reduction, and financial feasibility of treatments in order to inform their on-the-ground prioritization. The potential increase in supply material will not be dispersed evenly across the landscape, but will by necessity have the potential to benefit specific locations and not others, with concurrent benefits for particular rural communities. We developed the watershed impact scores as a way of incorporating information about communities into the prioritization of watersheds to treat. Our primary goal is that this analysis will help managers to understand the implications of actions in specific locations with respect to local communities, and to make intentional decisions when choosing where to act on the landscape.

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