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SCALE AND SOURCE OF GEOSPATIAL DATA FOR WILDFIRE RISK ASSESSMENTS: COMPARING NATIONAL DATA WITH LOCAL DATA IN THE DESCHUTES NATIONAL FOREST

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DESCHUTES NATIONAL FOREST

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ABSTRACT

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SCALE AND SOURCE OF GEOSPATIAL DATA FOR WILDFIRE RISK
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Chairperson: Dr. Anna E. Klene

Widespread use of geospatial data in environmental decision-making tools such as wildfire risk models has called attention to questions of availability, quality, and currency of input data layers. As wildfires are modeled with growing confidence and knowledge of how resources respond to fire is increasing, challenges must be addressed before geospatial data are acquired and used to represent resources of high value in wildfire risk assessments. Researchers at the Rocky Mountain Research Station and the Western Wildland Environmental Threat Assessment Center of the USDA Forest Service employ a framework for assessing wildfire risk to a range of human and ecological resources important in wildland fire management. This framework links spatially explicit fire behavior with potential fire effects and has been demonstrated to be scalable from national to project levels. Spatially identified resource "values" data are a necessary component to defining wildfire risk, and these data serve as baseline information useful in monitoring wildfire risk to resources of high value, as requested by various federal oversight agencies. Resources such as wildland-urban interface, critical habitat for plant and animal species, recreation infrastructure, and restoration of fire-adapted landscapes are important considerations in examining wildfire risk. A comparison study of "relative risk to resources" mapped at the national extent versus at the Deschutes National Forest extent provides a platform by which to discuss national data challenges of: (1) acquiring spatially explicit values data; (2) managing uncertainty surrounding these data; and (3) how use of these data for national assessments may alter or bias results. Relative patterns of wildfire risk to resources are demonstrated by plotting likelihood of burning against average simulated flame lengths for all pixels coincident with mapped values. Recommendations for describing spatial data uncertainty vary according to data type and associated metadata accounting for known errors. This research demonstrates a novel approach to exploring data uncertainties by comparing data developed for wildfire risk assessments at two different spatial scales.

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1. INTRODUCTION

Environmental models and assessments such as those used in measuring wildfire risk rely heavily on spatial data for model input and to accurately represent important infrastructure and natural resources. Often the results of these assessments are used to inform policy and management decision making. All too often, however, users of model results are unaware of the uncertainties associated with the data underlying these decisions (Hope and Hunter 2007). Geospatial data are widely available from Web and enterprise sources, but these data often have varying levels of associated documentation and metadata. Therefore, data limitations and uncertainties pertaining to the availability, currency, and consistency of spatial values data are particularly challenging for national and other broad-scale wildfire risk assessments.

Multiple reports from oversight committees strongly advise federal agencies to assess the effectiveness of management efforts to reduce wildfire risk to important human and ecological values (USDA - OIG 2006, GAO 2007, 2009). Reliable spatial data identifying privately-owned structures, natural and cultural resources, and critical infrastructure (USDA - OIG 2006), therefore, must be available for federal agencies to respond to these concerns and prioritize management decisions accordingly. While the multiple social and environmental dimensions of the wildfire risk problem challenge federal land management agencies, significant investments and improvements in the technology and science of wildfires have been made to better understand wildfire risk and prioritize placement of hazardous fuels treatments (Ager et al. 2007, Ager et al. 2010, Calkin et al. 2010, Finney et al. in press). However, national data challenges persist and must be addressed in order to improve future wildfire risk assessment efforts.

2. BACKGROUND

2.1. Defining risk

Broadly speaking, risk assessments examine the likelihood of an unwanted event and assess the resulting impact to identified resource values should the event occur (Fairbrother and Turnley 2005). Values of important human and ecological relevance needed for wildfire risk assessment include, but are not limited to: wildland-urban interface, critical habitat for plant and animal species, recreation resources and infrastructure, and fire-adapted landscapes with restoration priority which could benefit from fire. The Society for Risk Analysis (2010) defines risk as "the potential for realization of unwanted, adverse consequences to human life, health, property, or the environment," and states that risk is a product of the expected likelihood of an event occurring multiplied by the resulting value change, conditioned upon the event occurring. The Environmental Protection Agency (EPA) risk assessment paradigm echoes the above definition and identifies exposure and effects analysis as being two essential components of risk assessment (EPA 1998). Exposure analysis considers the probability, magnitude, and spatiotemporal association of the event, while effects analysis examines the related response of defined resources to the predicted event (Fairbrother and Turnley 2005). Risk assessments have broad applications ranging from the insurance and health sciences industries to the natural sciences and ecological applications. Regardless of the community served by the assessment, the basic tenants of these assessments are the same. They serve to provide managers with some information about the likelihood of future events and provide a basis for understanding the magnitude of the consequences; all in an

effort to identify a means by which damage or harm from those events might be mitigated (Fairbrother and Turnley 2005).

2.2. **Wildfires and risk assessment**

In the context of wildfire risk assessment, fires are considered the hazardous event and risk assessment examines the probability of fire occurring, the scale and intensity of the predicted wildfire (exposure analysis), and the effects of the fire on resource values of concern (Finney 2005). One important distinction (usually present) between wildfire and ecological risk assessments is that fire is not always an unwanted event or disturbance (as reflected in the current Federal Wildland Fire Management Policy (FEC 2009)). Therefore, it is necessary to consider not only the potential losses of a wildfire event, but also the benefit to ecosystems in need of restorative fuels treatments (Finney 2005, Scott 2006, Kerns and Ager 2007, Keane and Karau 2010). While fire of any intensity is unlikely to ever benefit residential structures in the wildland-urban interface (WUI), a wildfire may improve wildlife habitat and result in prevention of future losses by restricting the spread of subsequent fires under potentially more severe fire weather (Scott 2006, Keane et al. 2008). Therefore, wildfire risk must consider the cumulative *benefits* and *losses* sustained by all identified resource values to fires of varying intensity.

While multiple risk-based measures such as burn probability profiles and scatter plots can be derived (Ager et al. 2010), a common measure of risk is based on the quantitative definition of Finney (2005), which considers both fire behavior and fire effects (see also Ager et al. 2007, Bar Massada et al. 2009, Calkin et al. 2010, Thompson et al. 2010):

$$E[nvc] = \sum_{i=1}^{N} \sum_{j=1}^{n} p(F_i) \left[B_{ij} - L_{ij}\right]$$

where

  E[nvc] = risk

  p(F$_i$) = the probability of the ith fire behavior, and

B_{ij} and L_{ij} = the respective benefits and losses for the j_n^{th} value from the i_N^{th} fire behavior.

      Restated, risk is represented in terms of net value change (*nvc*), which is the product of burn probability at a given fire intensity (*p(F$_i$)*) and the resulting losses and benefits for all (N) fire behaviors and (n) values. Calculating risk at a given geographic location, therefore, requires spatially defined estimates of the likelihood and intensity of fire associated with identified resource values (Calkin et al. 2010).

      Quantitative wildfire risk assessments using this framework have been demonstrated at various geographic scales. Applications of this methodology at the landscape scale map risk to northern spotted owl (*Strix occidentalis* caurina) in a forest planning area in Central Oregon (Ager et al. 2007) and compare treatment alternatives in the wildland-urban interface with those preserving old forest structure (Ager et al. 2010). Calkin et al. (2010) employed this framework to examine wildfire risk to a range of human and ecological values nationwide to serve as a baseline assessment for resources of high value while noting the challenges in acquiring resource values data for a project of this scale. Therefore, successfully expanding this framework to assess national wildfire risk requires nationally modeled fire behavior data and nationally consistent resource values data.

Past efforts to model fire behavior at the national scale were challenged by technological and data limitations; however, recent advances in computing technology and nationally consistent fuels data through the LANDFIRE project (Rollins and Frame 2006) have made many of these products available. Finney et al. (in press) developed a simulation model to generate fire behavior data for 134 Fire Planning Units (FPUs) across the coterminous U.S. The Large Fire Simulator (FSim) employs historic weather and fire data to simulate large wildfire events (i.e. those that escape initial attack) over 10,000 to 50,000 simulated fire seasons. The outputs include burn probability maps at a 270×270 m resolution with corresponding conditional burn probabilities at each of six flame-length categories (0 - 0.6, 0.6 - 1.2, 1.2 - 1.8, 1.8 - 2.4, 2.4 - 3.7, and >3.7 m)[1]. The FSim model is scalable and is only restricted in output resolution by input fuels data resolution. Outputs can be as fine as 30×30 m resolution where the size of the analysis area allows for model processing without limitations. Validation efforts by Finney et al. (in press) demonstrate promising correlation between simulated burn probabilities and fire sizes relative to historic observations. The authors suggest confidence in use of these data to inform wildfire impacts to important ecological and economic resources.

2.3. **Values data for wildfire risk assessment**

The challenges to national wildfire effects analysis stem from issues of national data availability and completeness coupled with information about how identified resource values respond to fire. Once resources are spatially defined with the necessary attributes to separate resource values of high priority and with sufficient spatial precision,

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[1] These flame lengths correspond to 0-2, 2-4, 4-6, 6-8, 8-12, and >12 ft as output by the FSim model.

the remaining portion of the wildfire risk equation is to quantify benefits and losses by identifying resource response to fire of varying intensity.   A number of approaches exist to describe or quantify resource responses to wildfire. The Fire Effects Information System (FEIS, USDA Forest Service 2010) is a library database system which provides access to information about how organisms, soil, water, and air are impacted by wildland fires. Ager et al. (2007) used the forest vegetation simulator (FVS) to identify stand-specific flame length thresholds to identify fire effects to northern spotted owl habitat. Keane and Karau (2010) developed an approach to model burn severity and assess ecological benefits of wildfire by integrating fire behavior with the First Order Fire Effects Model (FOEFM) of Reinhardt et al. (1997). Calkin et al. (2010) employed stylized response functions to characterize the range of potential benefits and losses to a specific resource over varying flame lengths and linked response functions with burn probabilities at four flame length categories. These research efforts, combined with more information from specific resource specialists, will continue to improve fire effects analyses at the national level. However, the first step in defining national wildfire risk is to accurately and consistently spatially identify where resources of value exist on the landscape.

Multiple efforts are underway to employ and eventually improve upon nationally consistent datasets to inform wildland fire management and wildfire risk assessments (e.g. Fire Program Analysis (FPA 2010) and Wildland Fire Decision Support System (WFDSS) (Calkin et al. 2010, WFDSS 2010). Recent events, including natural disasters and terrorist attacks, have catalyzed development of human infrastructure data, resulting in enterprise databases of federally and commercially managed geospatial data (e.g.

geodata.gov, data.gov, nationalatlas.gov, and the Homeland Security Infrastructure

Program (HSIP)).   Natural resource data, on the other hand, are most often collected and

compiled at the district, forest, or local unit level within the jurisdictional federal agency.

For example, threatened and endangered species habitat and recreation values are often

mapped at a local scale and limited geographic extent (for example, National Forest,

National Park, or Wildlife Refuge boundary), resulting in data that do not accurately

represent the full habitat or resource extent. In order for these data to be used in national

mapping exercises, data must be compiled from all local units and integrated into larger

or national datasets. Currently, these endeavors are time intensive and often result in

datasets with gaps where geospatial data are unavailable or incomplete. Nelson (2009),

Executive Director for the Urban and Regional Information Systems Association, asserts

in her letter to the U.S. Congress that current efforts to voluntarily supply the data needed

by all levels of government is inefficient and uncoordinated, resulting in a lack of

available data during natural or manmade disasters – when the data need is most critical.

She continues to propose a "mechanism to create and maintain critical spatial datasets,

such as property records, aerial imagery, and topography" to be readily available

nationwide (Nelson 2009).

This same authority and national scope is needed to assemble natural and cultural

resource data produced by federal land management agencies. Although the federal GIS

community is engaged in this dilemma, as evidenced by projects like Wildland Fire

Decision Support System (WFDSS) and Fire Program Analysis (FPA), the solution of

consistent data in scale, currency, attributes, and mapped extent is likely years away.

Federal land management agencies must work together to establish data standards that

create consistent resource data across management boundaries. In the interim, many of these datasets must be used despite known uncertainties because alternatives do not exist and it is simply infeasible to create/recreate them without a significant and burdensome effort (Agumya and Hunter 1999).

2.4. **Uncertainty in wildfire risk assessment data**

Wildfire risk assessment lies at the interface of policy and science. In other words, decisions must often be made in the face of uncertainties, with imperfect data rather than fact (Borchers 2005, van der Sluijs 2007). Environmental assessments that examine unpredictable natural events, by their very nature, contain some degree of uncertainty. Although some of these uncertainties may be reduced through additional research and data collection, addressing and analyzing uncertainty illustrates the degree of confidence in the assessment and can help managers prioritize research efforts to reduce uncertainty (EPA 1998).

Data uncertainty, in the uncertainty typology described by Ascough et al. (2008), is categorized as a sub-type of knowledge uncertainty (referring to the limits of one's understanding). For example, species habitat is often defined in terms of the vegetation types believed to indicate habitat suitability. Data uncertainty stems from knowledge uncertainty about all of the necessary ecological components required by a species. These uncertainties are then propagated in the habitat boundary delineation based upon the vegetation characteristics comprising suitable habitat. Geospatial data, as illustrated, are inexact abstractions or interpretations of reality; and as such, they inherently contain some level of uncertainty (Hope and Hunter 2007). Therefore, geospatial data reflect not

only human limits of understanding and knowledge, but our inability to create spatial representations of real world phenomena with absolute certainty.

Multiple forms of uncertainty are present in the geospatial datasets examined herein and these types of uncertainties can have significant impacts on model outcomes and subsequent decision making (Maier et al. 2008). Maier et al. (2008) classifies data uncertainty as follows:

(1) "Measurement error" refers to information about how the data are recorded. This type of information is usually included in the metadata associated with spatial data.

(2) "Type and length of data record" refers to collection error stemming from time constraints and limited financial resources. This results in inaccurate and skewed representations of the real world phenomenon being recorded.

(3) "The way data are analyzed, processed, and presented" contributes to error and bias whereby data users generate uncertainty by emphasizing certain datasets, results, and factors over others.

According to Goodchild (1998), geospatial data uncertainty refers to "all that the database does not capture about the real world, or the difference between what the database indicates and what actually exists out there." When data are compiled from disparate sources (as with the national resources described above) with absent or varying levels of producer documentation, one cannot account for the dataset's divergence from real world observations. In light of this, a formal quantitative uncertainty analysis examining error propagation in the risk assessment is not possible (Goodchild 1998). Yet

information about how data uncertainty may adversely affect decisions and the degree to which a spatial database is used in decision making are critical components for assessing uncertainty impacts (Zwart 1991).

The term 'uncertainty' is often chosen to communicate hesitancy in the use of a spatial database when formal knowledge of error and error propagation throughout the model and geospatial processing are not available or documented (Hunter and Goodchild 1996). When a quantitative assessment of spatially explicit error cannot be conducted to identify the amount of uncertainty, other methods are required. The recommendations for addressing spatial data uncertainty vary widely according to the type of spatial data, the end users, the type of information available, and the type of uncertainty to be addressed. Goodchild (1998) recommends first identifying and describing the observed data uncertainties. In this research, a case study comparing locally developed to national datasets is used to identify observed differences in data at these respective scales. Presumably, data produced at a local-level, by individuals better able to assess their completeness and accuracy, are subject to fewer sources of uncertainty.

The fundamentally geographic topic of scale (Wiens 1989) is at the core of this research and must also be considered. The study area extent, the data describing the natural and constructed environment, and the resulting effects of the natural process like wildfire on the human and ecological values therein (and vice versa) are all subject to questions of scale and topics of geographical relevance. Space and place are central tenants of the geographic discipline and as stated by Howitt (1998), "…it is the interaction of environment, space and place (and scale) that is fundamental in creating the geographies that we study."

Geographers have long described their observations of the earth, and today those observations are frequently recorded as spatial data. The success then of accurately and completely describing these observations with respect to spatial extent and spatial accuracy is the underpinning of this study. Scale in this research applies to the mapped expanse of the datasets used, the map scale that describes the difference between the distance represented on the map and the distance on the ground , the grain size or resolution of the data, and also in reference to the extent of the analysis area (Quattrochi and Goodchild 1997).

Chen et al. (2003) note the importance of socioeconomic data in hazard and risk assessments of bushfires in Australia, recognizing that the scale of the assessment and subsequent decision making is highly dependent upon data availability and reliability. For example, census blocks, street blocks, and individual residence points all define human populations with different levels of detail (Chen et al. 2003). Further, spatial data are defined in areal units that can be somewhat arbitrarily defined. This quality of spatial data has been characterized as the Modifiable Areal Unit Problem (MAUP, Openshaw 1984) which describes the impact that zoning (drawing discrete boundaries for continuous resources) and aggregation (combining resources from neighboring zones) can have on assessment results. The data evaluated in this case study should be examined in light of the MAUP and other scale-related issues often pervasive in geospatial data.

2.5. **Research Questions**

The comparison presented in this study will, at a minimum, facilitate a discussion of the challenges associated with acquiring resource-specific geospatial data at the

national scale and highlight the specificity gained in finer-scale risk assessments. This study operates under the assumption that resource data developed at the local level are more likely to be accurate and field validated than are their national counterparts. The following questions are addressed:

(1) How do the data available for these assessments and our understanding of resources vary based upon the area for which they were developed?

(2) Does relative risk to each resource vary across the two project scales as a result of differences in geospatial values data and/or differences in fire behavior data?

(3) Is wildfire risk over- or understated with respect to certain resources due to their mapped extent, completeness of the database, and/or associated attribute records?

(4) Can national assessment resource value data be improved by examining input data from a finer scale assessment? How can these improvements refine effects analysis for future risk assessments?

(5) What is the best way to move forward with imperfect data?

This exploration of national scale data limitations is intended to highlight areas where careful interpretation and application of wildfire risk assessment results might be warranted. As mentioned previously, risk assessment and model results rely heavily on the geospatial data that are input to the algorithm. Users of these outcomes are likely to make more informed decisions when armed with knowledge about geospatial data uncertainties.

3. DATA AND METHODS

Geospatial data collected for use in wildfire risk assessment were compared to assess the differences in relative risk resulting from use of national-level resource values and Forest-level values. These data layers were interacted with spatially explicit fire behavior data at two different pixel resolutions to identify relative fire exposure. Additionally, local data were then compared to national-level fire behavior data to examine whether relative risk changes with respect to input resource-values data from finer-scale assessments. Further, relative risk to each resource was examined through the use of risk scatter plots to compare results from both project scales.

Questions 1 and 2 were addressed through a discussion of uncertainty typologies observed in the national data and by examining resource maps comparing spatial differences in how resources were defined at both scales. Research questions 3-5 are further explored in the Discussion Section (Chapter 5) with respect to the comparison results.

3.1. Study area

The Deschutes National Forest and surrounding areas serve as the analysis boundary for this comparison project (Figure 1). Recent work by Ager et al. (2010) and additional unpublished research by these authors examines wildfire risk to a number of important social, economic, and ecological resources across the Deschutes National Forest (DNF). This work uses the exposure and effects analysis framework described previously to assess wildfire risk, and employs the quantitative definition of risk which considers both fire behavior and resource values (Finney 2005). Additionally, many of the values defined for the DNF are consistent with those identified for the national

wildfire risk assessment completed by Calkin et al. (2010) and select resource themes serve as inputs to the analysis presented here. This comparison presents an opportunity for evaluation of a consistent methodology, consistent input data themes, and fire behavior information generated by the FSim model for risk assessments at two different spatial scales and analysis extents.
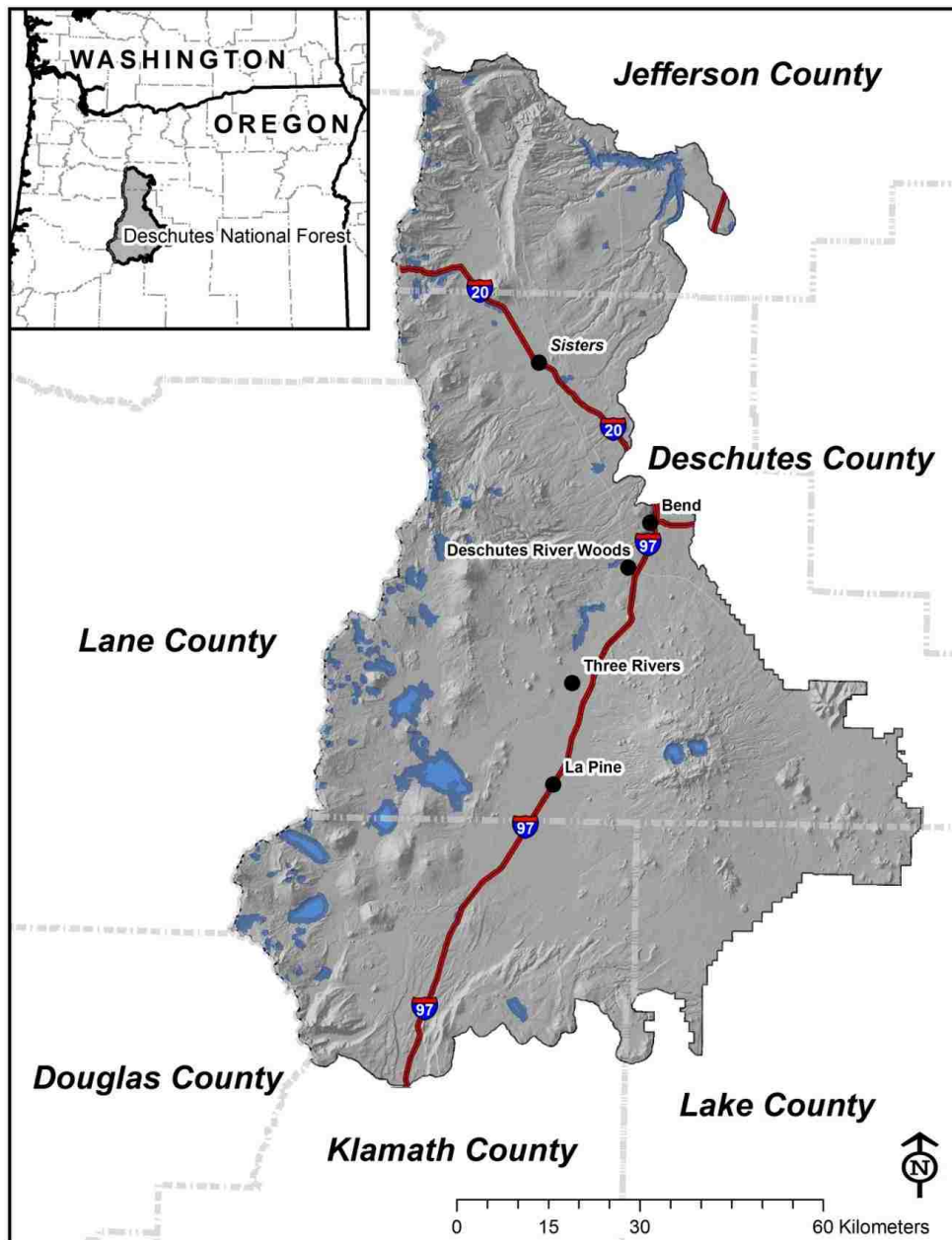
Figure 1. Overview and study area map as defined by the Deschutes National Forest.

3.2. **Fire Behavior Data**

Simulated fire behavior data used in this assessment were obtained from the Fire Program Analysis (FPA) Large Fire Simulator, hereafter referred to as FSim (Finney 2007, FPA 2010, Finney et al. in press). FSim incorporates historic weather and ignitions data (location and frequency) and interacts with spatial vegetation data to generate spatially explicit burn probabilities. The model runs 10,000 - 50,000 simulated weather years to predict wildfire ignition and growth. Information within the simulated weather years include Energy Release Component (ERC) from the National Fire Danger Rating System (NFDRS) to represent fuel moisture (Zachariassen et al. 2003), daily and seasonal weather variability, and patterns of wind speed and direction from historic weather records. The model uses data from LANDFIRE for fuels and topographic inputs and generates random ignitions based on relationships within historical fire and weather records.

Data used for national-level risk assessments were generated at a 270×270 m pixel resolution for the continental United States (Finney et al. in press). At the Deschutes National Forest level, FSim data were generated at a resolution of 90×90 m pixels using a combination of stand-level DNF vegetation information and modified LANDFIRE fuel models (Vaillant 2010, personal communication, 9 September 2010). For both the national- and Forest-level based simulations, model outputs include: (1) spatially explicit burn probabilities (BP) calculated as the number of times each cell burned divided by the number of simulated years, (2) the size distribution for all fires simulated within each Fire Planning Unit (FPU), and (3) the conditional burn probability within each flame-length category for every pixel (Finney et al. in press). The two FSim

products analyzed in this study include BP and conditional flame length (CFL).   While

BP is a product generated directly from FSim, CFL is a calculated output representing a

probability weighted average flame length for all simulated fires that burned in a given

pixel. CFL is calculated as follows:

$$CFL = \sum_{fl=i}^{n}(BP_i * \bar{X}_i)$$

where fl is a flame-length category, $\bar{X}$ is the mid-point of the flame lengths (measured in

feet) of the ith category, and BP_i is the marginal burn probability of the ith flame length

category, conditioned upon the pixel burning.   Flame-length categories in FSim include:

(0 - 0.6, 0.6 - 1.2, 1.2 - 1.8, 1.8 - 2.4, 2.4 - 3.7, and >3.7 m).[2]   Conditional flame length

for a hypothetical pixel could be calculated as:

CFL = (0.088*1) + (0.000*3) + (0.000*5) + (0.044*7) + (0. 622*10) + (0. 244*12).

For this example, CFL is equal to 9.5 feet (or approximately 2.9 meters). CFL estimates

the average simulated flame length for fires that burn within a given pixel, conditioned

upon the probability that the pixel burns. BP and CFL together make up the fire-behavior

component of the quantitative wildfire risk definition (Finney 2005) and describe both the

likelihood of fire and the average intensity (or flame length) expected.

3.3. **Geospatial Resource Values**

Geospatial resource values data examined for exposure and relative risk analysis

are categorized as follows: wildland-urban interface (WUI), northern spotted owl habitat

and home range, recreation values, and fire-adapted ecosystems. Table 1 displays the

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[2] These flame lengths correspond to 0-2, 2-4, 4-6, 6-8, 8-12, and >12 ft as output by the FSim model.

data layers and respective sources for all datasets analyzed. The categories above were chosen primarily for reasons pertaining to relevance to wildland-fire management and policy implications and the opportunity to explore national-scale data limitations. Specifically, the data themes were selected in accordance with the directive by the USDA Office of Inspector General (2006) that the Forest Service, at a minimum, "*needs to quantify and track the number and type of isolated residences and other privately-owned structures affected by the fire, the number and type of natural/cultural resources threatened, and the communities and critical infrastructure placed at risk*" (USDA - OIG 2006, p. 25). Additionally, one of the goals of "A Collaborative Approach for Reducing Wildland Fire Risks to Communities and the Environment: 10-YearStrategy" of 2001 is to "restore fire-adapted ecosystems" (Western Governors' Association [WGA] et al. 2001). The final reasoning for the selection of the four data themes was the opportunity to compare the different datasets at two different geographic scales.

Table 1. Datasets and respective sources for layers examined in this assessment.

Dataset	Source	
	National Level	**Deschutes Level**
Fire behavior	270 × 270 m FSim Fire Program Analysis (www.fpa.nifc.gov) Processed and compiled by USDA RMRS	90 × 90 m FSim Generated and provided by USDA PNW Research Station and WWETAC

Recreation	FS Campgrounds - http://fsgeodata.fs.fed.us/vector/index.html
	
	Ranger Stations- ESRI Data and Maps 9.3
	
	BLM Recreation Sites and Campgrounds- http://www.geocommunicator.gov/GeoComm/index.shtm
	
	NPS Visitor Services, Campgrounds & National Trails - http://www.nps.gov/gis/data_info and Facility Maintenance Software System
	
	FWS Recreation Assets - USDI Fish & Wildlife Service (FWS)
	
	National Alpine Ski Area Locations
	    National Operational Hydrologic Remote Sensing
	    Center - http://www.nohrsc.noaa.gov/gisdatasets/
		Deschutes N.F. Recreation Data
		DNF Land Resource Mgmt Plan (LRMP)

WUI	SILVIS - http://silvis.forest.wisc.edu	Deschutes, Jefferson, & Klamath County cadastral data Provided by the Counties to FGDC Cadastral Subcommittee & RMRS
Northern spotted owl habitat	NSO Critical Habitat - U.S. Fish and Wildlife Service Critical Habitat Portal (http://crithab.fws.gov/)	NSO Critical Habitat - U.S. Fish and Wildlife Service Critical Habitat Portal NSO Home range circles - provided by WWETAC/DNF staff
Fire-adapted Ecosystems & Priority Treatment Areas	Fire-adapted ecosystems LANDFIRE map products - http://www.landfire.gov	Restoration Priority Areas - The Nature Conservancy

3.3.1. <u>Wildland-Urban Interface: SILVIS and Cadastral data values</u>

Wildland-urban Interface (WUI) at the national level is represented by the nationally mapped SILVIS WUI product from the University of Wisconsin (Radeloff et al. 2005). The Federal Register defines WUI as "the area where houses meet or intermingle with undeveloped wildland vegetation'' (USDA and DOI 2001). The SILVIS product identifies areas of wildland vegetation adjacent to houses ("Interface WUI") and areas of intermixed housing and vegetation ("Intermix WUI") according to the housing density requirements defined in the Federal Register, using housing unit counts from the 2000 U.S. Census Bureau, and vegetation data from the U.S. Geological Survey National Land Cover Data (Radeloff et al. 2005). Housing unit counts are summed within census blocks and a density ratio is obtained by divided by the number of units by the area of the associated census block (Radeloff et al. 2005). The area mapped by a census block can vary from small areas in urban settings, to many square miles in rural areas (US Census 2001). All areas defined as WUI, including the Intermix and Interface categories defined previously, within the analysis area were selected as inputs for risk scatter plots and analysis in this study.

Cadastral data available for the study area include: Deschutes, Jefferson, and Klamath Counties, Oregon[3]. These data are available through the Parcel Data and Wildland Fire Management Project of the Federal Geographic Data Committee's Subcommittee for Cadastral Data to coordinate cadastral data in support of wildland fire

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[3] Lake County cadastral data was unavailable for this study and therefore not analyzed. Due to the lack of WUI identification in Lake County, this cadastral data omission was deemed irrelevant for comparisons of relative risk to identified resources.

management, planning and response (Stage et al. 2005). Researchers at the USDA

Rocky Mountain Research Station partnered with members of the Cadastral

Subcommittee to prepare parcel centroids (the geometric center of a parcel) for parcels

with an identified improvement value greater than zero. These centroids were generated

nationally for all data collected through the Parcel Data and Wildland Fire Management

Project (Stage et al. 2005). These points, called "building clusters," serve to represent

one or more improvements (generally residential structures) for strategic use by wildland

fire management agencies (Calkin et al. in press). A case study by Calkin et al. (in

press) demonstrated 90% overall accuracy for building clusters compared to GPS

structure locations within a 100 m distance tolerance. This level of accuracy is arguably

sufficient for strategic response and planning efforts such as wildfire risk assessments.

Building cluster points for Deschutes, Jefferson, and Klamath Counties were converted to

raster grids for the purposes of the comparative data study described herein. These data

are referred to as "cadastral" for the remainder of this paper.

3.3.2. Northern Spotted Owl Habitat

Nationally mapped northern spotted owl (*Strix occidentalis* caurina) critical

habitat, available from the U.S. Fish and Wildlife Service, generally identifies habitats

considered essential for conservation of this listed species (USFWS 2008). Northern

spotted owl critical habitat was included in a larger national critical habitat dataset as one

of the resource value layers acquired for the wildfire risk assessment demonstrated by

Calkin et al. (2010). Additionally, one of the goals identified in the Land and Resource

Management Plan (LRMP) for the Deschutes National Forest (DNF) is to manage habitat

to increase carrying capacity of northern spotted owls (USDA Forest Service 1990). At

the DNF level, northern spotted owl is represented by two datasets including: northern spotted owl critical habitat units and home range (active and potential nest sites or "owl circles"). These data were made available by Western Wildland Environmental Threat Assessment Center (WWETAC) and DNF personnel for the purposes of this study.

3.3.3. Recreation values

Recreation values acquired for the national analysis consist of six sub-category data layers including: U.S. Forest Service Campgrounds (FS) and Ranger Stations, Bureau of Land Management (BLM) Recreation Sites and Campgrounds, National Park Service (NPS) Campgrounds and Visitor Centers, Fish and Wildlife Service (FWS) Campgrounds, National Scenic and Historic Trails, and National Ski Areas (Table 1). FS Campgrounds were obtained from the FSGeodata Clearinghouse, Vector Data Gateway (USDA FSGeodata 2008). The "Miscellaneous Points" layer was used along with associated metadata to identify points labeled as FS campgrounds. Bureau of Land Management (BLM) Recreation Sites and Campgrounds were obtained from GeoCommunicator's National Integrated Land System (NILS) GIS Web service (BLM 2008). Recreation Sites and Campgrounds are two separate data layers that were combined to create the BLM Recreation layer. National Park Service Visitor Services and Campgrounds were downloaded from the NPS Data Store (Williams 2003). Selected attributes include Campgrounds, Headquarters, Lodges, Museums, Ranger Stations, and Visitor Centers. Within this dataset, some resources known to exist were absent from the records (e.g. lodges in Glacier National Park). The NPS Facility Maintenance Software System contains NPS building locations, facility names, and assigned dollar values. Using building names, all hotels and lodges were extracted and then matched with the

original NPS Visitor Services data layer to identify missing hotels and lodges. U.S. Fish and Wildlife Service (FWS) provided recreation asset data for all Regions. Campgrounds were extracted from the dataset provided, but there was no distinction between developed and undeveloped campgrounds. All records labeled "campgrounds" were included in the final recreation layer. Additional latitude and longitude points were provided for known FWS Visitor Centers and Environmental Education Centers in existence in 2007.

National Scenic and Historic Trails were obtained from the NPS Data Store (NPS 2003). This dataset contained 12 trails of National Scenic and Historic designation: the Appalachian Trail, Trail of Tears, Pony Express, Oregon Trail, Mormon Pioneer, Lewis and Clark Trail, El Camino Real de Tierra Adentro, California Trail, Iditarod Trail, North Country Trail, Ice Age Trail, and the Juan Bautista De Anza. An additional four datasets were added to represent trails not included in the NPS Data Store layer. These trails include: Continental Divide Trail, Pacific Crest Trail, Florida Trail, and Natchez Trace Trail. Although the dataset has known gaps, this final layer contained 16 of the 26 trails included in the National Trails system. Trails present in the Deschutes National Forest study area are limited to the Pacific Crest Trail. According to the national trails map (NPS 2010), this is accurate, indicating no data gaps exist within the study area.

Ranger stations were extracted from the "glocale" layer in the Environmental Systems Research Institute (ESRI®) Data and Maps v.9.3 database by selecting "ranger stations" identified in the attribute records. This dataset contains ranger stations located primarily on NPS and FS lands and records indicate both operational ranger stations and historic stations (no longer in use) are identified.

Lastly, a complete geospatial layer of national alpine ski areas could not be located for this study. National Operational Hydrologic Remote Sensing Center (NOHRSC) hosts access to a dataset of "Skiing Locations" in the lower 48 states (NOHRSC 2007). The dataset was reduced to alpine skiing locations only, due to the likelihood of developed infrastructure, as identified by associated attribute records. A Google Earth® .kml file titled "Geotagged Ski Areas U.S.," a visual comparison in Google Earth, and Web searches on the status of specific ski areas were used to modify the NOHRSC dataset to eliminate ski areas that no longer exist or whose locations were incorrectly reported to NOHRSC. The National Ski Area Association (NSAA) website was referred to for current statistics, in an effort to match geospatial data records with the correct number of ski areas by state. According to NSAA (2010), there were 481 total ski areas at the time of the original data collection (2007-2008). Presently, 471 ski areas are reported by the NSAA. It is likely that infrastructure for the ten closed ski areas is still in place and therefore valuable. In light of this, these data are likely still relevant for analysis of resource values at risk. The final data layer in the recreation resource layer includes 469 downhill ski area points approximating the ski area's main lodge – three-quarters of which were edited to correct original latitude and longitude assignment. In order to represent more of the ski area features potentially at risk of wildfire, these points were buffered by 1.6 km (1 mile).

Recreation values for the Deschutes National Forest used in this study include intensive, dispersed, and winter recreation management areas identified by the Deschutes LMRP, along with Wild, Scenic, and Recreational River areas. The LMRP identifies recreation goals that provide high quality recreation opportunities within these

management areas (USDA Forest Service 1990). While the national recreation values are represented primarily by points and lines identifying recreation sites, these management area boundaries highlight entire areas of recreation opportunity rather than specific recreation infrastructure or features.

3.3.4. <u>Fire-adapted Ecosystems and Restoration Priority Areas</u>

The dataset representing national fire-adapted ecosystems was built from portions of the LANDFIRE (Rollins and Frame 2006) database to define areas where fire was historically significant and where fire might be used as a management tool to re-introduce fire and more closely emulate historic fire regimes. The Fire Regime Groups product was used to identify pixels in a fire regime where fire frequency was less than 200 years, and where fire was low to mixed severity.   Selected codes from the Percent Low-severity Fire product identifies pixels where the percentage of low-severity fire under the presumed fire regime exceeded 50% (Calkin et al. 2010). The intent of this layer was to identify where non-lethal fire occurrence was historically part of ecosystem maintenance, not as a measure of departure from that presumed regime. The datasets were re-sampled to 1×1 km and combined in overlay analysis. Selected pixels had a fire regime group code of 1 or 3 and percent low severity fire code 11 through 20 (Calkin et al. 2010).

Restoration priority areas were defined by The Nature Conservancy for the Deschutes National Forest as fire-adapted vegetation types and stands that have a high degree of departure from historic fire regimes (The Nature Conservancy 2010). This 30×30 m dataset was built with a combination of plant association groups matched to biophysical setting (BpS) to describe potential historic vegetation, and correlated with fire-regime condition classes to identify stands that appear to be substantially different

from historic conditions. Selected pixels met the following criteria: contained ponderosa pine and dry mixed conifer species matching Fire Regimes I and III, had a successional stage with the greatest degree of historic condition departure (Condition Class 3), and had greater than 40% canopy closure (The Nature Conservancy 2010). This layer follows a similar logic to the fire-adapted ecosystems used in the national level analysis. However, restoration priority areas were developed with a methodology refined by stand-level data at a finer spatial resolution and include a departure index to identify areas for priority landscape restoration.

3.4. **Data Processing**

Data originated from various sources with formats ranging from vector data in point, line, and polygon form to raster data with various pixel resolutions. ESRI® shapefile data were converted to raster and matched to the extent and resolution of the respective fire-behavior data using the ArcGIS 9.3.1 and ArcGIS 10 toolboxes and Spatial Analyst extension. This data processing and preparation ensured that all pixels aligned across all raster layers for each analysis. Resource value layers were reclassified to binary (zeros and ones) values and clipped to the study area boundary. All national input layers, therefore, were converted to 270×270 m raster grids and Deschutes data were converted to 90×90 m raster grids.

3.5. **Analysis Methodology**

This study employs simulation modeling to examine geospatial data developed for wildfire risk assessments at two geographic scales. Uncertainties observed in the national datasets were examined using the data uncertainty categories provided previously by Maier et al. (2008), and relevant examples provided. Uncertainties pertaining to datasets

acquired at the DNF level were not explored. This study assumed that the local-level

data were validated to be accurate and sufficiently detailed to perform well in wildfire

risk assessments of this nature.

3.5.1. Risk Scatter Plots

A scatter-plot method was used to examine each resource's relative wildfire

exposure to likelihood and intensity of modeled fires. Fire behavior data (BP and CFL)

were extracted from all pixels coincident with identified resources. For each resource, a

scatter plot compares BP on the x-axis and CFL on the y-axis to examine the relative

exposure of the resource to fires of varying frequency (BP) and intensity (CFL).

The scatter-plot method demonstrates the relative exposure of resources with

respect to BP and conditional (or expected) flame length. Theoretically, these plots

reveal whether threats are due to frequency of fire (BP), intensity of fire (CFL), or a

combination of both. A quadrant overlay on the plot enables a discussion of the relative

threat to the resource. A manager should be most concerned about pixels/points that fall

in the upper-right quadrant indicating both high burn probability and high flame length

(or intensity), somewhat concerned with those in the upper left and lower right because

those pixels typically burn at high intensity but with a lower likelihood or have a high

likelihood of burning but at a low intensity, respectively.   The pixels of least concern are

those identified in the lower-left quadrant that have a low likelihood of burning and,

should they burn, would do so at a low intensity. The scale for both the x- and y-axes

was held constant to facilitate comparisons between resources.

3.5.2. <u>Quantitative and spatial comparison of resources</u>

To address the question of whether mean BP and CFL vary over the extent of the forest with respect to pixel resolution and fuel landscape, the fire-behavior data was compared statistically and spatially. BP and CFL datasets at 270×270 m versus 90×90 m were compared using a paired t-test to assess the statistical difference in mean BP and CFL (Wade et al. 2003). Both datasets represent a sample of pixels from the model output estimating BP and derived CFL across the Deschutes National Forest. The t-test examines the null hypothesis <u>that</u> differences between the means of both models are equal to zero, despite the change in resolution and the modified landscape files used to generate 90×90 m data. Summary statistics and box-whisker plots provide additional comparisons of the two datasets.

In addition to this statistical test, maps were built to compare BP and CFL at both scales. Figures showing each resource[4] were mapped using data from both sources to allow visual assessment of the spatial differences. Additionally, a table comparing total hectares of each resource affected provides areal measurements for comparison.

To complement the analyses above, a series of difference maps were made. Aggregating the 90×90 m grids to 270×270 m using a mean filter, allowed for differencing of the two grids to assess spatial patterns of differences in BP and CFL. Conversely, re-sampling the coarse 270×270 m grid to match the fine 90×90 m grid (whereby each new fine scale cell is populated with the same value as the "parent" coarse

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[4] For data security and resource protection, the northern spotted owl home range map identifying active and potential nest sites will not be displayed.

pixel), allowed for differencing of the two grids at a finer resolution and assessment of

potential edge-effect differences due to the change in pixel size.

4. RESULTS

The objective of this study was to understand how data for comparative risk assessments vary with respect to the source and scale of input data. This question was addressed through a number of different approaches outlined in the previous chapter. The following results summarize the observed uncertainties in the typology defined by Maier et al. (2008) to facilitate discussion and characterization of the observed issues, limitations, and data uncertainties associated with the data acquired for the national assessment uncertainties. Additional information was gained by examining resource maps compared for both project levels.

4.1. **Uncertainty in national geospatial data**

Results indicate that all datasets used in this analysis contain some level of uncertainty or error. All source layers were modified to some degree to work within this methodological framework. Some have been converted from point, line, or polygon to raster grid and datasets that originated in raster form were modified to match pixel size and grid alignment of the other datasets. This processing undoubtedly produces errors of various forms. These errors are difficult to quantify without data accuracy standards or ground-truthing. In the uncertainty typology described by Maier et al. (2008), this is described as analysis, processing, and presentation error. These errors arise when converting single points with no areal measurement to 270×270 m pixels encompassing approximately 7.3 ha. This processing overstates the actual area of the feature and creates the potential for biased results.

Each of the national datasets brings questions of data relevance and accuracy for use at the present date. An inherent lag time exists before data can be produced and made

available to subsequent users. Certain resources are more sensitive to issues of currency than others as a function of the real world phenomenon they represent (e.g. WUI identifying human population as a static number at stationary locations). Errors and uncertainties observed in the national-scale data vary according to dataset. These observed uncertainties and their possible implications for wildfire risk assessments were explored for each of the national datasets below.

4.1.1. SILVIS WUI

The SILVIS WUI limitations are best discussed in terms of the modifiable areal unit problem (MAUP) referring to the effect of aggregation on model results (Openshaw 1984). SILVIS uses U.S. Census housing counts within census blocks to interact with vegetation data (Radeloff et al. 2005). Census blocks vary in size from 0.01 km^2 as the median to 2,700 km^2 at the maximum (Radeloff et al. 2005), and the actual location of housing units can vary widely within the boundaries depending on the population density and census block size (e.g. Figure 2). As described by Openshaw (1984), boundary placement can significantly
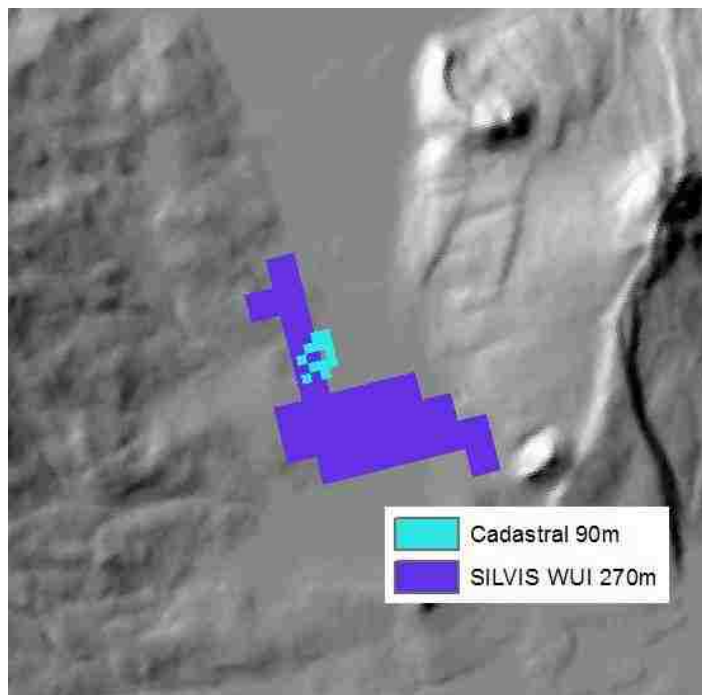
Figure 2. Example of challenges related to SILVIS-defined WUI and MAUP. Here, cadastral data shows the locations of housing concentrated in a much smaller area than the SILVIS data which was based upon coarse, irregularly shaped census blocks.

30

impact values and associated results. In the example provided by Figure 2, all pixels of WUI are defined by the same population density despite the clustering of houses (represented by cadastral) in one portion of the census block. Figure 2 provides an example of the specificity lost when counts of housing density are aggregated to the census block level. SILVIS WUI identifies considerably more area potentially "at risk" than cadastral in this example, and illustrates the potential for the results to be considerably impacted by the geospatial data selected for the analysis. Additional discussion of the limitations of the census block approach is provided by Calkin et al. (in press).

4.1.2. Northern Spotted Owl Critical Habitat

Metadata associated with the northern spotted owl critical-habitat layer does not define a spatial accuracy standard used to build the dataset, although one could assume some unknown degree of error due to the digitizing scale and data processing. Uncertainty related to this dataset differs somewhat from the others, in the sense that the definition of critical habitat for any given species depends primarily on landscape features and characteristics. Because it is unrealistic to consider spatially identifying each individual feature comprising critical habitat, these habitats are often generally mapped to encompass the areas know to provide the essential landscape characteristics upon which a particular species depends. In the case of the spotted owl, designated critical habitat has been abundantly mapped across the Northwest and the Deschutes National Forest, as discussed below in this section. If users of these data were to treat critical habitat for the northern spotted owl in the same way as a species with fewer areas of mapped critical habitat, the results could be skewed towards one species or another.

Additionally, the somewhat arbitrary boundaries defining critical habitat present another example of MAUP relevance. Boundary lines delineate habitat edges, marking a sharp transition from critical habitat on one side to an area of non-habitat on the other. In reality, species are unaware of the boundary lines humans use to define their habitats. The fuzzy tolerance and fuzzy membership literature (*cf.*Ascough et al. 2008) may provide opportunities for refinement from the binary approach often used in habitat delineation and mapping to a more gradual transition from habitat to non-habitat.

4.1.3. <u>National Recreation Values</u>

"Measurement error" and "type and length of data record" errors are abundantly present in the national recreation dataset. This resource layer was built by combining multiple individual geospatial datasets from many different sources. Measurement error observed in these layers was due to lack of spatial precision and accuracy in defining resource location and spatial extent. Spatial accuracy information was not available for all datasets. Visual comparisons against imagery in Google Earth® indicate that spatial accuracy varied widely across all datasets included in the recreation layer. It was not the intent of this study to quantify the observed inaccuracies; therefore, accounts of spatial inaccuracy are discussed generally rather than through quantitative analysis.

The USDI Fish and Wildlife Service (FWS) recreation assets documentation claimed to approximate the location of visitor center parking lots (Vandegraft, personal communication, 9 April 2009). An estimated 50% of the dataset approximates structure location (within ~0.8 km) visible from Google Earth imagery; however, FWS assumes no

liability or responsibility for data accuracy as these datasets are still in development

(Vandegraft, personal communication, 9 April 2009).

A dataset representing alpine ski area locations and area boundaries was desired at

the national scale. Surprisingly, this dataset could not be located from either a private or

government entity. Data gathered from two sources were combined instead and

manipulated as described in Section 3.3.3. Representation of ski areas as point locations

surrounded by a 1 mile buffer likely underestimated the areal extent of many ski areas

nationwide, but little information was available to improve this methodology nationally.

An example of the limitations of the simple buffer approach is at Mt Bachelor Ski Resort

in the DNF (Figure 3). The point (snowflake symbol) approximates the relative location

of the ski area, but not as successfully as a centroid derived from the management area boundary produced by the DNF. Additionally, the location of the ski area point relative to the actual ski area boundary impacts the accuracy of the buffered circle. Placement of a point away from the actual ski area results in
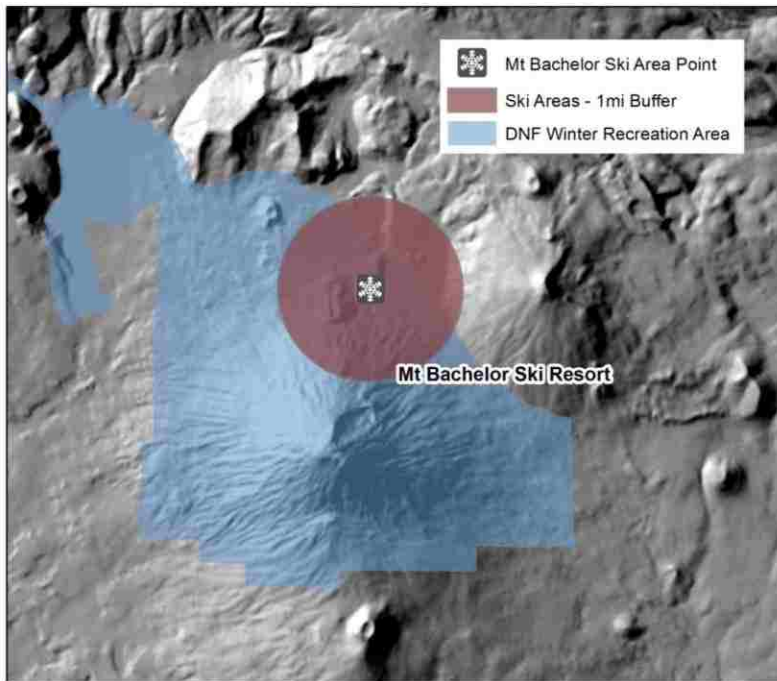

Figure 3. Mt Bachelor Ski Resort as depicted using the buffered point approach used to map ski areas at the national extent versus the management area polygon used by the DNF. The point location from the national dataset approximates the relative location of the ski area, but is quite limited in describing the extent of the recreation area.

valuing land that is not associated with the ski area rather than highlighting the resource itself. Thus, even if information about the size of each ski resort were available to build a buffer to include an area that corresponded to the actual size of the ski resort, this approach would not yield results that were optimal for risk assessment. Polygons delineating accurate boundaries are needed.

Along with the "measurement errors" defined above, "type and length of data record" uncertainties exist in the remaining recreation datasets. For example, nearly every source dataset had missing records and lacking or incomplete attribute records. For instance, attribute records for Forest Service campgrounds did not distinguish between developed and primitive campgrounds; while some attributes in the Bureau of Land Management campgrounds dataset distinguish between unimproved, developed, or semi-developed. Additionally, complete and consistent attribute tables were not available for all Parks and Units in the National Park Service data; therefore, all records for the themes listed above were included in the final recreation data layer. Because these attributes were absent from some agency datasets, and not from others, all records for the above data layers were included in the final recreation dataset to maintain consistency and prevent bias towards those agencies and units that made value distinctions in their attribute records. Risk (and subsequent mitigation funding) cannot be ascribed to a resource that has not been mapped; therefore, a negative bias would be introduced by eliminating sites labeled as 'primitive' or 'undeveloped.'

The National Park Service Long Distance Trails dataset, according to associated metadata, is intended to "support diverse planning activities including planning, management, maintenance, research, and interpretation." This dataset is not a full

representation of all National Scenic and Historic trails, however. Compared to the National Trails System map (NPS 2010), which provided a comprehensive list of all National and Historic Trails, the NPS Data Store dataset contained only 12 of the 26 trails (access date 1 August 2008) with National Scenic or Historic designation. This is an example of a known gap due to incomplete data collection. In theory, when all Parks, Units, and National Forests consistently and methodically submit their data to enterprise systems, these gaps will not exist. If they do persist, care to report areas with absent data will provide data users with the necessary information to assess the appropriateness of these data for their respective projects. Though the difficulty in national level data coordination among federal agencies is not trivial (Nelson 2009), as mentioned previously, efforts are underway through the WFDSS and FPA projects to develop interagency data standards (FPA 2010, WFDSS 2010).

4.1.4. Fire-adapted Ecosystems

Data describing fire-adapted landscapes are subject to many similar sources of uncertainty as northern spotted owl habitat, as they are both dependent on characteristics of the natural environment rather than the built environment. LANDFIRE products (Rollins and Frame 2006) are available with reliable and complete metadata for each specific product (http://www.landfire.gov, accessed 9 September 2010). The intent in this study was not to explore uncertainties within the LANDFIRE data inputs used to create fire-adapted ecosystems, but instead to explore the possible uncertainties introduced by modifying the LANDFIRE data to represent a new phenomenon. The process of aggregating 30×30 m data to 1×1 km causes a substantial loss in data detail. While the intent of this generalization was to improve processing speeds at the national

scale, one might consider maintaining the smallest resolution possible as processing

speeds increase and computational limitations continue to diminish.

Uncertainty related to "length of data record" of the LANDFIRE (or similar)

products can impact the reliability of the fire-adapted ecosystems dataset. For example,

if restoration activities or a recent wildfire event occurred in an area identified as a fire-

adapted ecosystem, the area might no longer be in need of restorative management

action.   Therefore, any future use or rebuilding of the fire-adapted ecosystems dataset

should include all available updates to LANDFIRE products to ensure the most current

vegetation and fuels information is incorporated. Further, all data related to wildfire are

subject to the temporal sensitivities of changing landscapes due to human-caused

disturbances such as fuels treatments, or construction and development; as well as to

alterations resulting from general forest succession, climate change, insect and disease,

invasive species, and wildfire events. Frequent and regular updates, as often as possible

or annually, at a minimum, are essential when dealing with the dynamic nature of

wildfires.

4.2. **Comparison of resource value data**

Total area identified from each dataset and for each resource is shown in Table 2.

Calculations were based on raster versions of all datasets matched to the resolution and

extent of the fire behavior data for both project levels (i.e. 270×270 m for national data

and 90×90 m for DNF). The most distinct difference in resource area between the two

scales was observed in the recreation values. Mapped area for the Deschutes National

Forest (DNF) was 95,318 ha – nearly 20 times more than 5,110 ha for national recreation

resources. Priority restoration areas for the DNF totaled 270,853 ha, while nationally

identified fire-adapted ecosystems occupied only 43,696 ha. Due to the specific

definition of designated critical habitat, northern spotted owl critical habitat only differed

by approximately 500 ha, likely due to the larger pixel size in the national layer. Adding

northern spotted owl home range circles to the resource values resulted in the addition of

44,429 ha to the DNF assessment. Conversely, area of WUI mapped nationally by

SILVIS was nearly three times as extensive as area identified by cadastral data (52,175

and 18,424 ha, respectively).

Table 2. Area in hectares for all mapped resources.

Resource	National (Hectares)		Deschutes NF (Hectares)	
WUI	SILVIS	52,175	Cadastral	18,424
Northern spotted owl critical habitat		38,958		38,432
Northern spotted owl home range		--		44,429
Restoration Areas	Fire-adapted ecosystems	43,696	Priority restoration	270,853
Recreation		5,110		95,318

Maps shown in Figures 4 – 7 display the various resource themes for both

national and DNF levels, demonstrating how the mapped areas not only vary spatially,

but also differ in terms of specificity according to the particular resource mapped. The

most obvious differences between resources from the two data sources exist in recreation

and fire-adapted landscapes/ restoration areas (Figures 6 and 7 respectively).
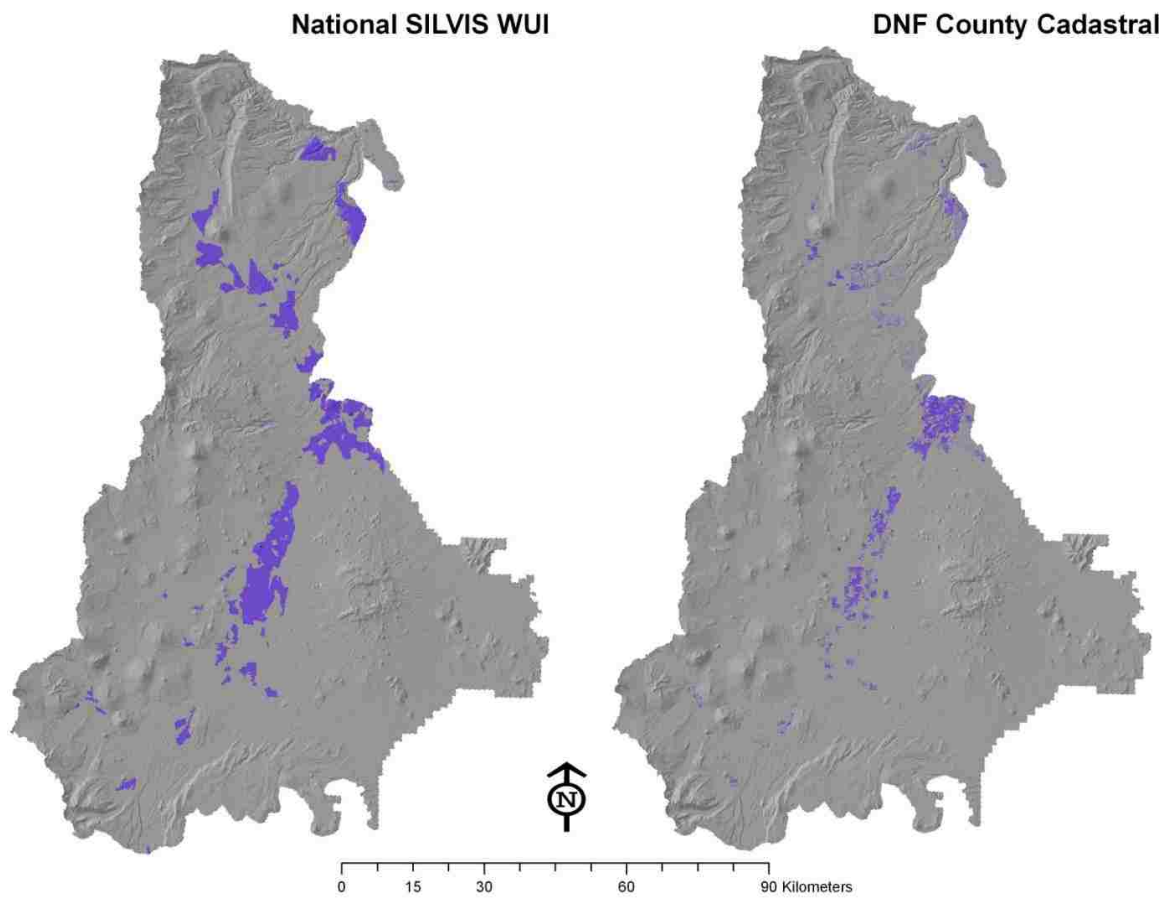
Figure 4. SILVIS WUI mapped using the national data (left) and county cadastral data for the Deschutes National Forest (right).

National Northern Spotted Owl   DNF Northern Spotted Owl

0   15   30   60   90 Kilometers
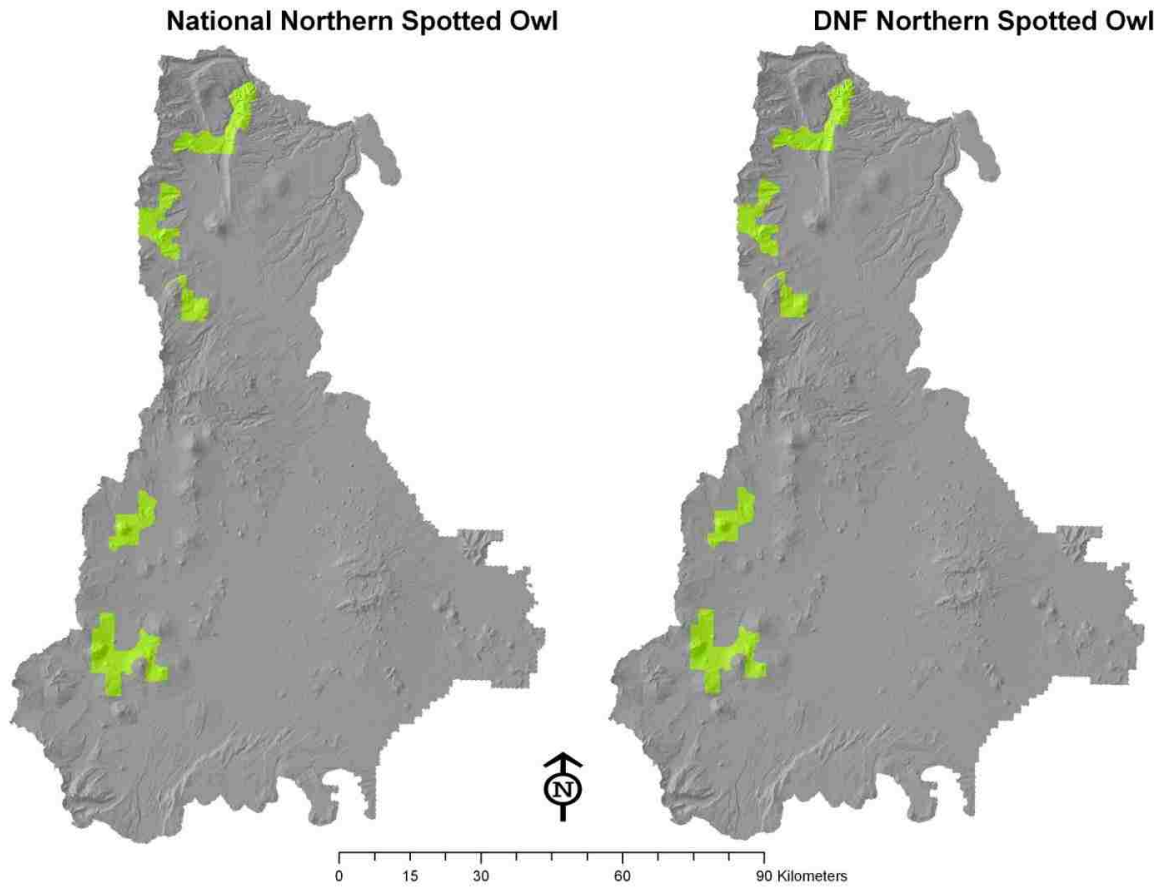
Figure 5. Northern spotted owl critical habitat mapped using the national data (left) and for the Deschutes National Forest (right).
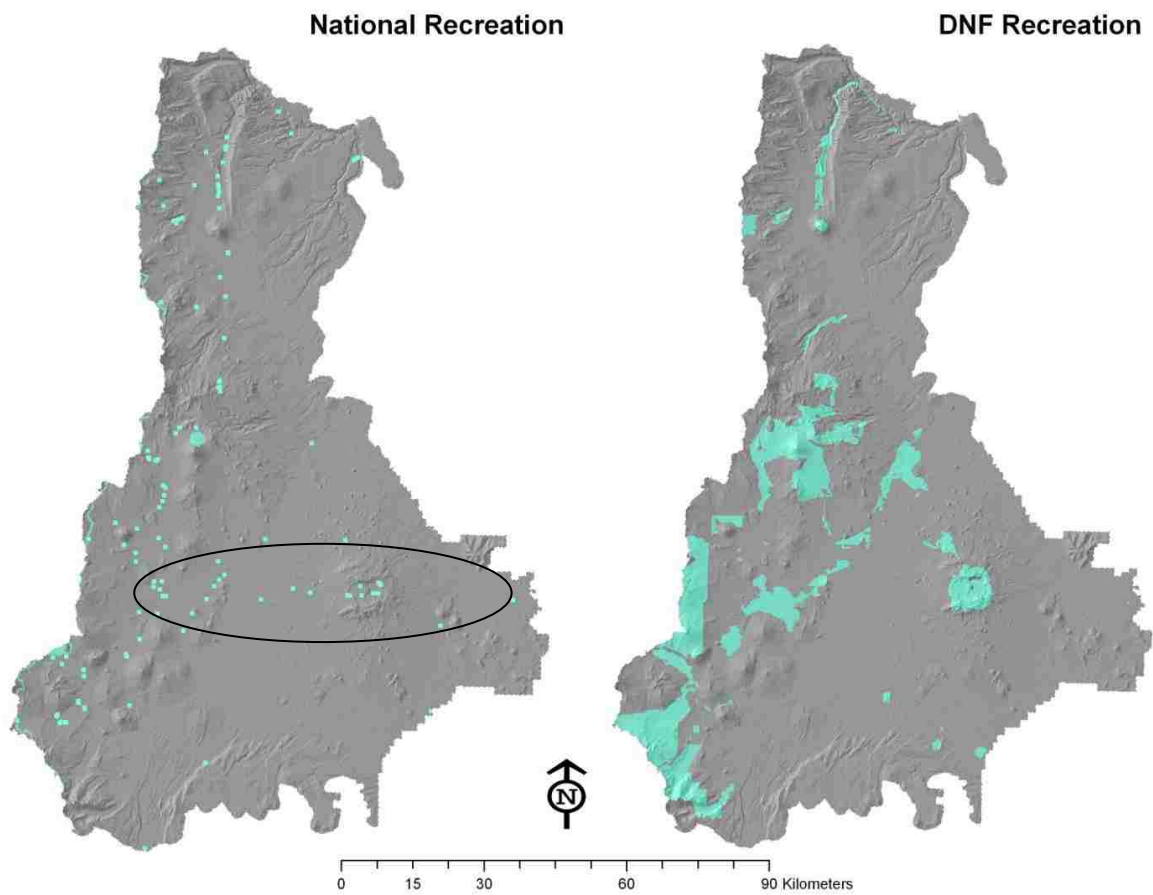
Figure 6. Recreational values mapped using the national data (left) and for the Deschutes National Forest (right). The black oval highlights individual pixels obscured at this map scale.

National Fire-adapted Ecosystems   DNF Restoration Priority Areas

N

0   15   30   60   90 Kilometers

Figure 7. Fire-adapted ecosystems mapped using the national data (left) and restoration priority areas for the Deschutes National Forest (right).

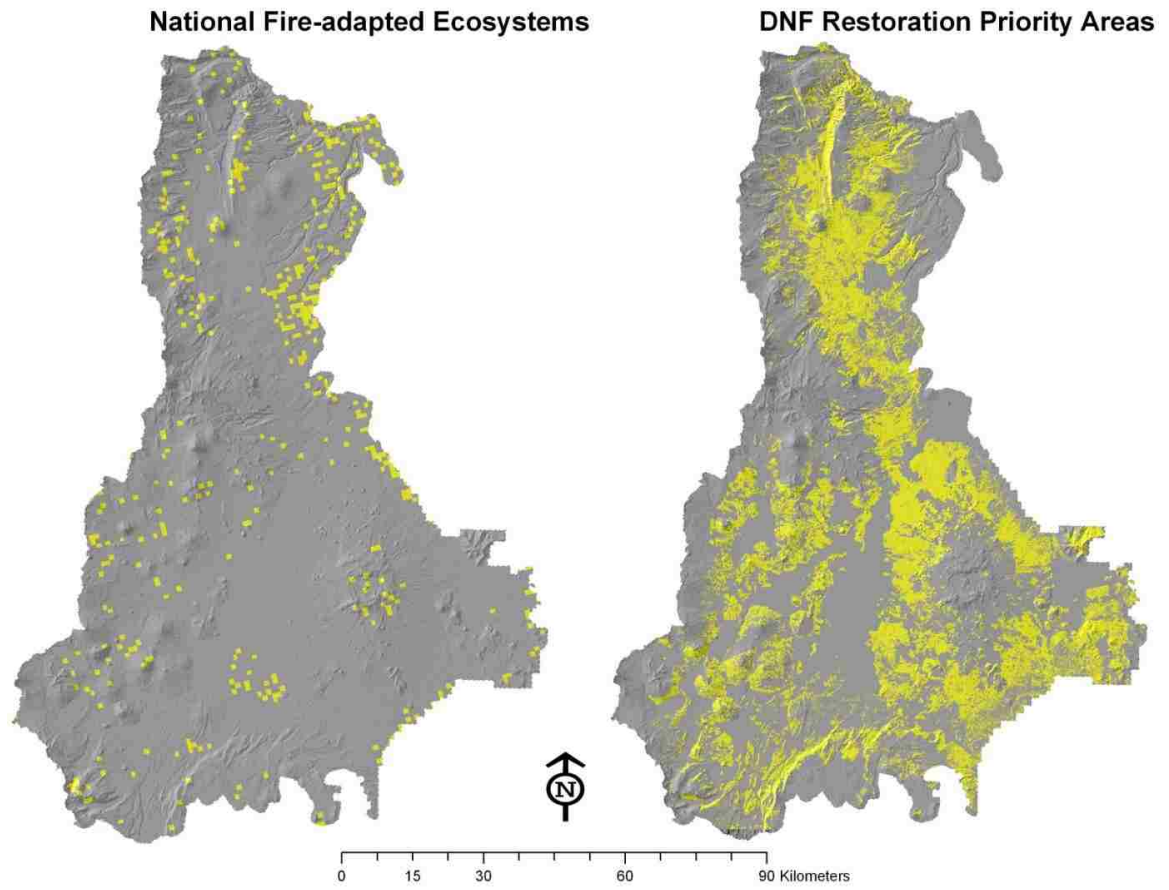4.3. **Statistical analysis of fire behavior data**

Summary statistics for burn probability and conditional flame length for the national and DNF datasets are given in Table 3. Overall, BP values in the DNF were higher than in the national dataset. The mean BP for national data was 0.0025/year with a maximum of 0.0123. Mean burn probability was approximately twice as high for the DNF at 0.0056, with a maximum value of 0.0225. These trends were also visible in the box-whisker plots for BP shown in Figure 8. Figure 8 also demonstrated that nearly 50% of the BP values in the DNF were higher than in the national data, as evidenced by the bottom (25th percentile) of the DNF box approximating the top of the national box (75th percentile).

Conditional flame length (CFL) did not vary to the same degree, however. Mean CFL for the national data was 3.50 ft, while the DNF mean CFL was 3.32 ft. The maximum CFL values were 12.00 ft and 11.98 ft for the national and DNF datasets, respectively. The box-whisker plots in Figure 8 for CFL demonstrated the similarities between the two datasets in terms of flame length. While the means were very similar, there was more variability around the mean in the national data. Additionally, paired t-tests performed in MATLAB$^{®}$ R2009b with a p-value less than 0.01 at an alpha equal to 0.05, indicated rejection of the null hypothesis for both BP and CFL that the means of the two datasets were equal.

Table 3. Burn probability and conditional flame length summary statistics.

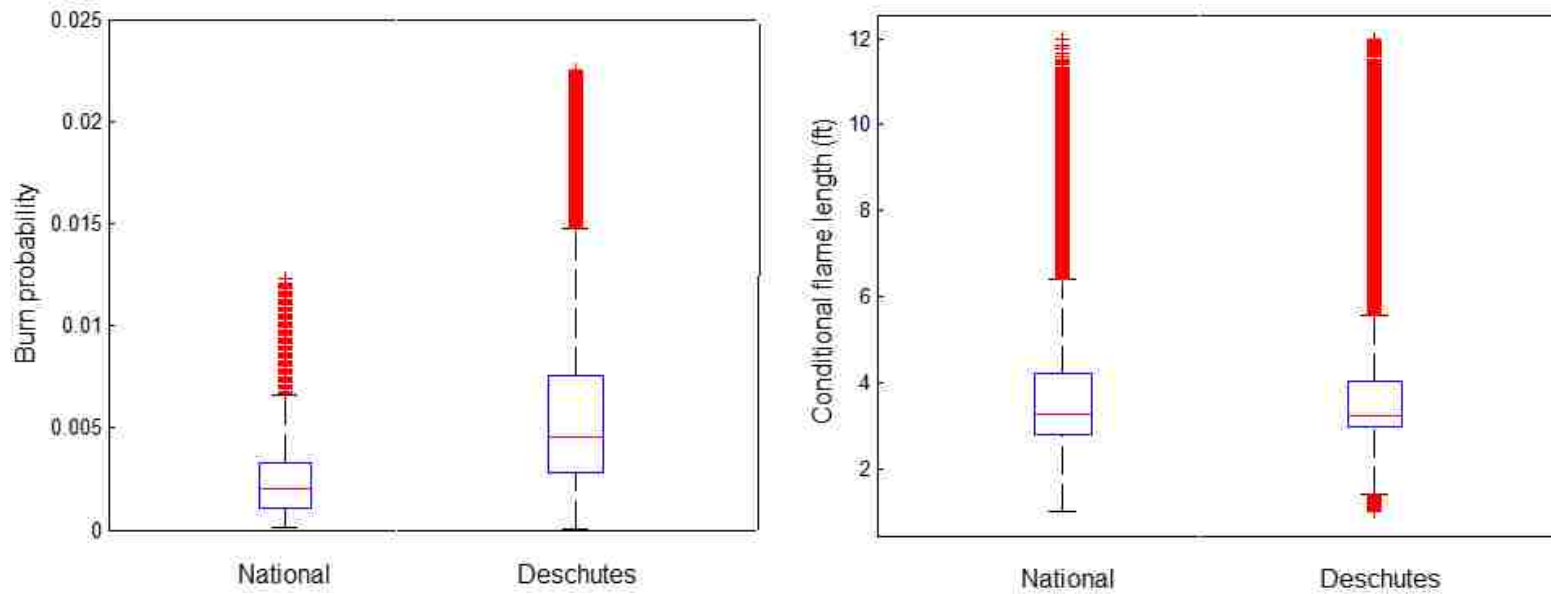|	Burn probability (chance/year)		Conditional flame length (feet)	
	National	Deschutes	National	Deschutes
Mean	0.0025	0.0056	3.5002	3.3286
Median	0.0020	0.0046	3.2667	3.2202
Minimum	0.0001	0.0000	1.0000	1.0000
Maximum	0.0123	0.0225	12.0000	11.9877
Std_Dev	0.0019	0.0040	1.5578	1.3926
Range	0.0122	0.0225	11.0000	10.9877

Figure 8. Box-whisker plots for burn probability and conditional flame length for the two datasets.

4.4. **Spatial comparison of burn probability differences**

Fire behavior data also varied according to data source. As demonstrated by Figure 9, burn probability (BP) values in the DNF data were substantially higher than in the national data, likely as a result of updated vegetation data as fuels input to the FSim model.   The same classification scheme was applied to map BP values in both datasets; however, the highest BP in the national data was 0.0123 while an additional value class in the DNF dataset ranged from 0.0124 to 0.0225 (mapped in red ink in Figure 9). Further comparison of the two maps shows the majority of the pixels with the highest BP values occurred in the upper right portion of the Forest, in the middle of the lower portion, and along the eastern boundary for both datasets, though magnitude differed.

Mathematical differences observed between burn probabilities in the two datasets were mapped in Figure 10. The divergence between the values was greatest in certain geographical areas including the northeastern, eastern, and south-central portions of the forest. These observations are consistent with the patterns observed in Figure 9.

Figure 11 displays histograms of pixel counts according to the classification scheme mapped in Figure 10, with colors defining the bins corresponding to colors displayed on the map. The majority of the differences in values between the two datasets were within one standard deviation, with comparatively low counts of difference values exceeding one standard deviation. The areas of greater divergence, according to Figure 10, were consistent with the differences observed in Figure 9 in the northeastern, eastern, and south-central portions of the forest.   These results indicate that while the difference

in mean burn probability is significant, it can be largely attributed to specific geographic

locations rather than widespread throughout the study area.
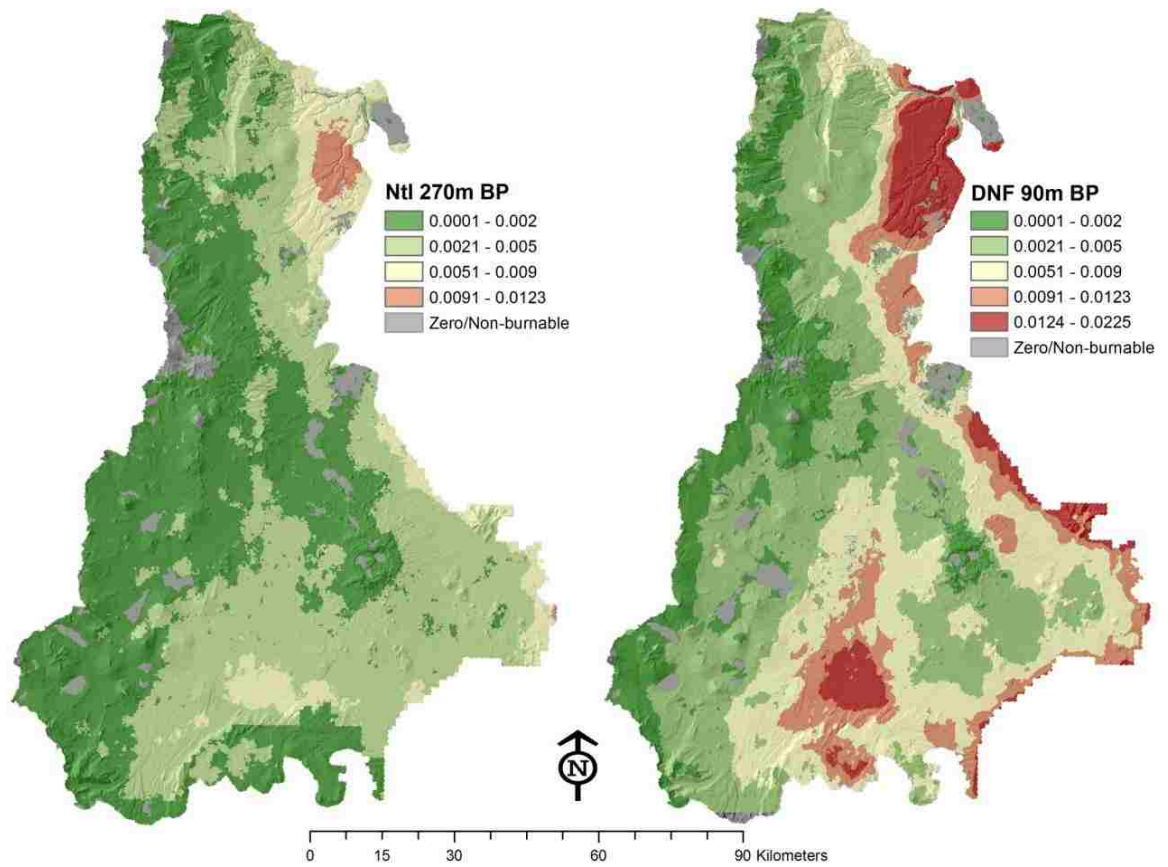
Figure 9. Comparison of burn probabilities for the national (left) and DNF (right) datasets.
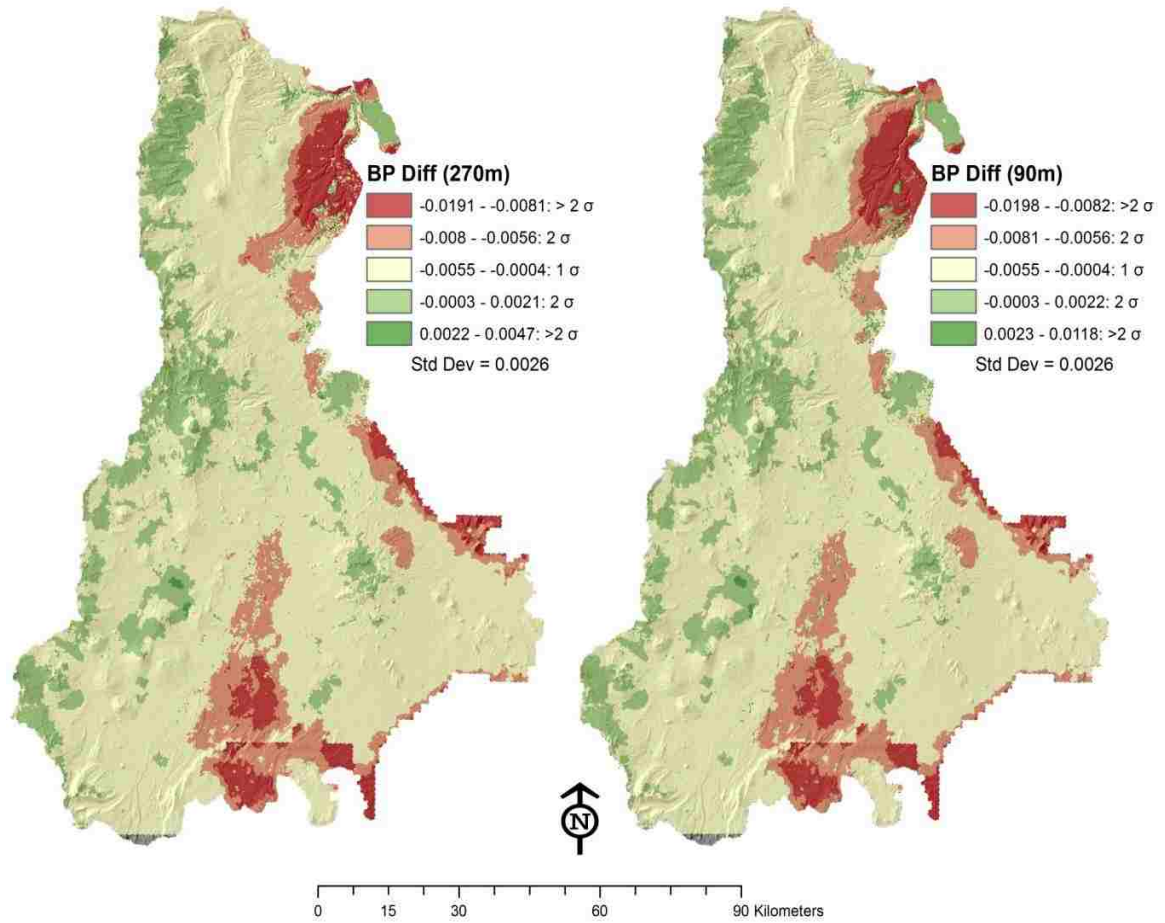
Figure 10. Comparison of mathematical differences in burn probabilities between both datasets, computed at the 270 × 270 m (left) and 90 × 90 m (right) resolutions. Difference was calculated National – DNF so negative values indicate larger BP using the DNF data and positive values indicate larger national data. While the general pattern is strikingly similar, there are small visible differences in the northeast and central areas.
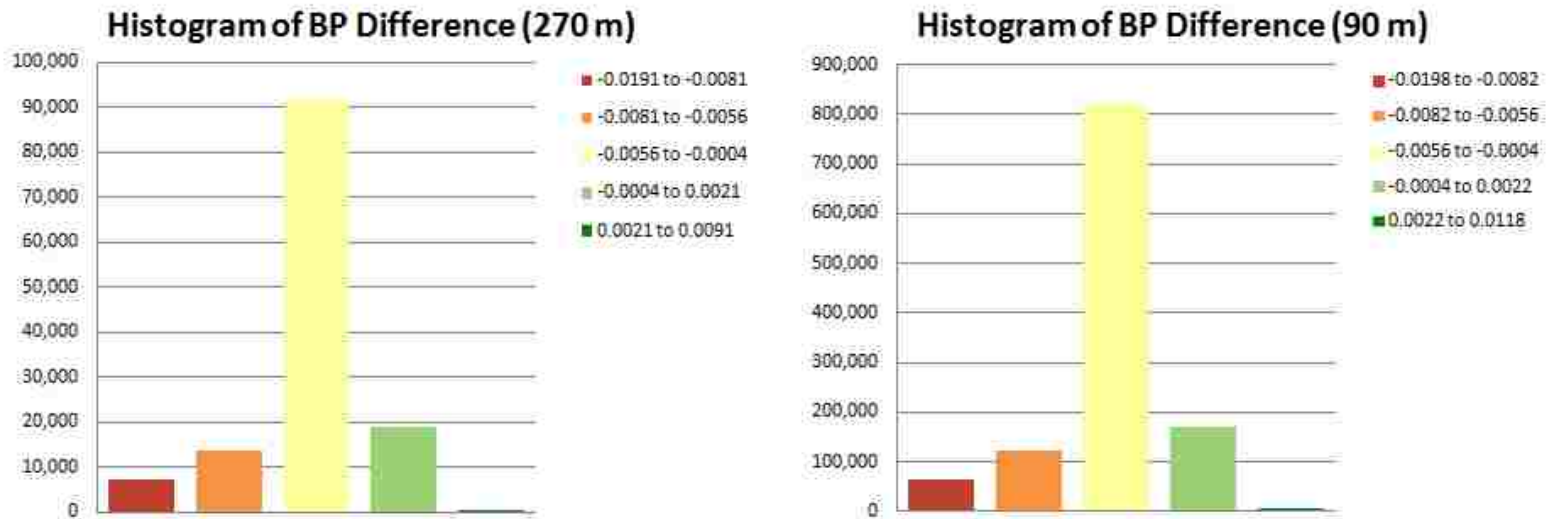
Figure 11. Histograms of pixel counts of the mathematical difference in burn probability computed at the 270 × 270 m (left) and 90 × 90 m (right) resolutions. Data groupings correspond to those used in Figure 13.

4.5. **Comparing conditional flame length differences**

Differences in conditional flame length between the two datasets were extremely subtle (Figure 12). General spatial trends were similar in both maps, with the largest flame lengths predicted in the north-central and eastern areas and with less obvious clustering of higher CFL in the mid-to-southern portion of the DNF.
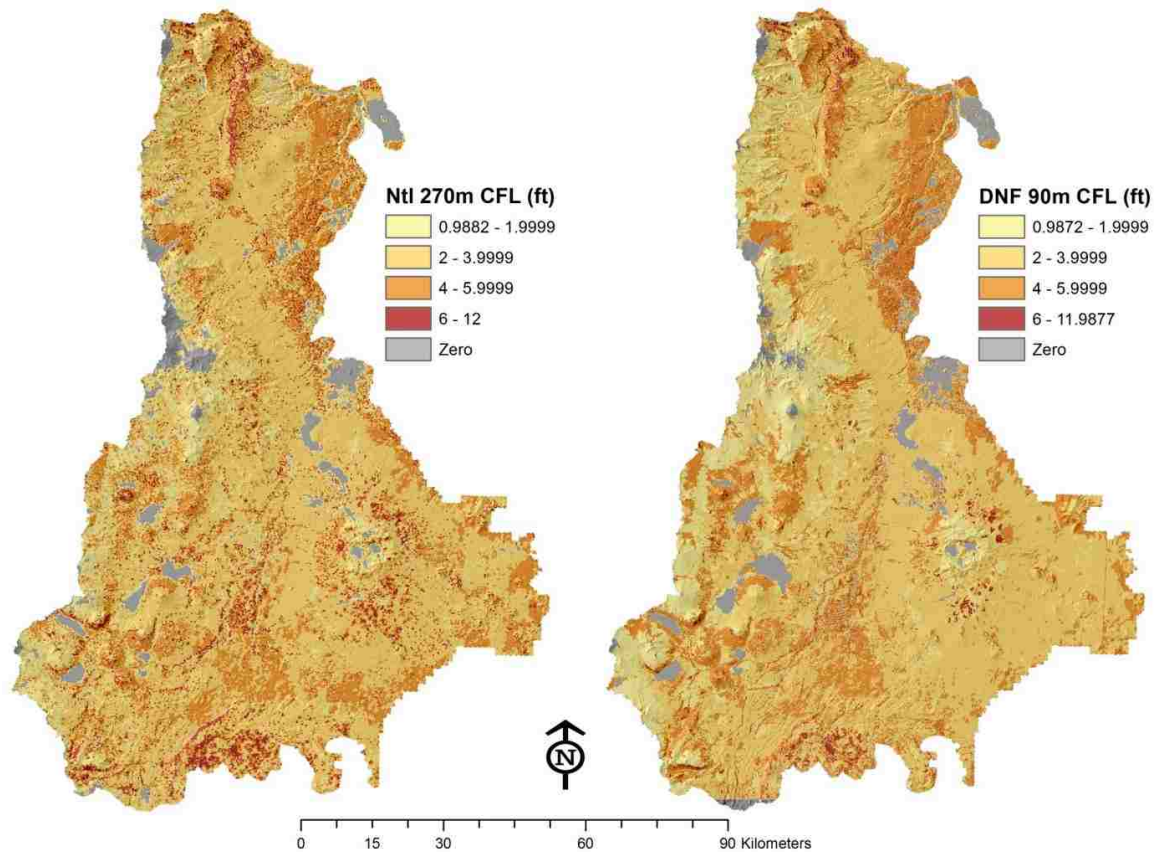
Figure 12. Conditional flame lengths mapped using the national data (left) and the Deschutes National Forest data (right).

The mathematical comparison revealed slight differences in the patterns, however. Areas of high divergence in CFL are observed in Figure 13, largely due to inconsistency in areas of "no data" and zero values. For example, a pixel with a zero in the 270×270 m dataset corresponds with a 3.95 ft flame length in the 90×90 m data.

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Observations such as these suggest that there is a need for future research into differences in landscape fuels and vegetation data used within each simulation.

Figure 14 displays histograms of pixel counts corresponding to the classification scheme mapped in Figure 13, with colors defining the bins corresponding to colors displayed on the map. Although areas with substantial differences in CFL do occur, they were a small proportion overall. This interpretation is consistent with previous comparisons of the two CFL datasets indicating that while differences in CFL values were present, overall they were relatively minor.
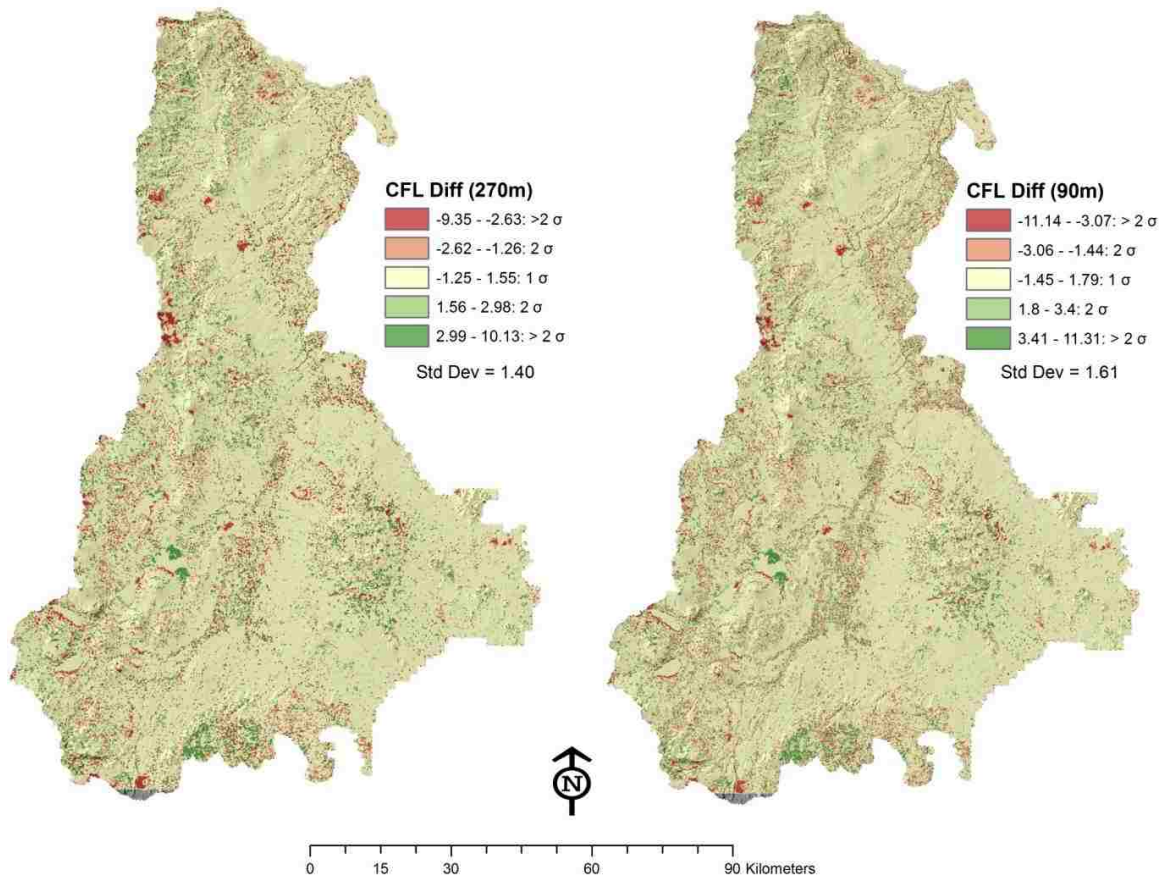
Figure 13. Comparison of mathematical difference in conditional flame length computed at the 270 × 270 m (left) and 90 × 90 m (right) resolutions. Difference was calculated National – DNF so negative values indicate larger CFL using the DNF data and positive values indicate larger national data.

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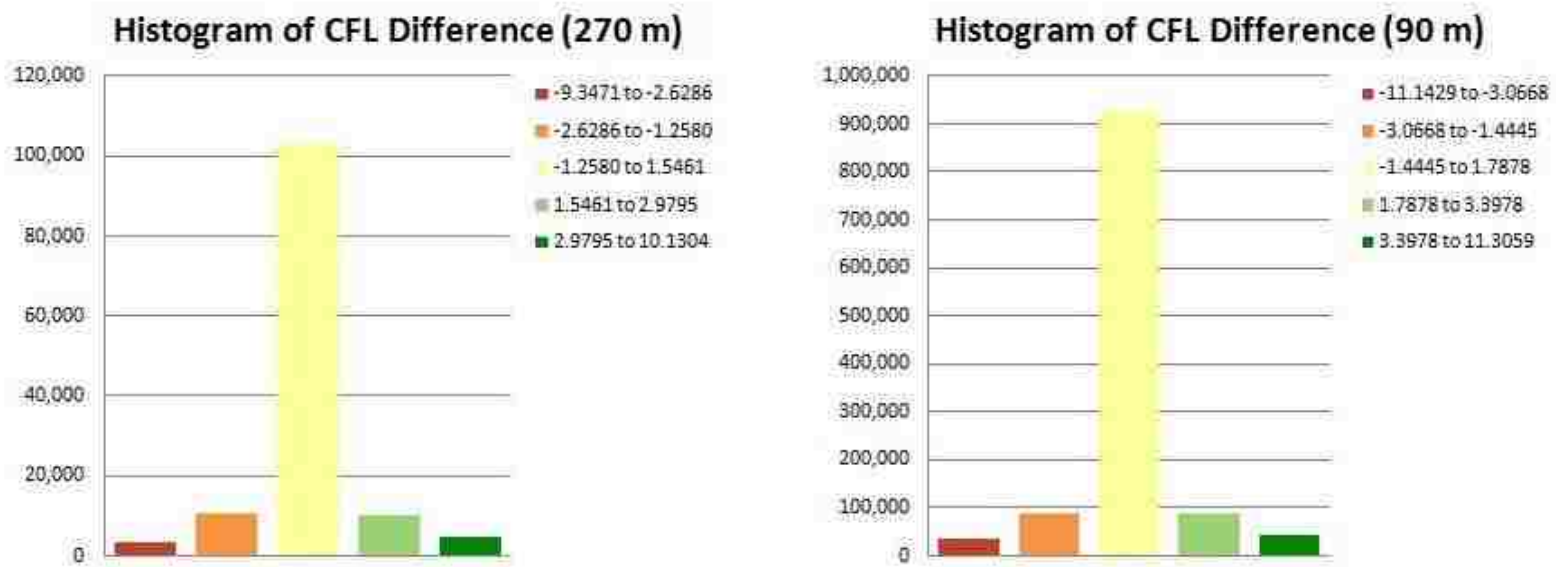
Figure 14. Histograms of pixel counts of the mathematical difference in conditional flame length computed at the 270×270 m (left) and 90×90 m (right) resolutions. Data groupings correspond to those used in Figure 13.

4.6. **Scatter plots**

Scatter plots compare burn probability as a measure of fire frequency with conditional flame length as a measure of fire intensity. Figure 15 compared BP and CFL for all pixels greater than zero, within the DNF boundary. The scatter plot provides information about the two datasets that the previous statistical and spatial comparisons could not; specifically that the DNF data predicted significantly more area of higher BP that are associated with higher CFL. This information is important context to use when examining resource-specific scatter plots created to assess relative fire exposure in the following sections.
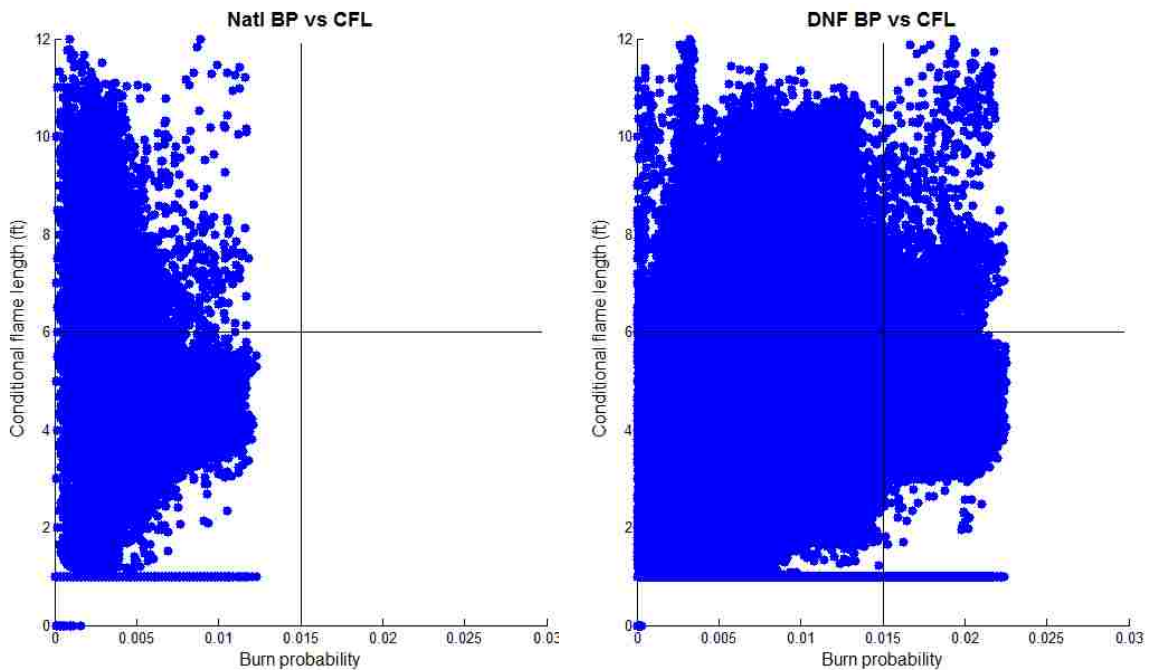
Figure 15. Scatter plots of burn probability and conditional flame length for the national data (left) and DNF (right).

Review of the scatter plots in Figure 15, reveals an obvious line of points at the 1 ft flame length. Close examination of the FSim data found marginal burn probabilities of 1 in the lowest flame length category. This can be interpreted as, given the likelihood of fire occurring in a certain pixel, all simulations predicted (in the 0-2 ft category, for example) that fire would always burn within that one category. Although less obvious, straight lines exist at whole-number flame lengths greater than one as well. These lines are an artifact of the mathematical calculation and categorization of continuous data values used to generate CFL.

As described previously, CFL is calculated by multiplying the burn probability within each of the flame length categories by the midpoint of that category. A value of 1 in the lowest flame-length category with zeros in all other categories would result in a CFL of 1 ft. This is due to the formula used to calculate CFL whereby the value of 1 is multiplied by the midpoint of the 0-2 ft flame length category (1 ft).

Scatter plots for all resource layers used in this comparison are shown in Figures 16 - 20. MATLAB® R2009b software was used to extract and plot burn probability and conditional flame length values for all pixels in each resource. Scatter plots for each resource theme include: (1) National resource to national fire behavior, (2) DNF resource to DNF fire behavior and, (3) DNF resource (aggregated to 270×270 m) to national fire behavior. The third plot is needed to identify whether differences in relative wildfire exposure are due to differences in the spatial data used to define resource values or due to differences in fire behavior data at the two scales.

4.6.1. SILVIS WUI and Cadastral scatter plots

Relative wildfire exposure to cadastral resources at the finer resolution exceeds exposure to SILVIS WUI according to the plots in Figure 16. Cadastral points occurred in all quadrants of the scatter plot, with many points located in the highest risk quadrant (upper right) representing frequent and intense wildfire. In comparison, the SILVIS WUI plot had no points in either the upper right or lower right quadrants, indicating exposure was largely from less frequent fires across the full range of intensities.

Comparing the cadastral data with the national fire behavior data, as shown in the third plot, results in a scatter plot very similar to the one shown for SILVIS WUI. This plot indicates that relative exposure to the WUI theme (cadastral and SILVIS) does not vary according to resource data used, but rather as a result of the fire behavior data used.

4.6.2. Northern spotted owl critical habitat and home range scatter plots

Scatter plots for northern spotted owl critical habitat (Figure 17) indicate relative wildfire exposure across all plots was due primarily to low frequency fires of varying intensity. The DNF critical habitat scatter plot shows more pixels of habitat in the upper-left quadrant identifying low frequency fires of high intensity and slightly greater relative risk. Comparing the DNF critical habitat layer with the national fire behavior data resulted in a seemingly identical plot as the national data. This was expected due to the strict boundaries used to define designated critical habitat.

Spotted owl home range data were not available at national scales. Figure 18 compares scatter plots for home range data compared with both the national and DNF fire behavior information. In both plots, BP values were relatively low, yet span the full

range of flame lengths (1 ft to ~11.5 ft). The patterns observed in the two plots were

inconsistent due to the different fire behavior data; however, differences were relatively

minor in terms of these exposure measures. Home range compared with DNF fire-

behavior data resulted in a cluster of points with BP greater than 0.005 and CFL greater

than 6 ft, which were not present in the national fire-behavior plot. This comparison

indicated that changes in BP did not drastically alter wildfire exposure to spotted owl

home range as measured by risk scatter plots.

4.6.3. Fire-adapted ecosystems and restoration priority areas scatter plots

Relative wildfire exposure was significantly greater for restoration priority areas

than for fire-adapted ecosystems (Figure 19), with many points occurring in the lower-

right and upper-right quadrants. The map in Figure 7 demonstrated the significant

differences in area mapped by the two different datasets and this was evidenced by the

volume of data points plotted in the center scatter plot. When restoration priority areas

were compared with national fire-behavior data, the pattern of risk changed significantly

and more closely mimicked the first plot. This again indicates that differences in BP and

CFL were the primary drivers of wildfire exposure, while spatial distribution of resource

values had a lesser impact.

4.6.4. Recreation value scatter plots

Scatter plots for recreation indicate greater exposure of DNF recreation to fire

intensity than observed in the national recreation data (Figure 20). These results were

consistent when compared with fire-behavior data at both scales. Compared with the

scatter plots for other resource themes, patterns of exposure in the recreation values

changed more drastically across the different plots. For all other resources, the scatter

plot on the right mimicked the pattern of the first. In this case, the DNF recreation with

national fire-behavior data looks more like the center scatter plot than the first plot. This

is primarily due to the large difference in the number of data points.

The first plot in this series demonstrated the paucity of recreation values mapped

at the national scale. The center plot showed an interesting finger-like pattern in the

upper-left quadrant that disappeared when DNF recreation was compared with national

BP and CFL, or perhaps the pattern was obscured due to the clustering of low BP in the

DNF recreation and national fire-behavior plot. A group of points in the lower-left

quadrant was evident in both the center and right-most plots. Further exploration into the

spatial location of these clusters may prove interesting, as it appears they might represent

the same recreation management area on the ground, highlighting distinct clusters of

higher BP and CFL values than observed in other recreation areas.
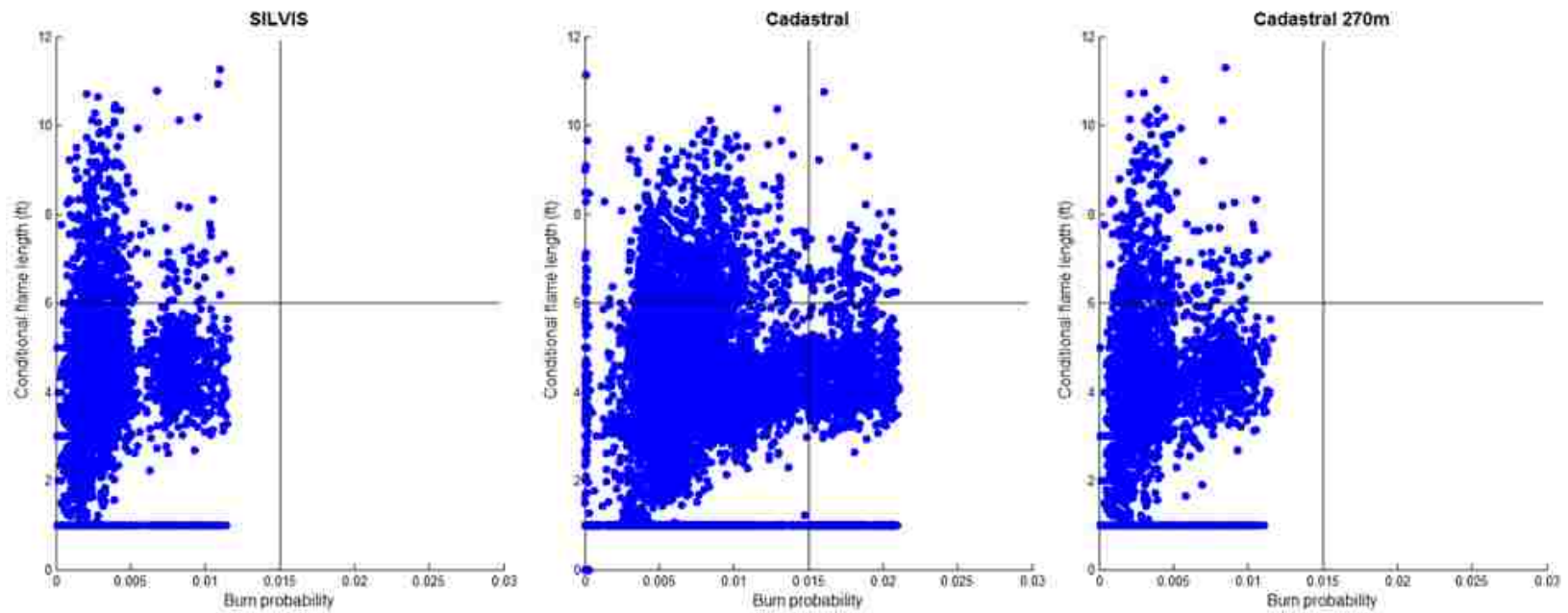
Figure 16. Scatter plots comparing results from the national SILVIS WUI vs. national fire behavior (left), DNF Cadastral to DNF fire behavior (center), and DNF Cadastral (aggregated to 270 × 270 m) to national fire behavior (right).
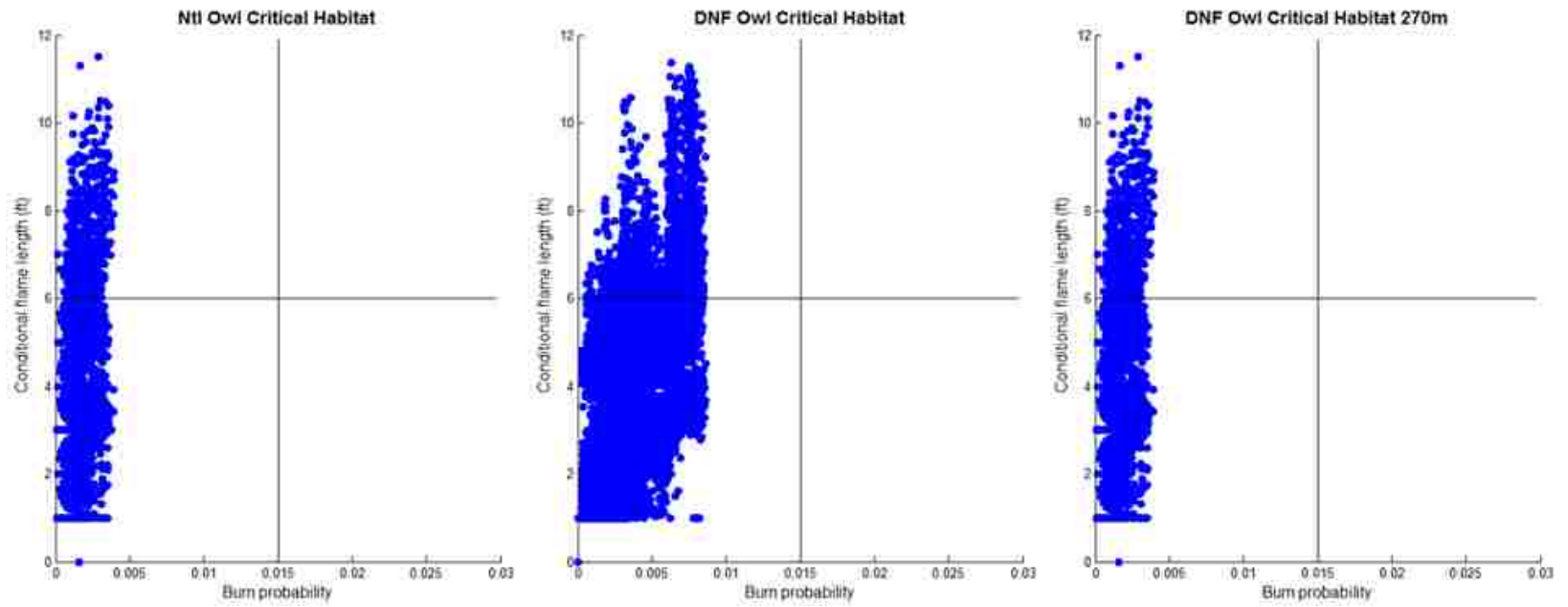
Figure 17. Scatter plots comparing results from the national northern spotted owl (NSO) critical habitat vs. national fire behavior (left), DNF NSO critical habitat to DNF fire behavior (center), and DNF NSO critical habitat (aggregated to 270 × 270 m) to national fire behavior (right).

Figure 18. Scatter plots comparing results from the DNF northern spotted owl home range to DNF fire behavior (center), and DNF NSO home range (aggregated to 270 × 270 m) to national fire behavior (right). Owl home range is available at the national scale.
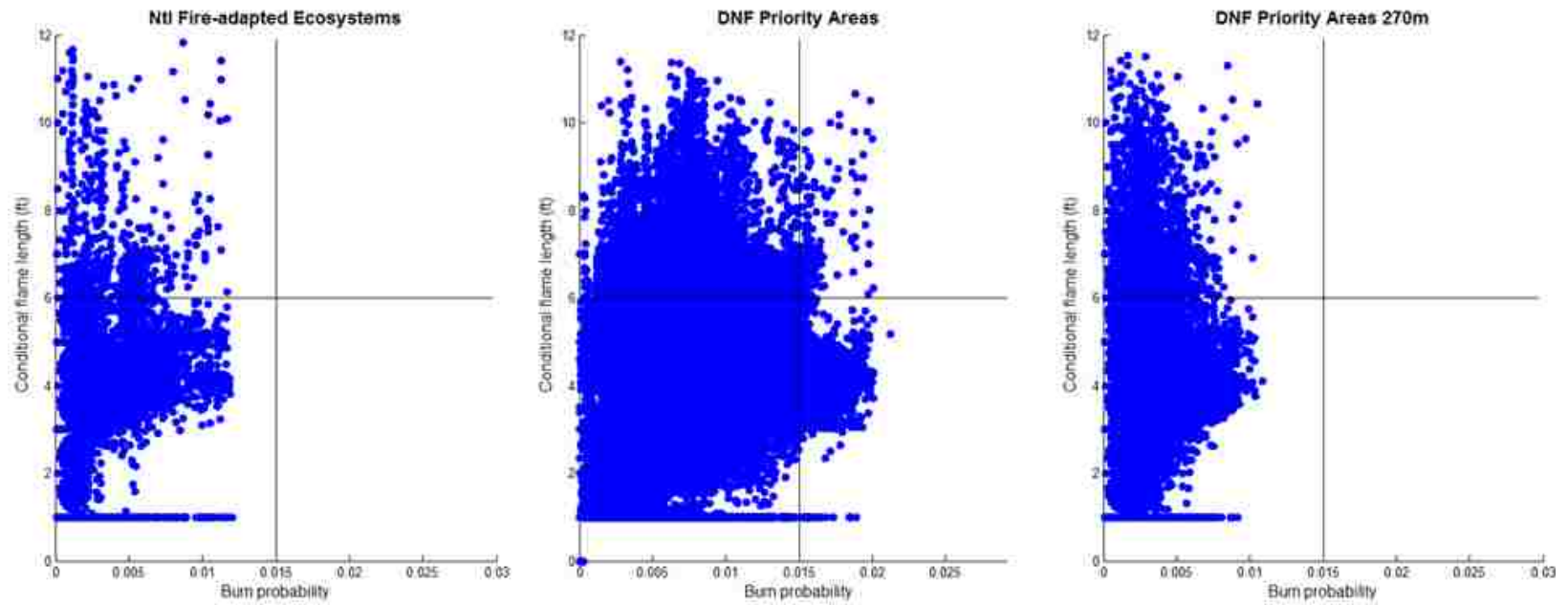
Figure 19. Scatter plots comparing results from the national fire-adapted ecosystems vs. national fire behavior (left), DNF restoration priority areas to DNF fire behavior (center), and DNF restoration priority areas (aggregated to 270×270 m) to national fire behavior (right).
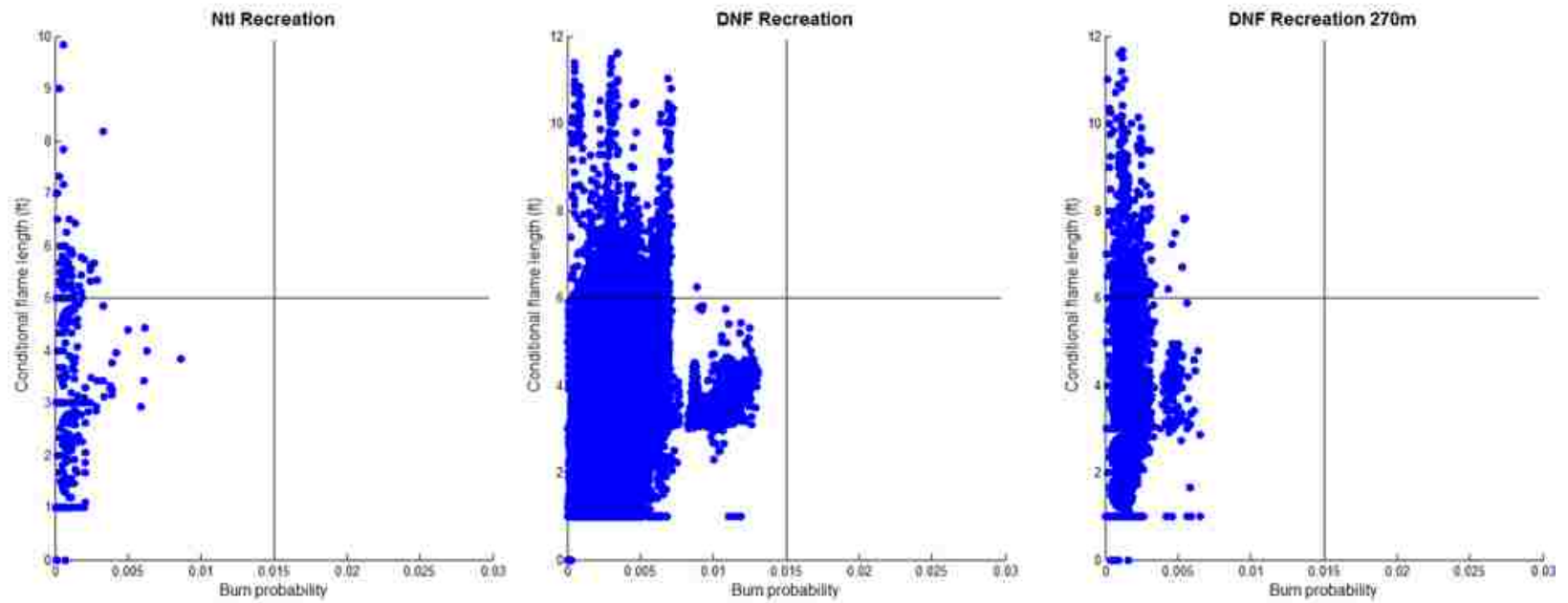
Figure 20. Scatter plots comparing results from the national recreation values vs. national fire behavior (left), DNF recreation values to DNF fire behavior (center), and DNF recreation values (aggregated to 270 × 270 m) to national fire behavior (right).

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5. DISCUSSION

The first research question addressed by this study asked how available resource data varied with respect to input data. The section above discussing the observed issues, limitations, and data uncertainties associated with the national assessment data demonstrates the challenges data users face in locating accurate and appropriate data for coarse, broad-scale wildfire-risk assessments. Figures comparing mapped resources provided information about how location and scale of identified resources varied according to the project scale.

Interestingly, for some resources, patterns of relative wildfire exposure and wildfire risk were more sensitive to changes in fire-behavior data than to changes in spatial distributions of mapped resources, as demonstrated in Figures 16 to 19. This study finding addressed the second research question which asked whether changes in geospatial values data or differences in fire-behavior data were the primary drivers of observed patterns of relative risk. The exception to the finding above was in the Deschutes National Forest recreation data, where exposure patterns held relatively stable for both DNF and national fire-behavior data as compared to other resources. This is both because the DNF recreation resources were not spatially coincident with areas of high burn probability (BP) values in the DNF BP dataset and due to the drastic differences in mapped area of national recreation resources compared to DNF recreation.

As demonstrated in the spatial comparison and mathematical difference between CFL datasets at the two scales, differences in BP values rather than CFL are responsible for the observed differences in scatter-plots patterns between national and DNF datasets.

This finding highlights the apparent influence of modified vegetation and fuels data used as input to the FSim fire behavior model. Whether differences are due to changes in fuel models to a fuel type that is likely to burn more frequently or due to differences in fire spread rate of the updated fuel models; further exploration into the influence of pixel resolution and vegetation/fuels data modification is warranted to determine the relative contribution of each factor to observed differences in BP.

The question of whether risk was over- or under-stated with respect to certain resources due to the amount of area mapped, completeness of the database, and/or associated attribute records was preliminarily addressed through the scatter-plot approach used in this study. The risk scatter-plot method was useful for identifying whether observed differences in relative risk to resources were due to differences in the geospatial values data or differences in fire behavior data, or a combination of both. The methodology was not appropriate for quantifying wildfire risk to resources, however. Resources with greater mapped area are often correlated with greater wildfire risk for area-based assessment measures (e.g.Calkin et al. 2010, Thompson et al. 2010). Without the ability to tie wildfire exposure to a common unit of measure across all resources, one can only describe the characteristics of wildfire exposure graphically and spatially, but not quantify how much of one resource is likely to be impacted by wildfire compared to another.

National wildfire-risk assessments offer an opportunity to identify regions in need of fuels treatments to protect resources of high value from potentially damaging wildfire or to restore historical fire regimes to fire-adapted landscapes. If the national datasets examined above were used in fire planning and budget allocations, financial resources

may be improperly apportioned due to over- or underrepresentation of certain resources over others. For example, data gaps in the national recreation dataset were discussed in reference to national trails and lodges in national parks. If fuels treatment dollars were distributed to address risk mitigation to recreation resources, data gaps may cause inaccurate allocations towards parks with more current or complete data records.   By demonstrating these limitations of the spatial data presently available, widespread agreement may be fostered between the agencies and individuals that manage these data to provide incentives for updating and improving existing data for future wildfire-risk assessment efforts.

One disadvantage to relying upon uncoordinated efforts in data refinement and collection is the possibility for "strategic behavior" (Rideout et al. 2008), wherein wildfire risk to a geographic region or particular resource could be exaggerated by coarsely mapping or incorrectly categorizing low-value resources as highly valued. Although not an example of an attempt to bias budgetary allocations, a demonstration of how generalization of species habitat can drastically overstate risk is demonstrated in Figure 21. The Canada lynx (*Lynx canadensis*) is a wide ranging species and habitat boundaries illustrated in this figure were coarsely drawn (USFWS 2009). This designation of lynx critical habitat is different from the very specific habitat that has been mapped for some relatively scarce species or those with habitat maps that have been more finely delineated (e.g. compare with Bull trout (*Salvelinus confluentus*) habitat mapped in Figure 21). Use of the Canada lynx habitat data in the risk equation defined previously would identify lynx as a species highly exposed to wildfire risk because more of the habitat would be coincident with burnable pixels. Risk to more finely mapped species

like the bull trout, in comparison, would be much lower in this hypothetical situation because fewer pixels would be coincident with burn probabilities. If these boundaries were used "as-is" to inform budgeting efforts, areas with Canada lynx habitat might receive substantially more financial resources than areas lacking lynx habitat or than those with bull trout habitat. Similar challenges exist in other coarsely mapped resource values, collectively leading to the potential for highly skewed risk results. These illustrations highlight some of the potential challenges of acquiring and employing data from disparate sources to consistently identify risk. Future assessments could greatly benefit from establishing data standards and accuracy guidelines to limit the potential for biasing or manipulation and provide consistent assessment input data nationwide and from project to project.
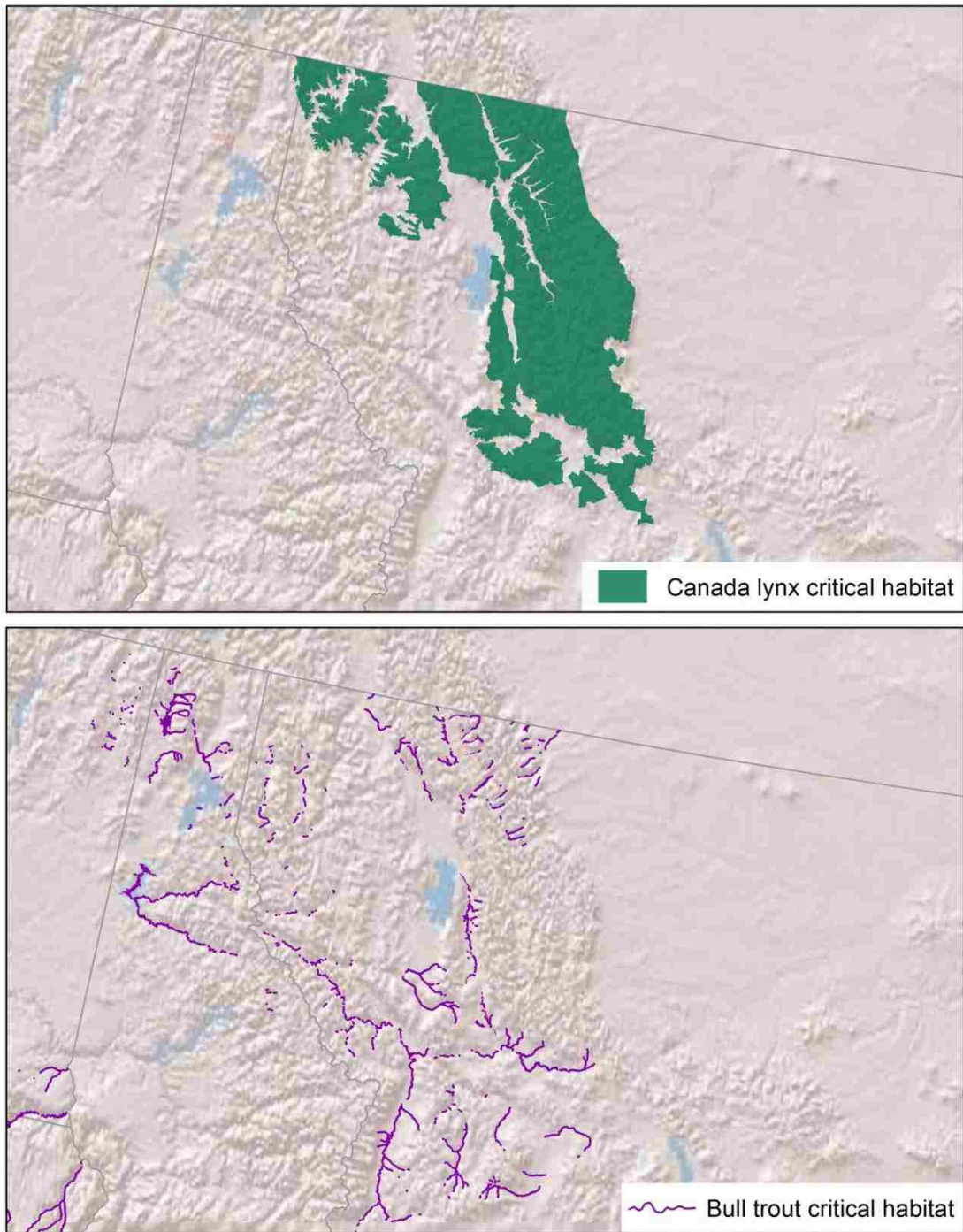
Figure 21. Canada lynx and bull trout critical habitat (USFWS 2005, 2009).

In the interim, research question number four sought information about how

national assessment data could be improved through knowledge gained from examining

input data at a finer scale. At a minimum, information gained in the recreation values comparison performed in this study suggest that the national dataset could be expanded to include Wild and Scenic River Corridors, identified by the Deschutes National Forest as recreation areas of high value. Additionally, a polygon-based ski areas dataset could likely be constructed through heads-up digitizing and aerial photography with minimal funding. This effort could greatly reduce spatial location errors and underrepresentation of areal extent resulting from use of the ski area data in their current form.

The second part of question four asked "how improvements can refine effects analysis for future assessments?" Again, with respect to opportunities for data improvement, the national recreation dataset provided several examples. A previous discussion of identified omissions and gaps in the national recreation data referred to the challenge of extracting only high value, developed campgrounds and recreation sites from the dataset. As explained, all records were retained in the final dataset to prevent data bias. Stratification of these resources according to relative value would facilitate discussions of resource prioritization within the identified datasets and among resources. For example, when characterizing resource response to fire, it is helpful to know the feasibility of resource replacement. If the last remaining stand of blight-resistant trees was coarsely mapped along with other, less ecologically valuable stands, it would impair resource specialists' ability to assign appropriate loss functions linking the consequence of a wildfire event to the probability of wildfire. Similarly, high use recreation sites with developed infrastructure are likely to suffer greater monetary losses to wildfire than primitive, undeveloped sites. Complete data records will likely improve fire effects analysis in future wildfire risk assessment efforts.

The last research question that this study attempted to address was how to move

forward with the imperfect data available for wildfire risk assessments. In the absence of

data developed according to data accuracy standards, full disclosure of known dataset

limitations should be provided, at the minimum. Users of data and model outcomes

should exercise caution as efforts to identify and address known errors are initiated.

Additionally, sensitivity analyses are recommended prior to any use of assessment

results, especially for the geospatial data layers suspected for over- or

underrepresentation.

6. CONCLUSIONS AND FUTURE RESEARCH

While uncertainties and errors in the spatial data layers representing resources of value are known to exist, particularly at the national scale, their use facilitates a baseline assessment of national wildfire risk and calls attention to needed improvements. Furthermore, wildfire risk assessments of this nature will continue to improve as data are refined and more information is received by the scientific community about how resources respond to fire. To be consistent with the risk definition of Finney (2005), which calculates net value change, resource specific response functions are needed to characterize effects from fires of varying intensities (as demonstrated by Calkin et al. (2010)).

A desired objective of the research described in this paper was to determine whether these data uncertainties lead to a systematic bias in identifying wildfire risk to certain regions of the country or towards certain resources. If these data were used to allocate funding for fuels treatment and wildfire risk mitigation, these biases might lead to more funding for areas with more complete spatial data or towards regions containing resources that have been coarsely mapped. In order to address this question in full, a sample of multiple, local, fine-scale assessments would be needed. Although these assessments and their respective resource values data are not readily available to directly answer the question of resource or regional biasing, this study begins to address some of the data gaps and uncertainties that would need to be examined before relying on these data to inform fuels treatment prioritization and budget distribution.

Notable differences in burn probability values were observed between the DNF and national fire behavior datasets. These differences were believed to be largely due to

modification of the vegetation and fuels data used as input in the FSim model. Use of

local knowledge and refined vegetation data appear to significantly alter burn probability

values. Stratton (2009) outlines a process by which local users can update LANDFIRE

fuels data based on field-level information and emphasizes the importance of calibration

to ensure believable model results. While it is generally accepted that the addition of

local information is an improvement to national-level data, and this input is encouraged;

sufficient validation is necessary to ensure any and all modifications are accurate. Future

research beyond this study is warranted to determine whether national- or Forest-level

simulated burn probability values are more closely aligned with historic burn

probabilities. The availability of nationally consistent vegetation and fuels data provided

by the LANDFIRE program enables nationally consistent wildfire modeling; however,

incorporation of local knowledge and vegetation data to refine fuels input is likely to

produce more accurate fire behavior results. Future model runs of FSim and future

wildfire risk assessments would likely benefit from these refinements following

calibration and validation of model results.

This study provided recommendations for improving national data to support

wildfire risk assessments, in an effort to reduce future uncertainties with respect to input

data and resulting decision making. Opportunities for improving national data were

outlined in the Discussion Section (Chapter 5) and include: use of fine-scale data where

possible to avoid mapping biases and over-representation of certain resources or regions

over others; development of a national polygon-based ski areas dataset to more accurately

depict location and size of ski areas potentially at risk of wildfire; and consideration of

the proportion of resource at risk relative to total mapped area of the resource

(particularly relevant in sensitive species habitat mapping) (Thompson et al. in press).

Further, federal agencies could greatly improve nationally mapped recreation data by

establishing and adopting data standards to ensure consistency within and among all

federal wildland fire management agencies.

Improvements to the national ski areas dataset appear to be relatively easy to

undertake, requiring minimal funding. Although ski areas often contain significant

developed infrastructure, they themselves are not identified as a dataset necessary for

wildland fire decision making at the national scale (*cf.* USDA - OIG 2006). Instead, ski

areas were highlighted in this paper as a fitting demonstration of the uncertainties found

in the dataset, the potential for those uncertainties to impact assessment results, and

opportunities to address uncertainties with relatively little effort as compared to other

resources examined.

Wildfire risk assessments are a decision-support tool with resource values

constituting only one component of the assessment. Although this research examines

only the knowledge uncertainty with respect to national geospatial data, wildfire risk

assessments are subject to other sources of uncertainty that must be explored (Ascough et

al. 2008, Thompson et al. 2010). Uncertainty with respect to modeled wildfire behavior,

resource response to fire, and how resulting information and respective uncertainties are

managed in decision making are all areas of recommended future research (Ascough et

al. 2008, Maier et al. 2008).

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