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Research Article

Assessing Wildfire Risk in the Wildland-Urban Interface: A Fire Prone Landscapes Approach

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Abstract

Wildfires in fire-prone landscapes pose significant threats to human communities and natural ecosystems, particularly in the Wildland-Urban Interface (WUI). To address these challenges, this study presents the Fire Prone Landscapes (FPL) approach, a geospatial analytical tool designed to assess wildfire risk within the WUI. The FPL analysis integrates key factors, including the Historic Fire Regime (HFR), Mean Fire Return Interval (MFRI), and Fire Regime Condition Class (FRCC), while emphasizing the unique risks faced by human populations in fire-prone environments.

The FPL approach builds upon the work of federal land management agencies and leverages geospatial data to quantify relative risk factors across large geographical regions. By considering vegetation cover, canopy closure, aspect, slope, and topographic position, the FPL analysis identifies areas where high population density intersects with heightened vulnerability to wildfire events.

Unlike traditional ecological assessments, the FPL analysis prioritizes the protection of human lives, structures, and infrastructure within the WUI. It provides valuable insights into areas where resources are potentially at risk of wildfire losses, enabling the prioritization of community protection measures and the enhancement of WUI home defensibility.

In this manuscript, we detail the methodology and application of the FPL approach, focusing on the Coeur d'Alene Indian Reservation and surrounding areas in Idaho, USA. We describe the data sources utilized, including remotely sensed images, digital elevation models, and past fire extents. The results of the FPL analysis demonstrate the spatial distribution of wildfire risk within the study area and highlight areas with elevated probabilities of wildfire occurrence.

These findings underscore the importance of mitigating wildfire fuel loads within the WUI to protect lives and preserve cultural values. The FPL approach serves as a valuable tool for assessing and managing wildfire risk in fire-prone environments, offering insights that can inform wildfire prevention, preparedness, and response strategies. By addressing the specific challenges of the WUI, the FPL approach contributes to the long-term viability and resilience of both human communities and natural ecosystems.

Keywords: Wildfire risk assessment; Fire prone landscapes; Wildland urban interface; Historic fire regime; Mean fire return interval; Fire regime condition class; Community protection; Home defensibility

Abbreviations: AGWA: Automated Geospatial Watershed Assessment; DEM: Digital Elevation Models; FPL: Fire Prone Landscapes; FRCC: Fire Regime Condition Class; GIS: Geographic Information System; GLS: Geographical Least Squares; HFR: Historic Fire Regime; IDL: Idaho Department of Lands; MFRI: Mean Fire Return Interval; NBR: Nominal Burn Ratio; NFPCS: Northern Fire Plan Cohesive Strategy Team; OLI: Operational Land Imager; PRISM: Parameter-Elevation Relationships on Independent Slopes Model; SWAT: Soil and Water Assessment Tool; USFS: US Forest Service; WUI: Wildland-Urban Interface

Introduction

Wildfires pose significant threats to human communities and natural ecosystems, especially in areas where urban development meets the risks of wildfires. The effective assessment and mitigation of this risk demand the utilization of analytical tools capable of evaluating and prioritizing areas with a high susceptibility to wildfires. This study introduces the FPL approach, a geospatial analytical tool tailored for the assessment and management of wildfire risk within the WUI [1].

The FPL analysis builds upon the foundational work of the US Forest Service (USFS) and other federal land management agencies, incorporating key factors such as HFR, MFRI, and FRCC. These metrics provide valuable insights into historical fire patterns, vegetation characteristics, and departure from natural fire regimes. However, while these assessments primarily focus on ecosystem management and restoration, they do not directly address the unique challenges posed by human settlements within fire-prone environments.

The objective of the FPL approach is to bridge this gap by assessing the specific wildfire risks faced by WUI areas. By integrating geospatial layers representing vegetation cover, canopy closure, aspect, slope, and topographic position, the FPL analysis quantifies the relative risk factors across large geographical regions. This enables the identification of areas where high population density coincides with heightened vulnerability to wildfire events.

Importantly, it is essential to note that the FPL analysis does not aim to predict the rate of spread or burn intensity of future wildfires. Instead, its focus is on identifying areas where human communities and critical infrastructure are potentially at risk of losses due to wildfire events. By overlaying the FPL analysis with WUI assessments, it becomes possible to prioritize community protection measures and allocate resources to enhance home defensibility.

In this manuscript, the methodology and application of the FPL approach are presented, with a specific focus on the Coeur d'Alene Indian Reservation and surrounding areas in Idaho, USA. The description of the data sources utilized includes remotely sensed images, digital elevation models, and past fire extents. Furthermore, the results of the FPL analysis are explored, and the implications for wildfire management and community protection are discussed.

Overall, the FPL approach offers a valuable tool for assessing and mitigating wildfire risk within the WUI. By incorporating both ecological and human factors, it provides a comprehensive understanding of wildfire-prone landscapes and their potential impacts on communities. Through the application of the FPL approach, the aim is to contribute to the development of effective strategies for wildfire prevention, preparedness, and response in fire-prone regions.

Materials and Methods

The approach used to investigate ecosystem management practices within the study area, particularly the geospatial tools, have been developed by the USFS. The USFS has long been dedicated to preserving and managing natural environments, prioritizing the health and viability of ecosystems and native plant and animal species. Their analytical tools, including the HFR, FRCC, and MFRI analyses, are designed to assess and understand natural biotic factors and historical fire patterns.

These tools provide valuable insights into the characteristics and dynamics of fire-adapted landscapes, contributing to the development of ecologically appropriate goals and objectives for land management. While the USFS approach primarily focuses on ecosystem health and resilience, it is important to recognize that its objectives do not encompass the direct protection of homes and communities from wildfires. The following subsections describe the methodologies employed, data sources utilized, and limitations considered in this study's analysis, which aims to shed light on the interface between ecosystem management and the challenges of protecting human settlements within fire-prone environments.

Fire regime condition class

The analysis of FRCC was conducted by the USFS Northern Fire Plan Cohesive Strategy Team (NFPCS) in Kalispell, Montana. In 2002, an analysis was completed, and it was revised in 2005 for distribution to land managers and analysts [2]. Since then, the LANDFIRE [3] project has significantly revised this analysis by incorporating new and insightful data analysis techniques. For this study, the FRCC data were utilized to analyze FRCC on the Coeur d'Alene Indian Reservation.

FRCC is a classification that assesses the degree of departure from the natural fire regime [4]. Coarse-scale FRCC classes have been defined and mapped by Hardy et al. [5] and Schmidt et al. [6]. Each fire regime includes three condition classes. The classification is based on a relative measure that describes the extent of departure from the historical natural fire regime, resulting in changes to various ecological components such as vegetation characteristics, fuel composition, fire frequency, severity, pattern, and other associated disturbances.

The three FRCC classes (nominal data) are as follows:

- FRCC I: Represents low departure from the central tendency of the natural fire regime, falling within the natural range of variability.
- FRCC II: Indicates moderate departure from the central tendency of the natural fire regime.
- FRCC III: Signifies high departure from the central tendency of the natural fire regime.

Characteristics of vegetation and fuel conditions within the natural fire regime are considered to be characteristic, while those that deviate from this regime are considered uncharacteristic. Factors contributing to departure include invasive species, alterations in forest composition and structure, or grazing practices that maintain grassy fuels at levels unsuitable for carrying a surface fire. The determination of departure amount is based on a comparison of composite fire-regime attributes to the central tendency of the natural fire regime, which then classifies the FRCC. Table 1 presents a simplified description of FRCC along with associated potential risks.

An analysis of FRCC on the Coeur d'Alene Indian Reservation shows that approximately 21% of the land area is in FRCC I (low departure from historical), just about 37% is in FRCC II (moderate departure), with 5% of the area in FRCC III (Table 1).

Table 1: FRCC by Area on the Coeur d'Alene Reservation.

FRCC by Area on the Coeur d'Alene Reservation.			
Fire Regime Condition Class		**Acres**	**Percent of Area**
Fire Regime Condition Class I	Low Vegetation Departure	72,508	21%
Fire Regime Condition Class II	Moderate Vegetation Departure	129,737	37%
Fire Regime Condition Class III	High Vegetation Departure	15,922	5%
Water		12,428	4%
Snow / Ice		120	0%
Urban		1,488	0%
Barren		158	0%
Sparsely Vegetated		160	0%
Agriculture		86,717	25%
Indeterminate Fire Regime Characteristics		28,220	8%
(LANDFIRE, 2006)	Total	347,458	

These data represent a substantial adjustment to the USFS NF-PCS Team (Kalispell, Montana) analysis of Fire Regime Condition Class in 2002 [2]. The LANDFIRE [3] data used in this analysis provide a substantially improved analysis basis and updated input data, leading to a better assessment of derivative data for both HFR and FRCC.

Historic fire regime

The assessment of HFR was also conducted by the USFS NF-PCST based in Kalispell, Montana. The revised distribution, represented by GIS layers, were utilized for analyzing the HFR within the Coeur d'Alene Indian Reservation as part of this study [2].

In fire-adapted ecosystems of the Upper Columbia Plateau, fire is a predominant process that shapes vegetation patterns, habitats, and species composition. The understanding of HFR, including fire frequency and severity before Euro-American settlement, is crucial for defining ecologically appropriate goals and objectives in a given area. Moreover, it enables managers to comprehend the spatial variability of historic fire regimes across the landscape.

Characterizing the historical range of variability is instrumental in enhancing ecological assessments, allowing managers to understand the variations in driving ecosystem processes and their past and potential effects. HFR plays a critical role in characterizing the historical range of variability in fire-adapted ecosystems, providing essential context for managing sustainable ecosystems and assessing risks to ecosystem components.

The Simulated Historical Fire Regime Groups [3] data layer classifies MFRI and fire severities into five fire regimes, as defined in the Interagency Fire Regime Condition Class Guidebook [7]:

1. Fire Regime I: 0-to-35-year frequency, low-to-mixed severity
2. Fire Regime II: 0-to-35-year frequency, replacement severity
3. Fire Regime III: 35-to-200-year frequency, low-to-mixed severity
4. Fire Regime IV: 35-to-200-year frequency, replacement severity
5. Fire Regime V: 200+ year frequency, any severity

These classifications are derived from vegetation and disturbance dynamics simulations using LANDSUM [8], which considers vegetation dynamics, topography, spatial context, as well as variability introduced by wind, dry years, and fire size characteristics. The Simulated Historical Fire Regime Groups layer provides information on HFR characteristics within the broader historical time period represented by the LANDFIRE Biophysical Settings layer and LANDFIRE Biophysical Settings Model Documentation.

The HFR data supplement other data required for assessing integrated risks and opportunities at regional and subregional scales. They estimate the relative change in disturbance processes and subsequent patterns of vegetation composition and structure. Coarse-scale definitions for natural (historical) fire regimes have been developed by Hardy et al. [5] and Schmidt et al. [6], and they have been interpreted for fire and fuels management by Hann and Bunnell [4]. At finer scales, these five classes may be defined with greater detail, while still retaining the hierarchy of the coarse-scale definitions.

General limitations

The HFR data were derived from fire history information obtained from various sources. They were designed to characterize broad-scale patterns of HFR for regional and subregional assessments. Field verification is strongly recommended for decisions based on these data, particularly at scales smaller than 1:100,000. While the HFR theme has a resolution of 30-meter cell size, its expected accuracy does not warrant its use for analyses of areas smaller than approximately 10,000 acres, such as assessments typically requiring 1:24,000 data, such as assessments in typical WUI zones.

Mean fire return interval

Broad-scale modifications of historical fire regimes and vegetation dynamics have occurred in numerous landscapes across the United States, influenced by land management practices, fire exclusion, ungulate herbivory, insect and disease outbreaks, climate change, and the invasion of non-native plant species. The LANDFIRE Project [3] generates maps of simulated historical fire regimes and vegetation conditions using the LANDSUM landscape succession and disturbance dynamics model. These maps, along with measurements of current vegetation departure, support fire and landscape management planning aligned with the goals of the National Fire Plan, Federal Wildland Fire Management Policy, and the Healthy Forests Restoration Act [9].

The Simulated Historical MFRI data layer [3] quantifies the average number of years between fires under the presumed historical fire regime. It is derived from vegetation and disturbance dynamics simulations using LANDSUM, which takes into account vegetation dynamics, topography, spatial context, wind patterns, dry years, and landscape-level fire size characteristics. This layer provides insight into the historical fire regime characteristics within the broader context of the LANDFIRE Biophysical Settings layer and LANDFIRE Biophysical Settings Model Documentation.

To calculate the mean fire return interval, the simulation length is divided by the number of fires recorded on each pixel. The simulations used for this layer spanned 10,000 years to capture the most comprehensive representation of fire regime characteristics within complex landscapes, considering computational limitations. However, it is important to note that these simulations do not precisely depict the last 10,000 years of measurable history, as they do not account for dynamic factors like climate change, vegetation species dispersal, and anthropogenic influences on vegetation and fire characteristics.

Simulated historical MFRI were classified into 22 categories, with varying temporal lengths to preserve finer detail for frequently burned areas and reduce detail for rarely burned areas. Additional data layer values were assigned to represent Water, Snow/Ice, Barren land, and Sparsely Vegetated areas. Vegetated areas that never experienced fire during the simulations were classified as "Indeterminate Fire Regime Characteristics," indicating either undefined fire behavior or extremely low probabilities of fire ignition [10].

Analysis of the MFRI on the Coeur d'Alene Indian Reservation reveals that nearly 70% of the land area is subject to a return interval of under 80 years, while the remaining half of the land area experiences mean fire return intervals ranging from 80 to 200 years. Approximately 90% of the land area has mean fire return intervals of under 150 years. The data exhibit considerable variability, with the largest land area category, representing 12% of the total land area (40,800 acres), falling within the mean fire return interval of 31-35 years. These findings indicate that the role of wildland fire in this region is highly variable and operates on temporal scales that surpass typical planning efforts.

Results and Discussion

Schlosser [11] developed a methodology to assess the location of FPL in both forested and non-forested ecosystems across the western United States. This approach has been applied in various contexts, including tribal and county-level fire mitigation plans [9], FEMA hazard mitigation plans, BIA, and BLM Fire Management Plans, and Environmental Assessments. The methodology has been implemented in over 50 project areas in Idaho, Montana, Nevada, Oregon, and Washington, enabling the determination of FPL characteristics within areas overlapped by the WUI.

The primary objective of the FPL analysis is to identify relative risk factors associated with the spread of wildfires across large geographical regions. This analysis relies on past fire occurrences as indicators of specific area characteristics and their propensity for future burning. Essentially, if certain combinations of vegetation cover type, canopy closure, aspect, slope, and hillside position have experienced frequent fires in the recent past (within the last 50 years), it is reasonable to assume that they will exhibit similar tendencies in the future, unless mitigation activities are undertaken to reduce the potential for wildfire.

The analysis technique involves integrating critical factors into a geospatial model using Geographic Information System (GIS) layers [12]. This allows for the determination of the area available for burning for each combination of input variables and subsequently evaluates the extent to which these areas have been affected by past fire events. In this study, the analysis focuses on the Coeur d'Alene Indian Reservation, located adjacent to and within Benewah County, Shoshone County, Latah County, and Kootenai County, Idaho, to ensure a robust sample area.

Building the mesoregion fire prone landscapes profile

The Mesoregion FPL Profile is a crucial framework for assessing wildfire risk in the study area. This section provides an overview of the process involved in constructing the profile, which serves as the foundation for understanding and evaluating the propensity of the landscape to burn. By integrating geospatial topographic information, historical fire occurrences, and vegetation characteristics, the aim is to identify areas within the mesoregion that are highly susceptible to wildfires. The utilization of diverse datasets, including remotely sensed images, digital elevation models, past fire extents, and other relevant sources, enables a comprehensive and multi-dimensional assessment of wildfire risk. Through this integrated approach, valuable insights are gained into the spatial distribution of fire-prone landscapes, which in turn inform effective wildfire management strategies and community protection measures.

Digital elevation and riparian zone analysis

Digital Elevation and Riparian Zone Analysis played a vital role in characterizing the topographic features and riparian zones across the FPL analysis area. To achieve this, Digital Elevation Models (DEM) were obtained from USGS 10-meter DEM data at quarter-quadrangle extents [13], and seamlessly merged to create a continuous elevation model covering the entire analysis area.

In conjunction with the digital elevation data, the Parameter-Elevation Relationships on Independent Slopes Model (PRISM) climate data were utilized to describe the timing and amount of precipitation [14]. This precipitation data, represented as raster grids, was incorporated into the Automated Geospatial Watershed Assessment (AGWA) tool. By leveraging the capabilities of the AGWA tool and integrating it with the Soil and Water Assessment Tool (SWAT) model, various vegetation characteristics derived from remote sensing vegetation identification were considered. This integration enabled the identification of stream locations and facilitated the determination of stream depth and velocity, taking into account soil and subsurface geology.

Using ESRI ArcMap spatial analyst tools, additional grids were generated from the DEM layer. A Flow Direction Grid was created to establish the position of each pixel on the hillslope, while a Flow Accumulation Grid aided in identifying the proximity of pixels to water-bearing stream courses. These grids played a crucial role in the creation of a Shreve Stream layer, which followed the principles outlined by Shreve [15].

The integration of digital elevation data, riparian zone analysis, climate information, and the Shreve Stream layer provided comprehensive insights into the topographic characteristics and hydrological features within the FPL analysis area. This integrated approach enhanced understanding of stream channels of different orders and their significance in assessing wildfire risk.

Remotely sensed images

Remotely Sensed Images were utilized to assess plant cover information and percent of canopy cover in the FPL analysis. Landsat 8 Operational Land Imager (OLI) images [16] were employed for this purpose. The Landsat OLI instrument is equipped with nine spectral bands, allowing for the capture of high-resolution image data of the Earth's surface. These spectral bands detect radiation at various frequencies, including visible, near-infrared, short-wave infrared, and thermal infrared, enabling the extraction of spectral information from the sun-lit Earth. The pixel sizes range from 15 meters in the panchromatic band to 30 meters in the visible, near infrared, and short-wave infrared bands, and 60 meters in the thermal infrared band.

Operating at an altitude of approximately 705 kilometers, the Landsat 8 satellite follows a sun-synchronous orbit with a 98.2-degree inclination and a descending equatorial crossing time of 10 a.m. daily. The use of image spectrometry offers significant benefits in monitoring vegetation and biophysical characteristics. Vegetation reflectance provides valuable insights into chlorophyll absorption bands in the visible and near-infrared regions, while plant water absorption can be identified in the middle infrared bands. Additionally, hyper-spectral analysis techniques allow for the differentiation of exposed soil, rock, and non-vegetative surfaces from vegetation.

For this project, two Landsat 8 OLI images from 2010 and 2011 were acquired to conduct hyper-spectral analysis. The analysis procedures followed the conventions outlined in the Idaho Vegetation and Land Cover Classification System, with modifications based on Redmond [17] and Homer [18]. Each imagery pixel was trained using physical site characteristics of known plant types and non-vegetative conditions. Land pixels with a resolution of 15 meters were identified and used to associate the propensity to burn based on the past fire geospatial database developed specifically for this project. The characterization of land vegetative type and canopy cover percent provided the necessary nominal data for this analytical effort.

Past fires

Past Fires serve as valuable indicators of areas on the landscape that have experienced wildfires in the past, forming a crucial baseline for the development of the FPL analysis. In this study, data regarding these fire extents were obtained from multiple sources in the north Idaho region, including the USFS Panhandle National Forest, the USFS Clearwater National Forest, Idaho Department of Lands (IDL), BIA, and the BLM.

Each recorded past fire event was geospatially documented, capturing important information such as the date of ignition and the corresponding burned area. The fire extents varied, with some events represented by single 10-meter pixel extents that signify ignition points, while others were identified by larger burn area polygons. In cases where fire extents were not explicitly recorded, manual digitization techniques were employed, aligning year of collection appropriate color imagery extents from the NAIP imagery dataset [19].

By overlaying this comprehensive fire history data with other previously documented datasets, the analysis successfully established the propensity to burn based on a combination of landscape factors. These factors include vegetation type, slope, aspect, topographic position on the landscape, as well as horizontal and vertical distance from riparian zones. The integration of past fire extents into the analytical framework enhances our understanding of fire behavior and allows for the identification of areas at greater risk of future wildfire events.

The utilization of multiple data sources and careful geospatial analysis enables a comprehensive evaluation of the relationship between landscape characteristics and past fire occurrences, providing valuable insights for effective wildfire management and mitigation strategies. Leveraging the power of historical fire events, this approach informs the assessment of fire-prone landscapes and their associated risks, contributing to more informed decision-making in wildfire management.

Raster data articulation

The analysis employed a geospatial regression approach to assess the propensity to burn across the study area, considering various landscape factors. By integrating variables such as vegetation type, vegetative cover percent, slope, aspect, topographic position, and proximity to water bodies, the FPL approach utilized geospatial regression analysis to generate a raster data layer at a resolution of 10 meters. This data layer provides a quantification of the potential propensity to burn on a scale ranging from 0 to 100 (Table 2).

The FPL approach offers a powerful means of assessing the risk of wildfire occurrence in the landscape, capturing the complex interplay between landscape characteristics and fire risk through geospatial regression analysis. By incorporating this approach, the FPL analysis produces a refined and detailed depiction of areas that are more susceptible to wildfire events.

Table 2: Fire *Prone* Landscapes Analysis Results on the Coeur d'Alene Reservation.

Risk Category		Acres	Percent
	0	13,288	4%
	1-10	-	0%
	11-20	97,078	28%
	21-30	13,126	4%
	31-40	32,946	9%
	41-50	32,042	9%
	51-60	40,660	12%
	61-70	84,884	24%
	71-80	33,428	10%
	81-90	-	0%
	91-100	-	0%
	Total	347,451	

It is important to note that the extent of the landscape analyzed in this study encompassed the entire Coeur d'Alene Reservation, along with the Idaho counties of Bonner, Kootenai, Shoshone, Benewah, Latah, and Clearwater. This expanded extent is situated within the Western Interior Woodlands and Shrublands Biome [20]. While climate was not directly incorporated into the FPL analysis, it remains a vital consideration in daily wildfire weather risk assessments, which complement and inform the broader understanding of wildfire dynamics and management strategies in the WUI.

Nominal burn ratio analysis

The Nominal Burn Ratio (NBR) analysis played a pivotal role in quantifying and evaluating wildfire risk across the FPL analysis area. This approach utilized a ratio-based methodology to assess the extent to which different landscape attributes had been affected by past fire events. By examining the NBR values, valuable insights were gained into the potential vulnerability of various vegetation types and land cover classes to wildfires.

The NBR analysis involved calculating the ratio of the burned area to the total available area for each specific attribute or land cover category within the study area. This approach allowed the determination of relative impacts of wildfires on different landscape components, providing a quantitative measure of their susceptibility to burn. A higher NBR value indicated a greater proportion of the area within a specific attribute or land cover class that had been affected by fire.

The individual physical characteristics, such as vegetation type, canopy coverage, slope, aspect, and proximity to water bodies, were combined to generate a comprehensive assessment of wildfire risk using the NBR analysis. This integration allowed identification of areas with higher NBR values, indicating a higher propensity for wildfire occurrence and greater vulnerability to fire events.

Furthermore, the NBR analysis facilitated prioritization of management and mitigation efforts based on the relative vulnerability of different landscape attributes. Areas with high NBR values may require targeted interventions, such as fuel reduction treatments or enhanced fire management strategies, to mitigate the potential impact of future wildfires.

By incorporating the NBR analysis into the broader FPL framework, a more nuanced understanding of the spatial patterns of wildfire risk across the study area was gained. This information is invaluable for informing land management decisions, land-use planning, and community preparedness efforts aimed at reducing the impact of wildfires on both human and natural systems.

The integration of the NBR analysis with other data sources and analytical approaches presented in this study provides a comprehensive and multidimensional assessment of wildfire risk. It underscores the significance of considering not only individual landscape attributes but also their combined effects in shaping wildfire dynamics and informing effective management strategies.

Geographical least squares

The Geographical Least Squares (GLS) analysis was employed to integrate the comprehensive dataset and assess the spatial patterns of wildfire risk across the study area. This powerful analytical tool allowed for the quantification of the relationships between landscape characteristics and wildfire risk, providing valuable insights for effective wildfire management and mitigation strategies.

The GLS analysis utilized the spatially stored data within the

ESRI ArcGIS bundle and the interactive SQL database, enabling efficient retrieval and analysis of the relevant variables. By leveraging the capabilities of GLS, the model incorporated the spatial context of the landscape factors, estimating the significance and coefficients of each variable while considering their spatial relationships (Figure 1).

The output of the GLS analysis was visually represented through a color-coded scheme, where green cells indicated areas of low relative wildfire risk, yellow cells represented moderate risk, and red cells depicted zones with the highest risks (Table 2). It is important to note that individual red cells may not necessarily indicate the most threatening zones; instead, it is the continuous hillsides painted red that correspond to high-intensity WUI zones that demand urgent mitigation efforts.

By employing GLS, the FPL analysis provided a comprehensive and spatially explicit assessment of wildfire risk (Figure 1). This approach not only identified areas with varying levels of risk but also highlighted the interconnectedness of landscape characteristics and their influence on wildfire dynamics. The visualization of the results offered a clear understanding of the spatial patterns of risk, enabling stakeholders and decision-makers to prioritize mitigation efforts and allocate resources effectively.

The integration of GLS analysis within the FPL framework demonstrated its efficacy in handling diverse datasets and capturing the complex interplay between landscape factors and wildfire risk. This approach enhanced the understanding of the spatial distribution of risk and empowered proactive wildfire management strategies, ultimately contributing to the protection of communities and the preservation of the natural environment.

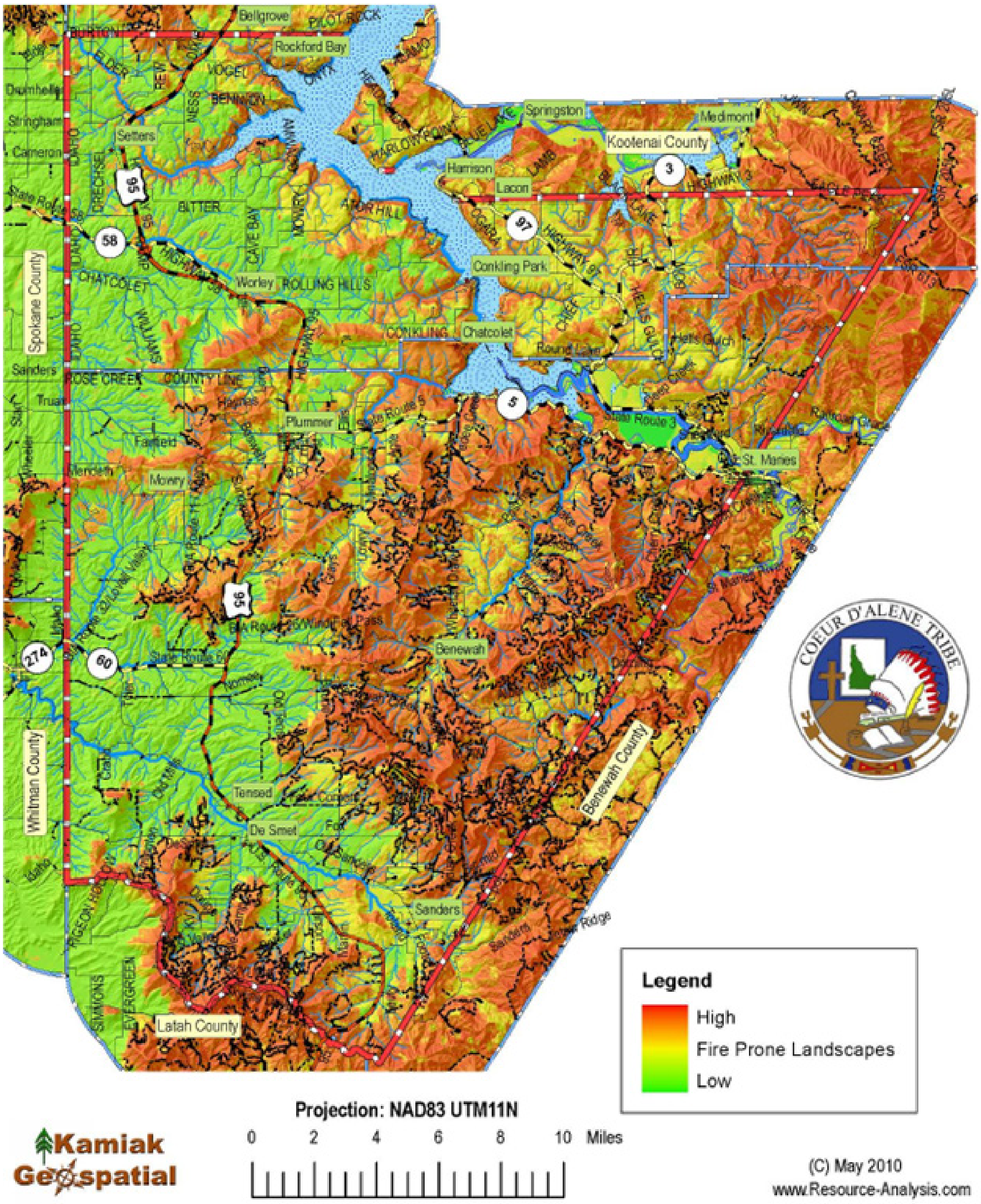

Figure 1: Fire Prone Landscapes of the Coeur d'Alene Reservation [24].

Discussion

The application of the FPL methodology developed by Schlosser [11,21], and refined for this project (2011), allowed for the assessment of landscape susceptibility to burning during the fire season in the event of ignition. Through the use of a linear regression analysis within the GIS program, each significant variable was assigned a value at the pixel level.

The FPL rating score for the Coeur d'Alene Reservation ranged from 0 (Coeur d'Alene Lake) to a maximum of 80. The distribution of these categories is provided in Table 2, and Figure 1 visually illustrates the results. The data exhibit a bimodal distribution, with one mode occurring at FPL rankings of 11-20 and another at 61-70.

The risk-rating score of zero represents no relative risk, while a score above 75 signifies severe risk. It is important to note that no areas were categorized with the highest risk score of 100. The rating scale should be interpreted as nominal data, allowing for sequential ordering of values without assuming multiplicativity. The scale provides relative comparisons between different sites.

The FPL analysis proves to be a valuable tool for assessing risks to people, structures, and infrastructure within the WUI. It geospatially identifies areas where landscape components converge, creating conditions conducive to historical fire occurrences. While the FPL analysis does not predict the rate of spread or burn intensity, it serves as an important resource for prioritizing community protection efforts and determining defensibility priorities for homes within the WUI.

Overall, the comprehensive assessment provided by the FPL methodology and the integration of various datasets, including topographic information, historical fire occurrences, and vegetation characteristics, contribute to a better understanding of wildfire risk in the study area. These insights enable stakeholders and decision-makers to develop effective wildfire management strategies, prioritize resources, and enhance community protection measures within the WUI.

Application of assessment tools

In this section, the application of different wildfire assessment tools is discussed, highlighting their specific contributions to wildfire management. The MFRI, HFR, and FRCC analyses were developed by federal land management agencies with a focus on quantifying departures from historical vegetation conditions. These tools are valuable for ecosystem restoration efforts, aiming to restore natural cycles of vegetation, fire, wildlife, and soil and water processes. FRCC should be considered as a valuable analysis tool, as it provides complementary insights into historical conditions and current departures.

On the other hand, the FPL assessment tool has been specifically designed to address wildfire risk challenges in the WUI. Unlike HFR and FRCC, FPL does not aim to measure departures from historical conditions. Instead, it focuses on evaluating fire risk based on topographic and vegetative factors. The tool identifies areas with high-risk ratings, often depicted as significant clusters of red on the maps (Figure 1), surrounding or adjacent to homes and infrastructure. Such areas indicate a higher probability of experiencing a wildfire event.

To estimate the probability of future wildfire events, the MFRI analysis and the FPL ratings can provide valuable insights. The MFRI analysis considers historical fire occurrence over a long period (10,000 years) and does not directly integrate current conditions to determine the current probability of wildfire return.

In contrast, FPL can be used to estimate the probability of future wildfire events. By converting the FPL rating score to represent a probability within a specific timeframe, such as a 25-year period, the relative score can be interpreted as the likelihood of a wildfire event occurring. The conversion can be performed using the Extreme Value Theory [22-25], where a lower FPL rating score corresponds to a lower probability of witnessing a 25-year wildfire event. It is important to note that these conversions serve as illustrative purposes, and the actual probability of occurrence may differ from these estimates.

Further extrapolation of these data can enhance the understanding of the probability of future wildfire events on the Coeur d'Alene Reservation. If left undisturbed and unmitigated, the risk rating score can estimate the likelihood of future wildfire events for each evaluated area, expressed as a percentage. For example, a rating score of 15 would represent a 15% probability of experiencing a wildfire event within the next 25-year period. Mitigation measures can be expected to decrease the likelihood of large-scale wildfire events.

Considering the topography, soils, lightning ignitions, and human-induced wildfires, the probability of wildfire events within the Coeur d'Alene Reservation is moderate to high. Specific areas within the reservation are more likely to experience damages due to wildfires. It is important to recognize that the Coeur d'Alene Reservation is expected to face frequent wildfire events, with multiple ignitions occurring every year.

Mitigation of wildfire fuel loads within the WUI not only holds significant potential for saving lives and protecting property but also carries profound cultural implications for all individuals residing within these populated areas. By implementing proactive measures to reduce fuel loads and enhance defensible space, communities can safeguard their homes, preserve natural environments, and honor the invaluable heritage tied to these landscapes. Embracing the importance of WUI mitigation fosters resilience, promotes sustainable coexistence, and safeguards the well-being of both present and future generations.

This concluding subsection emphasizes the different assessment tools used and their specific contributions to understanding wildfire risk. It also highlights the importance of mitigation measures and their potential for protecting lives, property, and cultural heritage within the WUI.

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Conflict of Interest

There are no conflicts of interest involving this article.

References

1. Schlosser W (2023) Defining the Wildland-Urban Interface: A Logic-Graphical Interpretation of Population Density. (S Taylor, Eds.) Online Journal of Ecology & Environment Sciences v. 1(2).
2. NFPCST (2005) Northern Fire Plan Cohesive Strategy Team. Kalispell, MT 59901: Flathead National Forest, 1935 3rd Ave.
3. LANDFIRE (2006) MFRI. (US Department of Interior, Geological Survey)
4. Hann W, Bunnell D (2001) Fire and land management planning and implementation across multiple scales. Int J Wildland Fire 10: 389-403.
5. Hardy C, Schmidt K, Menakis J, Samson N (2001) Spatial data for national fire planning and fuel management. International Journal of Wildland Fire 10: 353-372.
6. Schmidt K, Menakis J, Hardy C, Hann W, Bunnell D (2002) Development of coarse-scale spatial data for wildland fire and fuel management. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
7. Hann W, Shlisky A, Havlina D, Schon K, Barrett S, et al. (2004) Interagency Fire Regime Condition Class Guidebook.
8. Keane R, Holsinger LM, Pratt S (2006) Simulating historical landscape dynamics using the landscape fire succession model LANDSUM. Fort Collins, Colorado: US Forest Service, Rocky Mountain Research Station.
9. Healthy Forests Restoration Act (2003) Public Law 108-148. (Public and Private Laws. 108th Congress. HR 1904). (US Large, Compiler) Washington, DC: US Government Printing Office.
10. Keane RE, Parsons R, Hessburg P (2002) Estimating historical range and variation of landscape patch dynamics: limitations of the simulation approach. Ecological Modeling 151(1): 29-49.
11. Schlosser W (2004) Benewah County Hazard Mitigation Plan. St. Maries, Idaho: Northwest Management, Inc.
12. ESRI (2011) Knowledge Base-Technical Articles.
13. USGS (2010) US Geological Survey.
14. Daly C, Gibson W, Taylor G, Johnson G, Pasteris P (2002) A Knowledge-Based Approach to the Statistical Mapping of Climate. Climate Research 22(2): 99-113.
15. Shreve R (1967) Infinite Topologically Random Channel Networks. Journal of Geology 74: 178-186.
16. USGS (2018) Landsat-Earth observation satellites (ver. 1.4, August 2022).
17. Redmond K (1999) Climate-change issues in the mountainous and intermontane west. Proceedings of the Rocky Mountain/Great Basin Regional Climate-Change Workshop, pp.151.
18. Homer C (1998) Idaho/western Wyoming landcover classification report and metadata. Utah State University. Logan, UT: Department of Geography and Earth Resources.
19. Natural Resource Conservation Service (2011) National Agriculture Imagery Program. Ortho NAIP. Benewah County, Idaho, USA: Geospatial Data Gateway.
20. Smith T, Smith R (2012) Elements of Ecology (Eighth Eds.). Boston: Pearson Education, Inc.
21. Schlosser W (2010) Benewah County Wildland-Urban Interface Wildfire Mitigation Plan. St. Maries, Idaho: Kamiak Ridge, LLC.
22. Castillo E (1988) Extreme value theory in engineering. New York: Academic Press, Inc.
23. Quigley T, Gravenmier R, Graham R (2001) Interior Columbia Basin Ecosystem Management Project: project data. Station Misc. Portland, OR. US: Department of Agriculture, Forest Service, Pacific Northwest Research Station.
24. Schlosser W (2011) Coeur d'Alene Reservation Tribal Hazards Mitigation Plan. Plummer, Idaho: Kamiak Ridge, LLC.
25. Schlosser W (2012) Benewah County Multi-Jurisdictional Hazard Mitigation Plan. St. Maries, Idaho: Kamiak Ridge, LLC.