Wildland/Urban Interface and Communities at Risk

Joint Fire Modeling Project for Caribou County, Idaho
Bureau of Land Management, Upper Snake River District GIS
And
Idaho State University GIS Training and Research Center

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Abstract:

Wildland/Urban Interface (WUI) fires and Communities at Risk (CAR) projects are high priorities to federal land management agencies. It is important that the federal government help educate homeowners, firefighters, local officials, and land managers regarding the risk of wildland fire. The Bureau of Land Management's (BLM) Upper Snake River District (USRD) Geographic Information Systems (GIS) team and the GIS Training and Research Center (GISTReC) at Idaho State University (ISU), have created a model to predict potential wildfire risk areas for Caribou County, Idaho. During this project models were created of specific individual risks associated with wildfires: topography, fuel load, and the number of structures at risk. These models were evaluated together to create a final fire risk model for Caribou County, Idaho. This report describes each of the WUI fire risk components and what effect each has on the final fire risk model. This final model is an accurate depiction of the spatial distribution of wildfire risk in Caribou County and can be used by regional fire managers to manage wildfire risk.

Keywords: Fire, Wildfire, GIS, Caribou County, Idaho, BLM

Contents

Introduction:

The Wildland/ Urban Interface (WUI) is more than a geographic area. It is anywhere homes and other anthropogenic structures exist among flammable vegetative fuels (Owens and Durland, 2002). Because wildland fire is an essential component of healthy ecosystems, people need to live compatibly with wildland fire (Owens and Durland, 2002). As people move into the Wildland/ Urban Interface zones, planners and agencies responsible for fire management and protection are in need of tools to help them assess fire risk and make decisions regarding funding, development, and deployment of suppression resources. One valuable tool used by fire managers is Geographic Information Systems (GIS). GIS allows for spatial analysis of large geographic areas and is easily integrated with satellite imagery.

Using both GIS and remote sensing, we created a Wildland/Urban Interface (WUI) Fire Risk model. It is comprised of 7 sub-models that describe different aspects of fire risk:

- **Aspect: Sun Position -** takes into account varying fire risks associated with aspect, especially as it relates to desiccation effects.
- **Slope: Rate of Spread -** translates how the steepness of a surface affects the rate of spread of a fire.
- **Slope: Suppression Difficulty -** takes into account how varying slope influences suppression efforts by firefighters and their equipment.
- **Fuel Load: Intensity -** describes how different fuel load classes release heat energy during a fire and thereby affect their environment.
- **Fuel Load: Rate of Spread -** describes how different fuel types spread and affect fire risk.
- **Fuel Load: Vegetation Moisture -** takes into account how different levels of vegetation moisture affect fire risk.
- **Structures at Risk -** includes the density of man-made structures.

Each of these component models are weighted and summed to produce the Final Fire Risk Model. The Caribou County, Idaho WUI fire risk assessment is a continuation of WUI projects that have been completed and validated for the City of Pocatello, Idaho (Mattson *et al*, 2002) the city of Lava Hot Springs, Idaho (Jansson *et al*, 2002), Clark County, Idaho (Gentry *et al*, 2003), Bannock County, Idaho (Gentry *et al*, 2003), Power County, Idaho (Gentry *et al*, 2003), and Oneida County, Idaho (Franks *et al, 2004).*

Methods:

Utilized data sets:

- Digital Elevation Model (DEM) of Caribou County
- Landsat 7 ETM+ imagery for Caribou County and environs – Path 038, Row 030 and Path 038, Row 031.
- Digital Orthophoto Quarter-Quads (DOQQs) for Caribou County
- Transportation, place and county boundary datasets for Caribou County
- Structure density raster data provided by Josse Allen of Caribou County

Data Preprocessing:

DEM Data:

The DEM data for the Caribou County area was initially retrieved from the ISU GIS Center's Spatial Library as that for the AOC (Area of Concern) of which Caribou County is a part. This file was, however, found to contain numerous artifacts, which compromised its value for this application. Instead it was decided to reconstruct a DEM of Caribou County using the 55 individual DEMs that comprise the county's extent. These smaller DEMs were also retrieved from the ISU Spatial Library. The SPutnam Quad DEM was found to have been mislabeled and was not in the spatial library. We downloaded that DEM from the GIS Data Depot at http:\\www.geocomm.com and reprojected it to the Idaho Tranverse Mercator (NAD27) projection that was used for the other 54 DEMs.

In that several of the DEM images did not meet precisely, we found it necessary to fill the single-pixel inter-image NoData voids with pixels from adjoining images. This was done using ArcInfo 8.3 by creating a mask of the void area, shifting the adjacent images by 1 pixel to the southwest, multiplying the mask against the shifted images and adding the result to the original imagery.

Landsat Imagery:

No single Landsat scene completely encompasses all of Caribou County. Consequently, it was necessary to use two Landsat scenes: path 38 row 30 and path 38 row 31 for this project. The two Landsat scenes (Landsat 7 ETM+ Path 038, Row 030 and Row 031) were retrieved from the GIS TReC's archives as zipped ".tif" files (each including bands 1, 2, 3, 4, 5, and 7) and converted into ArcInfo grids using *imagegrid* of ArcInfo 8.3.

The grids were then processed, using a custom-written aml, to produce the associated reflectance and radiance grids. The separate reflectance and radiance grids were then mosaicked for each band using the ArcInfo *merge* command.

When the two reflectance images were mosaicked, it was observed that the overall image densities of the two reflectance images (row 30 and row 31) differed so the reflectances for both scenes were recalculated using the single solar angle value for row 30 and re-mosaicked.

DLG Datasets:

The Idaho county boundaries and Idaho places datasets were downloaded from the ESRI website at: http://arcdata.esri.com/data/tiger2000/tiger_download.cfm. The Caribou County boundary was selectively saved as a separate shapefile and re-projected as necessary.

The transportation dataset of roads and railroads was provided by Josse Allen, GIS Specialist/Mapper, of the Caribou County Assessor's Office.

Data Processing:

The WUI fire risk model consists of several sub-model risk components (*italic*) that can be categorized as follows:

- Topographic
  - Slope
    - *Suppression difficulty*
    - *Rate of spread*
  - Aspect
    - *Orientation to sunlight*
- Fuel Load
    - *Rate of Spread*
    - *Fire Intensity*
    - *Vegetation Moisture*
- Structures
    - o Structure Density

Each model component was treated separately to learn how each affected fire risk. To be able to merge the models together easily, we normalized the value range of each model to a scale from 0 to 1000, where 1000 is highest risk. We used weightings based on Mattsson *et al*. (2002) and Jansson *et al* (2002) to complete our analysis. After completing these analyses, we examined the impact each fire model component had on the overall fire risk in Caribou County, Idaho.

Topographic Sub-model Components

Creating the Topographic: Slope: Suppression Difficulty

Using the Caribou County area DEM as input, a slope grid was calculated using the ArcMap processing selection: Spatial Analyst → Surface Analysis → Slope. The resultant pixel intensity equates to the slope of the DEM at that point. The output pixel value unit of the resultant grids was degrees of slope, the z-factor was 1 and the output cellsize was set to30 meters.

To create the Slope: Suppression Difficulty sub-model, we used the original slope and applied weightings for Slope: Suppression Difficulty following Mattsson *et al.* (2002) (table B-6 in Appendix B) using ArcMap → Spatial Analyst → Reclassify, shown in (fig. 1).

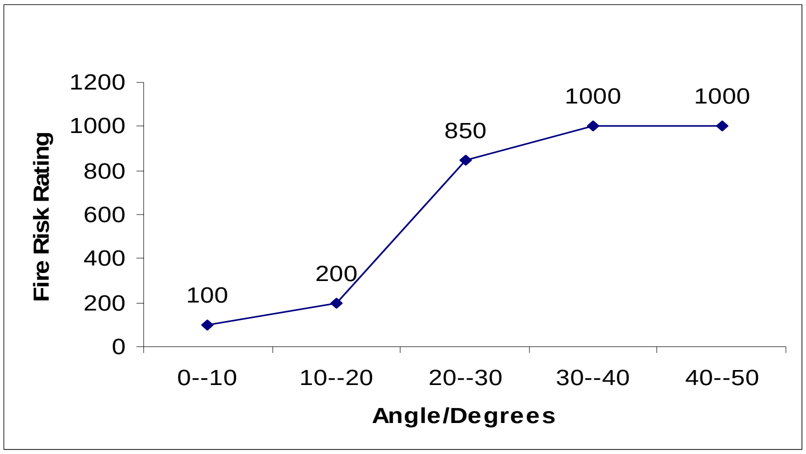

Figure 1. *Weightings for slope/suppression difficulties describe how suppression difficulties are affected by the angle of slope (Mattsson et al, 2002).*

Creating the Topographic: Slope: Rate of Spread

To make the Slope: Rate of Spread sub-model, we reclassified the Slope based on weightings from Mattsson *et.al.* (2002) using ArcMap → Spatial Analyst → Reclassify (fig. 2).
These weightings are shown in table B-5 in Appendix B.

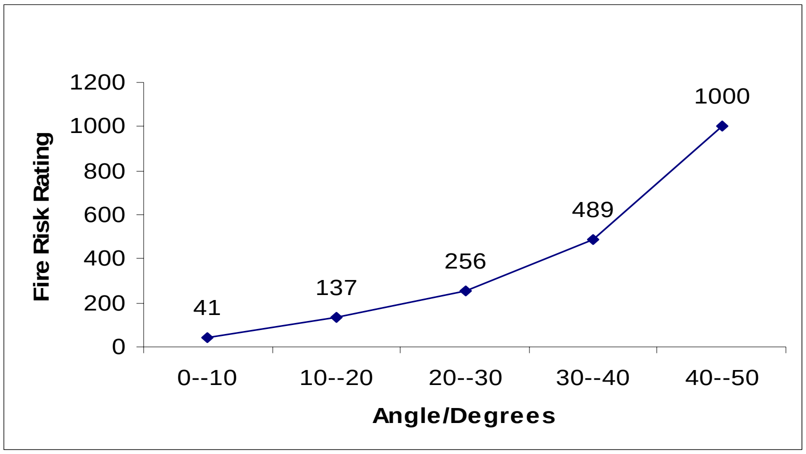

Figure 2.. *Weightings describe how spread rate increase with angle of slope. The weight proportion is essentially exponential with slope angle (Mattsson et al., 2002).*

Creating the Topographic: Aspect: Sun Position

Aspect indicates the horizontal *direction* of the instantaneous slope face. Using the Caribou County area DEM as input, an aspect grid was calculated. The resultant pixel intensity equates to the angular horizontal direction of the DEM slope at that point. The ArcMap processing selection was: Spatial Analyst → Surface Analysis → Aspect. The output units were degrees (where 0 is north, 90 is East, etc.) and the output cellsize was set to30 meters.

To create the Aspect: Orientation to Sunlight we reclassified the aspect grid, following Mattsson *et al* (2002) (table B-7 in Appendix B) using ArcMap → Spatial Analyst → Reclassify (fig. 3).

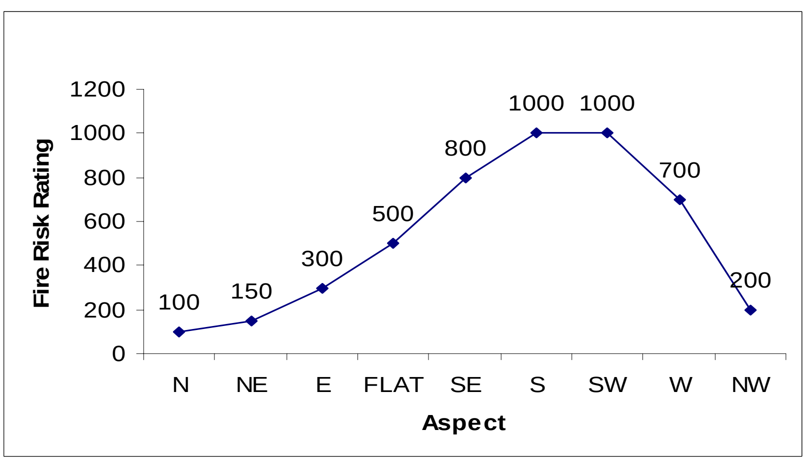

Figure 3. *Weightings for Aspect/Sun position describe how the sun desiccates the ground at different aspects (Mattsson et al, 2002).*

Fuel Load Sub-model Components

Creating the Fuel Load Fire Risk Components

The fuel fire risk components are all derived from the fuel load estimates determined from the Normalized Difference Vegetation Index (NDVI) calculated from the Landsat imagery.

We estimated vegetation cover with satellite imagery using the Normalized Difference Vegetation Index (NDVI) for Landsat 7 ETM+, dated 07-05-2003. The NDVI, which is an estimation of photosynthetically active vegetation, was calculated from band 3 (visible red) and band 4 (near infrared) of the original uncorrected Landsat 7 ETM + imagery. The resulting NDVI has an interval of –1 to +1, where –1 is no vegetation and +1 is pure photosynthetically active vegetation. ArcMap → Spatial Analyst → Raster Calculator was used to calculate the NDVI grid using the following equation:

$$NDVI = \frac{Band4 - Band3}{Band4 + Band3}$$

Equation 1: Equation for calculating NDVI.

Supervised classification of Landsat 7 ETM+ imagery through Idrisi Kilimanjaro (ver. 14.02) was used for estimating fuel load in Caribou County. To estimate fuel load, we used the sample points (143 sample points) that were collected in June of 2003 within the Oxford area of Bannock, Oneida and Franklin counties in southeastern Idaho. These points were collected by Chris Moller and Luke Sander. Each of the sample points was initially classified into 6 fuel load categories based upon on-site estimates of ground-cover (0.74, 1, 2, 4, 6 and >6 tons per acre). For this project, these categories were reclassified into a fuel load grid with the following 4 fuel load classes:

- 0 tons/acre (No vegetation)
- <2 tons/acre (Grassland with some Sagebrush)
- 2-6 tons/acre (Low and Typical Sagebrush)
- >6 tons/acre (Forest)

Using Idrisi, we created signature files for the field training sites using an NDVI model produced from Landsat 7 ETM+ imagery (Idrisi 32→ Image Processing → Signature Development → MAKESIG). The signature files were then used to create a fuel load raster grid using Idrisi 32→

Hard Classifiers → MAXLIKE. We validated the predictions of this model using techniques described in the next section "Fuel load Model Validation".

Fuel Load Model Validation

The fuel load model was validated using the following methodologies:

1. The first was a standard error matrix where each predicted (modeled) class was compared against the measured (field) class at all sample point locations. The results of these tests are reported in the text below.
2. A Kappa statistic was also calculated for our model. This statistic serves as an indicator of the extent to which the percentage correct values of an error matrix are due to "true" agreement versus "chance" agreement.

Fuel load: Vegetation Moisture

The fuel load grid (described above) was reclassified (to values 0, 1, 4, and 6) using ArcMap → Spatial Analyst → Reclassify as described in table B-1 (Appendix B).

A vegetation moisture grid was created (with values 100, 200 and 75) through reclassification of the NDVI grid using ArcMap → Spatial Analyst → Raster Calculator to delineate wet vegetation (> 0.6), dry vegetation (0.15 – 0.6), and no vegetation (< 0.15) using the NDVI values (shown in parentheses above) as described in table B-1 of Appendix B.

The fuel load grid (with values 0, 1, 4, and 6) was then multiplied by the vegetation moisture grid, using ArcMap → Spatial Analyst → Raster Calculator, to produce an intermediate raster grid. The intermediate grid was then reclassified using the weights based on Jansson *et al.* (2002). This latter part of the process is described in the heading of table B-2 in Appendix B.

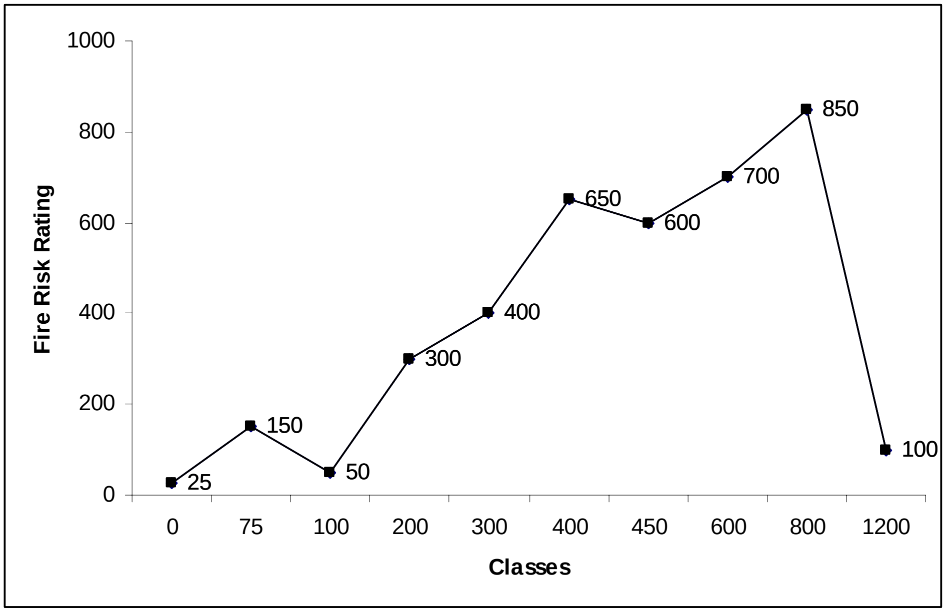

Figure 4.. *Weightings for Fuel Load/ Vegetation Moisture (Jansson et al, 2002).*

Fuel load: Rate of Spread

The fuel load-derived Rate of Spread was determined by a reclassification of the fuel load grid, following Mattsson *et al*. (2002) (table B-3 in Appendix B), using ArcMap → Spatial Analyst → Reclassify (fig. 5).

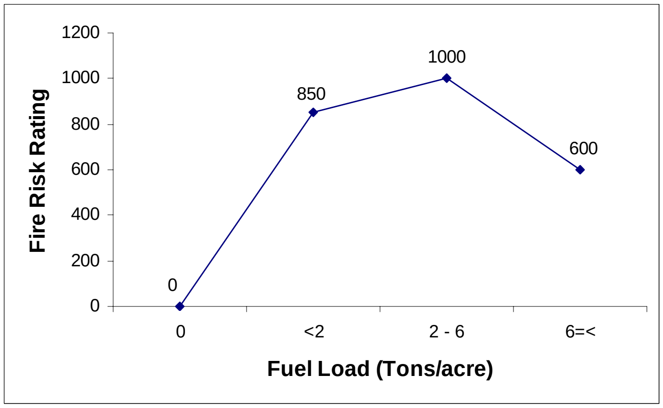

Figure 5 *.Weightings for Fuel Load/ Rate of Spread (Mattsson et al, 2002).*

Fuel load: Intensity

The fire intensity was similarly derived by a reclassification of the fuel load grid, using values following Mattsson *et al*. (2002) (table B-4 in Appendix B), with ArcMap → Spatial Analyst → Reclassify (fig. 6).

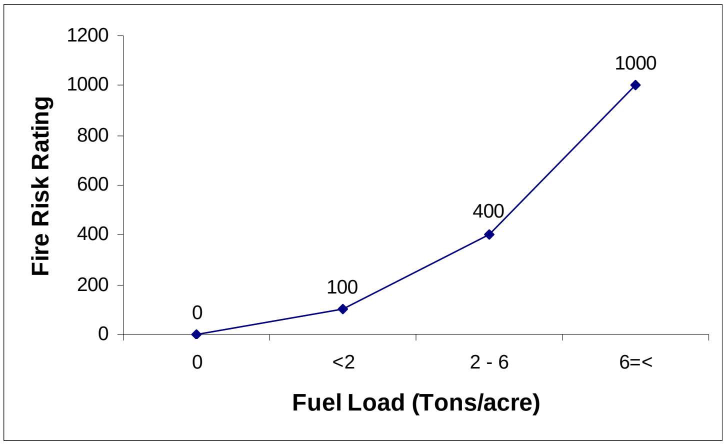

Figure 6. *This chart describes all weightings for Fuel Load/ Intensity (Mattsson et al, 2002*

Structure Sub-model Components

Structures at Risk

To create the Structures at Risk sub model we used a structure density raster image provided by Josse Allen of Caribou County. To make this component consistent with the other sub-models, the range of pixel values was stretched to a range of 0 - 1000.

The following information describing the ArcView process that was used to generate the structure density raster was supplied by Josse Allen:

> Spatial Analyst → Calculate Density → Grid Cell only affects resolution, so you can choose search Radius of 6000 ft. → Density Type = Kernel NOT SIMPLE (simple produces rings) → Area Units of Square Miles

WUI fire risk model

The final fire risk model is determined as a simple summation, using ArcMap → Spatial Analyst → Raster Calculator, of the 7 sub-model components. The weight of each component is described below. The weights were determined through consultation with a regional fire manager, Fred Judd (personal communication). See *Table 1*.

Component	**Description**	**Percentage**
Aspect	Sun position	5%
Slope	Rate of Spread	17%
Slope	Suppression Difficulties	11%
Fuel load	Vegetation Moisture	11%
Fuel load	Rate of Spread	17%
Fuel load	Fire Intensity	17%
Structures	Structures at Risk	22%

Table 1*: Components and weights of the Final Fire Risk Model*

Results:

We compared the WUI fire risk models for Clark County, Bannock County, Power County, Oneida County, and Caribou County, Idaho. Figure 8 shows portions of each county classified as low, medium, and high risk relative to individual areas. We did this by reclassifying the final fire risk model into three distinct classes (0-333 = low risk; 333-666 = medium risk; 666-1000 = high risk). Comparison between total acres classified as low, medium, and high fire risk is shown in table 1. Figure 9 describes the fuel load distribution for each county. Table 2 show total acres of BLM Land classified as low, medium, and high fire risk.

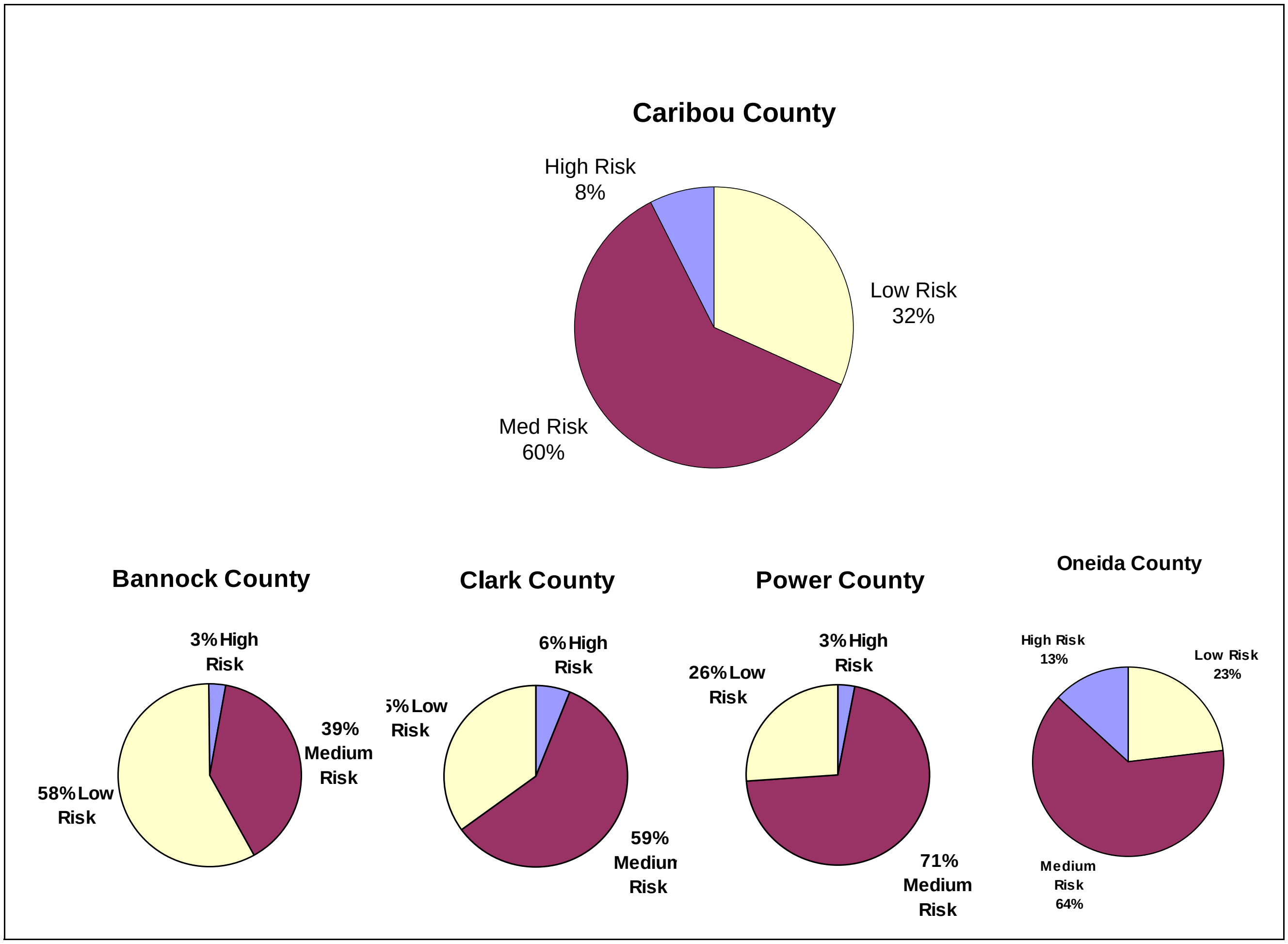

Figure 7. *Percent of Clark County, Bannock County, Power County , Oneida County and Caribou County considered low, medium, and high fire risk.*

Total Acres Classified as low, medium, and high fire risk					
	Clark County	**Bannock County**	**Power County**	**Oneida County**	**Caribou County**
Low	395,360	413,146	233,958	175,761	356,923
Medium	666,464	277,805	638,886	495,089	688,575
High	67,776	21,370	26,996	97,599	84,806
Total	**1,129,600**	**712,321**	**899,840**	**768,449**	**1,130,304**

Table 2*: . Total acres classified as low, medium, and high fire risk for Clark, Bannock, Power, Oneida, and Caribou County.*

BLM Land classified as to fire risk		
Fire Risk	**Acres**	**Percent**
Low	6,016	26%
Medium	15053	64%
High	2410	10%
Total	**23,479**	

Table 3: *BLM lands classified to low, medium and high fire risk.*

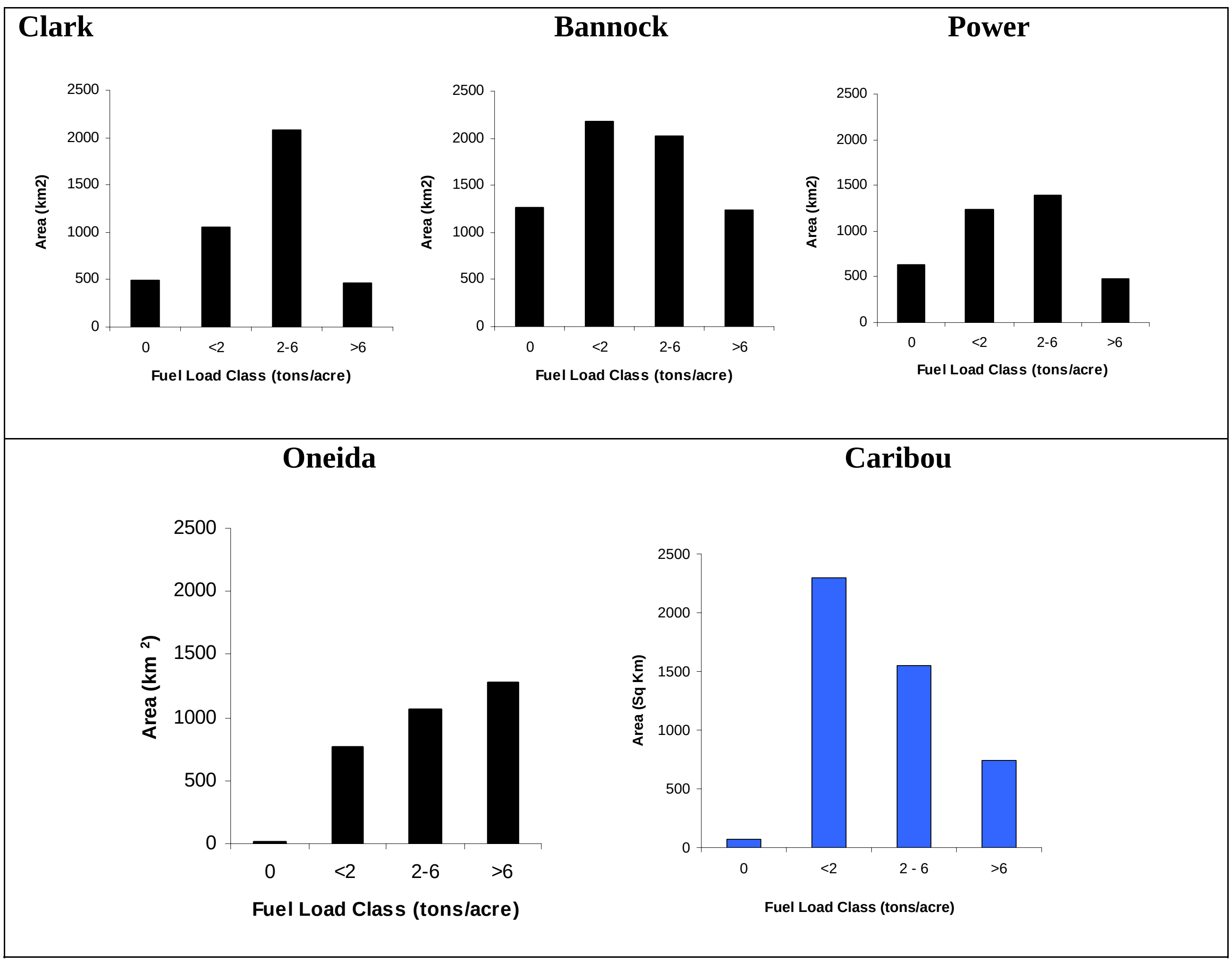

***Figure 8**: Comparison of fuel load distribution for Clark County (A), Bannock County (B), Power County (C), and Caribou County (D).*

The NDVI grid used to generate the fuel load model is shown in figure 10. The reclassified NDVI grid estimating the location of wet vegetation, dry vegetation and no vegetation is shown in Figure 11. Figure 12 illustrates the Fuel Load model derived from field training sites and Landsat 7 ETM+ satellite imagery. Table 2 shows the error matrix validation for the fuel load model. The overall Kappa statistic was determined to be 0.4380 indicating that the classification was approximately 43.8% better than chance.

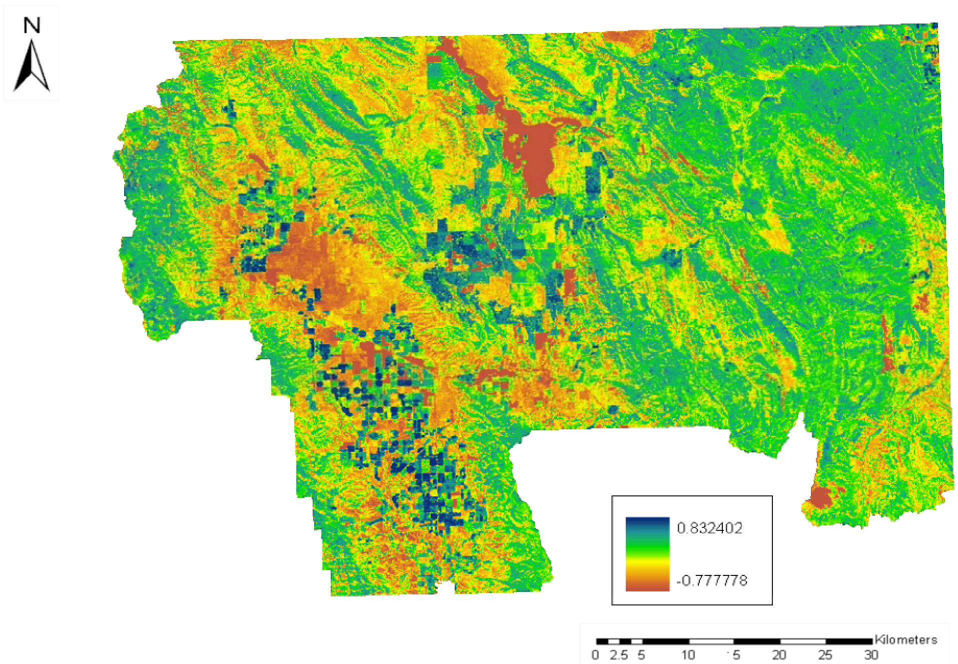

Figure 9: *The NDVI has an interval of –1 to +1, where –1 is no vegetation and +1 is pure vegetation.*

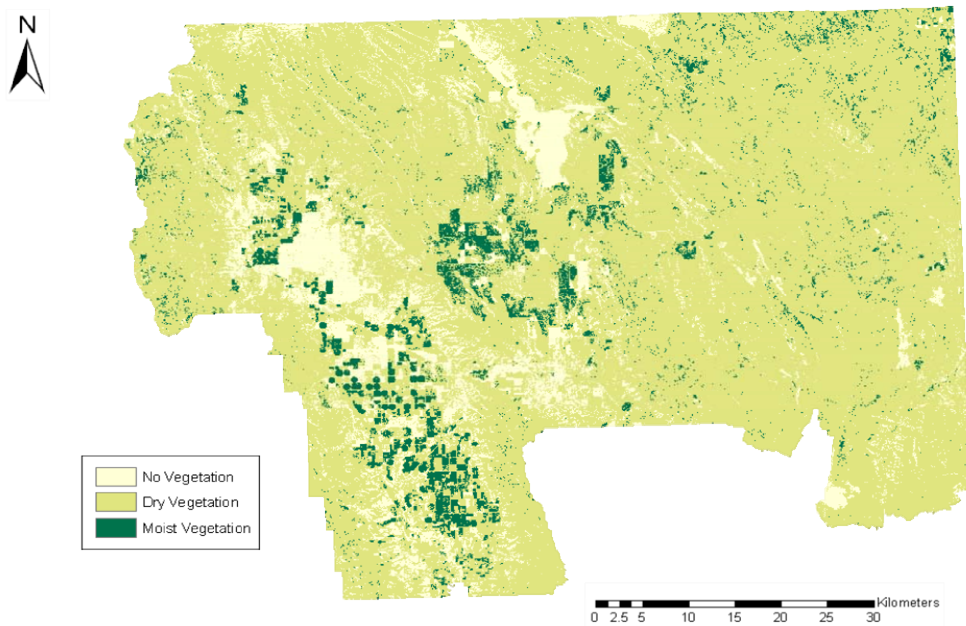

Figure 10:. *The results of the reclassification of NDVI into no vegetation (100), dry vegetation (200) and wet vegetation (75).*

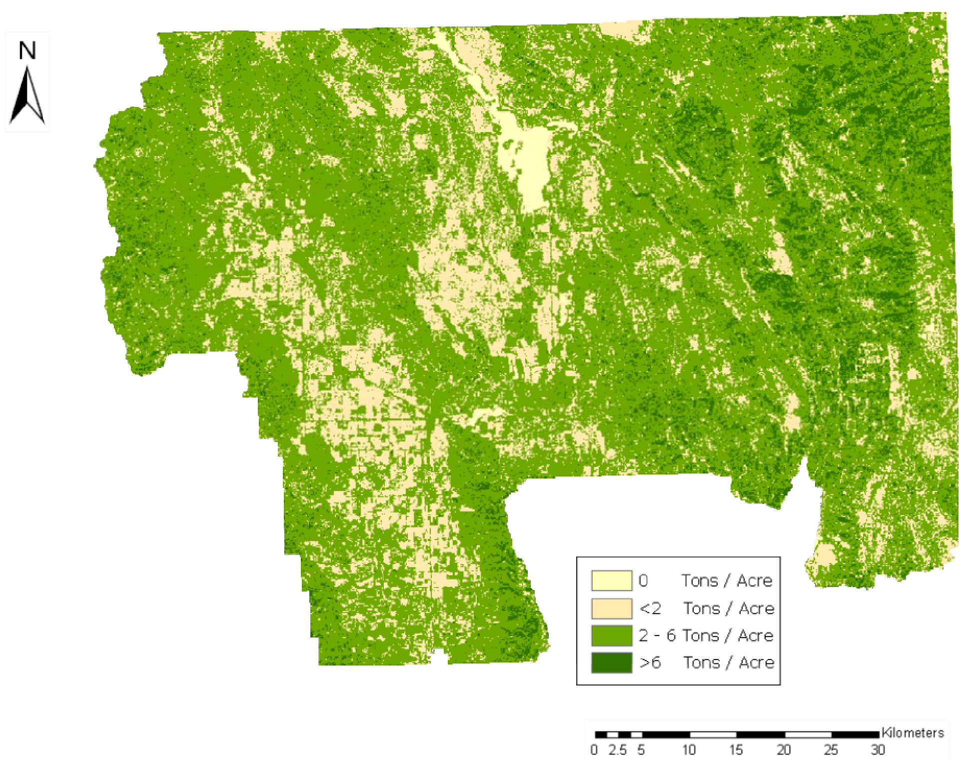

Figure 11: *The fuel load model and the distribution of different fuel load classes for Caribou County, ID.*

Table 4:. *Error matrix for the fuel load model.*

		Field Measurement (tons/acre)					
		0	**<2**	**2 - 6**	**>6**	**Total**	**Commission Accuracy**
Modeled Fuel Load (tons/acre)	**0**	7	0	0	0	**7**	100.00%
	<2	0	26	17	0	**43**	60.47%
	2 - 6	0	18	58	0	**76**	76.32%
	>6	0	6	9	7	**22**	31.82%
	Total	**7**	**50**	**84**	**7**	**148**	**Overall Accuracy**
	Ommission Accuracy	100.00%	52.00%	69.05%	100.00%		**66.22%**

The three component models derived from the fuel load model are shown in figures 13, 14, and 15. Figure 13 is the vegetation moisture model, irrigated and riparian areas contain the lowest risk values, while the grasses, shrubs, and mountainous areas throughout Caribou County contain the highest values. The high risk areas are due to the low moisture content associated with sagebrush steppe that dominates the area. The effect of fuel load on fire's spread rate is reported in figure 14. Mountainous areas, with larger fuel loads, contain the lowest values, where grasses and shrubs in the southwestern portion of Caribou County contain the highest values. The high risk areas are due to the high concentration of 2-4 tons/acre fuels. Finally, figure 15 is the intensity model. Conifers in the highlands, especially in the eastern and northwestern part of the county, comprise the highest risks for the most intense fires.

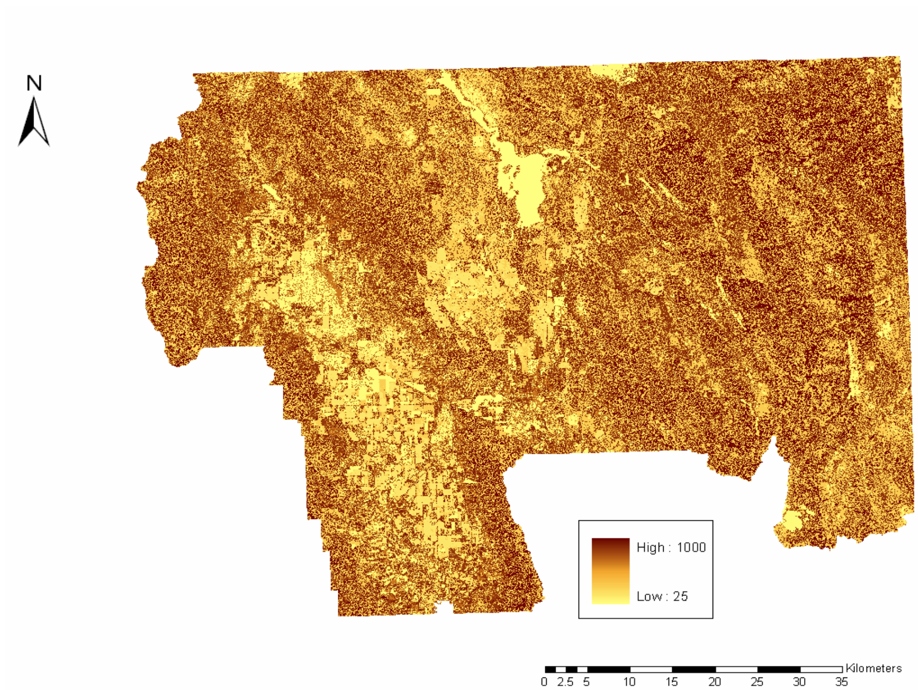

Figure 12*: The Fuel Load/ Vegetation Moisture model. This model expresses how vegetation moisture and the combination of different fuel load classes affect fire risk. This model was given an overall weighting of 11% of the final model.*

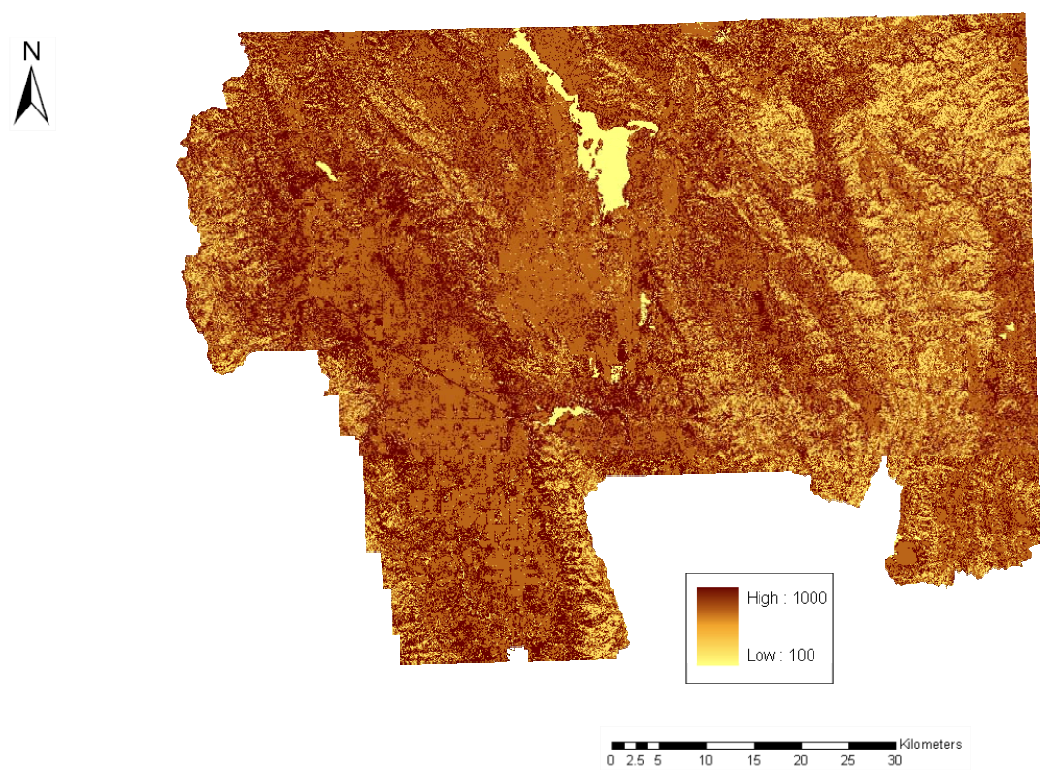

Figure 13*: The Fuel Load/ Rate of Spread model. This model expresses the fire risk associated with the spread rate of different fuel load classes. This model was given an overall weighting of 17% of the final model.*

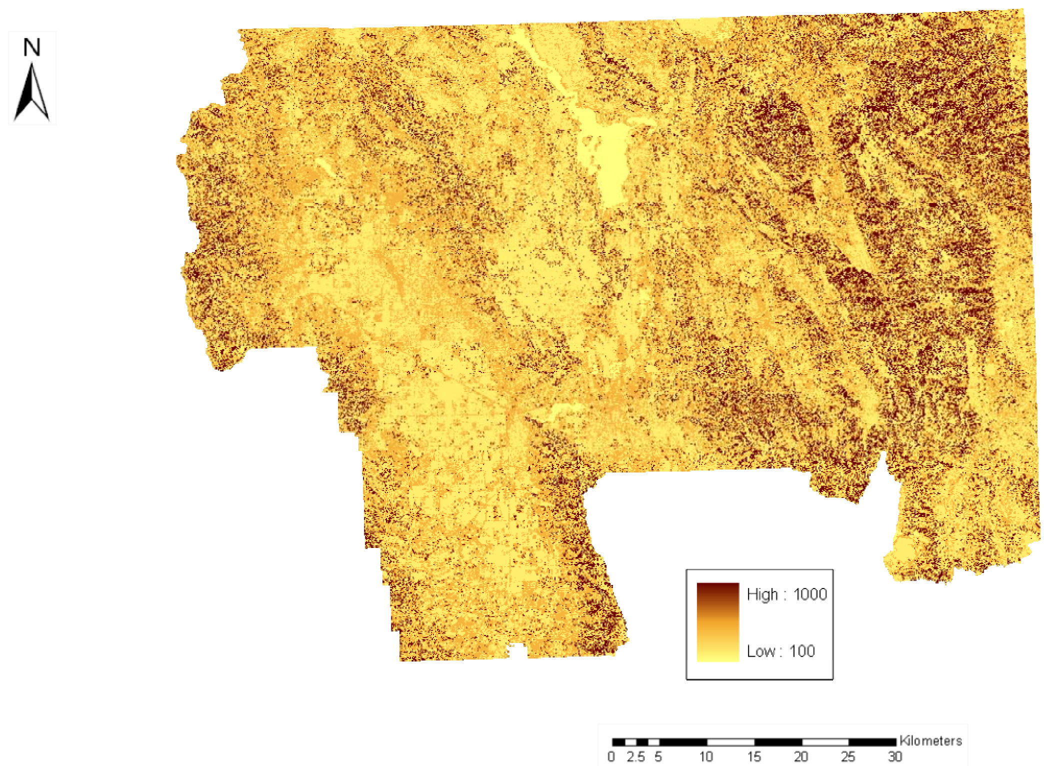

Figure 14*: The Fuel Load/ Intensity model. This model expresses the fire risk associated with the amount of heat energy (intensity) each fuel load class gives off. This model was given an overall weighting of 17% of the final model.*

Figures 16-18 are the component models generated using the Caribou County DEM. Figure 16 assesses the risk of fires spreading quickly due to steep slopes. Here, the highlands throughout the county received the highest values and the bottom land running southwest to northeast in the western portion of the county and from southeast to northwest in the eastern portion of the county, with shallow slopes, received the lowest values. Next is the suppression difficulty model (figure 17), where steeper slopes pose increasingly greater problems to fire fighters attempting to access fires in order to suppress them. The steeper terrain in the south, east, and extreme northeast is weighted the highest risk. Figure 18 is the Aspect: Orientation to Sun component model, south and southwest aspects contain the highest fire risk, due to the intense sunlight and prevailing wind exposure. North and east facing slopes, which are sheltered from intense sunlight and prevailing wind through much of the day, contain the lowest fire risk

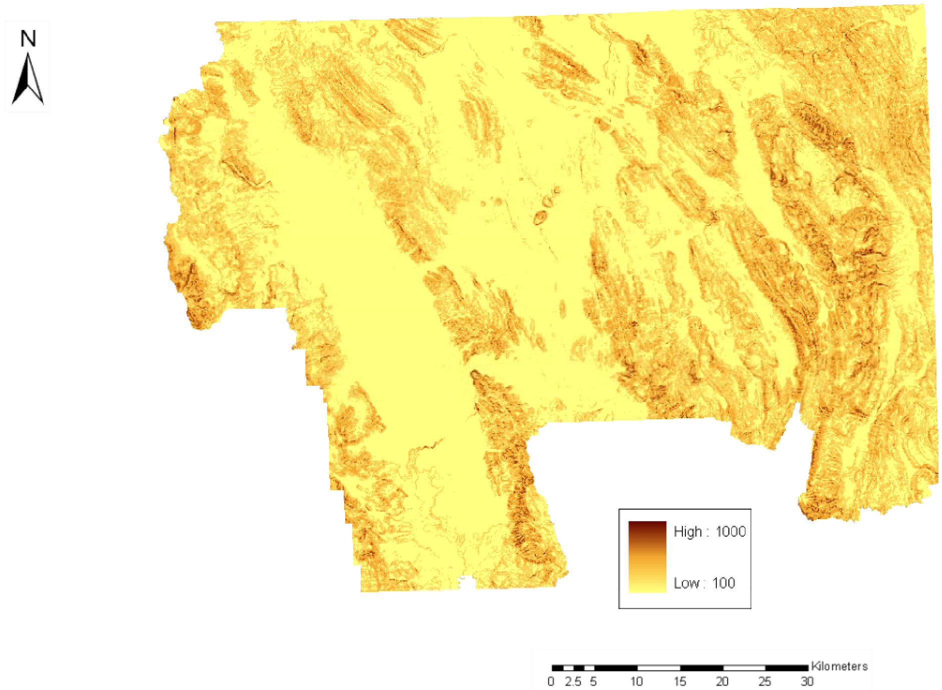

Figure 15*: The Slope/ Rate of spread model. This model expresses how different angles of slope affect the spread rate of fire. Steeper slops are given the highest fire risk. This model was given an overall weighting of 17% of the final model.*

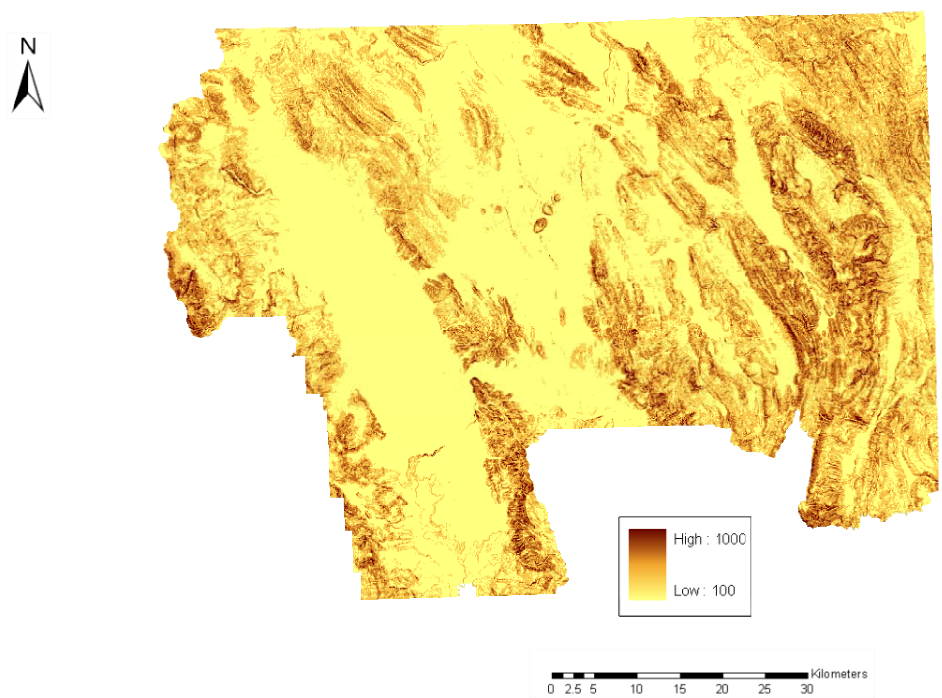

Figure 16: *The Slope/ Suppression Difficulty model. This model expresses how different slope angles affect suppression efforts of firefighters. This model was given an overall weighting of 11% of the final model.*

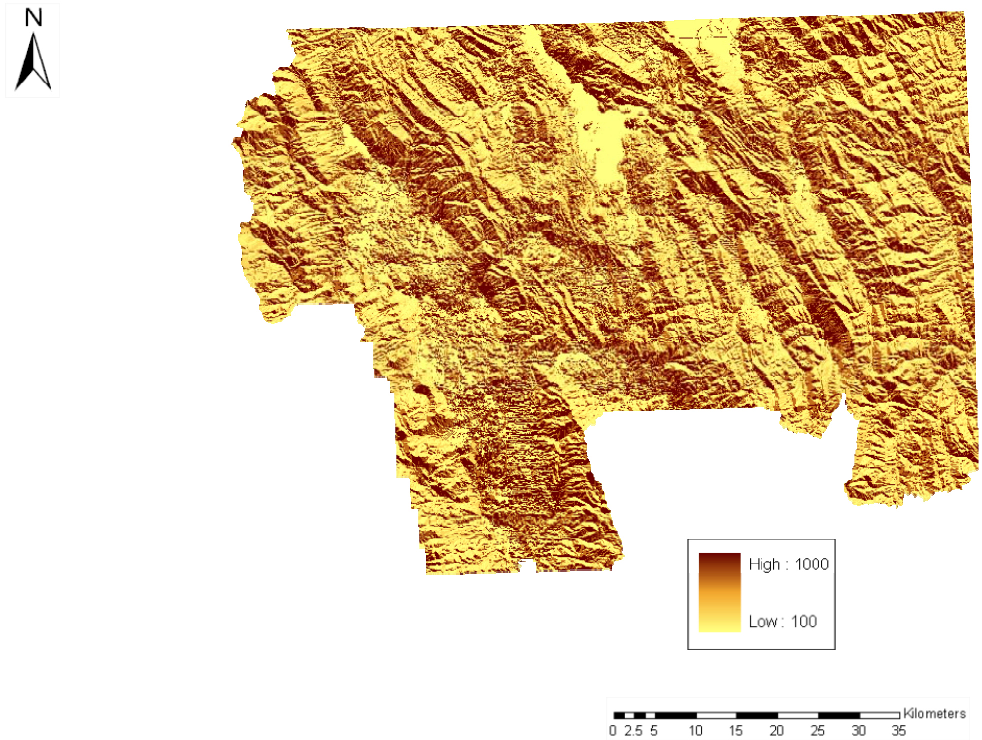

Figure 17*: The Aspect: Orientation to Sunlight. This model expresses how different aspects affect fire risk. Southern aspects have the highest fire risk. This model was given an overall weighting of 5% of the final model.*

The Structures at Risk component model is shown in figure 18. The three population centers of Caribou County, Soda Springs, Grace, and Bancroft, are not illustrated.

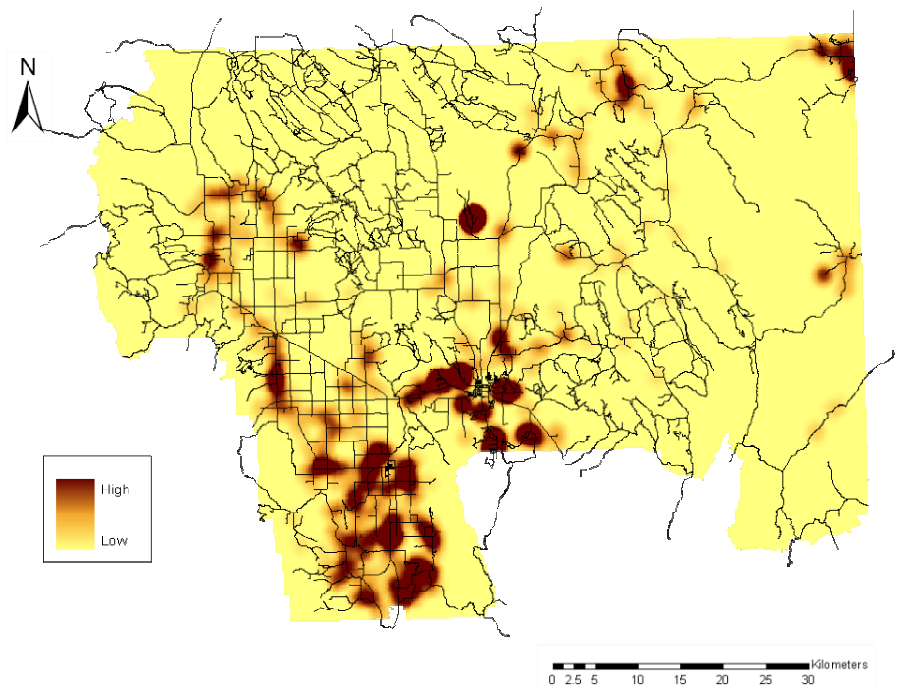

Figure 18*:* *The Structures at Risk model. This model expresses areas that are high risk due to high structure density and is given an overall weighting of 22% of the final model.*

The Final Fire Risk Model for Caribou County is shown in Figure 19: and the fire risk model with BLM lands superimposed is in Figure 20. Figure 21 shows the Fire History on public lands within Caribou County from 1939 – 2002 provided (*fireareas.shp*) by Josse Allen.

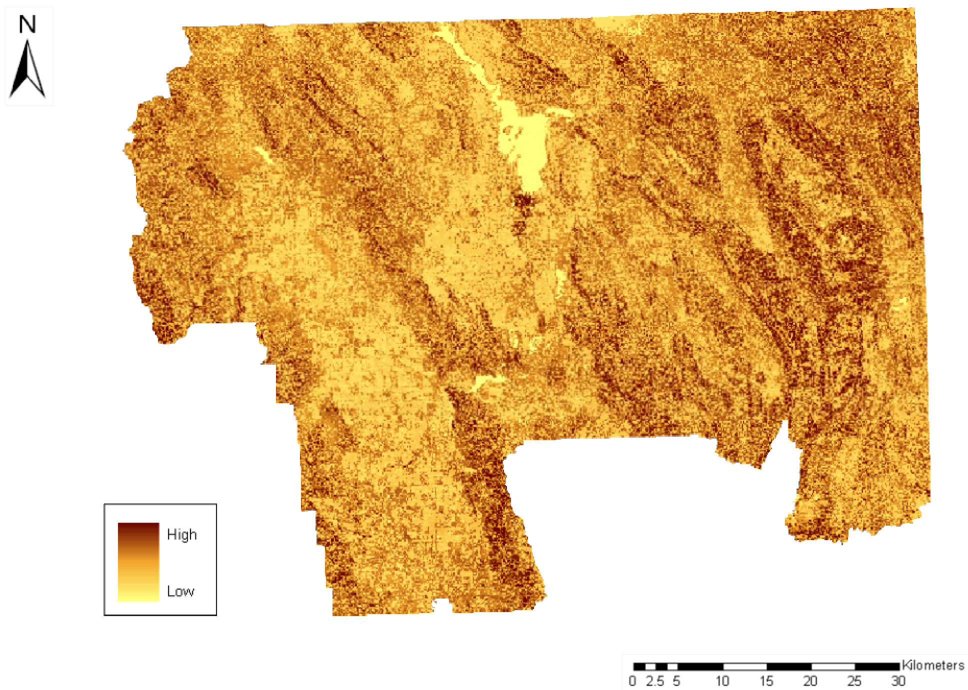

Figure 19*: . The Final Fire Risk Model for Caribou County, Idaho.*

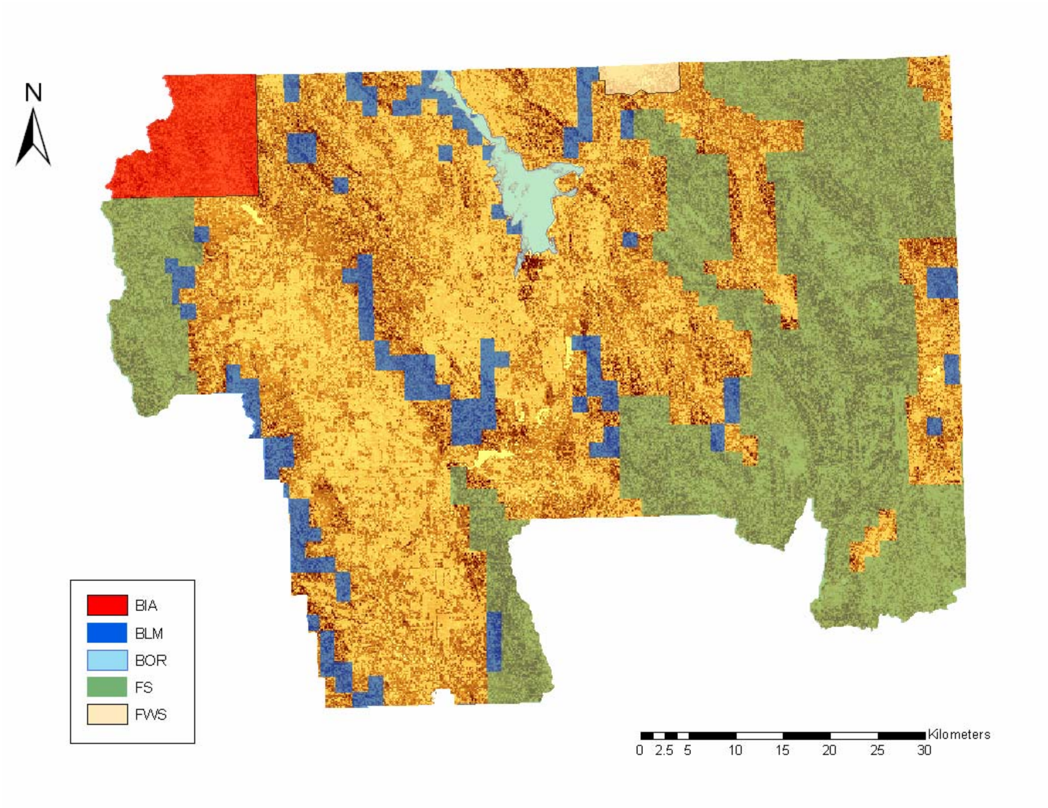

Figure 20*:* *BLM lands within Caribou County.*

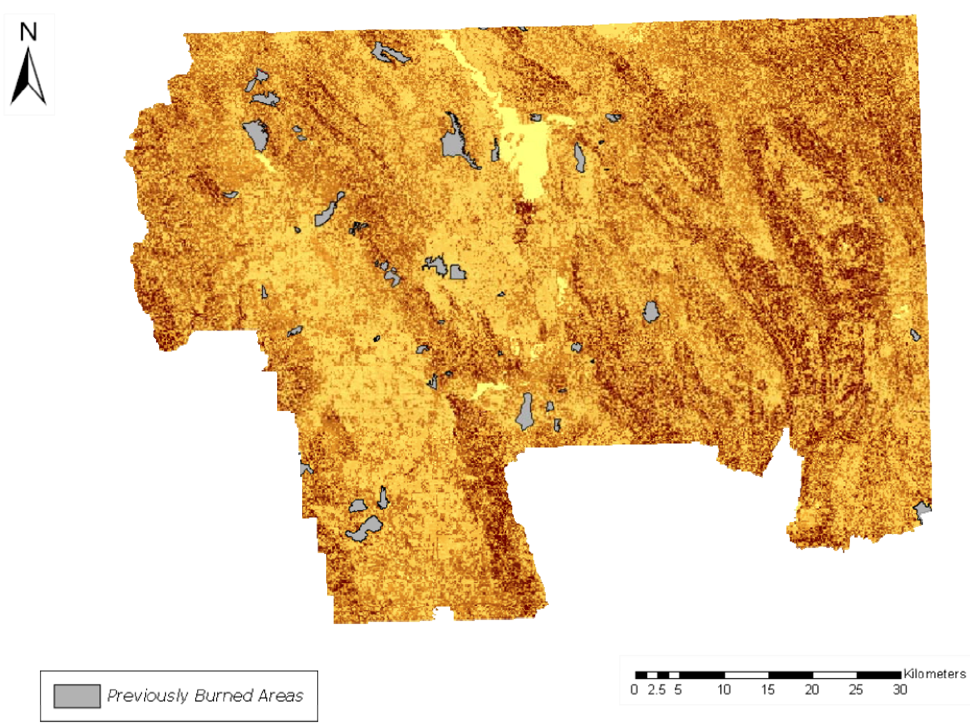

Figure 21*:* *Fire history for Caribou County, 1939-2002*

Fire Regime Condition Class (FRCC)

There are 3 condition classes used in this study. The 3 condition classes are used with 5 fire regimes. The 5 fire regimes are essentially fuel models. The condition classes indicate what condition the area is in relation to its historic fire regime as it relates to fire return interval. (*Conran,* personal communication).

The 5 fire regimes are broken out based on a vegetation community's historic fire return interval and historic fire severity (stand-replacing or not). The fire regimes resemble fuel models because fire frequency and severity directly affect fuel loading. An FRCC of 3 can also indicate a fire regime that is out of whack due to too much fire (too many acres burned). The sagebrush steppe in the Snake River Plain is a good example of a vegetation community that has had a dramatically increased fire return interval compared to the historic fire interval due to a continuous bed of cheatgrass (*Heide,* personal communication).

Construction of the Fire Regime Condition Class Alternate Fire Risk Model

In preparation for using the Fire Regime Condition Class data provided by the BLM in an alternate Fire Risk Model, each category was weighted from 0 – 1000 (figure 25). A normalized Fire Regime Condition Class sub model was then constructed (Figure 26) for use in construction of an Alternate Fire Risk Model.

An Alternate Fire Risk Model was created by substituting the Fire Regime Condition Class sub model in place of Fuel Load: Fire Intensity. The sub model components and weights comprising the Alternate Fire Risk model were multiplied by their own weighting percentage *(Table 18*). The resulting values were then added to produce the Alternate Fire Risk Model (Figure 27).

Component	Description	Percentage
Aspect	Sun position	5%
Slope	Rate of Spread	17%
Slope	Suppression Difficulties	11%
Fuel load	Vegetation Moisture	11%
Fuel load	Rate of Spread	17%
Fire Regime	Condition Class	17%
Structures	Structures at Risk	22%

***Table 4**: Sub model components of the Fire Regime Condition Class Alternate Fire Risk Model*

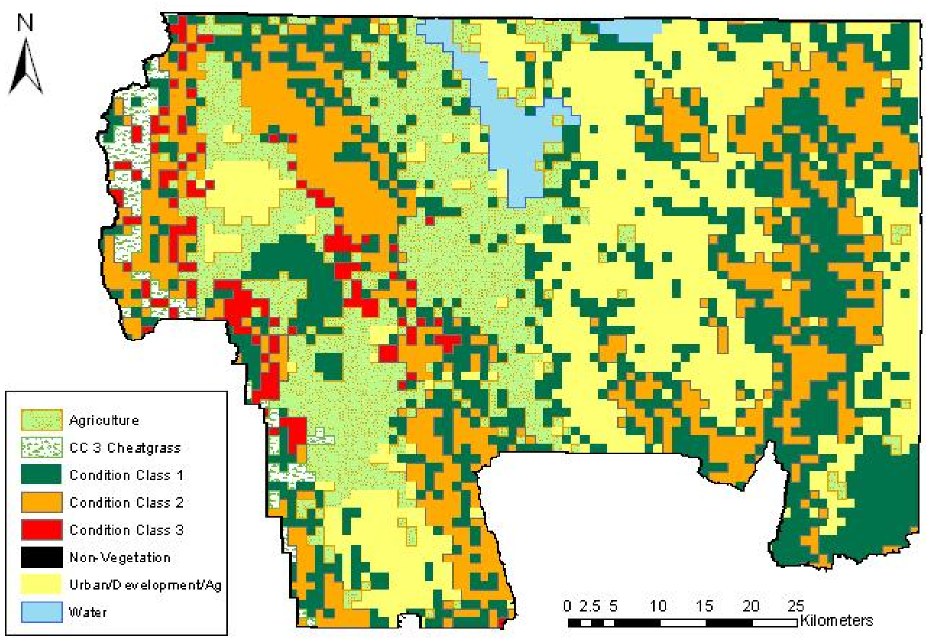

Figure 22 *Condition Classes of Caribou County from data provided by Lance Brady of the Bureau of Land Management*

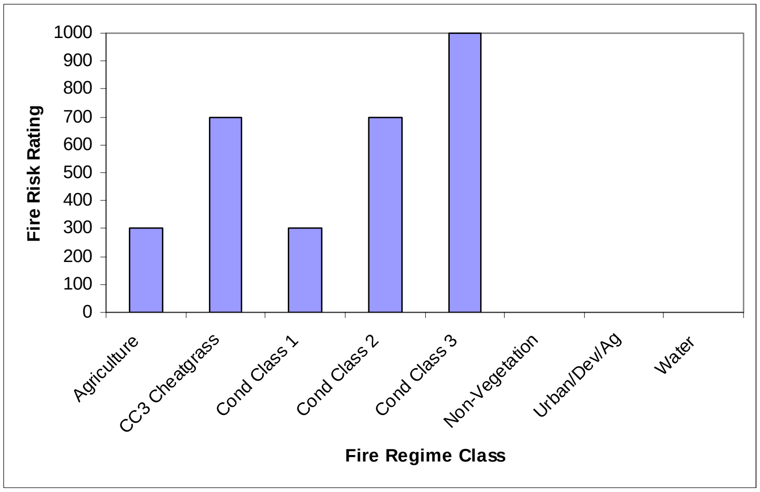

***Figure 23**: Fire risk ratings of Fire Regime Class components*

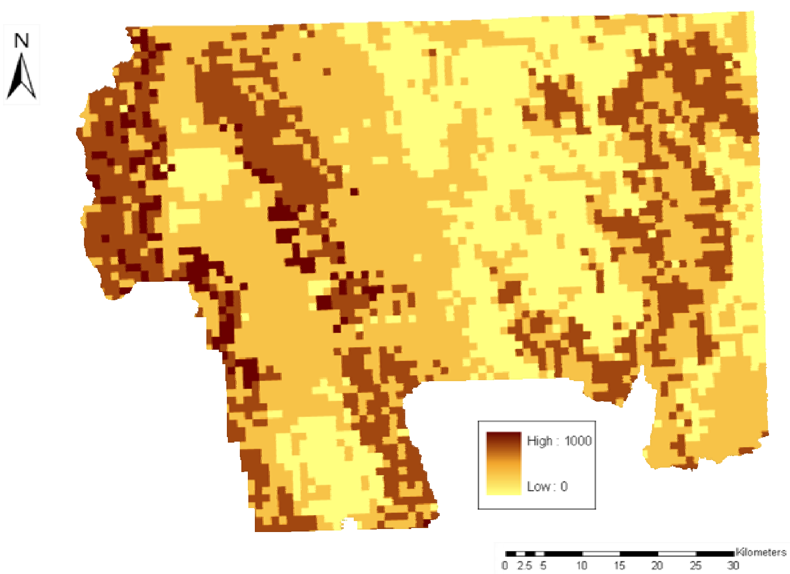

***Figure 24**: Normalized Fire Regime Condition Class sub model component*

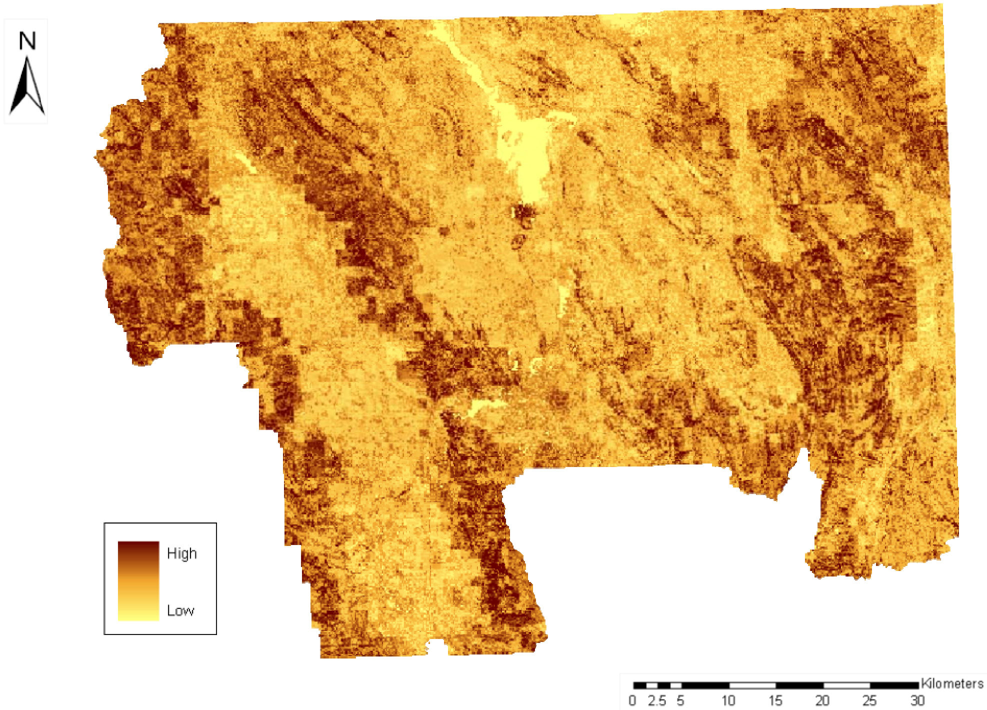

Figure 25*:* *Alternate Fire Risk Model for Caribou County using the Fire Regime Condition Class sub model in place of the Fuel Load: Fire Intensity sub model.*

Discussion:

Caribou, Clark, Bannock, Power, and Oneida counties all contain high desert sagebrush steppe ecosystems.

Of these counties, Caribou County has the largest area, with 1,799 square miles (1,130,304 acres). In order of size Clark County has the next largest area, with 1,765 square miles (1,129,600 acres), Power County with 1,406 square miles (899,840 acres), Oneida County with 1,200 square miles (768,000 acres) and Bannock County with an area of 1,113 square miles (712,321 acres).

Oneida County has the highest total acres classified as high fire risk with 97,599 acres. Caribou County has the second largest area classified as high fire risk with 84,806 acres. Clark County follows with 67,776 acres classified as high fire risk, followed by Power County with 26,996 acres and Bannock County with 21,370 acres. The high fire risk classification for all four counties is concentrated in the mountainous areas. This is due to the influence of the topography component models Aspect/ Sun Position, Slope/ Suppression Difficulty, and Slope/ Rate of Spread, as well as the fuel load >6 tons/acre.

Caribou County has the largest area classified as medium fire risk with 688,575 acres. Clark County and Power County have the next highest medium risk classification, followed by Caribou and Bannock County (495,089 and 277,805 respectively). The southern portion of Clark County and the northern portion of Power County are located within the Snake River Plain which consists of primarily < 2 and 2-6 tons/acre fuels.

NDVI values vary with absorption of red light by plant chlorophyll and the reflection of infrared radiation by water-filled leaf cells. It is correlated with Intercepted Photo-synthetically Active Radiation (IPAR) (Land Management Monitoring, 2003). In most cases (but not all) IPAR and hence NDVI is correlated with photosynthesis. Because photosynthesis occurs in the green parts of plant material the NDVI is normally used to estimate green vegetation. The NDVI is a nonlinear function which varies between -1 and +1 but is undefined when RED and NIR are zero (Land Management Monitoring, 2003). Early in this project we determined thresholds for no-vegetation, dry-vegetation, and moist vegetation using NDVI. We chose the value 0.15 as a threshold between no vegetation and general vegetation based on where and how well the NDVI values matched a DOQQ. We chose the second threshold (separating dry vegetation from moisture vegetation) using similar methods. The NDVI value of 0.6 was the threshold limit between dry vegetation and moist vegetation.

The Structures at Risk component was weighted most heavily (22%). Due to the nature of this project, we were most interested in quantifying risk for the Wildland/ Urban Interface. This model allowed us to emphasize the interface areas. Areas of high structure density received the highest fire risk values and areas of low or no structure got the lowest fire risk values. The Structures at Risk component shows that of all five counties, Bannock, by far, has the largest population with 75,323, while Caribou County has a population of 7,397. Oneida County's population is 4,131, and Clark County has 971 (U.S. Census Bureau Quick Facts 2003). Though each county has a relatively large area (Clark- 1,765 sq. miles; Power- 1,406 sq. miles; Oneida- 1,200 sq. miles; Bannock- 1,113 sq. miles), the structure density component model for Bannock

County shows the highest risk to structure (U.S. Census Bureau Quick Facts 2003) because of the number of urban areas within the county.

The Fuel Load/ Rate of Spread takes into account how fast a fire will spread depending on different fuel load classes. The lower fuel load classes were considered to be the primary carrier of fire (e.g. grasses) and have the fastest spread rate. Fuel Load class 2-6 tons/acre received the highest fire risk value, because of its high load of fine, low-standing fuels. Fuel Load class >6 tons/acre received the lowest fire risk value since these fuels are of a larger size and higher moisture content, so they will not ignite as quickly.

The Slope/ Rate of Spread component model takes into account how different angles of slope affect the rate of spread of a fire. When fire moves across flat land it moves more slowly than fire moving up a mountainside (Amdahl, 2001). The steeper angles in this model have the highest fire risk values, because fire increases exponentially with slope. Correspondingly, shallower angles have lower fire risk values.

The Fuel Load/ Vegetation component accounts for moist vegetation and different fuel load classes that may be abundant but not readily flammable. Areas with dry vegetation and high fuel load (>6 tons/acre) had the highest fire risk value. Areas that had wet vegetation and lower fuel load had the lowest fire risk values.

The Fuel Load/ Intensity component takes into account how intense a fire of different fuel load classes affects fire risk. Intensity is considered the amount of energy a fire produces. The more energy the fire produces, the more difficult it is for the firefighters to suppress it. Intense fires create their own wind system, drying out fuel ahead of the fire. This intensity depends on fuel load and other factors such as wind and ground conditions at the time of the fire. Thus, if firefighters do not suppress the fire, it will keep spreading. The fuel load class >6 tons/acre had the highest fire risk value, due to the high intensity fires associated with these larger fuels.

The Slope/Suppression Difficulties component describes how difficult it is for firefighters to suppress fire based on slope/terrain steepness. If firefighters cannot reach the fire, it will keep burning even though it may be a low risk area according to other criteria. Slopes that are > 20 degrees affect wheeled vehicle support and slopes > 30 degrees affect tracked vehicle support. Without the aid of motorized equipment support suppression efforts are slowed, allowing the fire to spread. Slopes with the greatest degree of inclination had the highest fire risk values and shallow slopes received the lowest fire risk values.

The Aspect/ Sun position component models the direction each slope faces and the extent to which the sun desiccates the ground/vegetation. The sun will desiccate the ground/vegetation more on southern aspects and least on northern aspects. Southern aspects received the highest fire risk values and northern aspects received the lowest.

Assessments of error and bias:

All estimations in this report are made based upon our knowledge of the criteria and the expert knowledge of Keith T. Weber, Felicia Burkhardt, Fred Judd, Lance Brady, Kevin Conran, Sarah Heide, and Josse Allen. We have discussed our analyses and results with these people and believe our results to be valid.

The goal for our model is to be a tool to assist fire managers and decision-makers. As we treated each analysis separately, we believe the results have accuracy adequate to fit this purpose. We further believe our model gives a good overview of the fire risk in our study area and that it is easy to understand. Because the model is easy to understand, it should be applied to other users, which was a primary objective with this study.

Not all conditions affecting wildfire could be accurately modeled in this study. Factors not taken into account, such as wind direction and wind speed, are difficult to model without building many assumptions into the model (e.g., yearly weather patterns). Since the scope of this study is broad, we felt that removing these factors from the final model helped its overall effectiveness as a management tool. This also allowed us to place more emphasis on the factors we, Fred Judd, and Kevin Conran (personal communication) felt were more important.

Lastly, the date (July 07, 2003) on which the Landsat 7 ETM+ data was acquired plays a significant role in the outcome of the Fuel Load-based components of the final model.

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Heide, Sarah Crocker; Idaho Bureau of Land Management

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Owens J. and Durland P. 2002. Wild Fire Primer/ A Guide for Educators. United States Government Printing Office.

Acknowledgements:

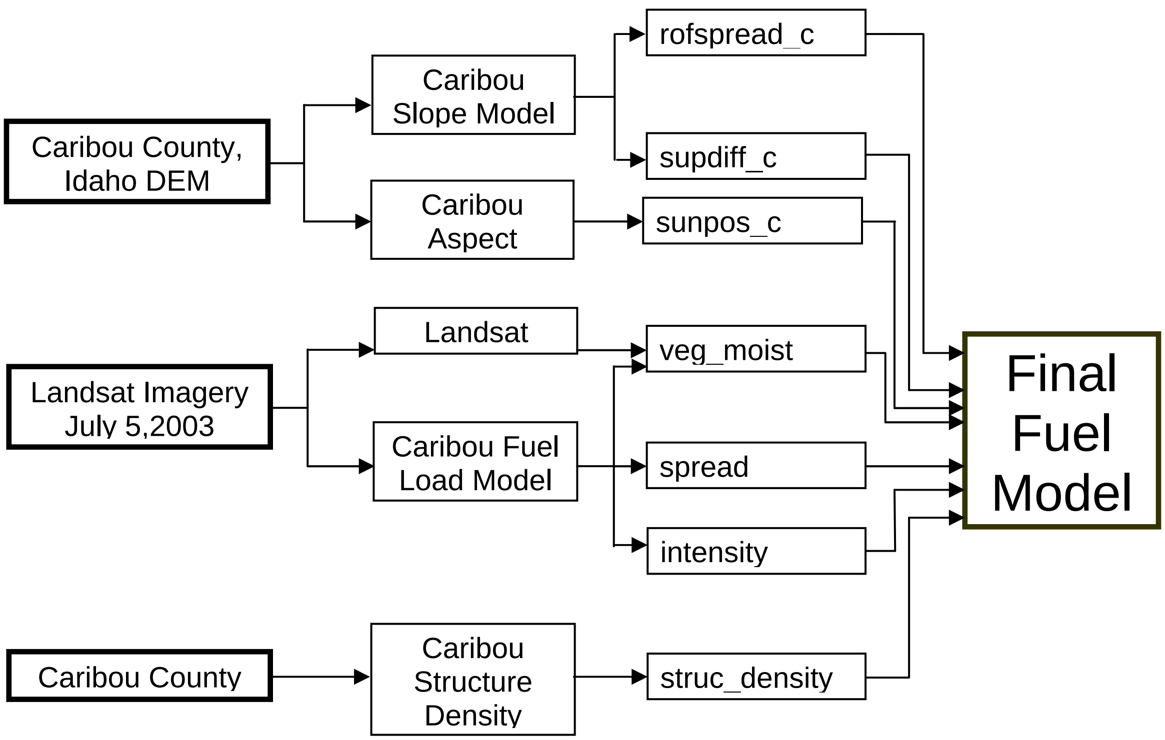
At an interim progress meeting held on June 28, 2004 , Kevin Conran from the Idaho Bureau of Land Management suggested that we incorporate Vegetation Condition Classes into our Fire Risk model. Shortly thereafter Lance Brady, also from the Idaho Bureau of Land Management, supplied the ISU GIS Center with Condition Class Data. This data has been used to develop an alternate Fire Risk Model for Caribou County. The same criteria used in the original model were used to construct this alternate Fire Risk Model with one exception. In the alternate model the Fire Regime Condition Class sub model was used in place of the Fuel load/ Fire intensity sub model.

After the original Fire Risk Model and the alternate Fire Regime Condition Class Fire Risk Model had both been completed, Josse Allen and Dennis Godfrey of Caribou County reviewed the procedure discussed above and suggested that the Fire Regime Condition Class data be used

in some manner as a multiplier for the original fire risk model rather than as a substitute for one of the sub model components. Their input is appreciated and may be considered in future projects.

<u>**Appendices**</u>

Appendix A – Cartographic Model



Appendix B – Weightings

These tables show the weightings we used to weight our fire risk model components.

Table B-1: Reclassification system of the Fuel Load and NDVI grids. Compare with figure1.

Fuel Load	NDVI
0 = 0 tons/acre	100 = No Vegetation
1 = <2 tons/acre	200 = Dry Vegetation
4 = 2-6 tons/acre	75 = Moist Vegetation
6 = >6 tons/acre	

Table B-2: Weighting data for Fuel Load/ Vegetation Moisture component model (Jansson et al. 2002). Compare with figure 1.

Fuel Load *	Vegetation =	Class	Weights
1	100	100	50
1	200	200	300
1	75	75	150
4	100	400	650
4	200	800	850
4	75	300	400
6	100	600	700
6	200	1200	100
6	75	450	600
0	*	0	25

Table B-3: Weighting data for Fuel Load/ Rate of Spread. Compare with figure 2.

Classes (Tons/acres)	Weights
0	0
1	850
4	1000
6	600

Table B-4: Weighting data for Fuel Load/ Intensity. Compare with figure 3.

Classes (Tons/acres)	Weights
0	0
1	100
4	400
6	1000

Table B-5: Weighting data for Slope/ Rate of Spread. Compare with figure 4.

Angle/degree Intervals	Weights
0—10	41
10—20	137
20—30	256
30—40	489
40—50	1000

Table B-6: Weighting data for Slope/ Suppression Difficulties. Compare with figure 5.

Angle/degree Intervals	Weights
0--10	100
10--20	200
20--30	850
30--40	1000
40--50	1000

Table B-7: Weighting data for Aspect/ Sun Position. Compare with figure 6.

Degree Interval	Aspect	Weight
337.5--22.5	N	100
22.5--67.5	NE	150
67.5--112.5	E	300
112.5--157.5	SE	800
157.5--202.5	S	1000
202.5--247.5	SW	1000
247.5--292.5	W	700
292.5--337.5	NW	200

Appendix C – Data dictionary

Data		File name		Full path to dataset		Description		Format
County boundary		car_idtm83		\GIS_Data\DRGs		Boundary of Caribou county		polygon coverage
Roads		Roads_idtm83.shp		\GIS_Data\DRGs		Roads and streets in Caribou County		line shapefile
Bands used for NDVI		b3_c		\GIS_Data\Landsat_Imagery		Landsat Band 3 for Caribou County		Grid - 28.5m pixels
		b4_c		\GIS_Data\Landsat_Imagery		Landsat Band 4 for Caribou County		Grid - 28.5m pixels
		ndvi_utmland		\GIS_Data\WUI_ModelComponents\Fuel_Load\NDVI		Landsat NDVI model for Caribou County		Grid - 28.5m pixels
Fuel Load		fuel_load		\GIS_Data\WUI_ModelComponents\Fuel_Load		Fuel Load model for Caribou County. Classes are <2 tons/acre, 2-4 tons/acre, and 4> tons/acre		Grid - 28.5m pixels
DEM		caribou_dem		\GIS_Data\DEM		Digital Elevation Model of Caribou County		Grid - 30m pixels
Component models		sunposition		\GIS_Data\WUI_ModelComponents\Topography\Aspect		Risk associated with aspect angle **i.e**. North, East,…….		Grid - 30m pixels
		rofspread		\GIS_Data\WUI_ModelComponents\Topography\Slope		Risk associated with how fire spreads with angle of slope.		Grid - 30m pixels
		supdiff		\GIS_Data\WUI_ModelComponents\Topography\Slope		Risk associated with how suppression efforts are affected by angle of slope.		Grid - 30m pixels
		spread		\GIS_Data\WUI_ModelComponents\Fuel_Load\Rate_of_Spread		Risk associated with how quickly different fuel load classes spread during a fire.		Grid - 26m pixels
		intensity		\GIS_Data\WUI_ModelComponents\Fuel_Load\Fire_Intensity		Risk associated with how intense (release of heat energy) different fuel load classes burn.		Grid - 26m pixels
		veg_moist		\GIS_Data\WUI_ModelComponents\Fuel_Load\Vegetation_Moisture		Risk associated with vegetation moisture.		Grid - 26m pixels
		struc_density		\GIS_Data\WUI_ModelComponents\Structure		Risk associated with structure density.		Grid - 30m pixels
Final Model		fire_risk		\		Final risk model		Grid - 30m pixels
		fire_risk_cc		\		Final risk model using condition classes		Grid - 30m pixels
Reports		Caribou_WUI_Report		\Final Report		Report covering methods, results, & conclusions of WUI modeling		Word Document