# Wildland/Urban Interface and Communities at Risk

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

May 1, 2005

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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 susceptibility areas for Bear Lake County, Idaho. During this project models were created of specific individual susceptibility associated with wildfires: topography, fuel load, and the number of vulnerable structures.  These models were evaluated together to create a final fire susceptibility model for Bear Lake County, Idaho. This report describes each of the WUI fire susceptibility components and what affect each has on the final fire susceptibility model. This final model is an accurate depiction of the spatial distribution of wildfire susceptibility in Bear Lake County and can be used by regional fire managers to manage wildfire susceptibility.

## Keywords:  Fire, Wildfire, GIS, Bear Lake 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 susceptibility 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 Susceptibility model.  It is comprised of 7 sub-models that describe different aspects of fire susceptibility:

- **Aspect: Sun Position** - takes into account varying fire susceptibility 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 susceptibility.
- **Fuel Load: Vegetation Moisture** - takes into account how different levels of vegetation moisture affect fire susceptibility.
- **Structure Vulnerability:** - includes the density of man-made structures.

 Each of these component models are weighted and summed to produce the Final Fire Susceptibility Model.  The Bear Lake County, Idaho WUI fire susceptibility 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),  Oneida County, Idaho (Franks *et al, 2004),* Caribou County, Idaho (Bulawa *et al,* 2004) and Bingham County, Idaho (Neves, *et al,* 2004).

## Methods:

**Utilized data sets:**

- Digital Elevation Model (DEM) of Bear Lake County
- Landsat 5 imagery for Bear Lake County and environs –Path 038m , Row 30 and Path 38, Row 31.
- Digital Orthophoto Quarter-Quads (DOQQs) for Bear Lake County (NAIP)
- Transportation, place and county boundary datasets for Bear Lake County
- Campgrounds data set provided by U.S. Forest Service, Montpelier office
- Structures of Bear Lake County (digitized from DOQQ by Jackie Langille).
- Fire Regime Condition Class data provided by Lance Brady, BLM, Idaho Falls Office.

**Data Preprocessing:**

### *DEM Data:*

The DEM data for the Bear Lake County area was initially retrieved from the ISU GIS Center's Spatial Library as that for the AOC (Area of Concern) of which Bear Lake County is a part.  This file was, however, found to be to low of a resolution to use. It was 90 meter pixel resolution. A 30 meter DEM was obtained from the Inside Idaho website, and this dataset was ultimately the one used to produce the slope and aspect component models.

### *Landsat Imagery:*

The imagery used was Landsat imagery from Path 038 Row 030, and Path 038, Row 31. The Landsat Imagery was ordered from the USGS website, http://edcsns17.cr.usgs.gov/EarthExplorer/ . The imagery ordered was called N83 UTM 28.5 CC N MAP N GEO, (CC= cubic Convolution, GEO= geometric).  It was created on August 25, 2004.
The imagery included bands 1, 2, 3, 4, 5, and 7 (band 8 being the metadata) and was converted into ArcInfo grids using *imagegrid* of ArcInfo 9.0

## DLG Datasets:

The Idaho county boundaries and Idaho places datasets were downloaded from the Spatial Library (located on the ISU GIS Center website, http://giscenter.isu.edu/data/data.htm ). The Bear Lake County boundary was selectively saved as a separate shapefile and re-projected as necessary.

The roads dataset was also obtained from the Spatial Library, shown above.

**Data Processing:**

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

- Topographic
  - Slope
    - *Suppression difficulty*
    - *Rate of spread*
  - Aspect
    - *Sun Position*
- Fuel Load
  - *Rate of Spread*
  - *Fire Intensity*
  - *Vegetation Moisture*
- Structures
  - *Structure Vulnerability*

Each model component was treated separately to learn how each affected fire susceptibility. 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 susceptibility.  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 susceptibility in Bear Lake County, Idaho.

## *Topographic Sub-model Components*

### *Creating the Topographic: Slope: Suppression Difficulty*

Using the Bear Lake County area DEM as input, a slope grid can be 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 to 30 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).
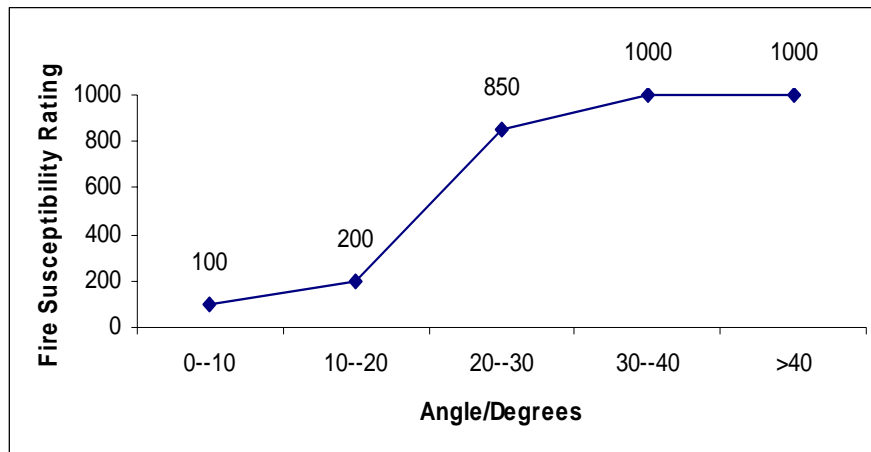


**Figure 1**. *Weightings for slope/suppression difficulties describe how suppression difficulties are affected by the angle of slope (Mattsson et al, 2002).*

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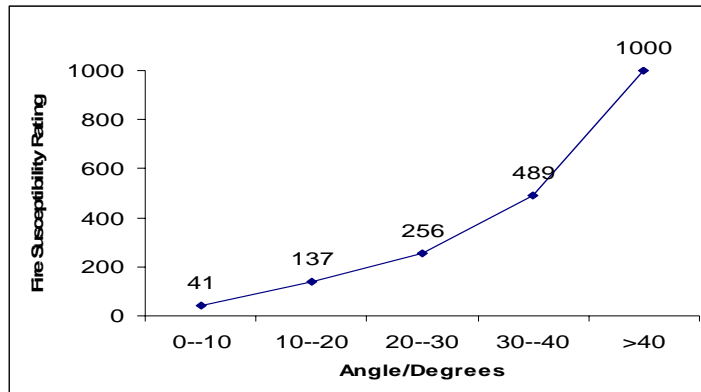
**Figure 2.**. *Weightings describe how spread rate increases with angle of slope. The weight proportion is essentially exponential with slope angle (Mattsson et al., 2002).*

### *Creating the Topographic: Aspect: Sun Position*

Aspect indicates the horizontal *direction* of the instantaneous slope face. Using the Bear Lake County area DEM as input, an aspect grid can be 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 to 30 meters.

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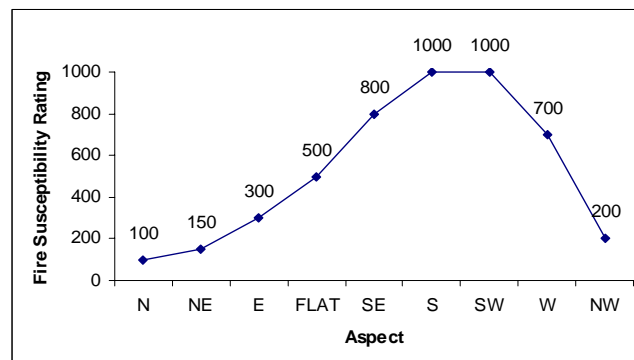


**Figure 3**. *Weightings for Aspect/Sun position describe how the sun desiccates the ground at different aspects (Mattsson et al, 2002).*

### *Fuel Load Sub-model Components*

### *Creating the Fuel Load Fire Susceptibility Components*

The fuel fire susceptibility 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 5 dated 08-25-2004. 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 5 imagery. The resulting NDVI has an interval of −1 to +1, where −1 is no vegetation and +1 is pure photosynthetically active vegetation. Idrisi → Image Processing→ Transformation→ VEGINDEX 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 5 imagery through Idrisi Kilimanjaro (ver. 14.02) was used for estimating fuel load in Bear Lake County.  To estimate fuel load, we used the sample points (231 sample points) that were collected in June of 2004 in Oneida County by Jed Gregory and Luke Sander. This data was placed in a folder called *Oxford*, and stored on the GIS Center computer called *Alpine*. While these field training sites are not located in Bear Lake County, they are within the Landsat scene used for the Bear Lake County study and therefore produced acceptable results. Additional field training sites were also established within Bear Lake County in September of 2004 by GIS technicians Luke Sander, Jackie Langille, Jill Norton, Richard Neves, and Francisco Garcia. Fuel Load data was collected from 56 sites within Bear Lake County

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)
- <3 tons/acre (Grassland with some Sagebrush)
- 3-6 tons/acre (Low and Typical Sagebrush)
- >6 tons/acre (Forest)

The breakpoint between <3 tons/acre and 3-6 tons/acre was established at 35% shrubs. The breakpoint was established and validated through a frequency analysis conducted by Dr. Murat Ercanoglu, Visiting Faculty from Ankara, Turkey.  (figure 4)
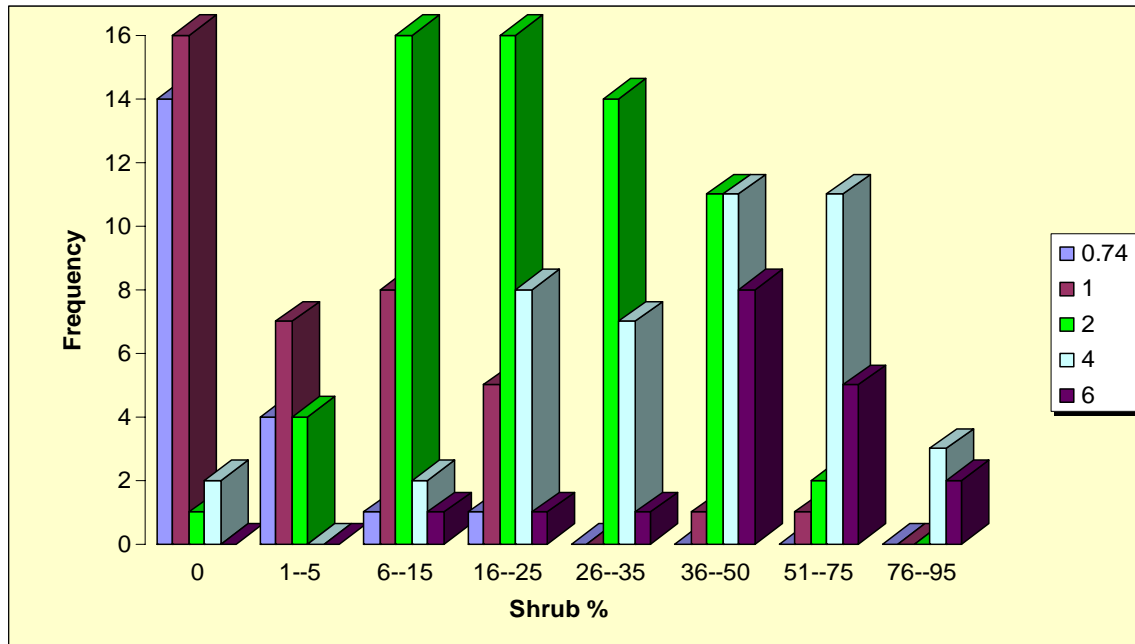
***Figure 4.*** *Frequency analysis conducted by Dr. Murat Ercanoglu to establish <3 and 3-6 tons per acre fuel load categories*

Using Idrisi, we created signature files for the field training sites using an NDVI model produced from Landsat 5 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 (Table 3).

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 → Reclassify 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).
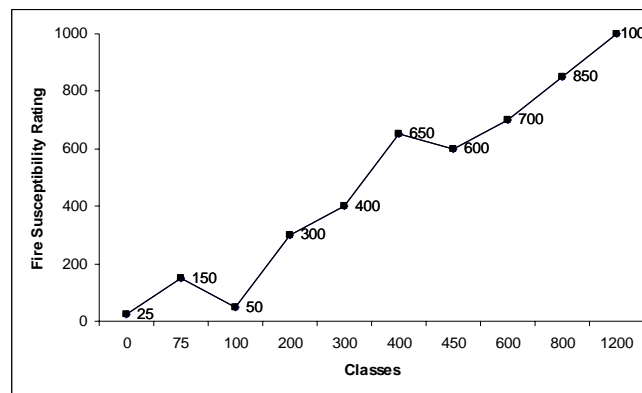This latter part of the process is described in the heading of table B-2 in Appendix B.



**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 →
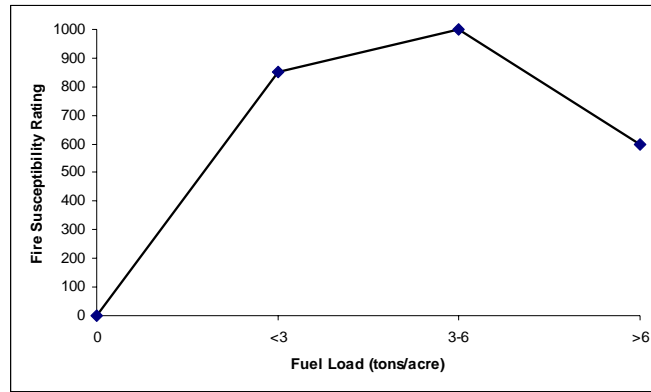Reclassify (fig. 5).

*Figure 6* .*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).
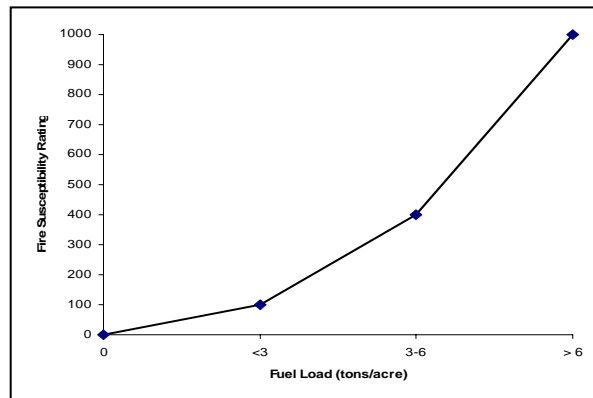


*Figure 7. This chart describes all weightings for Fuel Load/ Intensity (Mattsson et al, 2002*

### Structure Sub-model Components

#### Structure Vulnerability

To create the Structure Vulnerability sub model we first requested structures data from Bear Lake County officials. Caribou National Forest officials provided us with a shapefile that designated the location of Forest Service campgrounds, and requested that this data be incorporated into our structures file. Bear Lake County officials indicated that they did not have structures data available, and suggested we not use US Census files to extrapolate structures data as they considered that information to be of questionable accuracy.

We then considered several options to obtain structures data for Bear Lake County. We first downloaded the one meter full color NAIP imagery available through the State of Idaho. It's original projection was NAD 83 UTM 12 N. It was reprojected to IDTM and the structures were heads up digitized using the DOQQ. Structures 150 meters inside city boundaries were removed to better depict the wildland urban interface. To calculate the structure density from the shapefile, using ArcMap→ Spatial Analyst → Density. To make this component consistent with the other sub-models, the range of pixel values was stretched to a range of 0 - 1000.

### WUI fire susceptibility model

The final fire susceptibility 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*.

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

| 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 | Structure Vulnerability | 22% |

## Results:

We compared the WUI fire susceptibility models for Clark County, Bannock County, Power County, Oneida County, Caribou, Bingham and Bear Lake County, Idaho. Figure 8 shows portions of each county classified as low, medium, and high susceptibility relative to individual areas. We did this by reclassifying the final fire susceptibility model into three distinct classes (0-333 = low susceptibility; 333-666 = medium susceptibility; 666-1000 = high susceptibility). Comparison between total acres classified as low, medium, and high fire susceptibility 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 susceptibility.
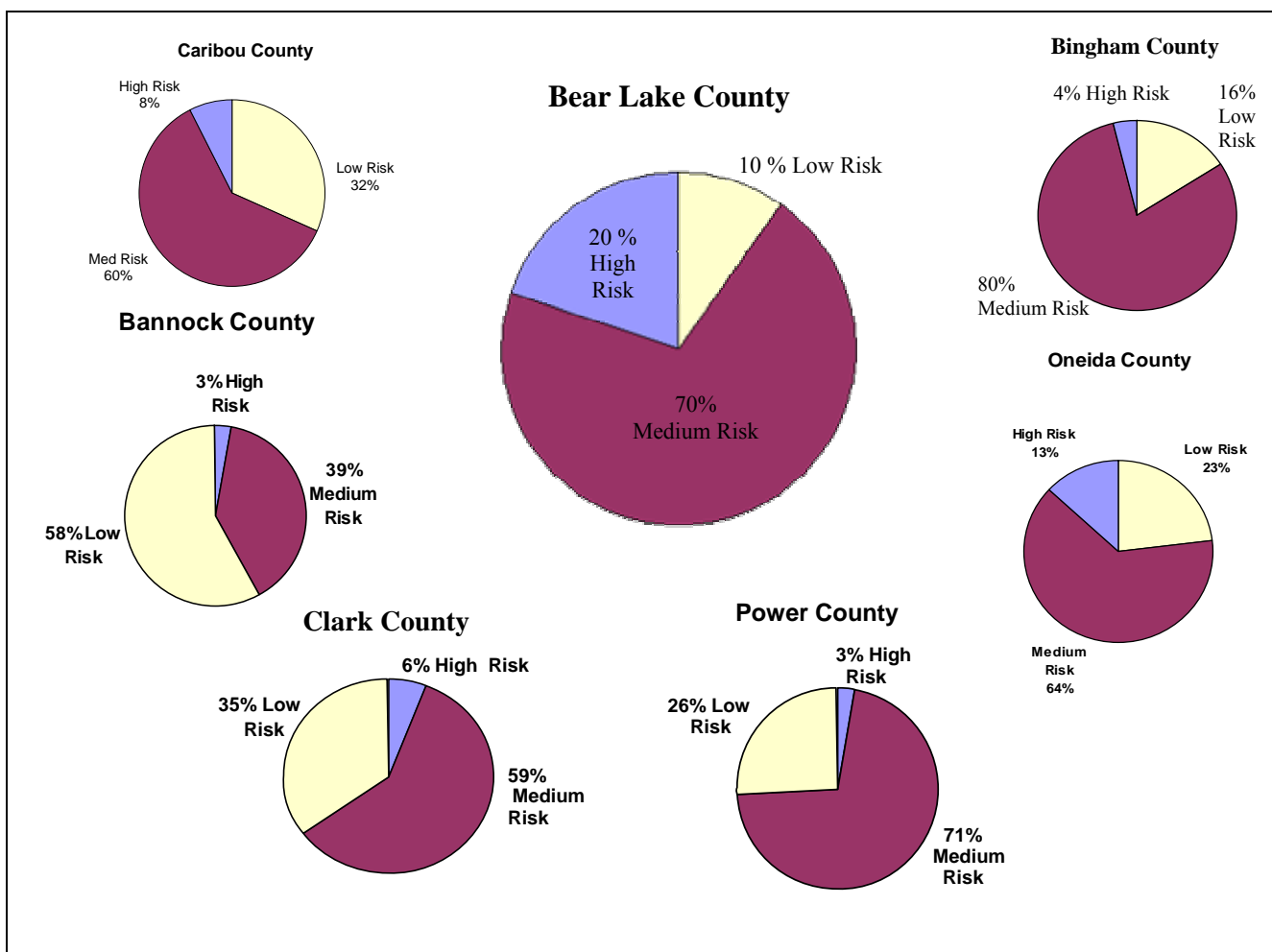


**Figure 8**. *Percent of Clark County, Bannock County, Power County , Oneida County, Caribou, Bingham, and Bear Lake County considered low, medium, and high fire susceptibility.*

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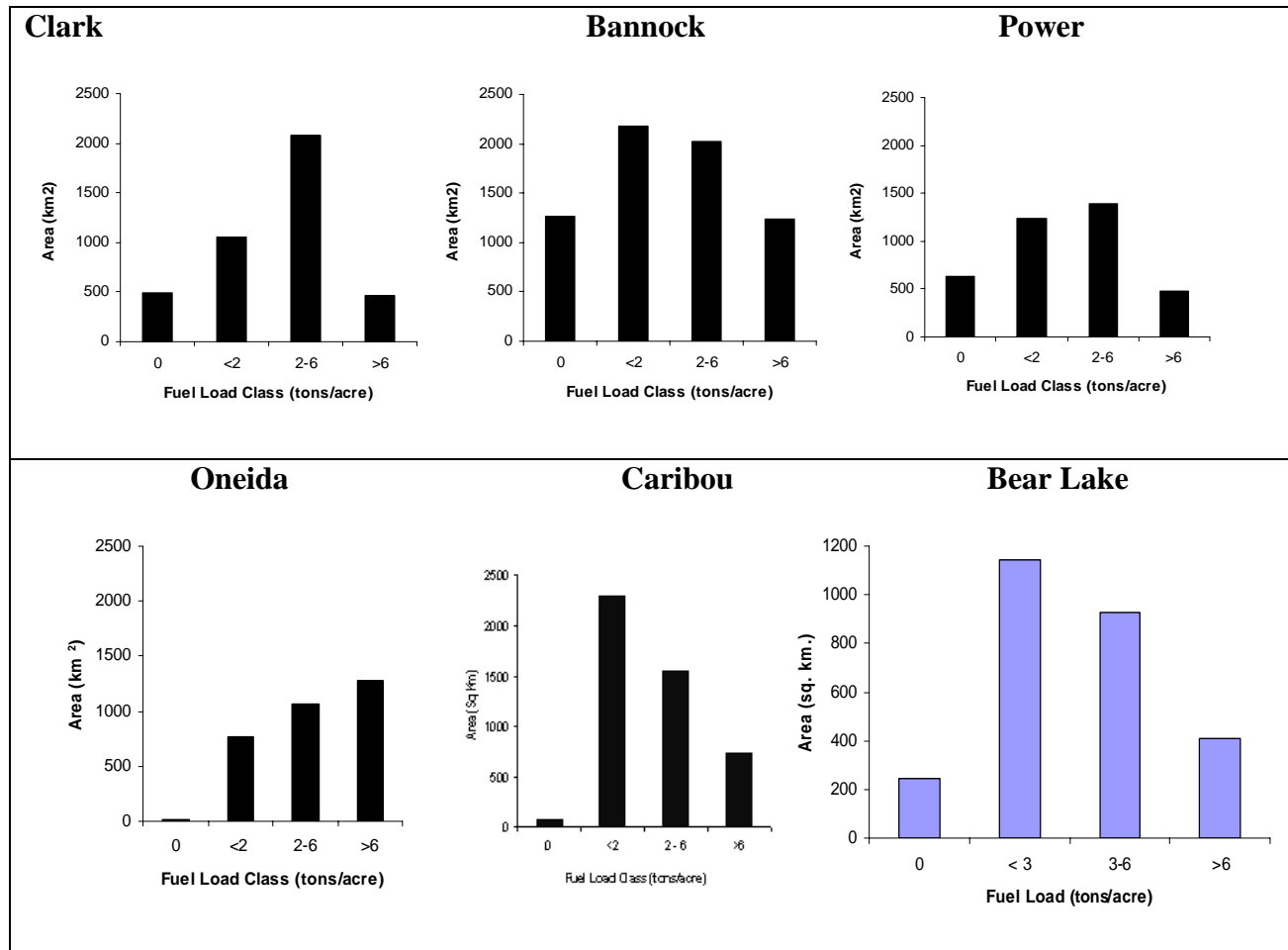


**Figure 9:** *Comparison of fuel load distribution for Clark County, Bannock County, Power County, Oneida County, Bingham County, Caribou County, and Bear Lake County.*

The NDVI grid used to generate the fuel load model is shown in figure 9. The reclassified NDVI grid estimating the location of wet vegetation, dry vegetation and no vegetation is shown in

| Total Acres Classified as low, medium, and high fire susceptibility | | | | | | |
|---|---|---|---|---|---|---|
| | Bear Lake County | Clark County | Bannock County | Power County | Oneida County | Caribou County |
| Low | 62,080 | 395,360 | 413,146 | 233,958 | 175,761 | 356,923 |
| Medium | 435,008 | 666,464 | 277,805 | 638,886 | 495,089 | 688,575 |
| High | 124,288 | 67,776 | 21,370 | 26,996 | 97,599 | 84,806 |
| Total | 621,376 | 1,129,600 | 712,321 | 899,840 | 768,449 | 1,130,304 |

Figure 10. Figure 11 illustrates the Fuel Load model derived from field training sites and Landsat 5 satellite imagery. Table 4 shows the error matrix validation for the fuel load model. The overall

Kappa statistic was determined to be 0.7083 indicating that the classification was approximately 70.8% better than chance.
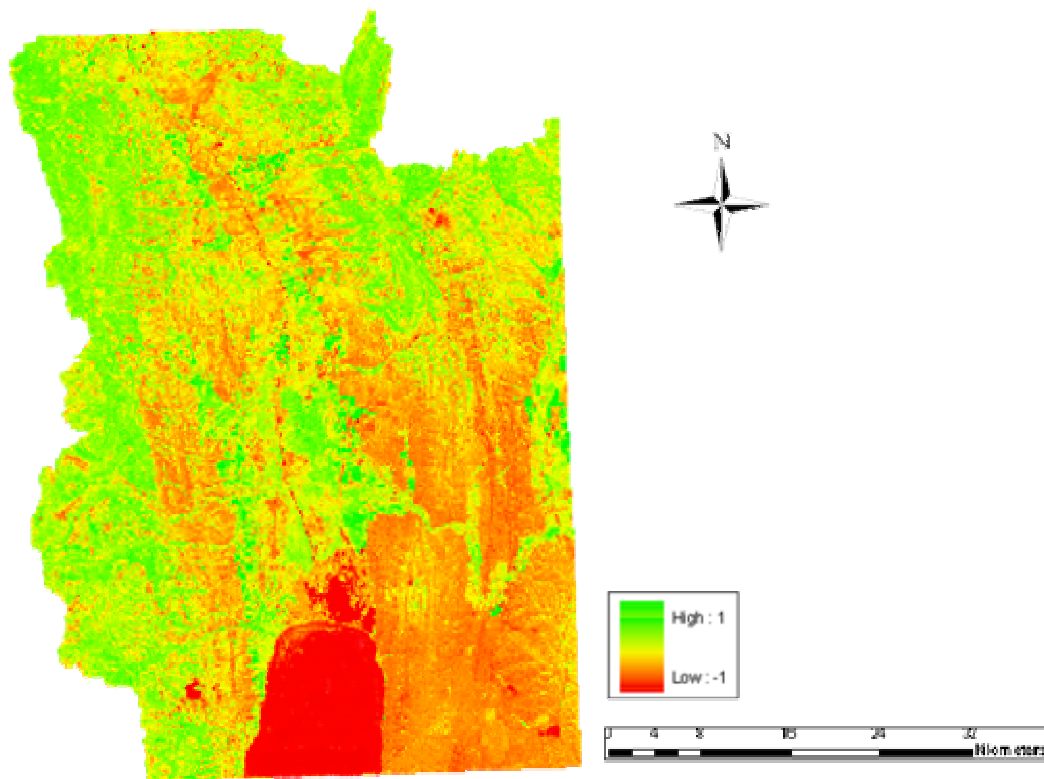


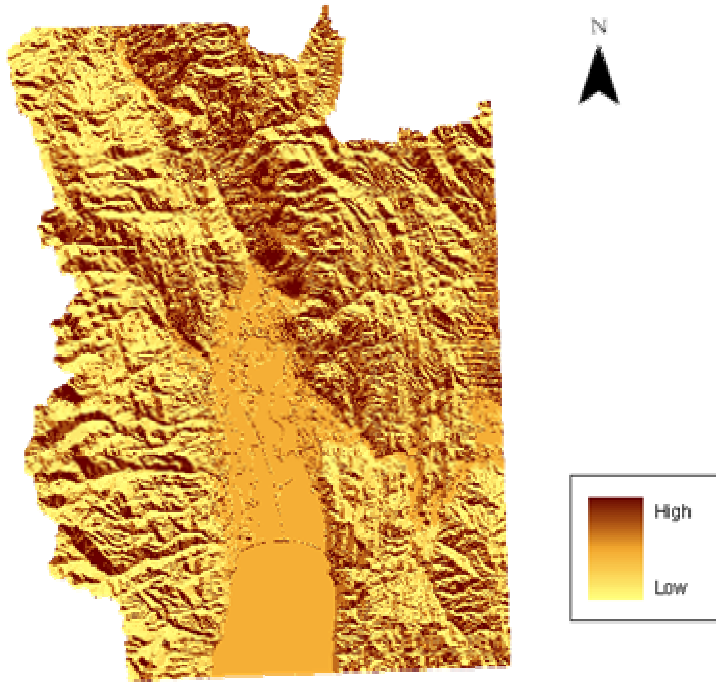**Figure 10:** The NDVI has an interval of −1 to +1, where −1 is no vegetation and +1 is pure vegetation.

**Figure 11:**. *The results of the reclassification of NDVI into no vegetation (100), dry vegetation (200) and wet vegetation (75).*
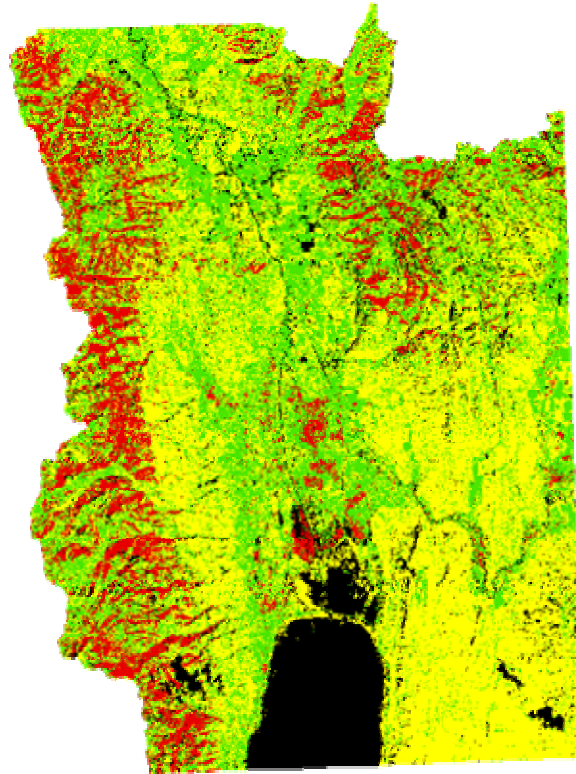


**Figure 12**: *The fuel load model and the distribution of different fuel load classes for Bear Lake County, ID.*

**Table 3:**. *Error matrix for the fuel load model.*

| | | Field Measurement (tons/acre) | | | | | |
|---|---|---|---|---|---|---|---|
| | | **0** | **<3** | **3 - 6** | **>6** | **Total** | **Commission Accuracy** |
| **Modeled Fuel Load (tons/acre)** | **0** | 15 | 0 | 0 | 0 | **15** | 100.00% |
| | **<3** | 0 | 34 | 17 | 0 | **51** | 66.67% |
| | **3 - 6** | 0 | 24 | 33 | 0 | **57** | 57.89% |
| | **>6** | 0 | 0 | 0 | 20 | **20** | 100% |
| | **Total** | **15** | **58** | **50** | **20** | 143 | **Overall Accuracy** |
| | **Ommission Accuracy** | 100.00% | 58.62% | 66% | 100.00% | | **71.33%** |

 

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 susceptibility values, while the grasses, shrubs, and mountainous areas throughout Bear Lake County contain the highest values.  The high susceptibility 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 valley portion of Bear Lake County contain the highest values. The high susceptibility areas are due to the high concentration of 3-6 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 susceptibilities for the most intense fires.
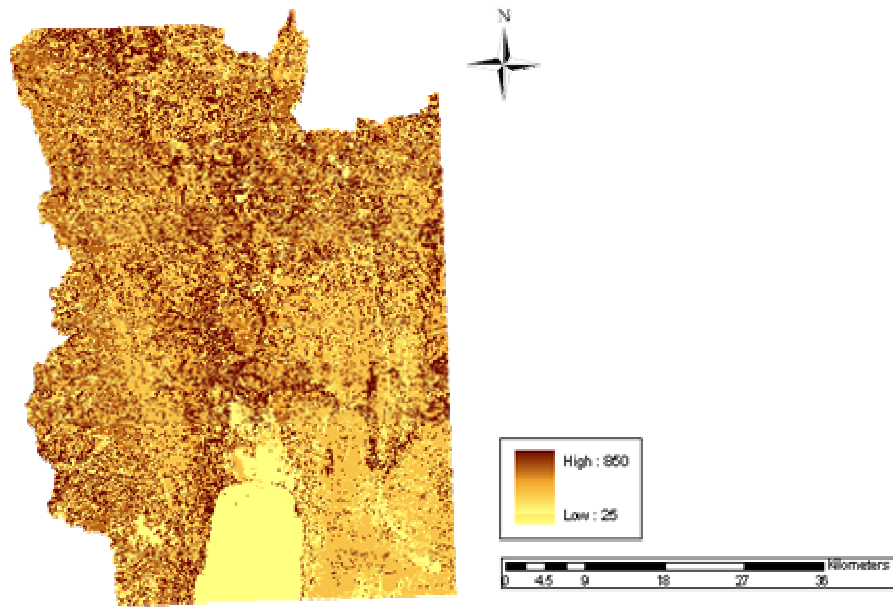
**Figure 13***:  The Fuel Load/ Vegetation Moisture model.  This model expresses how vegetation moisture (or lack of moisture) and the combination of different fuel load classes affect fire susceptibility.  This model was given an overall weighting of 11% of the final model.*
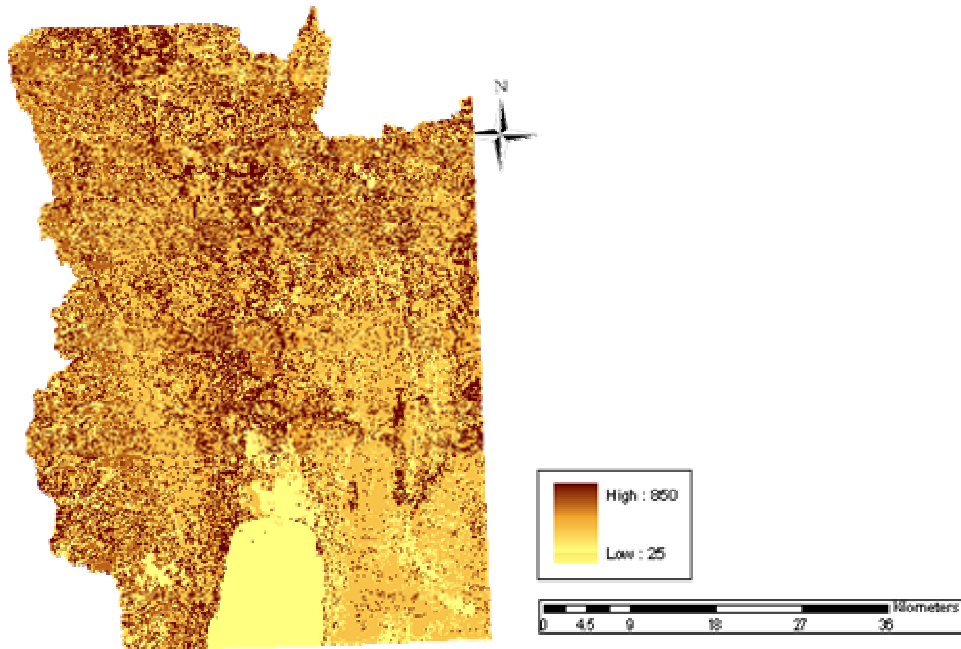


***Figure 14****:    The Fuel Load/ Rate of Spread model.  This model expresses the fire susceptibility associated with the spread rate of different fuel load classes.  This model was given an overall weighting of 17% of the final model.*
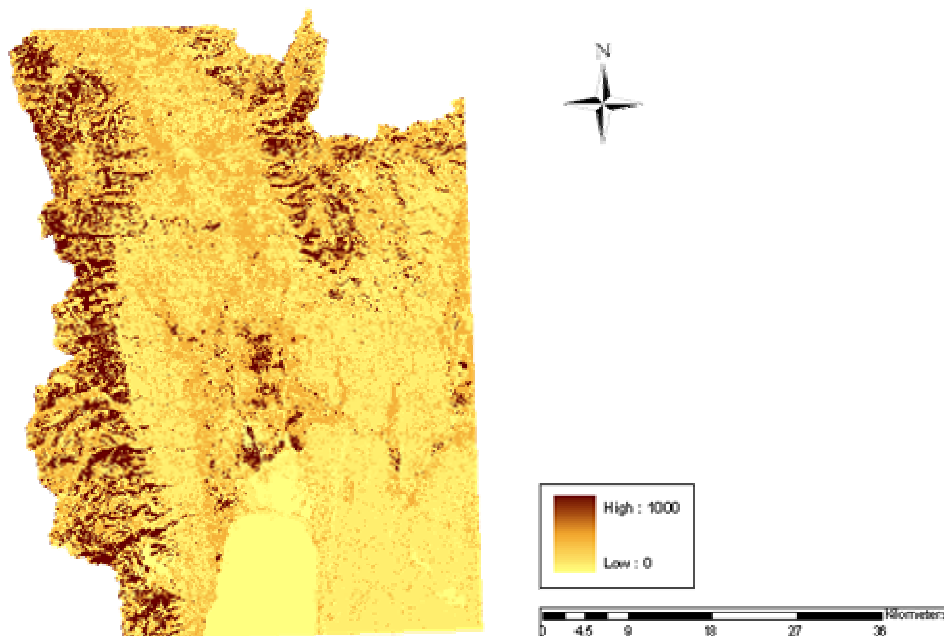
*Figure 15: The Fuel Load/ Intensity model. This model expresses the fire susceptibility associated with the amount of heat energy (intensity) each fuel load class gives off. This model was given an overall weighting of 17% of the final model.*

Figures 16-18 are the component models generated using the Bear Lake County DEM. Figure 16 assesses the susceptibility of fires spreading quickly due to steep slopes. Here, the highlands throughout the county received the highest values and the bottom lands throughout 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 susceptibility. Figure 18 is the Aspect: Sun Position component model, south and southwest aspects contain the highest fire susceptibility, 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 susceptibility
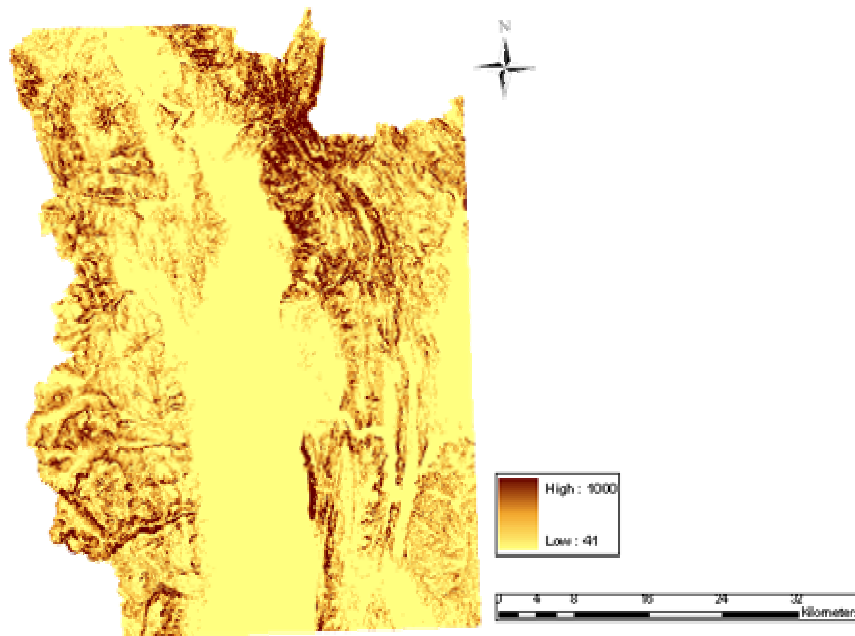
**Figure 16***: The Slope/ Rate of spread model. This model expresses how different angles of slope affect the spread rate of fire. Steeper slops are given the highest fire susceptibility. This model was given an overall weighting of 17% of the final model.*
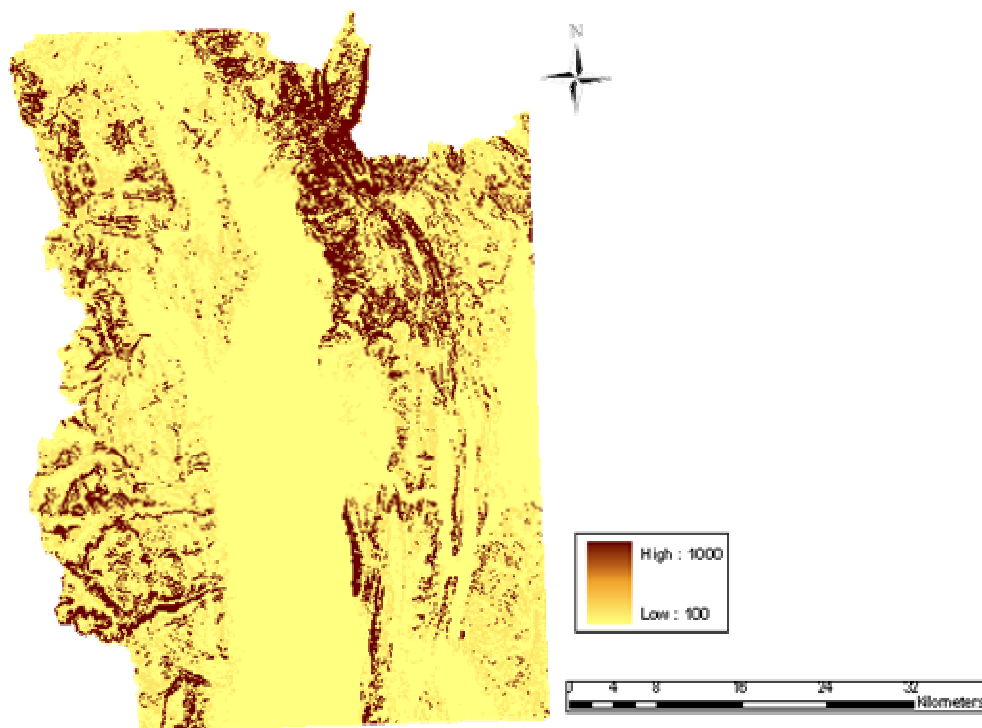


**Figure 17: The Slope/ Suppression Difficulty model. This model expresses how different slope angles affect suppression efforts of firefighters. This model was given an overall weighting of 11% of the final model.**
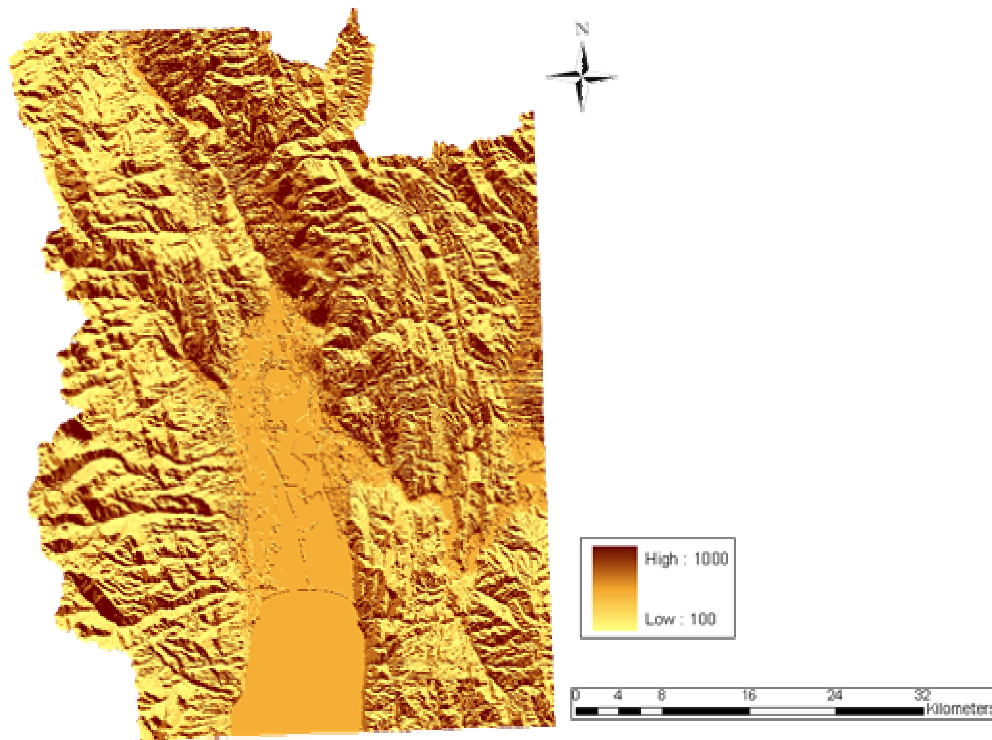
*Figure 18: The Aspect: Sun Position. This model expresses how different aspects affect fire susceptibility. Southern aspects have the highest fire susceptibility. This model was given an overall weighting of 5% of the final model.*

The Structures Vulnerability component model is shown in figure 19. The population centers of Bear Lake County include Georgetown. Montpelier, Paris, Bloomington, Bennington, and St. Charles.
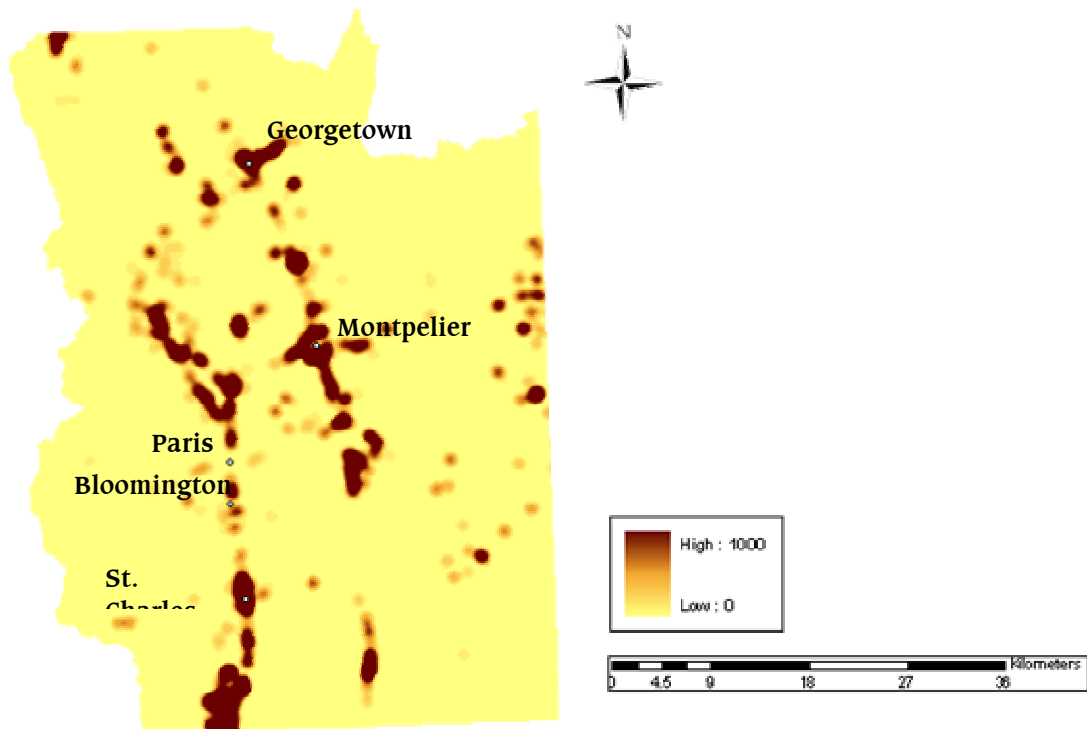
*Figure 19:* *The Structures at Risk model. This model expresses areas that are highly susceptibility due to high structure density and is given an overall weighting of 22% of the final model.*

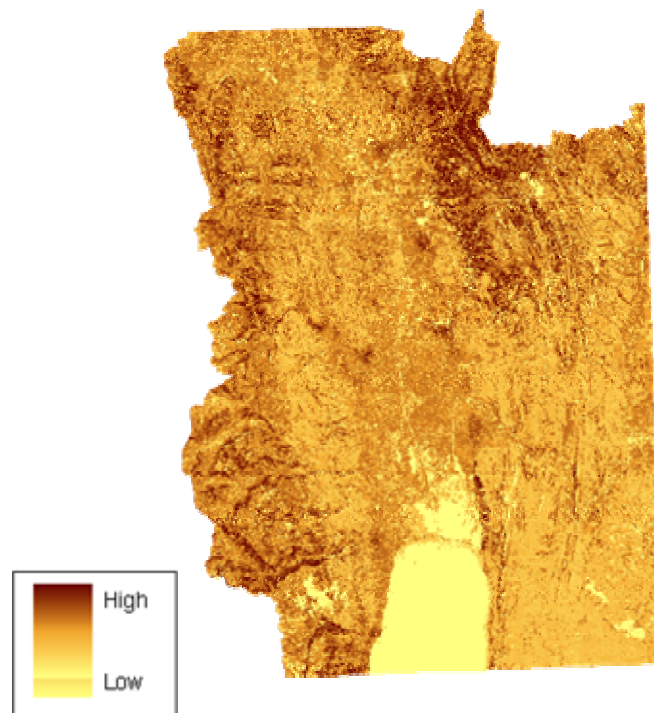The Final Fire Susceptibility Model for Bear Lake County is shown in Figure 20.



*Figure 20:* *The Final Fire Susceptibility Model for Bear Lake County, Idaho.*

## 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 Susceptibility Model

In preparation for using the Fire Regime Condition Class data provided by the BLM in an alternate Fire Susceptibility Model, each category was weighted from 0 – 1000 (figure 21). A normalized Fire Regime Condition Class sub model was then constructed (Figure 22) for use in construction of an Alternate Fire Susceptibility Model.

An Alternate Fire Susceptibility 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 Susceptibility model were multiplied by their own weighting percentage *(Table 5)*. The resulting values were then added to produce the Alternate Fire Susceptibility Model (Figure 23).

*Table 5*: *Sub model components of the Fire Regime Condition Class Alternate Fire Susceptibility Model*

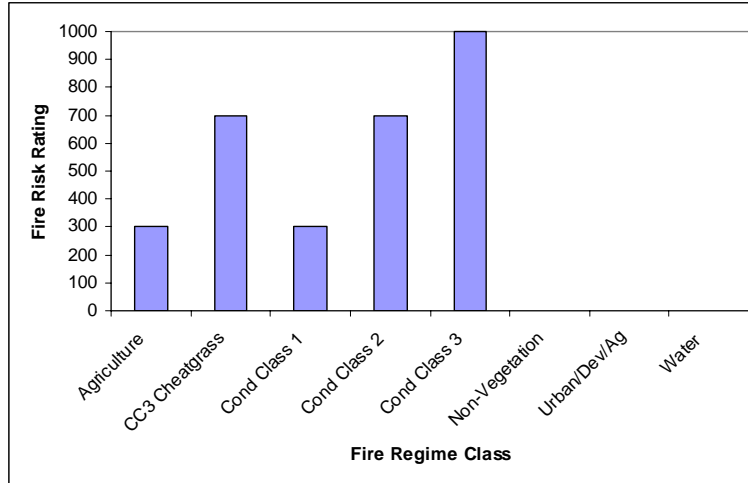| Component | Description | Percentage |
|---|---|---|
| Aspect | Sun position | 5% |
| Slope | Rate of Spread | 17% |
| Slope | Suppression Difficulties | 11% |
| Fuel load | Vegetation Moisture | 11% |
| Fuel load | Rate of Spread | 17% |
| Fire Regime | Condition Class | 17% |
| Structures | Structure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



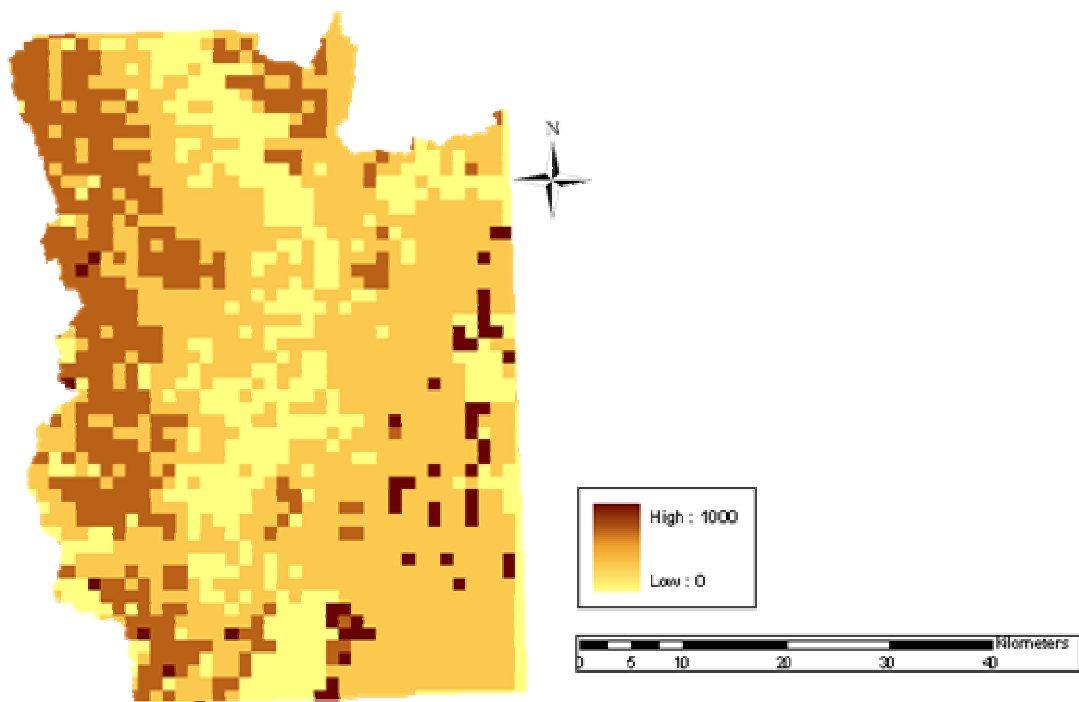*Figure 21*: *Fire susceptibility ratings of Fire Regime Class components*

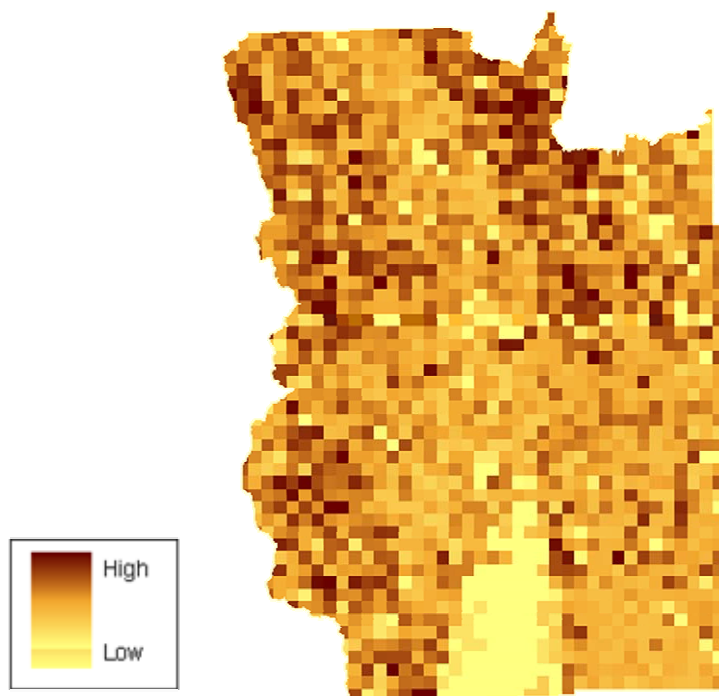**Figure 22**: Normalized Fire Regime Condition Class sub model component



**Figure 23***: Alternate Fire Susceptibility Model for Bear Lake County using the Fire Regime Condition Class sub model in place of the Fuel Load: Fire Intensity sub model.*

## Discussion:

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

Of these counties, Bear Lake County has the smallest area, with 971 square miles. In order of size Clark County has the largest area, with 1,765 square miles, Power County with 1,406 square miles, Oneida County with 1,200 square miles and Bannock County with an area of 1,113 square miles.

Bear Lake County has the highest total acres classified as high fire susceptibility with 124,288 acres. Oneida County has the second largest area classified as high susceptibility with 97,599 acres. Caribou County follows with 84,806 acres classified as high susceptibility, followed by Clark County with 67,776 acres and Power County with 26,996 acres. Bannock County has the least acres as high susceptibility at 21,370 acres. The high fire susceptibility classification for all six 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 susceptibility with 688,575 acres. Clark County and Power County (66,464 acres and 638,886acres) have the next highest medium susceptibility classification, followed by Oneida, Bear Lake, and Bannock Counties (495,089 acres, 435,008 acres, and 277,805 acres 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 Structure Vulnerability component was weighted most heavily (22%). Due to the nature of this project, we were most interested in quantifying susceptibility for the Wildland/ Urban Interface. This model allowed us to emphasize the interface areas. Areas of high structure density received the highest fire susceptibility values and areas of low or no structure got the lowest fire susceptibility values. Bannock, by far, has the largest population with 75,323, while Bingham has a population of 7,397. Bear Lake County has a population of 6, 409. 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 3-6 tons/acre received the highest fire susceptibility value, because of its high load of fine, low-standing fuels. Fuel Load class >6 tons/acre received the lowest fire susceptibility 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 susceptibility values, because fire increases exponentially with slope. Correspondingly, shallower angles have lower fire susceptibility 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 susceptibility value. Areas that had wet vegetation and lower fuel load had the lowest fire susceptibility values.

The Fuel Load/ Intensity component takes into account how intense a fire of different fuel load classes affects fire susceptibility. 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 susceptibility 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 susceptibility 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 susceptibility values and shallow slopes received the lowest fire susceptibility 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 susceptibility 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 susceptibility 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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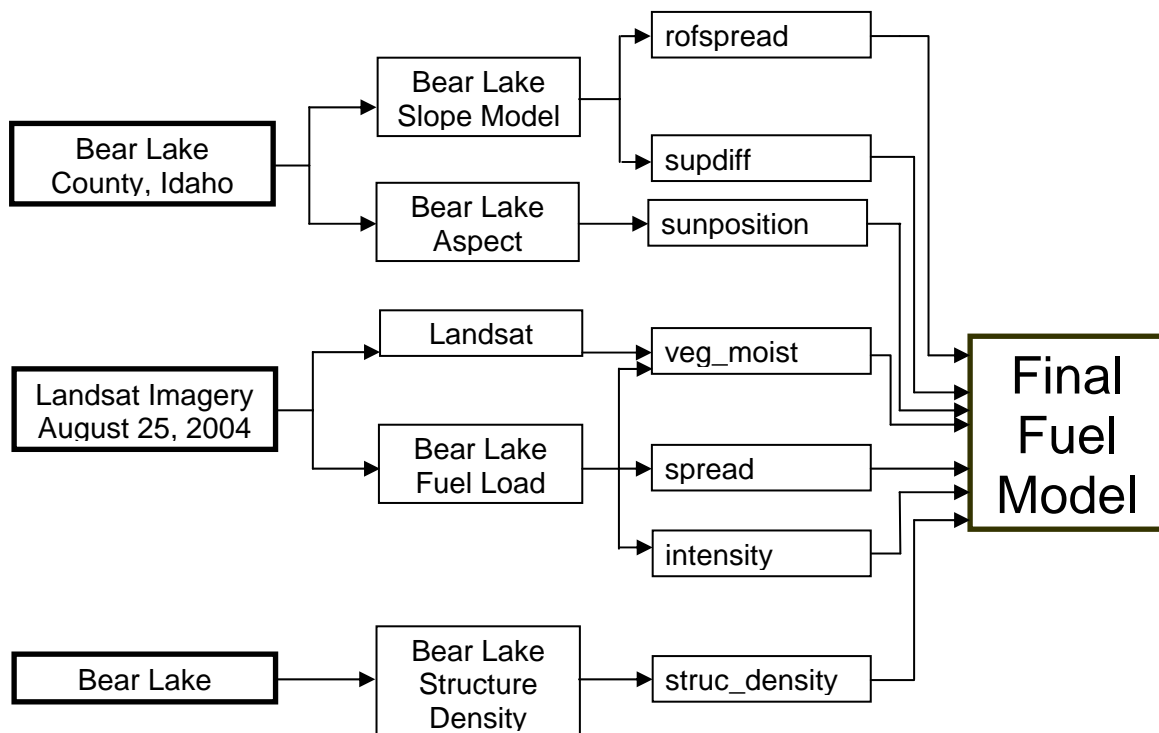    Government Printing Office.

# Acknowledgements:

were used to construct this alternate Fire Susceptibility 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.

## Appendices

**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 = <3 tons/acre | 200 = Dry Vegetation |
| 4 = 3-6 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 | | b_lake_bnd.shp | | C:\Data\BearLakeWUI\CD_Data | | Boundary of Bear Lake county | | polygon coverage |
| Structures Dataset | | Structures_150.shp | | C:\Data\BearLakeWUI\CD_Data | | Data set of structures | | Shapefile |
| Bands used for NDVI | | Band3b | | C:\Data\BearLakeWUI\CD_Data | | Landsat Band 3 for Bear Lake County | | Grid  - 28.5m pixels |
| | | Band4b | | C:\Data\BearLakeWUI\CD_Data | | Landsat Band 4 for Bear Lake County | | Grid  - 28.5m pixels |
| NDVI | | NDVI | | C:\Data\BearLakeWUI\CD_Data | | NDVI for Bear Lake County | | Grid  - 28.5 pixels |
| Fuel Load Model | | fuel_load_c | | \C:\Data\BearLakeWUI\CD_Data | | Fuel Load model for Bear Lake County.  Classes are <3 tons/acre, 3-4 tons/acre, and 6> tons/acre | | Grid  - 28.5m pixels |
| DEM | | dem | | C:\Data\BearLakeWUI\CD_Data | | Digital Elevation Model of Bear Lake County | | Grid  - 30m pixels |
| Component models | | sun_pos | | \C:\Data\BearLakeWUI\CD_Data | | Risk associated with aspect angle **i.e**. North, East,……. | | Grid  - 30m pixels |
| | | srate_spread | | C:\Data\BearLakeWUI\CD_Data | | Risk associated with how fire spreads with angle of slope. | | Grid  - 30m pixels |
| | | supp_diff | | C:\Data\BearLakeWUI\CD_Data | | Risk associated with how suppression efforts are affected by angle of slope. | | Grid  - 30m pixels |
| | | fl_rt_sprd | | C:\Data\BearLakeWUI\CD_Data | | Risk associated with how quickly different fuel load classes spread during a fire. | | Grid  - 26m pixels |
| | | fl_intensity | | C:\Data\BearLakeWUI\CD_Data | | Risk associated with how intense (release of heat energy) different fuel load classes burn. | | Grid  - 26m pixels |
| | | fl_vegmoist | | C:\Data\BearLakeWUI\CD_Data | | Risk associated with vegetation moisture. | | Grid  - 26m pixels |
| | | strctr_final | | C:\Data\BearLakeWUI\CD_Data | | Risk associated with structure density. | | Grid  - 30m pixels |
| Final Model | | final_mdl | | C:\Data\BearLakeWUI\CD_Data | | Final susceptibility model | | Grid  - 30m pixels |
| FRCC Final Model | | frcc_final | | \C:\Data\BearLakeWUI\CD_Data | | Final susceptibility model using condition classes | | Grid  - 30m pixels |
| Reports | | Bear Lake_final_report | | C:\Data\BearLakeWUI\CD_Data | | Report covering methods, results, & conclusions of WUI modeling | | Word Document |