# Wildland/Urban Interface and Communities at Risk

## Joint Fire Modeling Project
## 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 are high priorities to federal land management agencies. The Bureau of Land Management (BLM) Upper Snake River District (USRD) Geographic Information Systems (GIS) team, in cooperation with Idaho State University's (ISU) GIS Training and Research Center (GIS TreC), have created a model to predict potential fire risk areas around the city of Pocatello, Idaho. The study area is Pocatello, Idaho city limits with a buffer of approximately 1 mile surrounding it. To create a wildland/ urban interface fire model the criteria that were considered are topography and vegetation characteristics, and suppression access. Data presented in this report contains detailed conclusions of the effect that each criterion will have on the model, and the result as a complete model. With the data available we believe that we have produced a reliable, accurate, yet not overly complicated model of community areas at risk to wildfire.

Keywords: Fire, GIS, WUI (Wildland/Urban Interface).

Introduction: This study was conducted to produce a wildland urban interface (WUI) fire model using GIS. The fire model may be used by fire managers, land managers, and as public information to work proactive to prevent fire. The fire model will show fire hazard areas at the interface between wildland and urban areas. Wildland is, in this case, the natural areas outside the city limits of Pocatello, Idaho. Earlier studies have been done on the subject but then with a more generalized approach. Examples are Fire Area Simulator Model Development and Evaluation (FARSITE) and National Fire Danger Rating System (NFDRS).

Methods: Each criterion was first treated separately to find out how it affects fire risk. Each criterion is weighted from 0 to 10 to make it easier to compare the different criteria, 10 is the highest fire risk in each criterion. Then the criteria were put together according to accepted weightings to produce a WUI fire risk model.
To offer an overview, we have developed graphs showing the weight proportions of each criterion, the exact values for each criterion is shown in appendix A.

GIS Data
The background data that were used for this Wild land Urban Interface Communities At Risk (WUI/CAR) model are:
Digital Elevation Model (DEM), 30 m cell size.
Road coverage with attributes "Seconds" and "ONEWAY" to be able to run the Network Analyst extension in Arc/View 3.2.
Fuel Load model, Landsat 7, Enhanced Thematic Mapper (ETM+). This satellite image was supervised classified with information collected from the Snake River Plain, 30m cell size.

**Slope: Spread Rate**
Slope was split into two parts. 1) how slope affects the rate of spread and 2) how slope affects suppression efforts. According to FARSITE, Finney 1998, the spread rate of a fire is linear and the surface of a fire increases exponentially to the angle of slope. In our study area since we have a really dry climate and according to Rick Belger, Bureau of Land Management (BLM), the spread rate of a fire should increase exponentially to the angle of slope, (fig. 1).

GIS Process
Software: Arc Map 8.1
Extension: Spatial analyst

> Command: Spatial Analyst/ Surface Analysis/ Slope…
> Input surface: Digital Elevation Model Area of Interest (DEM_AI)
> Output measurement: degree
> Z factor: 1
> Output cell size: 30
> Command: Spatial Analyst/ Reclassify…
> Then we used values from figure 1 or table 1 in appendix A and reclassified the grid to create our slope/ spread rate grid.

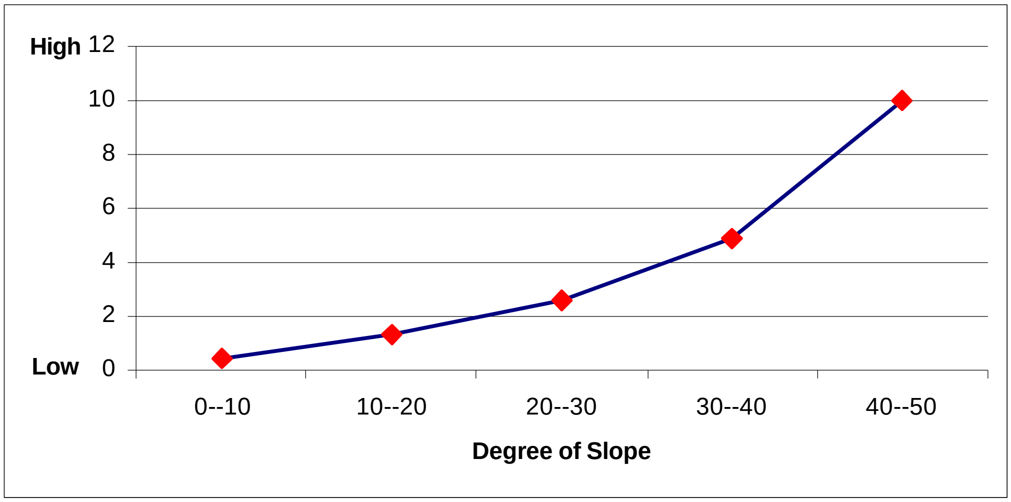


Figure 1. The weight proportion of how spread rate increase by the angle of slope is assumed to be exponentially with slope angle.

We created a map (fig. 2) that shows how rate of spread, as modeled by slope, affects fire risk in our study area.

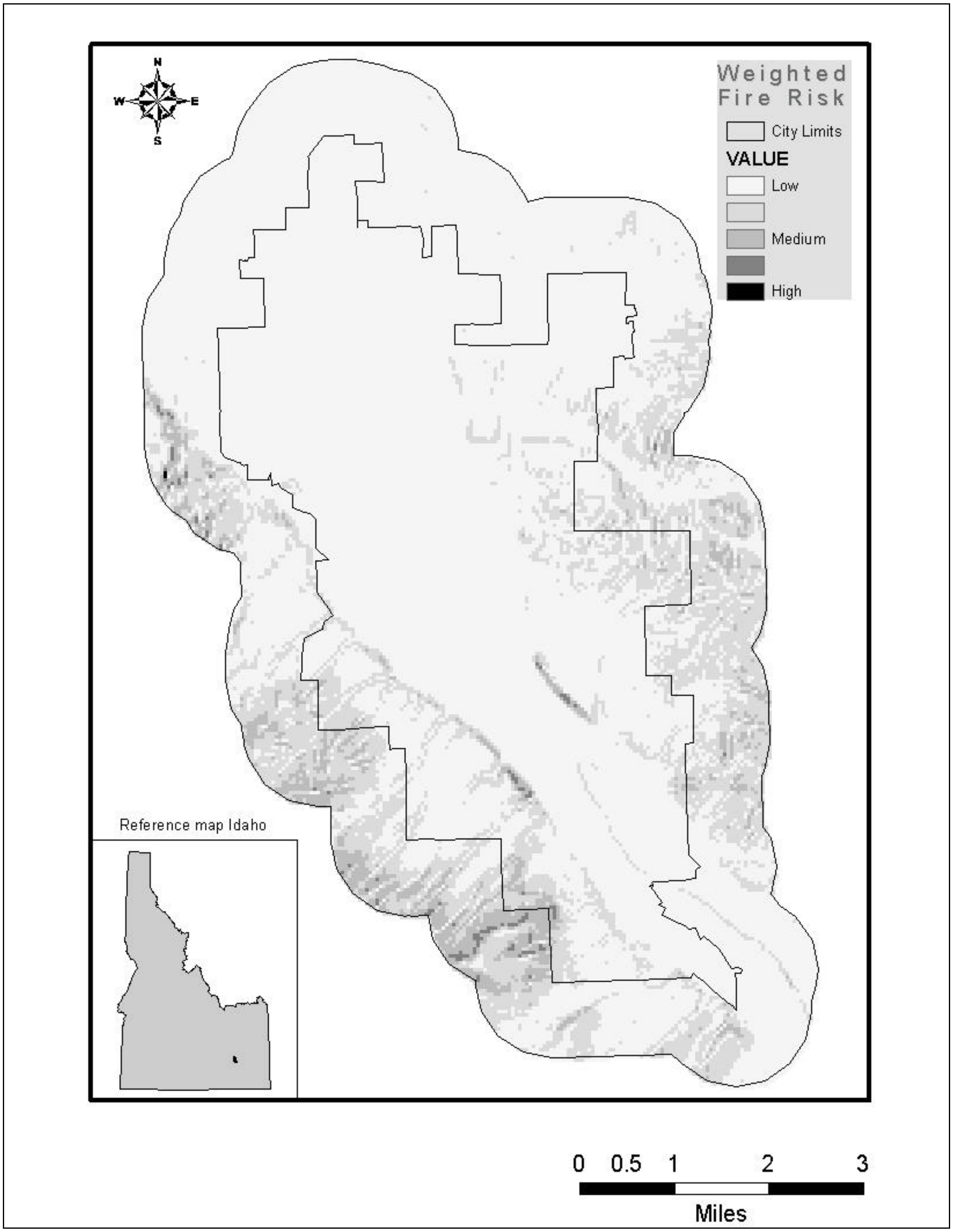

Figure 2. This map shows how rate of spread increases in areas with a steeper slope, these areas have a higher fire risk.

**Slope: Suppression Difficulties**
Regarding suppression efforts, the difficult of suppression is not considered to be affected where slope < 25 degrees. Once slope exceeds 20 degrees, suppression difficulties increases substantially. On slopes > 25 degrees, heavy fire suppression machinery usually has severe difficulties operating, thus we have put a higher weighting on slope > 25 degrees. Slopes from 25 to 50 degrees can still be suppressed, but only without vehicle support, (fig.3).

GIS Process
Software: Arc Map 8.1
Extension: Spatial analyst

> Command: Spatial Analyst/ Surface Analysis/ Slope…
> Input surface: Digital Elevation Model Area of Interest (DEM_AI)
> Output measurement: degree
> Z factor: 1
> Output cell size: 30
> Command: Spatial Analyst/ Reclassify…
> Then we used values from figure 3 or table 2 in appendix A and reclassified the grid to create our slope/ suppression difficulties grid.

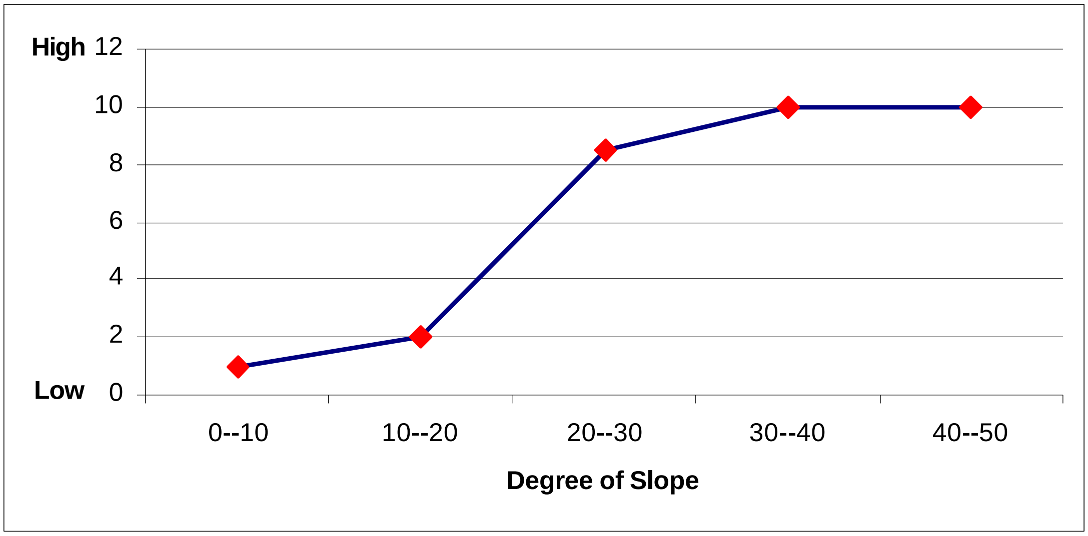


Figure 3. Weighting used to describe how suppression difficulties are affected by the angle of slope.

We created a map (fig. 4) that illustrates how suppression difficulty, depending on slope, affects fire risk in our study area.

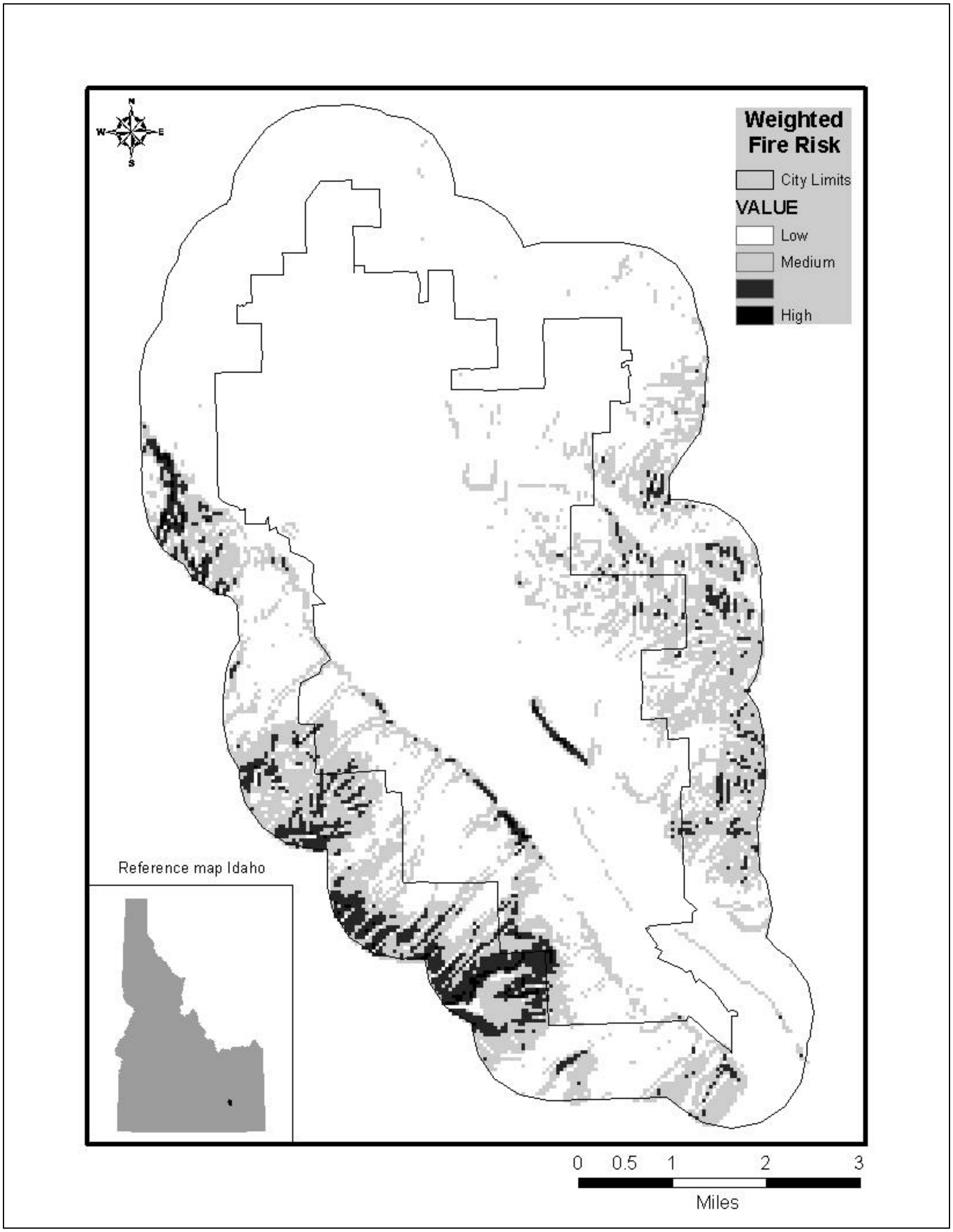


Figure 4. This map shows how the suppression difficulties increase on areas with a steeper slope and therefore higher fire risk.

**Aspect: Sun Position and Daily Temperature**

The sun is predicted to desiccate the ground and vegetation more on south facing slopes compared to east and west. We have also assumed that the effect from the sun is greater in the afternoon due to the cumulative effects of increasing daily temperature (fig. 5). Areas with slope < 5 degrees are considered flat areas. Flat areas are given a medium weight, because they have an "average" sun exposure. This information is gathered from the "Fire Protection Handbook", (Cote 1997) and local Bureau of Land Management (BLM) fire management officers.

GIS Process

Software: Arc Map 8.1

Extension: Spatial analyst

Command: Spatial Analyst/ Surface Analysis/ Aspect…

Input surface: Digital Elevation Model Area of Interest (DEM_AI)

Output cell size: 30

To exclude areas with slope angle < 5 degrees, we did a condition calculation in raster calculator.

Command: Spatial Analyst/ Raster Calculator: con((slope > 5), aspect, -1)

Command: Spatial Analyst/ Reclassify…

Then we used values from figure 5 or table 3 in appendix A and reclassified the grid to create our Aspect/ Sun position and Daily temperature grid.

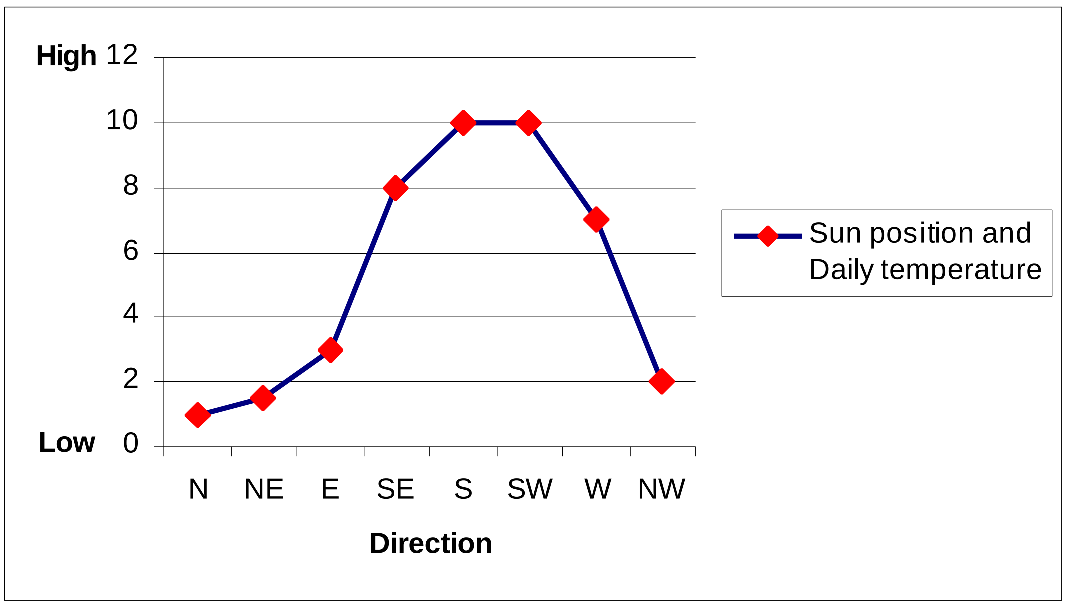


Figure 5. The sun desiccates the ground more on south facing aspects. West facing aspects are given a higher value due to the cumulative effects of increasing daily temperatures.

We created a map (fig. 6) that shows how the sun position and daily temperature affects fire risk in our study area.

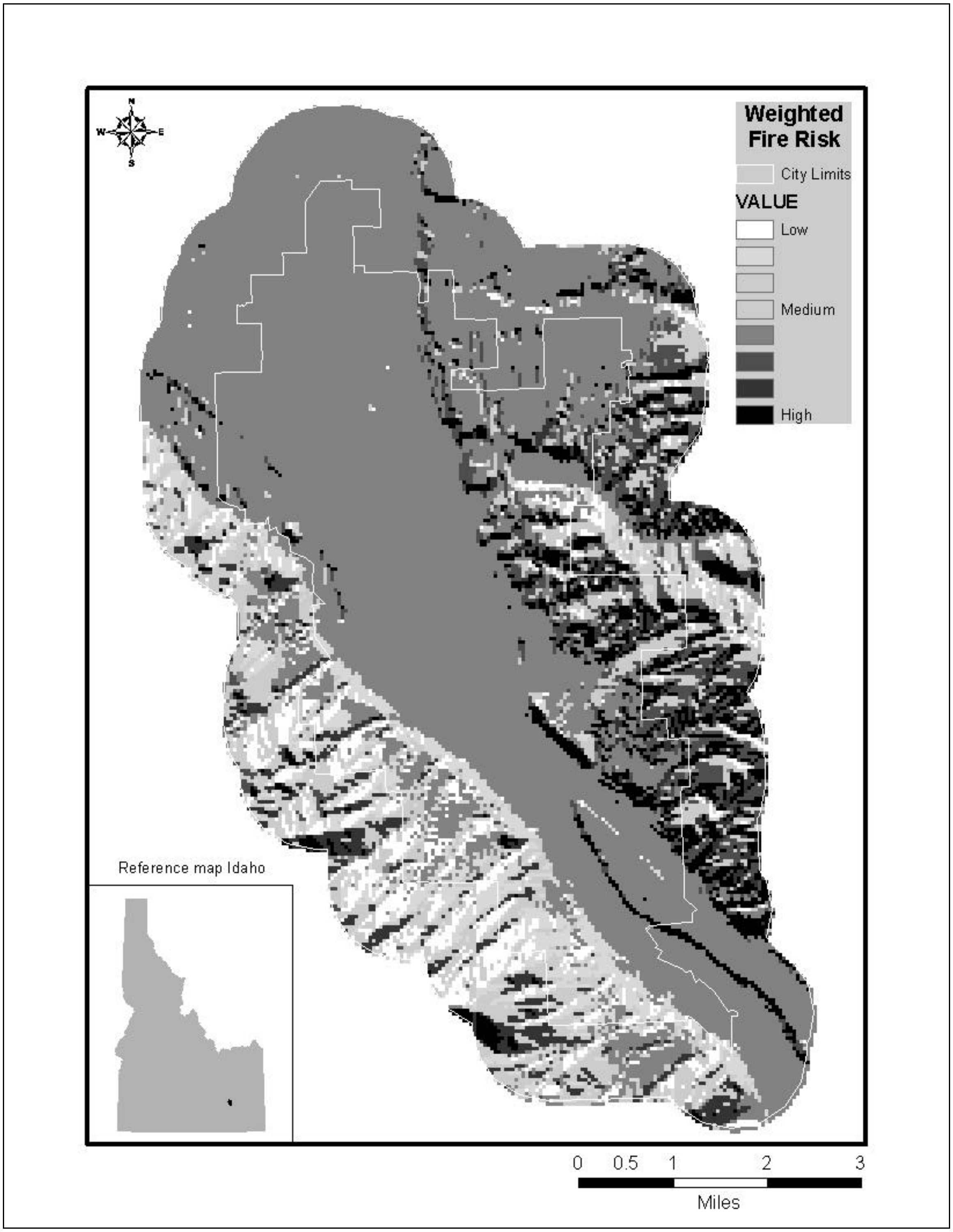

Figure 6. This map shows how sun position and daily temperature affects fire risk.

**Fuel Load**

Supervised classification of Landsat 7 Enhanced Thematic Mapper (ETM+) imagery, were used for estimating fuel load in our area. Sample points have been gathered on the Snake River Plain on 128 different sites, to estimate fuel load. On the Snake River Plain there are generally low fuel loads, so the fuel load model may have difficulties determing high fuel load areas. Thus we looked at different high fuel load areas around Pocatello and it seemed to match the fuel load classification well. One concern with the fuel load model is that it seem to have problems detecting juniper vegetation in some areas. The fuel load model will be validated in the summer of 2002 and these problems will be corrected.

The different fuel load classes that appear in our study area (measured in tons/acre) are: 0 = Water and rocks, 0.74 = Grassland, 1 = Grassland with some Sagebrush, 2 = Low Sagebrush, 4 = Typical Sagebrush, 6 = Juniper, 10 = Forest.

In the Wildland/ Urban Interface (WUI) model we used fuel load in two different ways. 1) how the fire spread rate is affected by the fuel load in our study area. 2) how the fire intensity depends on the fuel load.

**Fuel Load: Spread Rate**

We have considered the low fuel load such as grass and shrubs to be the primary carrier of the fire, thus it has the fastest spread rate. Fuel load class 4 has a higher spread rate than fuel load classes < 4 because the vegetation is more dense and the fire burn more intense, thus it spreads faster. In fuel loads > 4, the vegetation that carries the fire reduces in density and the moisture content increases making the spread rate slower for our study area (fig. 7).

GIS Process
Software: Arc Map 8.1
Extension: Spatial analyst
Command: Spatial Analyst/ Reclassify

Then we used values from figure 7 or table 4 in appendix A and reclassified the fuel load grid to create our Fuel Load/ Spread Rate grid.

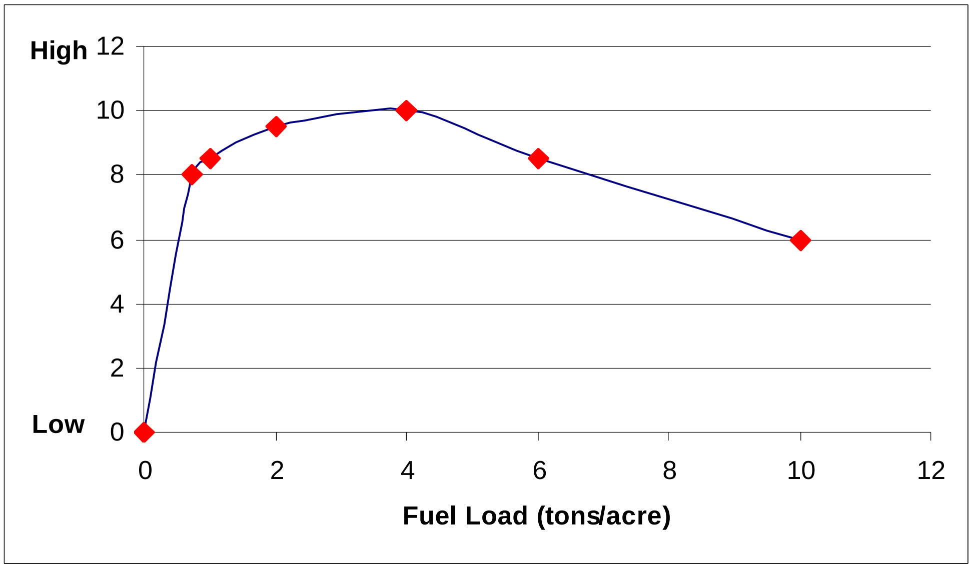


Figure 7. This chart shows how the fuel load affects the fire spread rate in our study area.

We created a map (fig. 8) that shows how fuel load affects fire spread rate in our study area.

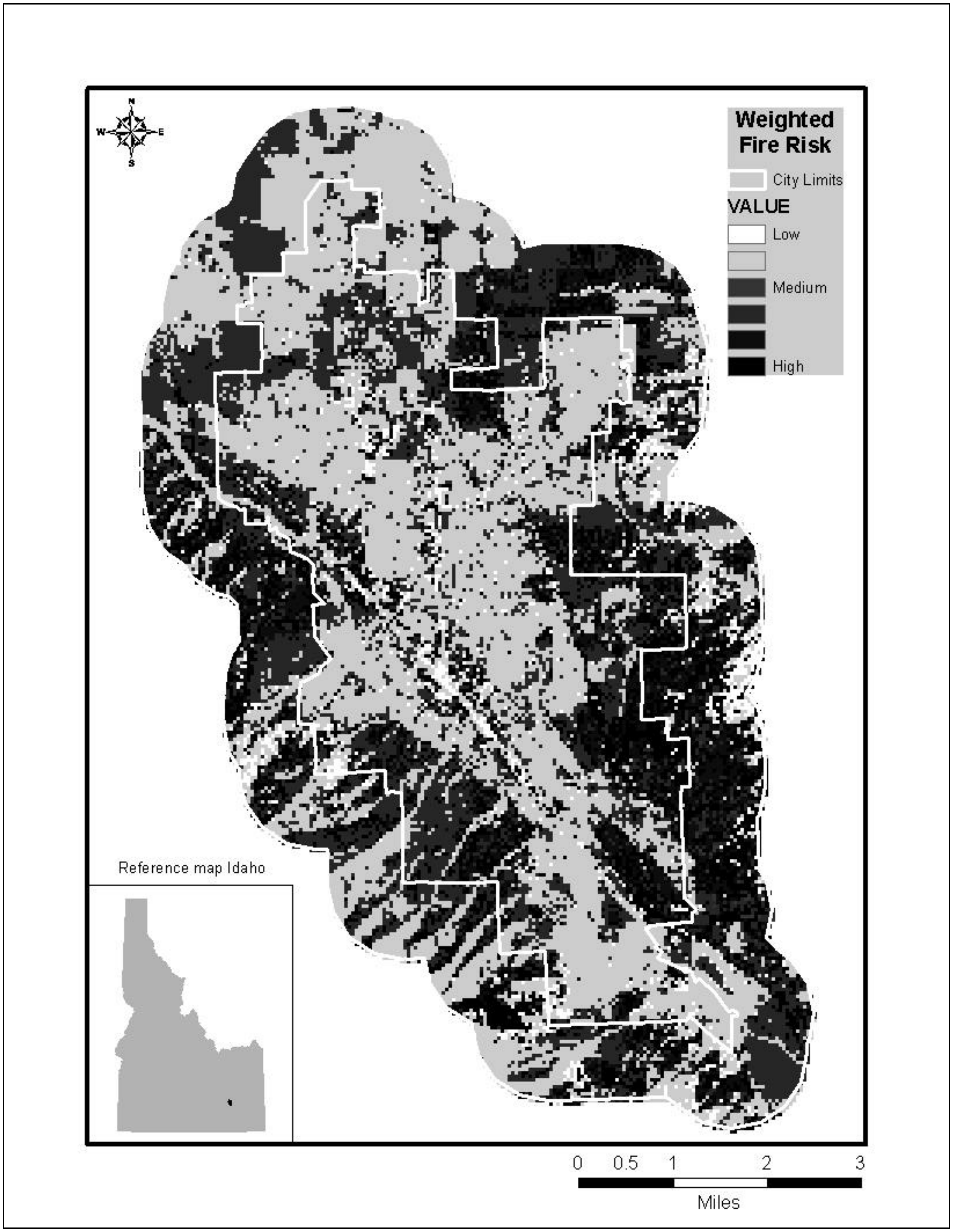

Figure 8. This map shows how fire spread rate is affected by fuel load within our study area.

**Fuel Load: Intensity**
We assume that the intensity of a fire is linear, depending on the fuel load. In this case we consider "intensity" as the energy that the fire produces. The more energy a fire produces the more difficult it is to suppress, thus it has a higher fire risk to the communities.

GIS Process
Software: Arc Map 8.1
Extension: Spatial analyst
    Command: Spatial Analyst/ Reclassify
Then we used values from figure 9 or table 5 in appendix A and reclassified the fuel load grid to create our Fuel Load/ Intensity grid.

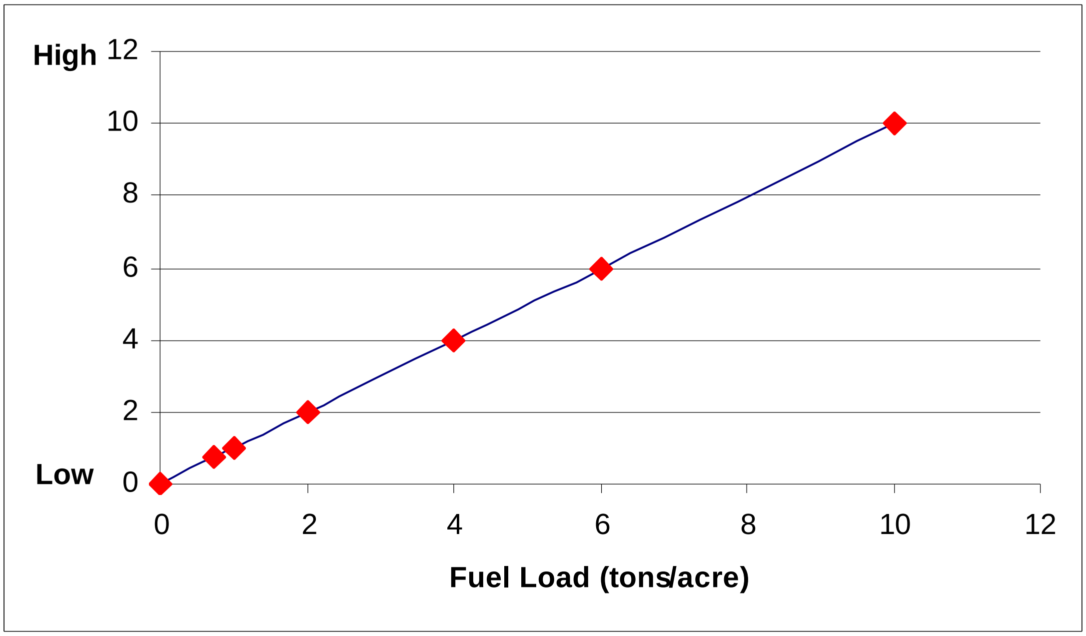


Figure 9. This chart shows how the fire intensity depend on the fuel load.

We created a map (fig. 10) that shows how the intensity of a fire is affected by the fuel load in our study area.

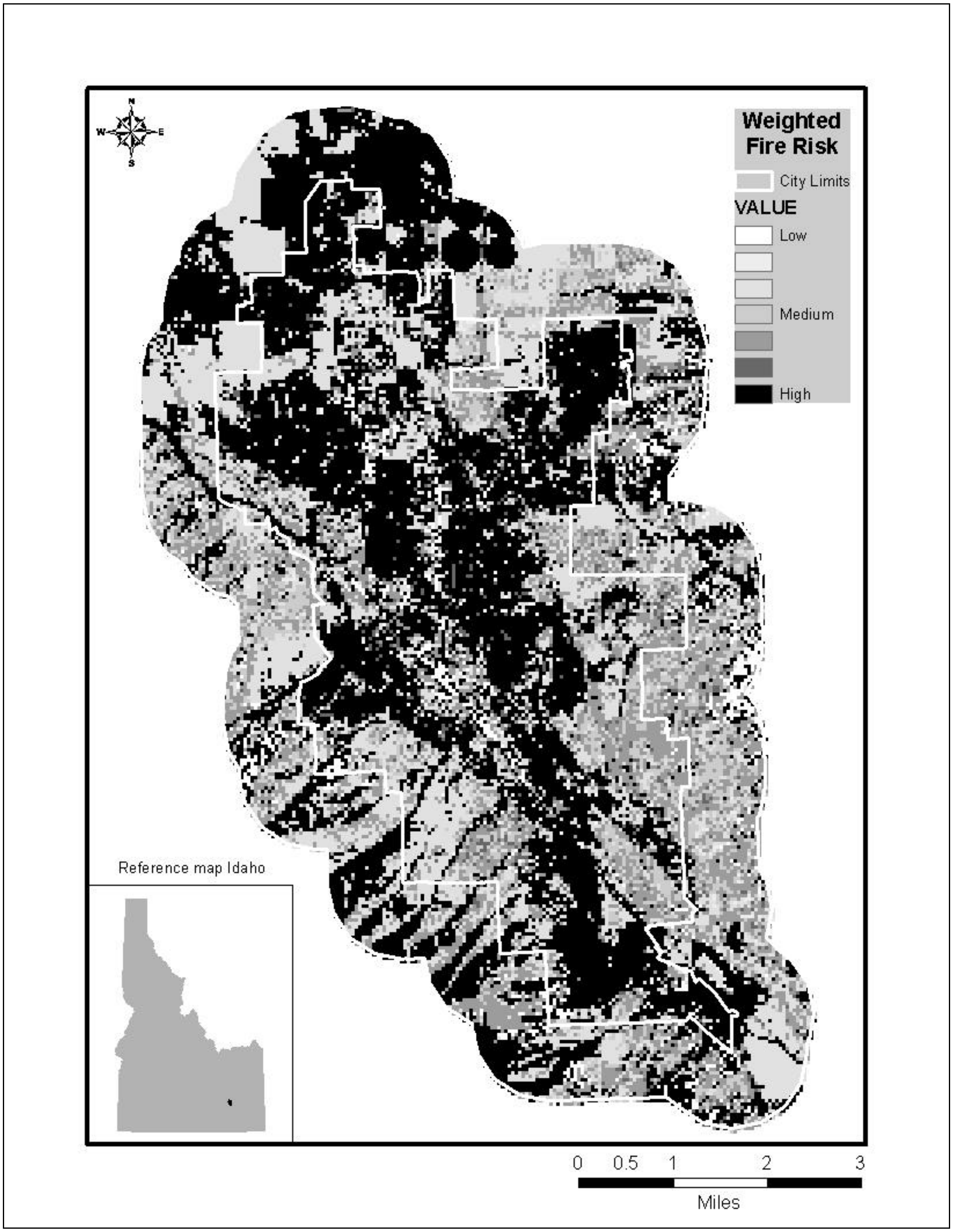

Figure 10. This is how the fire intensity is affected by the fuel load.

**Response Time**
Response time weights increase slightly exponentially to estimated travel time for fire fighters (fig. 11).

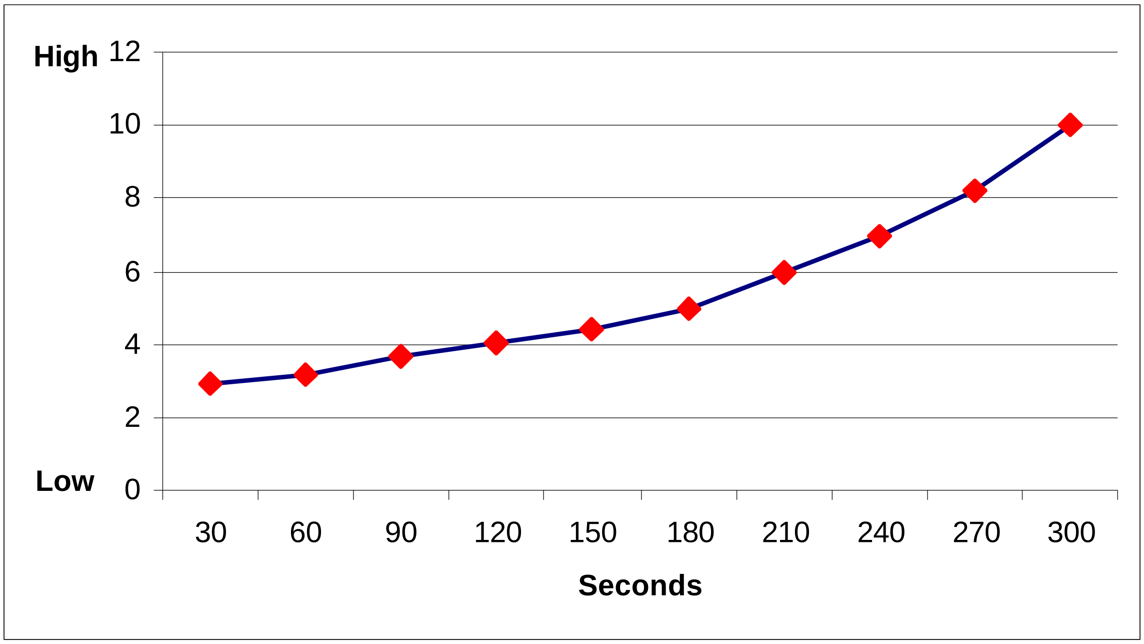


Figure 11. Weighting used to describe how fire risk due to delayed travel time for fire fighters influences the fire risk.

Response time data was verified by practical tests made by Pocatello Fire Department. We compared the times from Pocatello Fire Department with our network analyst calculated times, and they matched well except for some roads. The reason why some roads do not match well could be a result of low speed roads that are wide, allowing the fire trucks to go faster than the speed limit. Another reason why the fire trucks go faster than the calculated value could be roads with fewer intersections to cross.

Figure 12. This figure shows how the calculated response time (line), for fire station 1 in Pocatello, compares to the tested response time (points).

GIS Process
Software: Arc/View 3.2
Extension: Network Analyst

Menu: Network/ Find Service Area
Load Sites/ Fire stations, delete all except one.
Properties/ Cost Field: seconds
Choose 30 seconds interval (30, 60, 90, …, 900) in the "costs" field up to the time (ex. 900 sec) that covers your entire study area (this is important for coming condition calculations).
Repeat this process for all stations. The polygon shape files that are created are not accurate enough, but we still want to have a grid as a product, therefore we have to do as follows. Save street shape files permanent under one workspace.

Software: Arc/Info Workstation

Command: Shapearc <in_street_shape_file> <out_cover>
Repeat this for all street shape files.

Command: Linegrid <in_street_cover> <out_street_grid> {value_item/ cost}
Repeat this for all street coverages.
Command: Gridpoint <in_street_grid> <out_street_cover> {pat_item/ cost}
Repeat this for all street grids.

Software: Arc Map 8.1
Extension: Geostatistical Analyst, Spatial Analyst

Command: Geostatistical Analyst/ Geostatistical Wizard
Input Data: out_street_cover
Attribute: cost
Methods: Inverse Distance Weighting
NEXT
Neighbors to include: 8
Include at least: 8 (for the other fields, use default value)
When the inverse distance weighting is completed for all point coverages, then make the grids permanent. Reclassify the grids in to 30 seconds interval.
Command: Spatial Analyst/ Reclassify
Now we want to compare all the grids to each other to get the shortest time for a given point in the grid. In order to use the condition command all the different grids has to overlap the entire area of interest.
Command: Spatial Analyst/ Raster Calculator
Con((street1 < street2), street1, street2) name this resulting grid "street12".
Con((street12 < street3), street12, street3) and so on until you have compared all the station and got the final response time grid.
Command: Spatial Analyst/ Reclassify
Then we used values from figure 13 or table 6 in appendix A and reclassified the grid to create our Response Time grid.

The time we calculate is the time when emergency vehicles leave the station until they arrive at the emergency. The base for this assumption was information gathered from the "Fire protection handbook", (Cote 1997) (fig. 13).

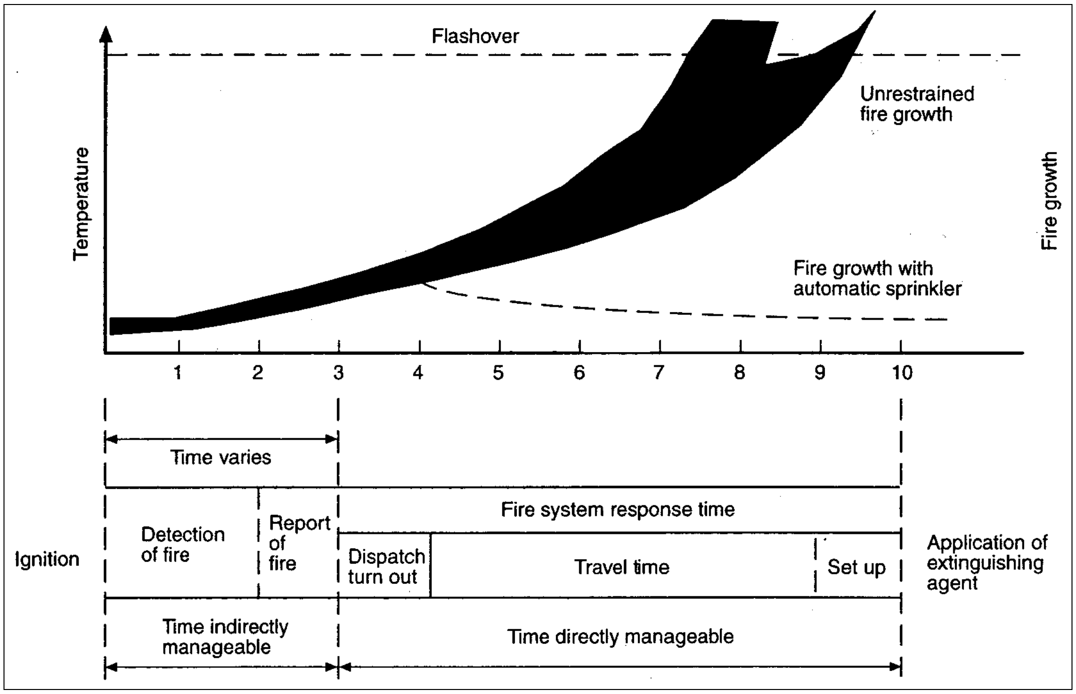

Figure 12. This chart shows how fire grows during the time when emergency vehicles travels to the fire. This chart was excerpted from the "Fire protection handbook", Cote 1997.

We created a map (fig. 14) that shows how response time affects fire risk in our study area.

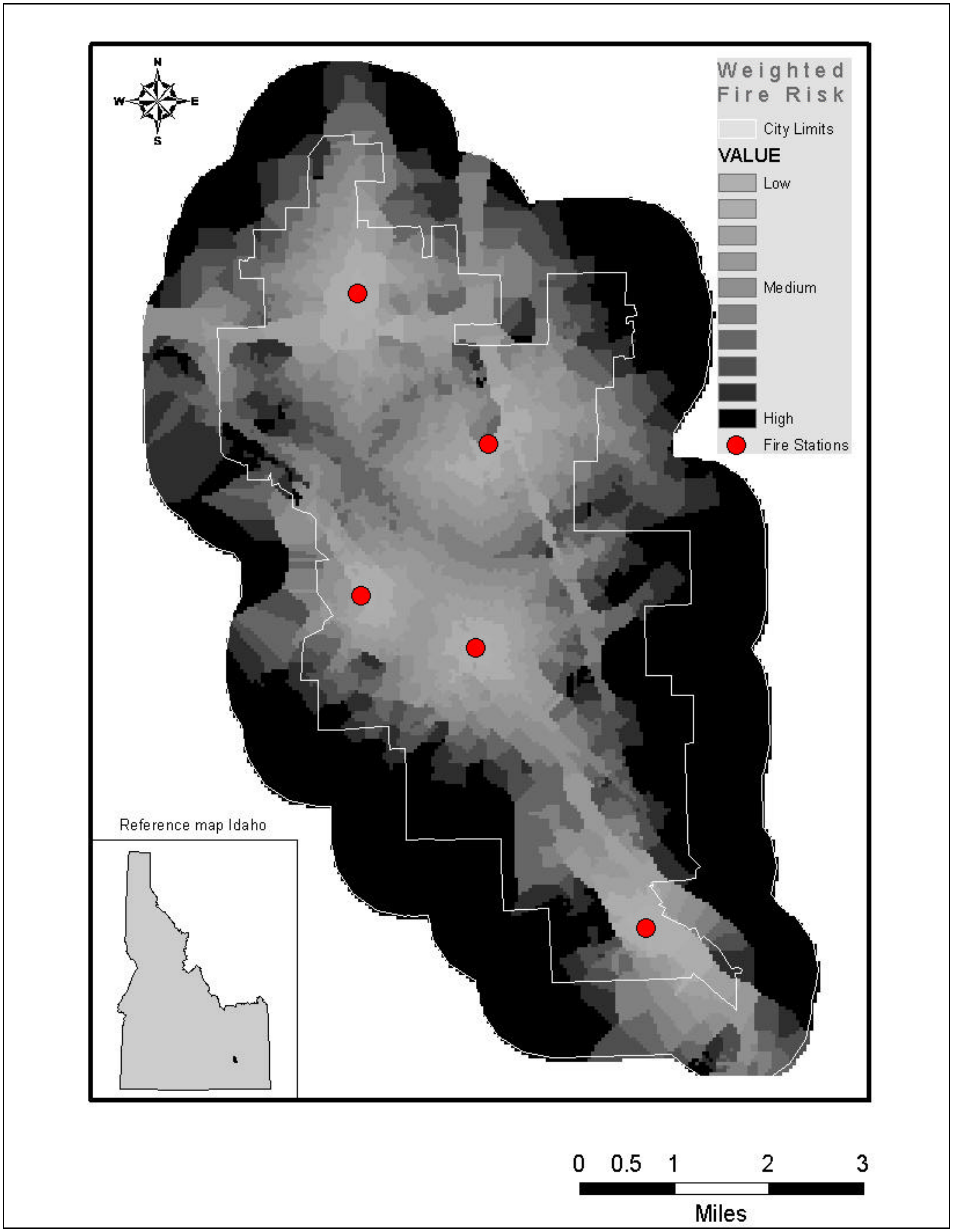

Figure 14. This map shows how response time is distributed within our study area.

Results:

After each criterion was estimated and acceptable models were developed we looked at the complete model. As seen in figure 14, slope and fuel load were split into two factors. Considering Communities At Risk (CAR) we distributed the different criteria as shown in figure 14. This model has been developed considering the conditions that exist on an extreme day with high temperatures and low humidity.

Beginning with the highest rated criterion, we distributed the criteria as follows:

Fuel Load/ Spread Rate 25% (of total fire model)

We choose this criterion to be the highest risk for communities, because of that fast spreading fires are the most dangerous fires when they get close to houses. A fast spreading fire logically gives the fire fighters a shorter time to suppress the fire before it gets to the urban areas.

Fuel Load/ Intensity 22%

When we consider intensity we mean how much energy a fire produces, and therefore how much energy (water) the fire fighters has to put in, to suppress it. Thus it has a significant risk to communities.

Slope/ Suppression Difficulties 19%

This is a “key” criterion because if the fire fighters can not get to the fire, it will burn although other criteria are rated low risk in that area. Thus we rated this criterion relatively high so that these areas are represented well in the total model. This criterion gives an indication of how efficient the fire can be suppressed depending on slope angle.

Slope/ Spread Rate 14%

Spread rate is, as we presented in Fuel Load/ Spread Rate, a high risk for communities. In this case however the spread rate is depending on slope, not fuel load. This criterion is an additional factor to the spread rate. In areas with steeper terrain the spread rate and also the fire risk for communities will be higher.

Aspect/ Sun Position and Daily Temperature 12%

At the end of the summer when most of the fires occur, all vegetation will be dried out. This criterion is rated relatively low because on a hot day with low humidity it would have low importance in which direction the slope is facing. If the fire starts it is going to burn independent of what direction the slope is facing.

Response Time 8%

The time frame that we calculate with is from when a house catches on fire until it flashes over, this is where we get the weighting from. A wildfire that spreads into urban areas is most likely to be detected a while before it reaches the houses. Thus, the time it takes for the fire fighters to get to the houses on the roads, is less relevant and the criterion gets a lower risk rate in the total model.

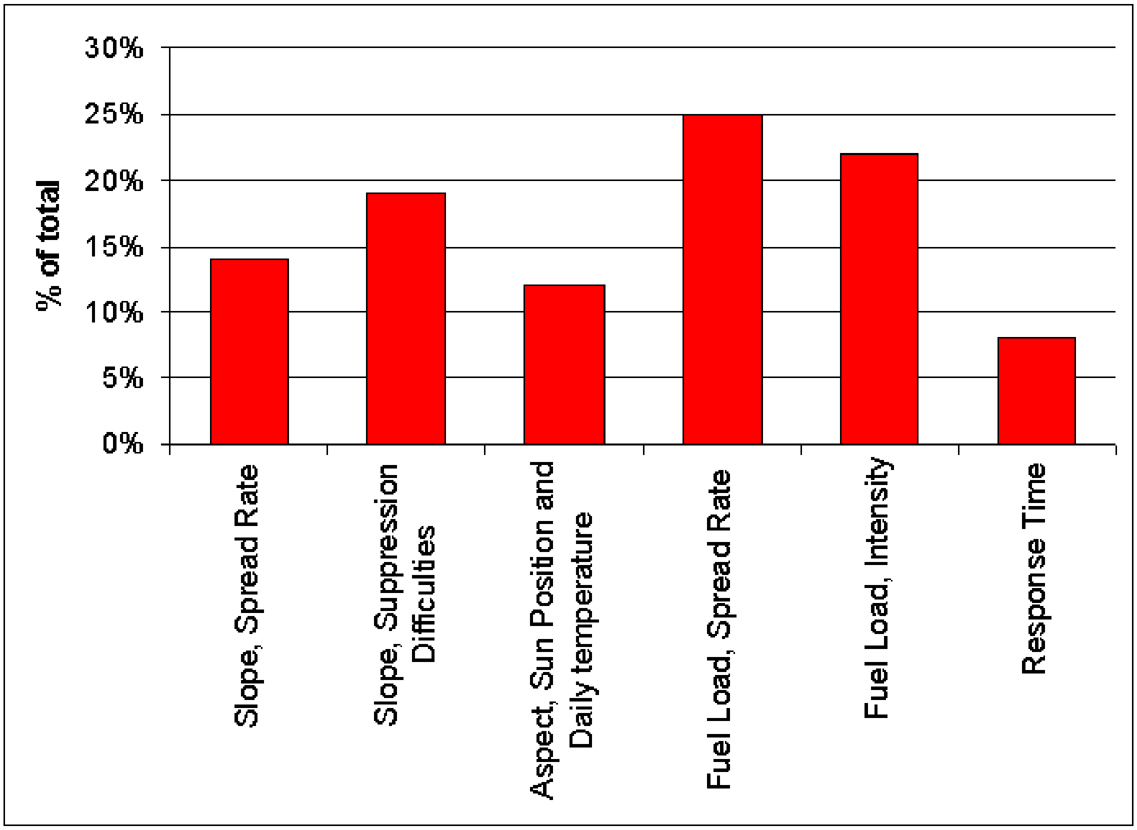


Figure 15. Distribution of weighted proportions for various criteria included in the WUI/CAR fire model. Fuel Load/ Spread Rate is assumed to be the most important criterion of the total fire model. Fuel Load/ Spread Rate is then followed by Fuel Load/ Intensity, Slope/ Suppression Difficulties, Slope/ Spread Rate, Aspect/ Sun Position and Daily Temperature, and Response Time respectively.

We created a map (fig. 16) showing the complete WUI fire risk model

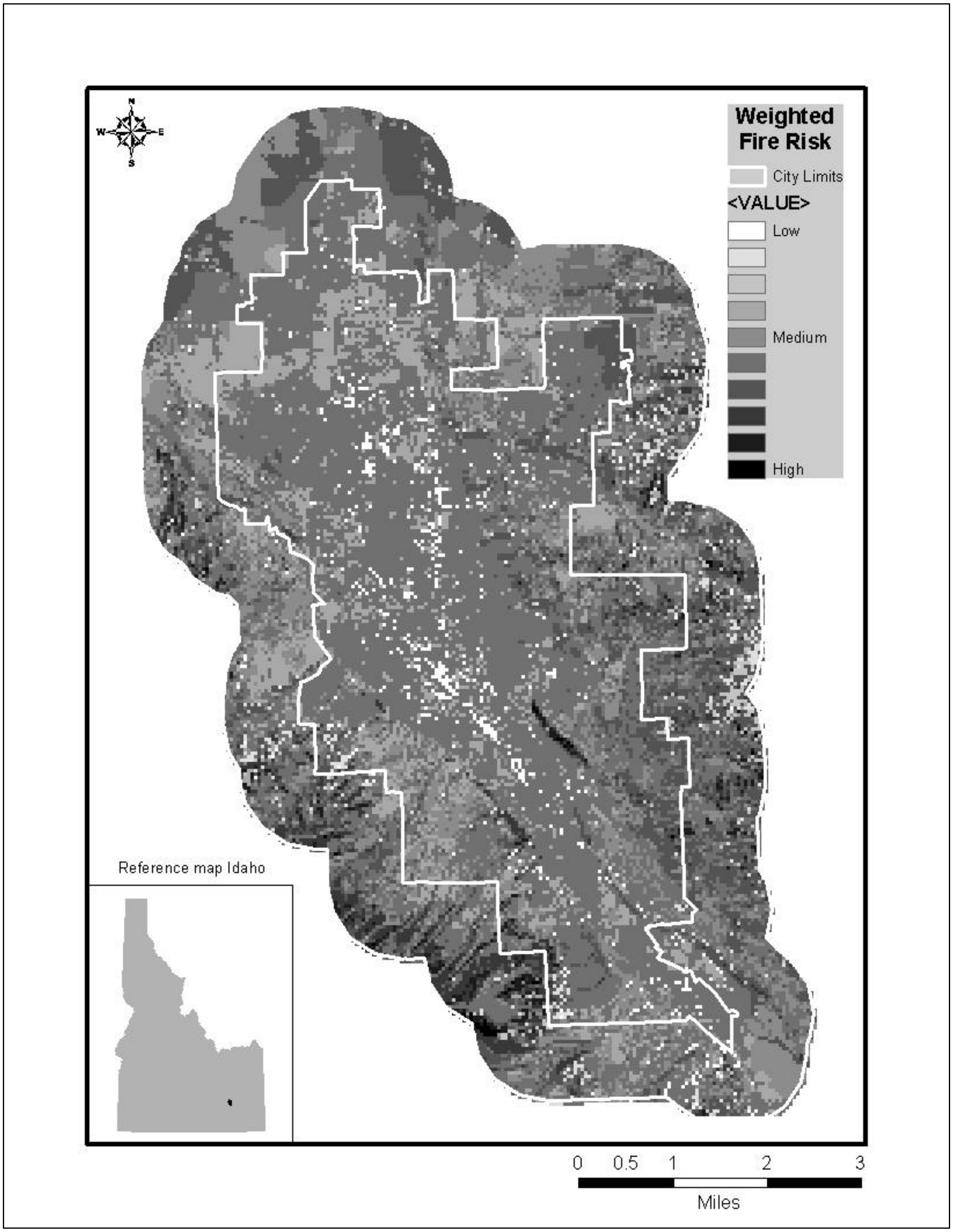


Figure 16. Resulting WUI/CAR fire model. Preliminary version (15-feb-2002)

Discussion: Since this is an estimation of criteria, we are not expecting it to be a completed product but rather a tool to assist decision makers. Since we treated each criterion separately we think that we have a result with accuracy adequate to fit our purpose. The result gives us a good overview of our model and is easy to understand. This makes our model applicable to other users, which was a primary purpose with this study. We have contacted persons with specific knowledge of each criterion. More research can still be done both on single criterion and on the total distribution of weighed proportions. It may be necessary to include other criteria such as shadowing from nearby mountains, etc, to further improve this model for the Pocatello, Idaho urban area.

Further development can be done, in the area of Aspect/ Wind:
We investigated the effect that wind would have on our model. We assumed that the highest wind speed comes from the direction of prevailing wind and decreases only slightly on adjacent sides of the mountain. Wind speed is assumed to stay high even where the aspect is not directly facing the wind. The wind effect decreases greatly on the lee side, away from the main wind direction (fig. 16).

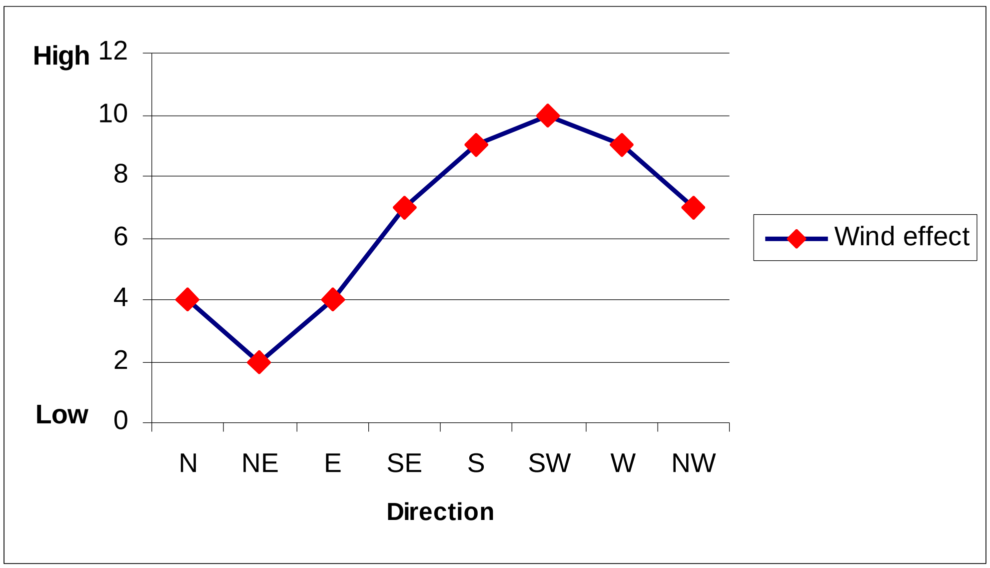


Figure 17. Weighting used to describe how wind speed changes across various aspects. The weight is high on windward and adjacent aspects (in this case south, southwest and west) and decreases quickly towards the lee side.

The high and low pressure systems are positioned so that the wind in the summer time is mostly due west. The topography forces the wind to be more southwest in our study area. Therefore we assigned southwest facing slopes the highest wind speed.
Areas with slopes < 5 degrees are considered flat areas. The flat areas are given a weight of moderate 6, because these areas are expected to be more windy than “average”.
The wind speed is assumed to affect our model in two ways: Fire spread rate, and vegetation desiccation.

According to FARSITE, Finney 1998, fire spread rate increases exponentially depending on the wind speed. This assumption will better apply to smaller fires, since larger fires tend to create their own wind systems. The fire spread rate is the primary part of the Aspect/ Wind criterion.
The wind will desiccate heavy vegetation, such as trees with deep root system more on windward slopes, but it will only dry out the surface of the plant. The heavy vegetation has its watersource from the ground, therefore the core of the plant may not be affected by wind speed. The light vegetation, such as grass will be more affected by the wind, because the wind also desiccate the surface soil layer where the grass takes its water. We assume this to be a minor part of the Aspect/Wind criterion, since the core of heavy vegetation will stay unaffected by the wind speed.
The wind criterion can not be used in our area of interest because of the characteristics of the topography. The valley that Pocatello lies within is a north to south valley therefore the southwest wind will make rotors and turbulent air in our valley, and it would be hard to predict an average main wind direction. This criterion however can be used in other areas, where the wind direction can be predicted.

Assessment of Errors and Bias: The estimations are made based upon our knowledge of the criteria. We have also discussed our criteria with Keith T. Weber and Glenn Russell, mostly regarding the fuel load, aspect, and slope.
Response time models were produced with cooperation of Ben Estes, Chief Pocatello Fire Department. The fuel load model has difficulties in detecting junipers in some areas, but in the summer of 2002 it will be validated and the errors corrected.

Reference cited:
Finney, M.A. 1998. FARSITE: Fire Area Simulator-Model Development and Evaluation, USDA, Research Paper RMRS-RP-4.
Cote, A.E. 1997. Fire Protection Handbook.

Acknowledgements:
On February 7, 2002 we had a meeting with different peoples with knowledge about suppression methods, topography and vegetation characteristics, and suppression access in our study area. Our assumptions in the different criteria are supported by the discussion with these people. The following people where attending at the meeting:
Ben Estes, Chief Pocatello Fire Department
Kevin Quick, Pocatello Fire Department
Rick Belger, Fire Management Officer, Upper Snake River District (USRD) - Eastern Idaho Area BLM
Bob Mallett, Assistant Fire Management Officer, USRD - Eastern Idaho Area BLM
Fred Judd, Fire Mitigation/Education Specialist, USRD - Eastern Idaho Area BLM
Nancy Fetterman, Cartographic Technician, USRD - Eastern Idaho Area BLM
Felicia Burkhardt, GIS Coordinator, USRD BLM
Keith Weber, GIS Director, Idaho State University (ISU), GIS Training and Research Center (GISTreC)
Glenn Russell, GIS/Remote Sensing Technician, ISU, GISTreC
Daniel Mattsson, GIS Intern, ISU, GISTreC
Fredrik Thorén, GIS Intern, ISU, GISTreC

## Appendix A

This is the weighting data for each criterion.

| Angle/degree interval | Weight |
|---|---|
| 0--10 | 0.41 |
| 10--20 | 1.37 |
| 20--30 | 2.56 |
| 30--40 | 4.89 |
| 40--50 | 10 |

Table 1. Weighting data of Slope/ Spread rate.
Compare with figure 1 in report.

| Angle/degree interval | Weight |
|---|---|
| 0--10 | 1 |
| 10--20 | 2 |
| 20--30 | 8.5 |
| 30--40 | 10 |
| 40--50 | 10 |

Table 2. Weighting data of Slope/ Suppression Difficulties.
Compare with figure 3 in report.

| Degree interval | Aspect | Weight |
|---|---|---|
| 0 - 22.5 | N | 1 |
| 22.5 - 67.5 | NE | 1.5 |
| 67.5 - 112.5 | E | 3 |
| 112.5 - 157.5 | SE | 8 |
| 157.5 - 202.5 | S | 10 |
| 202.5 - 247.5 | SW | 10 |
| 247.5 - 292.5 | W | 7 |
| 292.5 - 337.5 | NW | 2 |
| 337.5 - 360 | N | 1 |
| | | |
| | Flat | 5 |

Table 3. Weighting data of Aspect/ Sun position and Daily temperature.
Compare with figure 5 in report.

| Classes (tons/acre) | Weight |
|---|---|
| Low < 0.74 | 0 |
| 0.74 | 8 |
| 1 | 8.5 |
| 2 | 9.5 |
| 4 | 10 |
| 6 | 8.5 |
| High > 6 | 6 |

Table 4. Weighting data of Fuel Load/ Spread Rate. Compare with figure 7 in report.

| Classes (tons/acre) | Weight |
|---|---|
| Low < 0.74 | 0 |
| 0.74 | 0.74 |
| 1 | 1 |
| 2 | 2 |
| 4 | 4 |
| 6 | 6 |
| High > 6 | 10 |

Table 5. Weighting data of Fuel Load/ Intensity
Compare with figure 9 in report.

| Time (seconds) | Weight |
|---|---|
| 30 | 2.92 |
| 60 | 3.19 |
| 90 | 3.67 |
| 120 | 4.03 |
| 150 | 4.44 |
| 180 | 5.00 |
| 210 | 5.97 |
| 240 | 6.94 |
| 270 | 8.19 |
| 300 | 10.00 |

Table 6. Weighting data of Response time. Compare with figure 11 in report.

# Appendix B

| Catalog structure | | | | | | Format | Translation |
|---|---|---|---|---|---|---|---|
| \\Alpine\Data\urbint | | | | | | | |
| | covers | | | | | | |
| | | grid | | | | | |
| | | | dem | | | | |
| | | | | dem_ai | | Raster Dataset | Digital Elevation Model_ Area of Interest |
| | | | doqq | | | | |
| | | | | doqq_ai | | Raster Dataset | Digital Orthophoto of Quarter Quadrant_ Area of Interest |
| | | | | new_05s34e33 | | Raster Dataset | Township 05 South, Range 34, Section 33. |
| | | | | sid | | | |
| | | | | | new_05s34e33 | Raster Dataset | Township 05 South, Range 34, Section 33. |
| | | | criteria | | | | |
| | | | | aspect | | | |
| | | | | | aspect_s | Raster Dataset | Aspect Sun and Daily Temperature |
| | | | | | aspect_w | Raster Dataset | Aspect Wind |
| | | | | | aspect_ai | Raster Dataset | Aspect area of interest |
| | | | | fuelload | | | |
| | | | | | fuelload_ai | Raster Dataset | Fuel loads area of interest |
| | | | | | fl_intens | Raster Dataset | Fuel loads weighted with fire intensity |
| | | | | | fl_spread | Raster Dataset | Fuel loads weighted with fire spread rate |
| | | | | moisture | | | |
| | | | | | moist_ai | Raster Dataset | Moisture area of interest |
| | | | | resptime | | | |
| | | | | | respt_ai | Raster Dataset | Response time area of interest |
| | | | | slope | | | |
| | | | | | slope_sd | Raster Dataset | Slope Suppression Difficulties |
| | | | | | slope_sr | Raster Dataset | Slope Spread Rate |
| | | | | | slope_ai | Raster Dataset | Slope area of interest |
| | | vector | | | | | |
| | | | fires | | | | |
| | | | | blm_fire39-97new | | Shapefile | Bureau of Land Management, fires 1939-1997 new |
| | | | plss_idtm_ai | | | Coverage | Public Land Survey Systems, area of interest |
| | | | pokyroad | | | Coverage | Roads area of interest |
| | | | streams_ai | | | Shapefile | Streams area of interest |
| | | point | | | | | |
| | | | f_stat.shp | | | Shapefile | This is the firedepartments of Pocatello, used for network analyst |
| | report | | | | | | This is the final report |