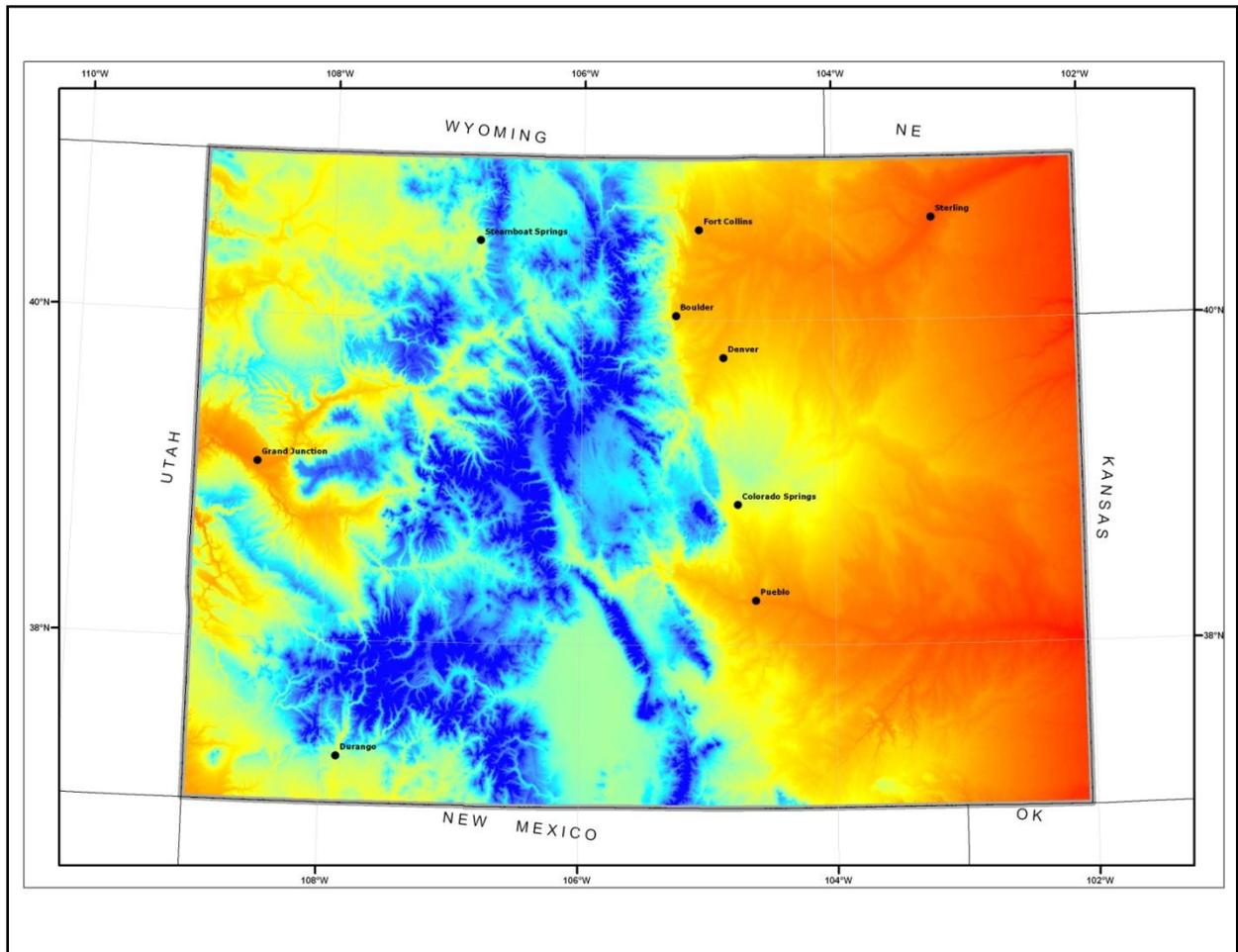


Using the Revised Universal Soils Loss Equation as a Metric for Ranking Watersheds via a Geographic Information System for the State of Colorado



By: Michael Tuffly
ERIA Consultants, LLC
2/9/2009



Introduction

The Soil Conservation Service (now the Natural Resource Conservation Service (NRCS)) created the Revised Universal Soil Loss Equation (RUSLE) (Wischmeier, 1978) a widely used metric for quantifying soil erosion. The RUSLE is discussed by Renard (1997).

In summary there are four general components that determine soil erosion: 1) Climate, 2) Soils type, 3) Slope, and 4) Land Use. This paper discusses techniques, data sets, and spatial modeling processes to produce a soil erosion model via the RUSLE that result in relative ranking values of soil erosion potential by watershed. For the purpose of this test we will use the State of Colorado.

It is further known that biotic and abiotic factors influence watershed quality. Biotic factors such as insect and disease infestation reduce forest canopy and can alter the biogeochemical composition of streams and influence hydrological cycles (Rhoades et al. 2005). Abiotic factors such as fires reduce forest canopy alter soils chemistry (Vogl 1973). This paper attempts to assign a relative ranking category to watersheds over a large landscape using general guide lines outlined by Wischmeier (1978).

Methods

The RUSLE uses the formula: $A = R * K * L * S * C * P$ (Wischmeier, 1978) to calculate soil erosion.

Where:

- **A** is the computed soil loss per unit area.
- **R** is the rainfall and runoff factor.
- **K** is the soil erodibility factor, the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6-ft length of uniform 9-percent slope continuously in clean tilled fallow;
- **L** is the slope-length factor, the ratio of soil loss from the field slope length to that from a 72.6-ft length under identical conditions;
- **S** is the slope-steepness factor, the ratio of soil loss from the field slope gradient to that from a 9-percent slope under otherwise identical conditions;
- **C** is the cover and management factor, the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow;
- **P** is the support practice factor, the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope.

Using a Geographic Information System (GIS) we can derive similar factors from spatial data and implement a spatial explicit state wide watershed analysis. The following are detailed descriptions of the input data sets used in this modeling effort.

R is derived from the 30-year average precipitation from the PRISM data set.

(<http://www.prism.oregonstate.edu/index.phtml>) (Figure 1). Or from two-year six-hour rain fall

intensity data from the National Oceanic and Atmospheric Administration (NOAA) Atlas 2, Volume 11 <http://www.nws.noaa.gov/oh/hdsc/Precipitation> (Figure 2). We tested both data sets and decided to let the reader decide.

The PRISIM 30-year average precipitation is in inches per year, are of type integer with a 4 kilometer cell size. These data are sub-sampled to 30 meter cell size using a nearest neighbor resampling process. The assumption was that higher amounts of precipitation will lead to a higher probability for soil erosion. Since the RUSLE is multiplicative no modification in the amount of precipitation was needed. The values ranged from 7 to 62 inches per year (Figure 1).

The rain intensity two-year six-hour rain fall intensity data are integer and range from 65,000 to 217,500. Native data were 4 kilometer GRID cells sub-sampled to 30 meters using a nearest neighbor resampling process.

Figure 1. The "R" factor for the State of Colorado derived from the 30-year average precipitation (Source:PRISM)

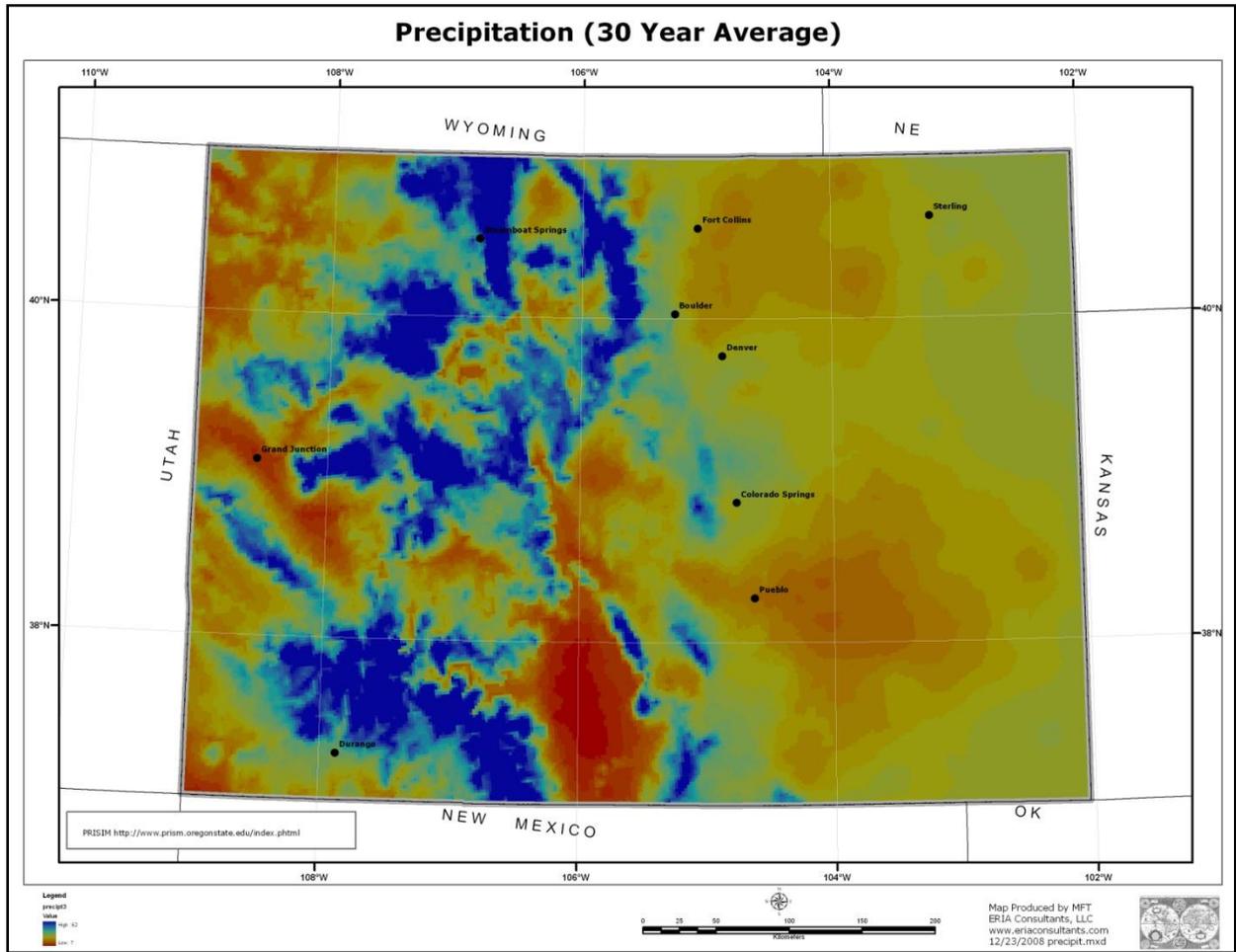
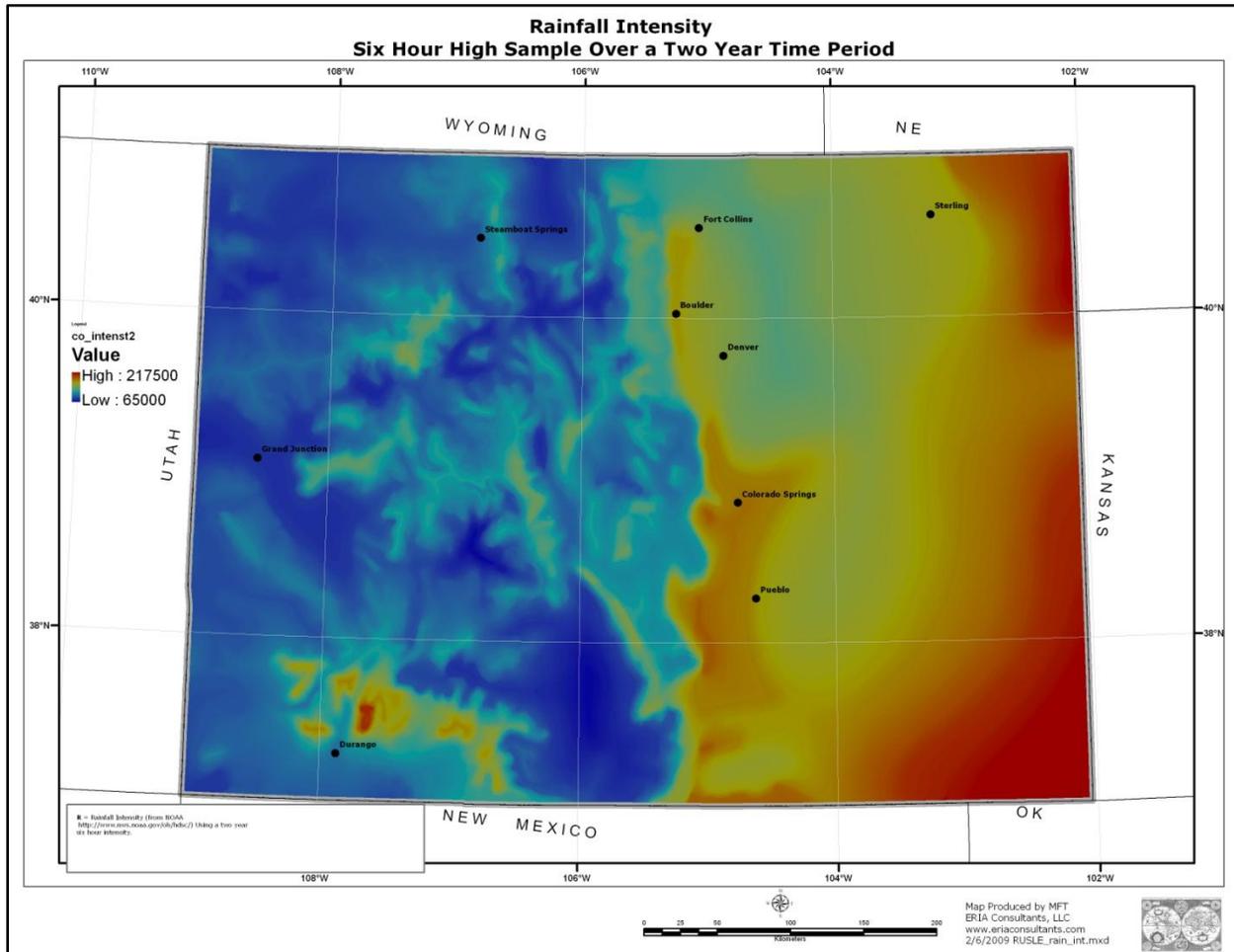
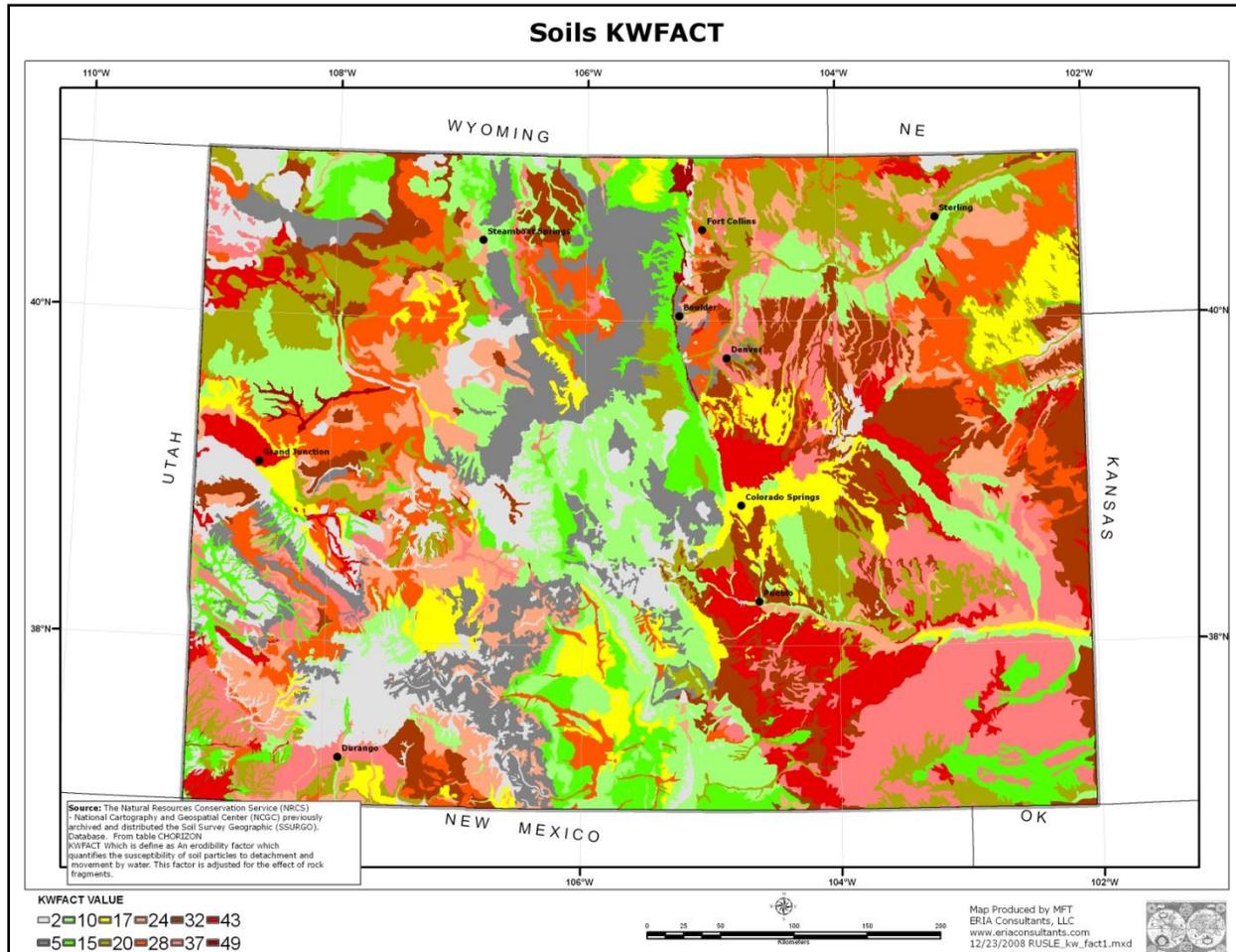


Figure 2 The "R" factor for the State of Colorado derived from the two-year six hour rain intensity average (Source:NOAA)



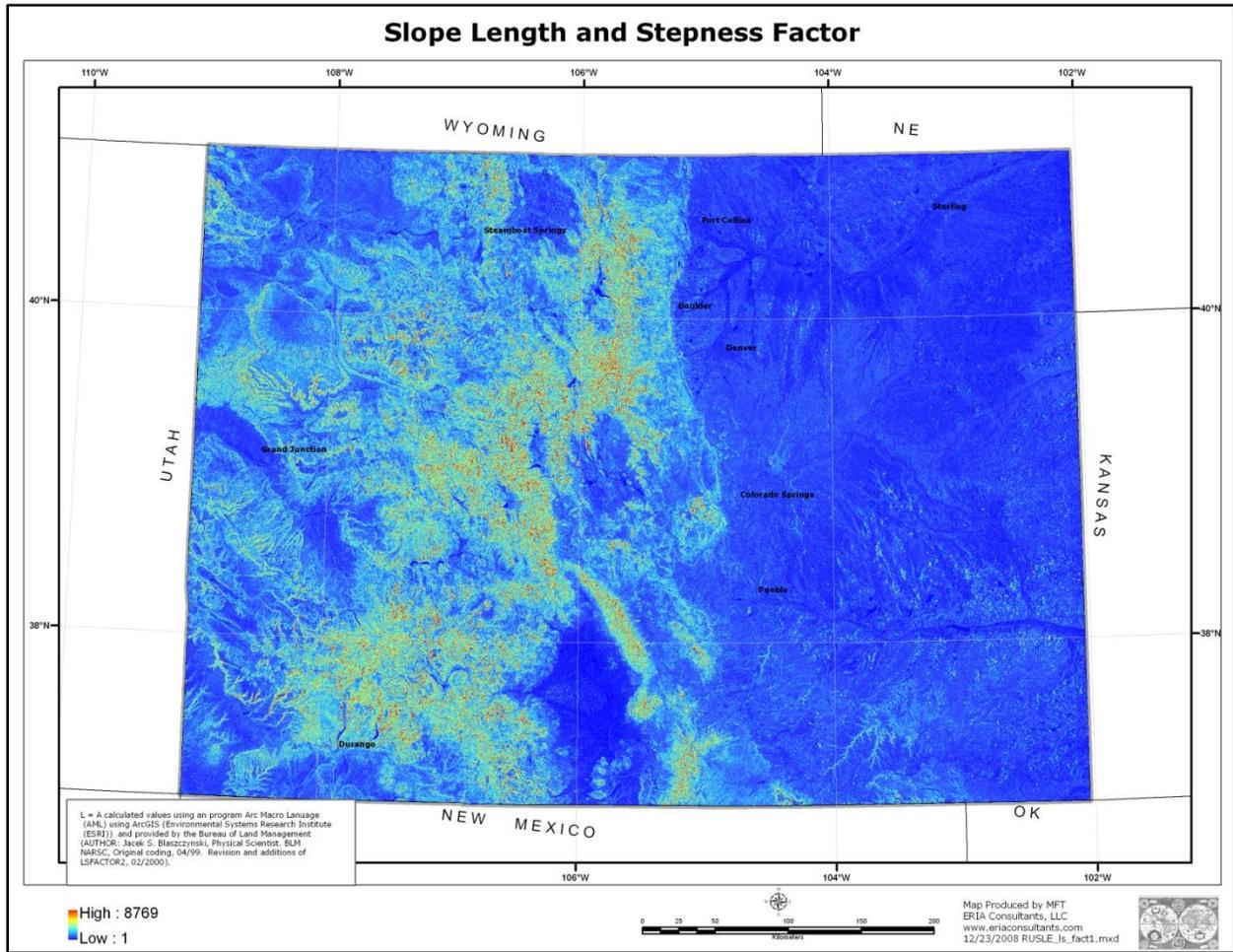
K was derived from the KWFACT field contained in the Soils Survey Geographic Database (SSURGO) from the United States Department of Agriculture (USDA Natural Resource Conservation Service (NRCS)) (<http://soils.usda.gov/survey/geography/ssurgo/description.html>). The KWFACT values ranged from 0.02 to 0.49 (for the State of Colorado). These data were multiplied by 100 and converted to integer. Data were in polygon format, and were converted to a GRID at 30 meters cell size. The assumption was that the higher KWFACT value the higher degree of soil erosion may occur. The values ranged from 2 to 49 (Figure 3).

Figure 3. The “K” Factor for the State of Colorado (Source: USDA NRCS).



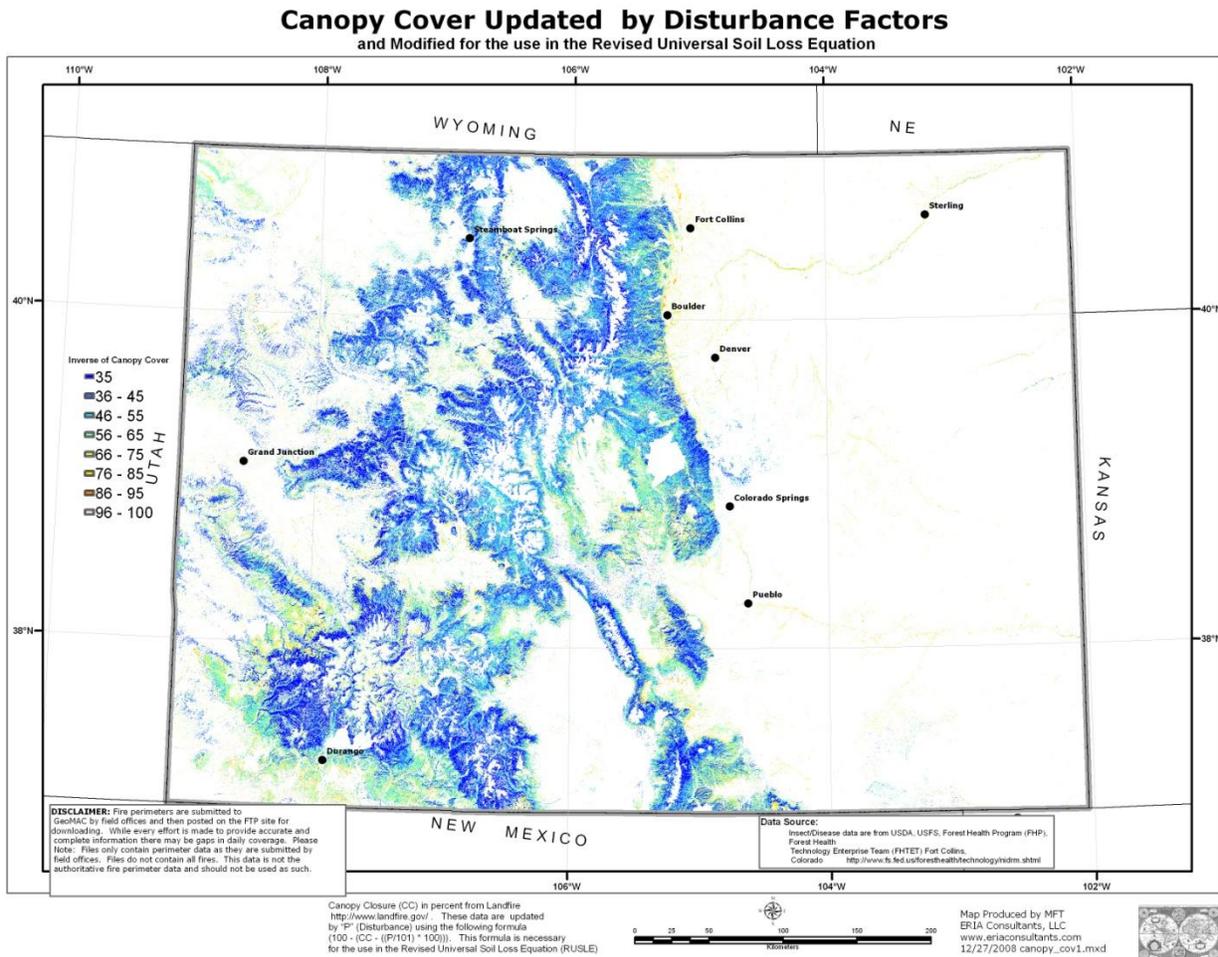
LS, the combination of the “L” and “S” factors was calculated using a program written in the Arc Macro Language (AML) (Appendix 1) for use in Arc/Info © (Environmental Systems Research Institute (ESRI)) (<http://www.blm.gov/nstc/ecosysmod/rusle.html>). This AML, that was provided by the Bureau of Land Management (BLM), calculates the RUSLE terrain (**LS**) factors from a Digital Elevation Model (30 meter cell size) using two methods: one developed by the DOS RUSLE program, and the other using methods suggested by Mitasova (1993) and based on work of Moore (1992). For this analysis we used the technique by Moore (1992). Resulting values were multiplied by 100 and converted to integers. The results from the AML produces areas of NODATA. The RUSLE will error with areas of NODATA. Therefore, a value of 2 was added to the entire GRID and NODATA values were converted to 1. The assumption was that the higher the LS value the higher probability of soil erosion. Values of LS ranged from 1 to 8769 (Figure 4).

Figure 4. The “LS” factor for the State of Colorado.



C was derived from Canopy Closure (CC) in percent from Landfire (<http://www.landfire.gov/>) and from “P” (Percent disturbance) using the following equation: $C = 100 - (CC - (P/101) * CC)$. The “C” value was modified by “P” because CC was independent of disturbance. Data were in 30 meter cell size. The assumption was that areas that have high canopy closure will have lower watershed impacts. Values ranged from 35 to 100 (Figure 5).

Figure 5. The “C” factor, derived from canopy closure and disturbance (“P”).

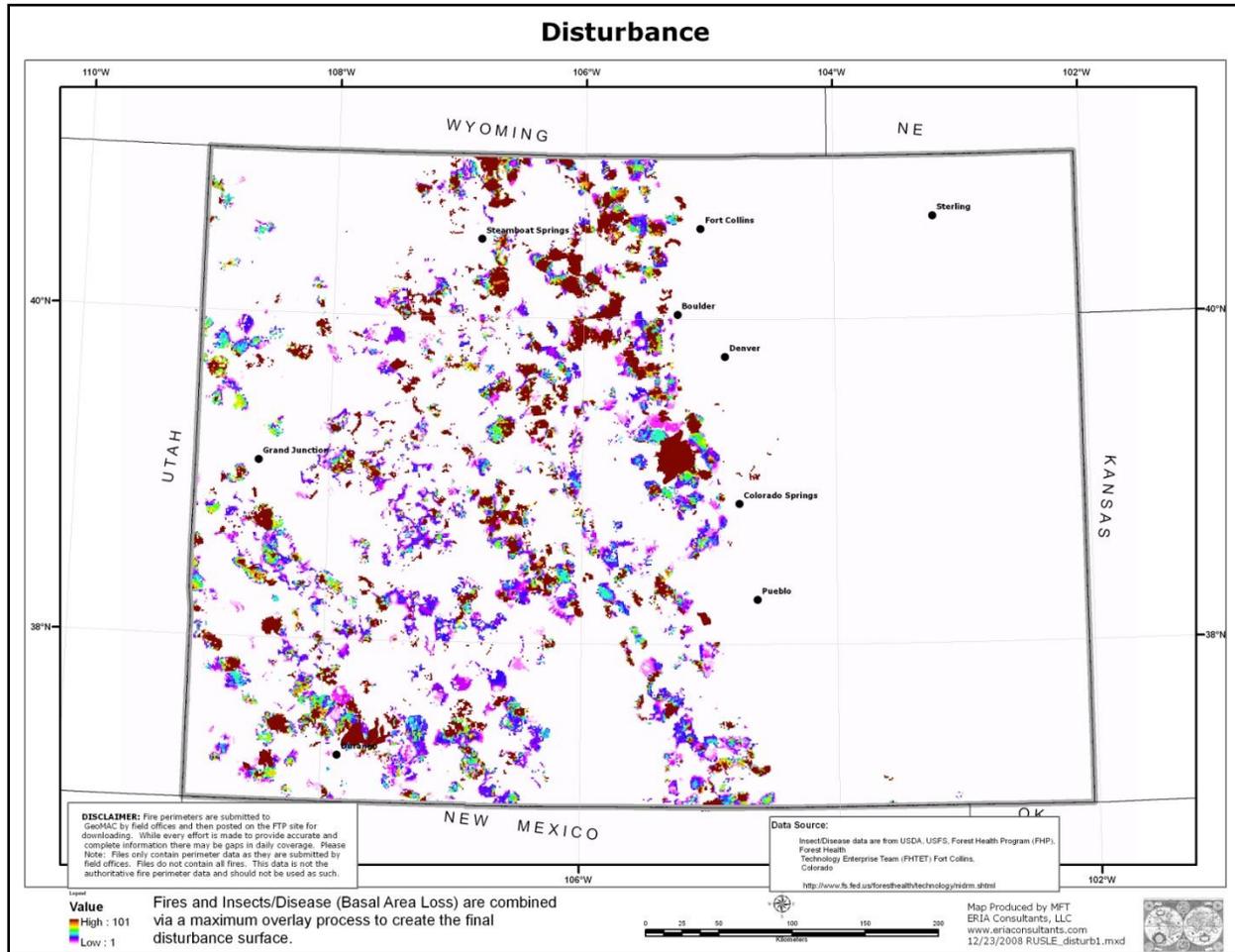


P was percent disturbance derived from two data sources. First, the USFS Forest Health Technology Enterprise Team (FHTET) Risk Maps (<http://www.fs.fed.us/foresthealth/technology/nidrm.shtml>) for Insects /Disease. Second, was fires from Geomac <http://www.geomac.gov/>. The FHTET Risk map depicts percent basal area loss (PBAL) as integer values with 1 kilometer cell size and contained data values that ranged from 0 – 100. For this exercise the data from the FHTET risk maps was partitioned into two groups. One group were data values from 1 – 100. The other group was data values 0 and NODATA. Data values from 1 – 100 were increased by a constant of 1, creating values from 2 – 101. The 0 values and NODATA values were converted to a constant of 1. These two data groups from FHTET were reassembled into one insect/disease PBAL data set with values that ranged from 1 – 101. These data are resampled to 30 meter cell size using nearest neighbor resampling. It was decided that **P** would only be used as a modifier of **C** and not as an independent data set plugged into the RUSLE.

The fire data originally created in polygon format, were converted to a GRID at 30 meter cell size. Fire data were binary in nature; hence contained two values 101 = fire and 1 = no fire. Both fire and insects/disease were combined in a maximum overlay process. The assumption was that areas that

have disturbance (e.g. Fire or Insect/Disease infestation) may be predisposed to higher rates of soil erosion and biogeochemical change when compare to areas that have little or no disturbance (Figure 6).

Figure 6. The “P” factor depicting disturbance (Source: USDA Forest Service FHTET and the USGS GEOMAC)



When all of the spatial data sets were multiplied together ($A = R * K * LS * CP$) a unit-less continuous surface at 30 meter cell size was created. However, the continuous surface depicting “A” needed to be converted into a manageable number of categories or classes to avoid exceeding the limitations of ArcGIS © software. The approach was to take the natural log (ln) of the “A” value and convert the data into integer (i.e. rounded) values to produce a manageable number of unique categories (ln(RUSLE)). Next, using the combine function (ArcGIS © software) with the United States Geological Survey (USGS) Hydrological Units Code (HUC) HUC12 (commonly referred to as the 6th level watershed) and the ln(RUSLE) as input data gave us the number of GRID cells by watershed coupled with the associated “A” values. Finally, the watershed erosion potential was computed as the natural log of the weighted sum of the “A” values for each watershed using the following function: $\ln \sum (\text{number of cells} * e^{(\ln(\text{RUSLE}))})$. Values converted to integers ranged from 31 to 262 and 12 – 135 figure 7 and figure 8, respectively.

Figure 7. The watershed impact potential for 6th level watersheds in the State of Colorado using 30 year average precipitation.

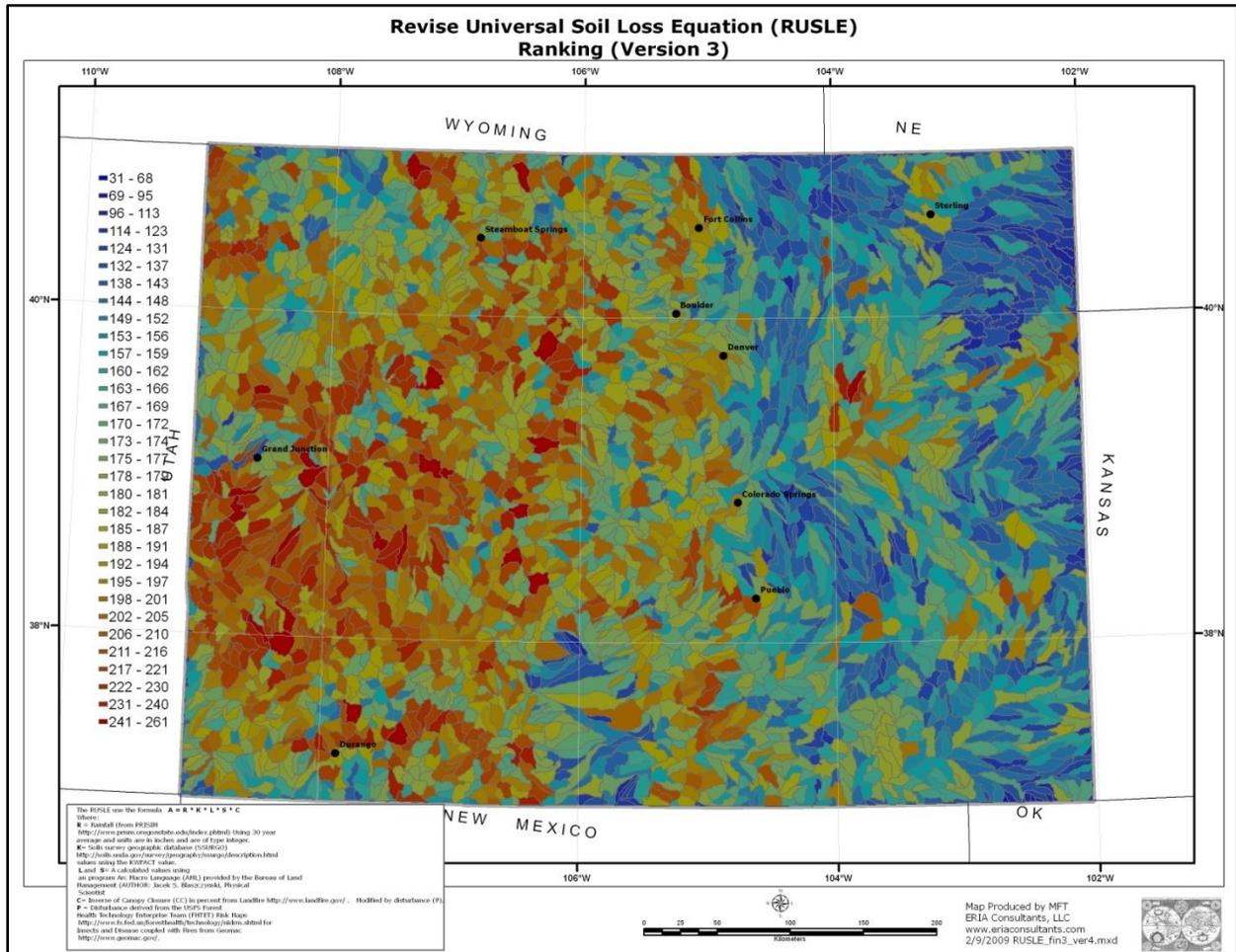
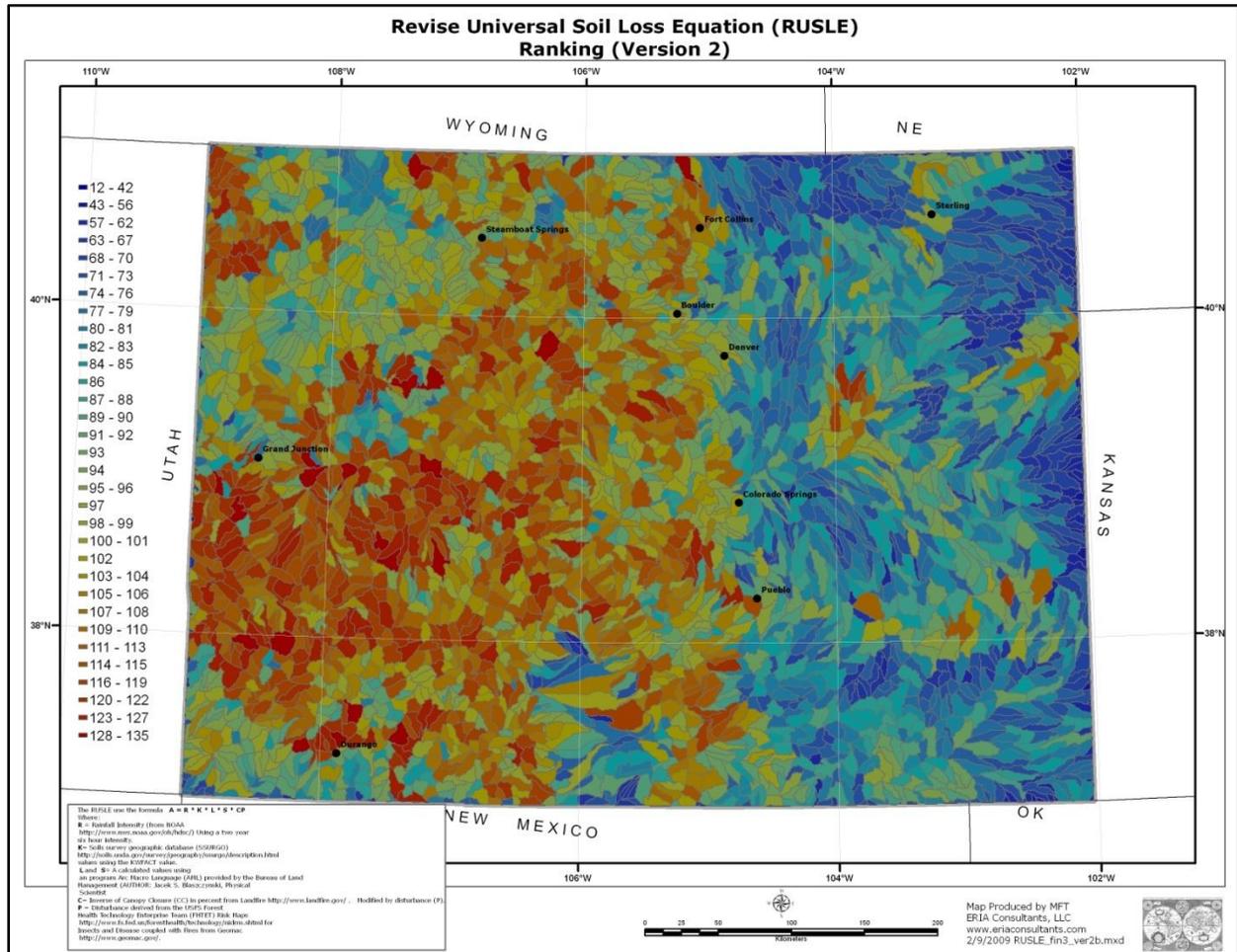
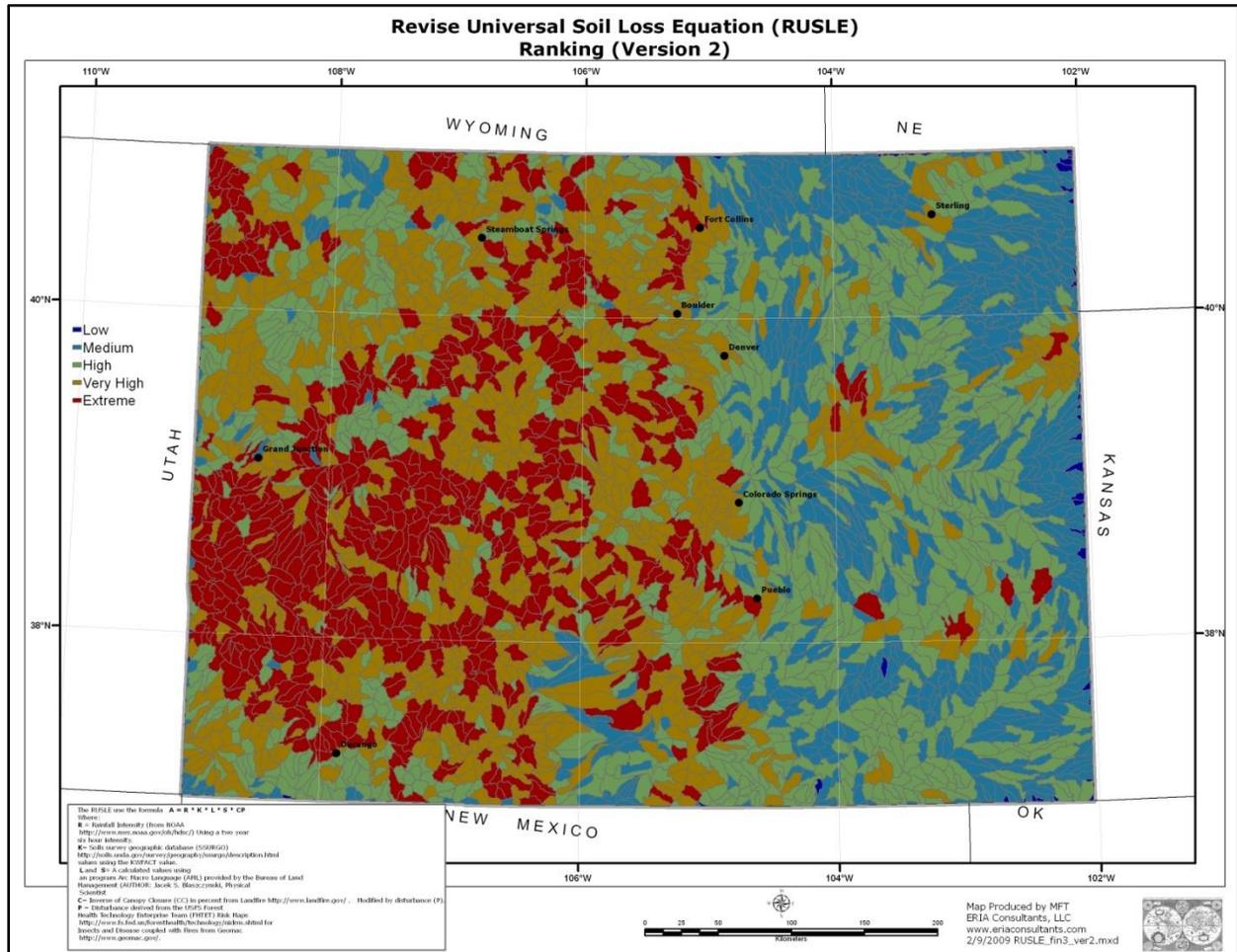


Figure 8 . The watershed impact potential for 6th level watersheds in the State of Colorado using the six-hour two year rain fall intensity.



The final step was to group or reclass the watershed impact potential into 5 classes (low, medium, high, very high, and extreme) (Figure 9 and Figure 10). Rather than doing a manual classification with uniform increments we applied the Jenks' Natural Breaks function to these data. The reason for using Jenks' rather than uniform break intervals was that these data were not normally distributed, and were logarithmic in nature; hence, partitioning the classes using uniform break intervals would create classes that had either no data, or too few, or too many occurrences per class. Conversely, Jenks' takes into account the population or frequency of values by class coupled with the number of classes. For a brief explanation on Jenks' Natural breaks classification go here (http://www.terraser.com/help/stis/interface/map/classify/About_natural_breaks.htm).

Figure 10 Watershed impact potential grouped into five classes for the State of Colorado using the six-hour two year rain fall intensity.



Results

The final product from this analysis (Figure 9 and Figure 10) is a relative impact ranking of watersheds for the entire state of Colorado. The assumption is the higher the “A” value the higher the impact potential exists. Therefore, watersheds that have, high precipitation or high rain fall intensity, high KWFACT, steep slopes, low canopy cover, and high disturbance will have high impact potential. As would be expected the mountainous watersheds have the highest “A” values. Conversely, the valley bottoms and Great Plains have the lowest “A” values. For figure 9 the largest category was high and included 32.37% for all of Colorado’s 6th level watersheds while the smallest category, low, included 5.20% (Table 1). For figure 10 the largest category was high and included 30.47% for all of Colorado’s 6th level watersheds while the smallest category, low, included 2.20% (Table 2).

In summary both results look very similar; however, figure 10 has bit more concatenated watersheds. This is most like due to the fact that the rain intensity data has less spatial variation when compare to the 30-year average precipitation.

Table 1. The number of 6th level watersheds and relative percents for the State of Colorado using the 30 year average precipitation.

Category	Number of Watersheds	Percent
Low	164	5.21
Medium	621	19.71
High	1020	32.37
Very high	901	28.59
Extreme	445	14.10
Total	3151	100.00

Table 2. The number of 6th level watersheds and relative percents for the State of Colorado using the six-hour two year rain fall intensity.

Category	Number of Watersheds	Percent
Low	70	2.22
Medium	665	21.10
High	960	30.47
Very high	876	27.80
Extreme	580	18.41
Total	3151	100.00

Discussion

Through inspection of the results (figure 9 and figure 10) we see that watersheds located in the mountainous regions have the highest "A" values. This was due primarily to the spatial coincidence of two primary components "LS" coupled with "C". That is the high "LS" values which is dictated by the large topographic relief of the Rocky Mountains coupled with the low canopy closure.

A sensitivity analysis was completed, and not included in this paper, where the values in each data set were scaled so that the range of values for each factor were more similar. The results of this analysis indicated that scaling values had little net influence of the final results.

The RUSLE is a scientifically accepted and well documented approach for quantifying soil erosion. Furthermore, the RUSLE limits the use of expert opinion. Expert opinion can be biased, non-scientific, and carries a high degree of uncertainty. Therefore, when using expert opinion strategies outline by Morgan (1990) should be implemented to quantify the degree of uncertainty.

Next, all these spatial data sets are currently available to the public for the contiguous United States. Therefore, these data coupled with this modeling process can be computed and compared between and across state lines, watersheds, USGS Mapzones, and individual National Forests. Furthermore, when new spatial data becomes available base layers can be updated. For example, when new data that depicts forest fires, forest blow-down, logging, mining, insect/disease infestations, and invasive plant encroachment become available, the forest disturbance data sets can be updated via these new data sets and the model can be rerun; thus, updating the final results.

Weighting the results from the RUSLE by the area (number of GRID cells) in an individual watershed then summing up all the values by watershed is a preferred approach, when compared to averaging the results by watershed. Averaging the results by watershed will reduce the variability, thus making the overall analysis less sensitive. Spatial weighting influences the relative ranking of each watershed by taking into consideration the area represented by each "A" value from the RUSLE. Spatial weighting is a common and accepted procedure which is discussed by Reich (2005).

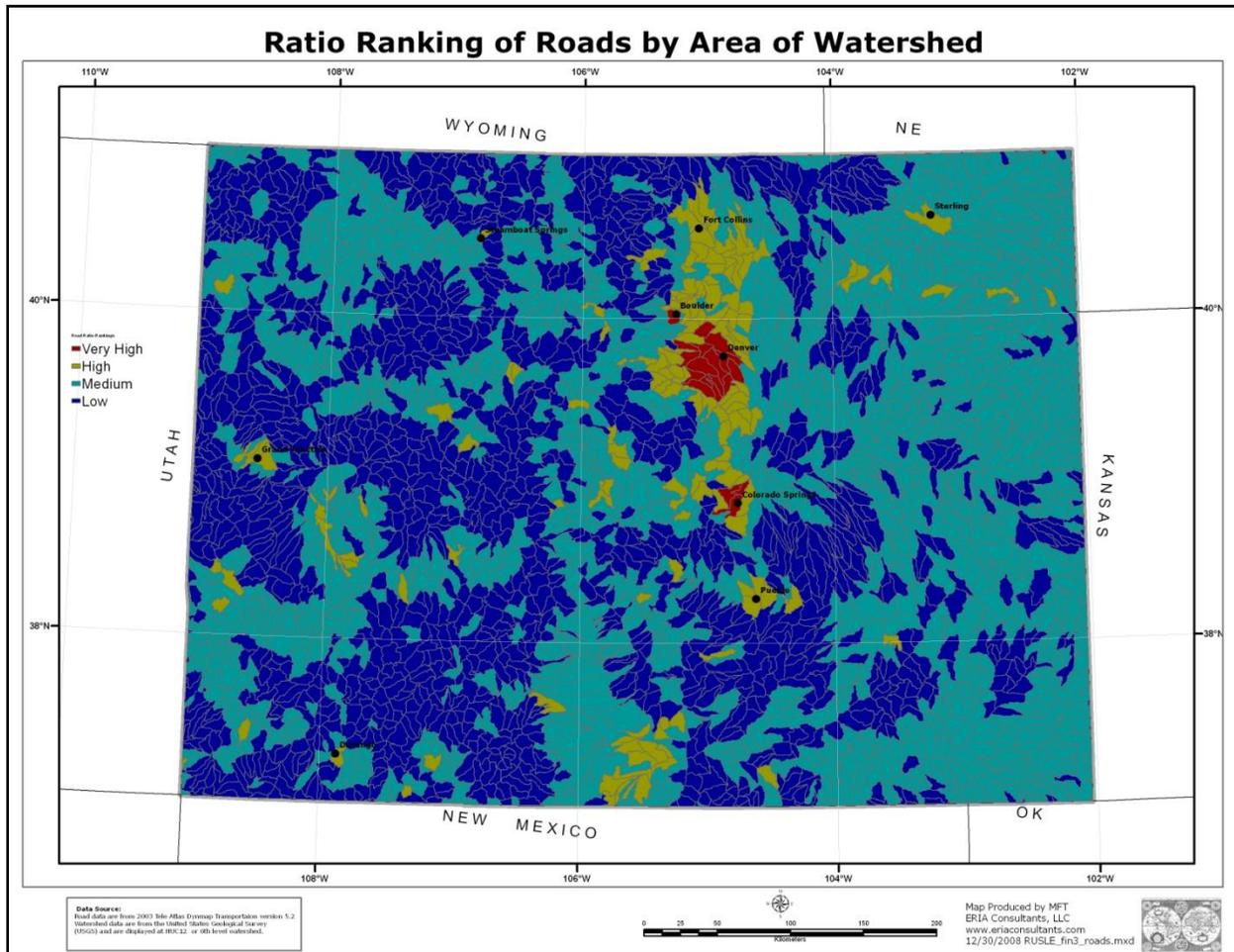
The NRCS SSURGO data and the RUSLE were primarily designed for agricultural soils (Wischmeier,1978). Surrogates for "R", "C", and "P" values as described in the RUSLE have been used in this model. That is, "R" as described in the RUSLE is the rainfall and run off factor. We substituted "R" with precipitation in inches (30 year average from PRISM) or rain intensity from NOAA. Next, "C" is defined in the RUSLE as the cover and management factor and is the ratio of soil loss from an area with specified cover and management from an identical area in tilled continuous fallow (Wischmeier,1978). We used a surrogate for "C" which is a modification of forest canopy closure by forest fires and forest insect/diseases infestation (GEOMAC and FHTET, respectively). Furthermore, "P" is defined by the RUSLE as the support practice factor. Which is the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope (Wischmeier,1978).). We used a surrogate for "P" as a disturbance factor (forest fires and forest insects/diseases, GEOMAC and FHTET, respectively) and use "P" only as a modifier of "C". The results of spatially modeling the RUSLE using surrogates produces a continuous surface that is unit-less in nature; therefore, the values in the final RUSLE surface are relative values. We feel that the method outlined in this paper is valid for large forested areas and non-agricultural landscapes where detail watershed impact potential data does not exist.

Using the results of this large area analysis, we can look at individual watersheds that provide domestic, industrial, or agricultural water and evaluate the watersheds with respect to soil erosion potential.

Ancillary work can be applied to the results from the spatial modeled RUSLE. It has been concluded that stream sedimentation on forested lands is greatly exacerbated by road construction (USFS PSW-GTR,

1998) and mining operation (Tuffly, 2000). Therefore, quantifying the distance of all roads (i.e. paved, dirt, and railroads) by sample areas can be used as an additional input to describe soil erosion in a forest landscape (i.e. “P” factor). Summarizing the ratio of roads by sample area is described by Tuffly (2005). However, in forested areas there are few roads when compared to urban areas. Therefore urban areas will contain disproportionately large ratio of roads by sample area when compared to forested landscapes. Consequently, the approach of using ratio of roads by sample area offers little modification when forested landscapes and urban areas are being concurrently evaluated (figure 11).

Figure 11



Conclusion

The spatial explicit RUSLE is well suited for modeling the potential for watershed impacts over large area landscapes. Furthermore spatial explicit RUSLE can produce standard watershed impact categories; therefore, these data can be compared to other landscapes. Watersheds that have the highest “LS” values also contain other factors (e.g. R, K, C and P) that proportionally increase watershed impacts. The ratio of roads by watershed has limited used when rural and urban areas are being

simultaneously evaluated. The spatial explicit RUSLE has limitations when applied to forest landscapes. Finally the input data for the spatial explicit RUSLE can be updated with new information that influences watershed impacts.

References

Environmental Systems Research Institute (ESRI) ArcGIS © 2008, Redland, California.

Mitasova, H., and L. Mitas 1993. Interpolation by Regularized Spline with Tension: I Theory and Implementation. *Mathematical Geology*, Vol 25, No. 6, 1993.

Morgan, M. G. and Henrion, M. Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis. Cambridge University Press. 1990.

Moore, I. D. and J. P. Wilson, 1992, Length-slope factors for RUSLE: Simplified method of estimation, *Soil Science Society of America Journal*, vol. 50, pp. 1294-1298,

Reich, R. M. and J.E. Lundquist. 2005. *Use of spatial statistics in assessing forest diseases*. Chapter 14, pp 127-144, In: *Forest Pathology: From Genes to Landscapes*. J.E. Lundquist and R.C. Hamelin eds. APS Press, The American Phytopathological Society, St. Paul, MN, 175p.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Department of Agriculture, Agricultural Handbook 703, 404 pp.

Rhoades C., K. Elder, R. Hubbard, and M. Dixon 2005. Assessing Biogeochemical & Hydrologic Change During Incipient Bark Beetle Outbreak in Managed and Unmanaged Subalpine Watersheds. <http://www.fs.fed.us/rm/boise/AWAE/scientists/profiles/Rhoades/MPBThreatsWebAug08.pdf>

Tuffly M., G. Newton, S. Reynolds, S. Newton-Reed, E. Miller, S. Reeves, and J. Mistchenko. 2000. Using a Geographic Information System, the Global Positioning System and a Relational Data for the Inventory of Abandoned Mines in California. California Department of Conservation, Office of Mine Reclamation, Abandoned Mine Land Unit. Environmental Systems Research Institute Professional Papers: <http://gis.esri.com/library/userconf/proc00/professional/papers/PAP536/p536.htm>

Tuffly, M., and P. Comer, 2005. Generating Conservation Scenarios for Puerto Rico. NatureServe. ESRI Professional Papers. <http://gis.esri.com/library/userconf/proc05/papers/pap1931.pdf>

United State Department of Agriculture (USDA) Forest Service General Technical Report, Pacific Southwest Research Station General Technical Report 168, 1998. Proceedings of the Conference on Coastal Watershed: The Caspar Creek Story.

Vogl, R.J. 1973. Ecology of Knobcone Pine in the Santa Ana Mountains, California. *Ecological Monographs*. 43: 125 – 143.

Wischmeier, W. H., and D.D. Smith. 1978. Predicting rainfall-erosion losses - a guide to conservation planning. U.S. Department of Agriculture, Agricultural Handbook 537. 58 pp.

Appendix 1

```
/*-----  
/*  
/* NAME: lsfactor.aml  
/*  
/*-----  
/* AUTHOR: Jacek S. Blaszczynski, Physical Scientist. BLM NARSC, Original coding, 04/99  
/*      Revision and additions of LSFACOR2, 02/2000  
/*P----- Purpose -----  
/*  
/* To calculate grids of values for the terrain factor of the Revised  
/* Universal Soil Loss Equation from digital elevation model data using the  
/* empirically based LS factor equation described in the BLM RUSLE diskette  
/* (Simanton, 1987) and physical-process based LS equation developed  
/* by Moore and Wilson (1992) and Mitasova (1993).  
/*  
/* The results of the statistical analysis of about 10000 plot  
/* years of data was used in developing what is now a well known  
/* model for sheet and rill soil loss prediction called the  
/* Universal Soil Loss Equation. Soil loss equations are  
/* empirical (based on field collected data) models developed to  
/* enable conservation planners to project limited erosion data  
/* to the many localities and conditions that have never been  
/* directly represented in field research. The Revised USLE was  
/* developed by the Agricultural Research Service to further extend the  
/* USLE (prepared for croplands) to wild areas of rangelands, particularly in  
/* arid and semi-arid climates. The RUSLE reflects the basic USLE structure:  
/*  
/*      A = R * K * L * S * C * P  
/*  
/*      where  
/*  
/* A is the computed soil loss per unit area, usually in tons per  
/*      acre per year;  
/*  
/* R is the rainfall and runoff factor and is the number of rainfall  
/*      erosion index units;  
/*  
/* K is the soil erodibility factor, is the soil loss rate per  
/*      erosion index unit for a specified soil as measured on a unit plot,  
/*      which is defined as a 72.6-ft length of uniform 9-percent slope  
/*      continuously in clean tilled fallow;  
/*  
/* L is the slope-length factor, is the ratio of soil loss from the  
/*      field slope length to that from a 72.6-ft length under identical
```

/* conditions;

/*

/* S is the slope-steepness factor, is the ratio of soil loss from
/* the field slope gradient to that from a 9-percent slope under
/* otherwise identical conditions;

/*

/* C is the cover and management factor, is the ratio of soil loss
/* from an area with specified cover and management to that from an
/* identical area in tilled continuous fallow;

/*

/* P is the support practice factor, is the ratio of soil loss with
/* a support practice like contouring, stripcropping, or terracing to
/* that with straight-row farming up and down the slope (Wischmeier and
/* Smith, 1978).

/*

/* The automated AML capability provided here works in ARC GRID to determine
/* the topographic, terrain, or the slope gradient (S)-slope length (L) /*
/* factors of the RUSLE equation. The mathematical methods for determination
/* of the terrain factor used in preparation of the AML were obtained from the
/* RUSLE diskette prepared for the BLM in 1987. The AML first prepares two
/* grids from Digital Elevation Model (DEM): a slope gradient grid, and a
/* slope length grid, after which the two are mathematically combined to
/* prepare the LS-factor grid. Because the equation does not work for slopes
/* over 800 ft long, all the slope lengths in the slope length grid do not
/* exceed 800 ft. After the LS-factor grid has been prepared it can then be
/* classified into low, medium, and high levels of potential erosion.

/*

/* The LS-factor only provides a method for analysis of the influence of
/* terrain, while the overall soil loss potential is calculated not only from
/* terrain, but also other data since the RUSLE model is multidisciplinary.
/* Therefore the terrain factor map provides only partial information on
/* potential erosion. The information will be more accurate if soils data are
/* available which contain values for soil erodibility or K-factor for each of
/* the soil types (link to soils page), and even more accurate if vegetation
/* data (link to vegetation cover map) are available which can permit
/* calculation of the surface cover, or the C-factor for each surface cover
/* type. Multiplying grids containing K-factor values per soil type and C-
/* factor values per vegetation type by the LS factor map will result in a
/* most accurate model of potential erosion, but in absence of these
/* additional data sets the terrain factor can serve as a tool for at least
/* partial evaluation of the erosiveness of the landscape.

/*

/*

/*

/*A----- Arguments -----

/*

/* input_dem raster map of elevations (Digital Elevation Model)

```
/*
/*H----- History -----
/*
/* AUTHOR: Jacek Blaszczynski, Physical Scientist, BLM NARSC
/* DATE: 4/99
/* EVENT: Original Coding
/*
/*E=====
&severity &error &routine bailout
&args input_dem cell_size

/* Check arguments
&call chkargs

/* Do the work
&call main

&call exit
&return /* End of LSfactor.aml

/*-----
&routine chkargs
/*-----
&if [SHOW PROGRAM] <> GRID &then &do
  &type This aml must be run from GRID.
  &call bailout
&end
&do arg &list input_dem cell_size
  &if [NULL [VALUE %arg%]] &then &do
    &call usage
    &call bailout
  &end
&end
&if not [EXISTS %input_dem% -GRID] &then &do
  &type Input grid: %input_dem%, does not exist.
  &call bailout
&end
&return /* End of routine chkargs
/*-----
&routine main
/*-----
&wat lsfactor.wat

/*-----
/*
/* CLEAN MAPS PRODUCED ON THE PREVIOUS LFACTOR.AML RUN
/*
```

```
/*-----
```

```
&if [EXISTS mmap -GRID] &then &do  
  kill MMAP all  
&end  
&if [EXISTS smap -GRID] &then &do  
  kill SMAP all  
&end  
&if [EXISTS smap2 -GRID] &then &do  
  kill SMAP2 all  
&end  
&if [EXISTS bmap -GRID] &then &do  
  kill BMAP all  
&end  
&if [EXISTS slopes0to8 -GRID] &then &do  
  kill SLOPES0TO8 all  
&end  
&if [EXISTS slopes8to50 -GRID] &then &do  
  kill SLOPES8TO50 all  
&end  
&if [EXISTS lfactor1 -GRID] &then &do  
  kill LFACTOR1 all  
&end  
&if [EXISTS sfact0to8 -GRID] &then &do  
  kill sfact0to8 all  
&end  
&if [EXISTS sfact8to50 -GRID] &then &do  
  kill sfact8to50 all  
&end  
&if [EXISTS sfactor1 -GRID] &then &do  
  kill SFACTOR1 all  
&end  
&if [EXISTS lsfactor1 -GRID] &then &do  
  kill LSFATOR1 all  
&end  
&if [EXISTS lsfactor2 -GRID] &then &do  
  kill lsfactor2 all  
&end  
&if [EXISTS lsfactor3 -GRID] &then &do  
  kill lsfactor3 all  
&end  
&if [EXISTS lfactor2 -GRID] &then &do  
  kill lfactor2 all  
&end  
&if [EXISTS sfactor2 -GRID] &then &do  
  kill sfactor2 all  
&end
```

```
&if [EXISTS lfactor3 -GRID] &then &do
  kill lfactor3 all
&end
&if [EXISTS sfactor3 -GRID] &then &do
  kill sfactor3 all
&end
&if [EXISTS sloplenm -GRID] &then &do
  kill sloplenm all
&end
&if [EXISTS temp3 -GRID] &then &do
  kill TEMP3 all
&end
&if [EXISTS sloplenft -GRID] &then &do
  kill sloplenft all
&end
&if [EXISTS sloplenft2 -GRID] &then &do
  kill sloplenft2 all
&end
&if [EXISTS flowcounta2 -GRID] &then &do
  kill flowcounta2 all
&end
&if [EXISTS flowlengtha2 -GRID] &then &do
  kill flowlengtha2 all
&end
&if [EXISTS flowcountz2 -GRID] &then &do
  kill flowcountz2 all
&end
```

```
/*-----
/* Set the environment
/*-----
```

```
&terminal 9999
display 9999 2 position cr
&echo &off
&echo &brief
setwindow %input_dem% %input_dem%
mape %input_dem%
```

```
/*-----
/* Calculate LSFATOR1 based on equations from Simanton, 1987
/*-----
```

```
&if not [EXISTS flowdira -GRID] &then &do
  &type Preparing a flowdirection map for an unfilled DEM...
  flowdira = flowdirection (%input_dem%)
```

```
buildsta flowdira
&end
gridpaint flowdira value linear nowrap gray

/*-----
/* CALCULATE THE SLOPE LENGTH FACTOR
/*-----

&if not [EXISTS flowcountz2 -GRID] &then &do
  &if not [EXISTS flowcountz -GRID] &then &do
    &if not [EXISTS flowdirz -GRID] &then &do
      &if not [EXISTS filled -GRID] &then &do
        fill %input_dem% filled
        buildsta filled
      &end
      flowdirz = flowdirection (filled)
      buildsta flowdirz
    &end
    flowcountz = flowaccumulation (flowdirz)
    buildsta flowcountz
  &end
  /*-----
  /* Generate a map consisting only of hillslope areas by setting
  /* all filled dem flow accumulation (flowcountz) values above
  /* 50 to a null or NODATA value. By editing this value we can
  /* change the extent of what we consider hillslopes. Another
  /* alternative is to use an existing stream coverage to create
  /* a FLOWCOUNTZ2 map prior to running this AML (contact author)
  /*-----
  flowcountz2 = con (flowcountz < 50, 1, setnull (flowcountz) )
  buildsta flowcountz2
&end

/*-----
/* Build a flow length map calculating the distance along steepest
/* flow path. The flow length is calculated for the unfilled DEM
/* so that slope lengths represented are between surface depressions
/* in the terrain. Slope lengths are calculated only for the areas
/* that have been identified in map FLOWCOUNTZ2 as hillslopes,
/* i.e. not part of a drainage.
/*-----

&if not [EXISTS flowlengtha2 -GRID] &then &do
  &if not [EXISTS flowlengtha -GRID] &then &do
    flowlengtha = flowlength (flowdira, #, upstream)
    buildsta flowlengtha
  &end
```

```
flowlengtha2 = flowlengtha * ( int ( flowcountz2 ) )
buildsta flowlengtha2
&end
```

gridpaint flowlengtha2 value linear nowrap gray

```
/*-----
/* This LS-factor equation uses feet and has the limitation of
/* working only on slope gradients less than 50 percent and
/* slope lengths less than 800 feet. We maintained use of feet
/* rather than meters as units for slope length to keep it
/* as much the same as the equation in the BLM RUSLE program
/* as possible. We renumbered all values greater than 800 feet
/* to 800.
/*-----
```

```
&if not [EXISTS sloplenft -GRID] &then &do
  sloplenft = flowlengtha2 * 3.28
  buildsta sloplenft
&end
```

gridpaint sloplenft value linear nowrap gray

```
&if not [EXISTS sloplenft2 -GRID] &then &do
  sloplenft2 = con(sloplenft > 800, 800, sloplenft)
  buildsta sloplenft2
&end
```

gridpaint sloplenft2 value linear nowrap gray

```
&if not [EXISTS slopeperc -GRID] &then &do
  slopeperc = slope (%input_dem%, percentrise)
  buildsta slopeperc
&end
```

gridpaint slopeperc value linear nowrap gray

```
SMAP = ( SIN( ATAN ( SLOPEPERC / 100 ) ) )
SMAP2 = POW ( SMAP, 0.79 )
BMAP = ( ( ( SMAP / 0.0895999 ) * 0.5 ) / ( ( 2.96 * SMAP2 ) + 0.56 ) )
kill smap all
kill smap2 all
MMAP = BMAP / ( 1 + BMAP )
kill bmap all
LFACTOR1 = POW ( ( SLOPLENFT / 72.6 ), MMAP )
/*buildsta lfactor1
```

```
gridpaint lfactor1 value linear nowrap gray
kill mmap all
```

```
/*-----
/* calculate the slope gradient factor (s) using two equations: one for
/* slopes less than 8 percent and the other for slopes 8-50 percent.
/* these maps are combined to create an s-factor map in which all areas
/* over 50 percent is slope gradient are excluded (given a nodata value)
/*-----
```

```
SLOPES0TO8 = CON (SLOPEPERC > 8, SETNULL (SLOPEPERC), SLOPEPERC)
```

```
if (SLOPEPERC lt 8 or SLOPEPERC gt 50)
  slopes8to50 = setnull ( SLOPEPERC )
else
  slopes8to50 = SLOPEPERC
endif
```

```
SFACT0TO8 = ( ( SIN ( ATAN ( SLOPES0TO8 / 100 ) ) ) * 10 ) + 0.027
SFACT8TO50 = ( ( SIN ( ATAN ( SLOPES8TO50 / 100 ) ) ) * 17.2 ) - 0.56
SFACTOR1 = MERGE (SFACT0TO8, SFACT8TO50)
/* buildsta sfactor1
kill sfact0to8 all
kill sfact8to50 all
kill slopes0to8 all
kill slopes8to50 all
gridpaint sfactor1 value linear nowrap gray
```

```
/*-----
/* Calculate the LS (terrain) factor according to the equation used
/* in the BLM RUSLE program (contact author for the program). The output
/* units are equivalent to the units calculated using the second method
/* that follows, even though here we are using feet and slope percent and
/* in the second method we are using slope degrees and meters. Since
/* this equation is limited to calculations within 800 feet slope length
/* and not greater than 50 percent slopes, the LS-factor values here
/* are lower than in the second equation which calculates the factor for
/* all slope gradients and slope lengths.
/*-----
```

```
LSFACTOR1 = LFACTOR1 * SFACTOR1
/* buildsta lsfactor1
```

```
describe lsfactor1
gridpaint lsfactor1 value linear nowrap gray
```

```
/*-----  
/* Calculate LSFACOR2 using methods developed by Moore, I. D. and J. P. Wilson, 1992,  
/* Length-slope factors for RUSLE: Simplified method of estimation, Soil Science Society  
/* of America Journal, vol. 50, pp. 1294-1298, and Mitasova, H., 1993, Surfaces and  
/* modeling, Grassclippings, Spring 1993. The calculation of the factor is based on  
/* physical process analysis and the results are equivalent to LS-factor values  
/* calculate through other means. Since this method calculates the LS-factor for  
/* all slope gradients and slope lengths it might produce extremely high values for  
/* some locations (compare the output maps produced by this program).  
/* This method calculates LS-factor for flow accumulations not greater than 50 cells  
/* which is equivalent to a drainage area of about 122 acres. That means that  
/* accumulation of flow from an area of 122 acres has to happen before we consider  
/* these locations as drainages (channels) rather than hillslopes. Therefore the method  
/* uses a flow count map to define hillslope erosional areas  
/*-----  
  
lfactor2 = POW ( ( flowlengtha2 / 22.13 ) , 1.3 )  
slopedeg = slope (%input_dem%, 1, degree)  
sfactor2 = POW ( ( ( sin (slopedeg DIV DEG) ) / 0.0896 ) , 0.6 )  
buildsta sfactor2  
lsfactor2 = lfactor2 * sfactor2  
buildsta lsfactor2  
describe lsfactor2  
gridpaint lsfactor2 value linear nowrap gray  
&type TO BETTER UNDERSTAND RESULTS (NO DATA AREAS) CREATE A STREM MAP WITH 50 FLOW  
THRESHOLD  
&type USING STREAMNETWORK.AML AND DISPLAY IT (OR ANOTHER APPROPRIATE STREAM MAP) OVER  
THE LSFACOR MAPS  
&wat &off  
/*  
/*  
&return /* End of routine main  
  
/*-----  
&routine usage  
/*-----  
&type Usage: &r lsfactor <input_dem> <cell_size>  
&type (Overwrites output maps prepared on the previous run)  
  
&return /* End of routine usage  
  
/*-----  
&routine exit  
/*-----  
&do grd &list lsfactor  
  &if [VARIABLE %grd%] &then &do  
    &if [EXISTS [VALUE %grd%] -GRID] &then &do  
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```

```
&type LSFACTOR grid is ready.  
&end  
&end  
&end  
&return /* End of routine exit  
  
/*-----  
&routine bailout  
/*-----  
&severity &error &ignore  
&call exit  
&return &error Bailing out of lsfactor.aml...
```

Author:

Michael Tuffly is Manager of ERIA Consultants, LLC. He is a Natural Resource Scientist with 25 years of experience in Forestry, Environmental Assessment, and Spatial Analysis. He holds a BS and MS in Forestry from Humboldt State University and is a Doctorial candidate at Colorado State University.

If you have questions or comments please send email to:

mtuffly@eriaconsultants.com

ERIA Consultants, LLC

165 South 32nd Street

Boulder, Colorado, 80305 USA

Phone/Fax (303) 449 - 5146 Cell (720) 841 - 6188

<http://www.eriaconsultants.com>



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