Potential Impacts of Climate Change on Soil Erosion Vulnerability Across the Conterminous U.S.

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Soil Erosion

- Natural process by which soil particles are detached and removed from the surface

- Depends on multi-factors represented in 4 parameters:
  - Climate (precipitation)
  - Soil susceptibility
  - Land cover
  - Slope

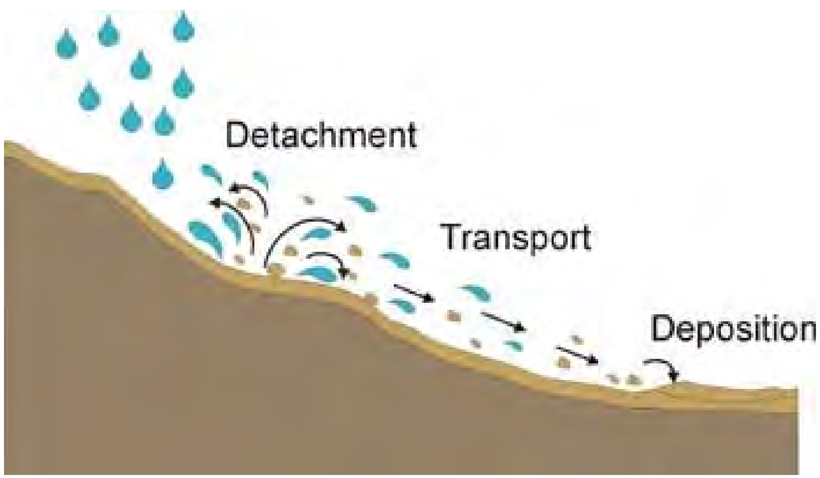
Background

Universal Soil Loss Equation

$$A = R \times K \times LS \times C \times P$$

↑

Average Soil Loss



http://www.landfood.ubc.ca/soil200/soil_mgmt/soil_erosion.htm

R: Erosivity
Depends on Precipitation

K: Erodibility
Depends on the soil type

LS: Slope
Depends on the topography

C: Land cover
Depends on the vegetation

P: Conservation practice
Depends on management (contour planting, strip cropping, etc.).

Background

Which of these factors changes with climate change?

$$A = R \times K \times LS \times C \times P$$

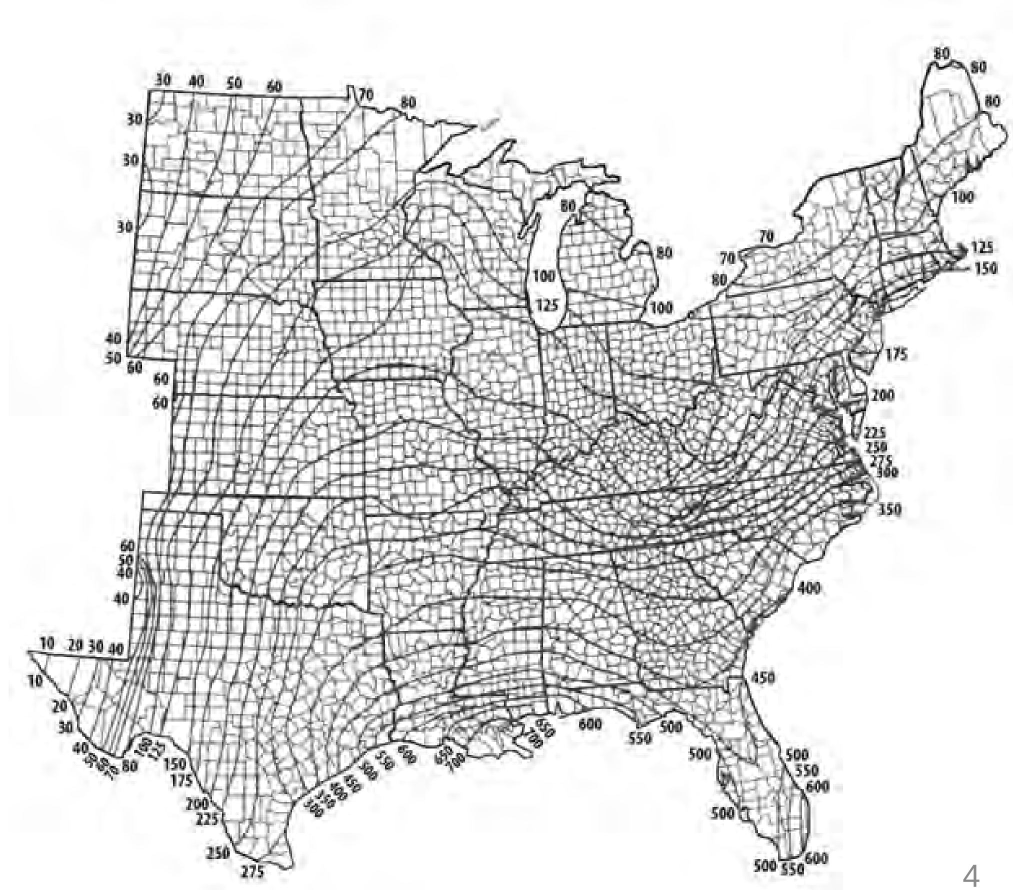
R = 10-700 or 170-12,000

K varies =0.05-0.6

LS = 0.1 - 30

C =0.003-0.5

P = 0.5-1

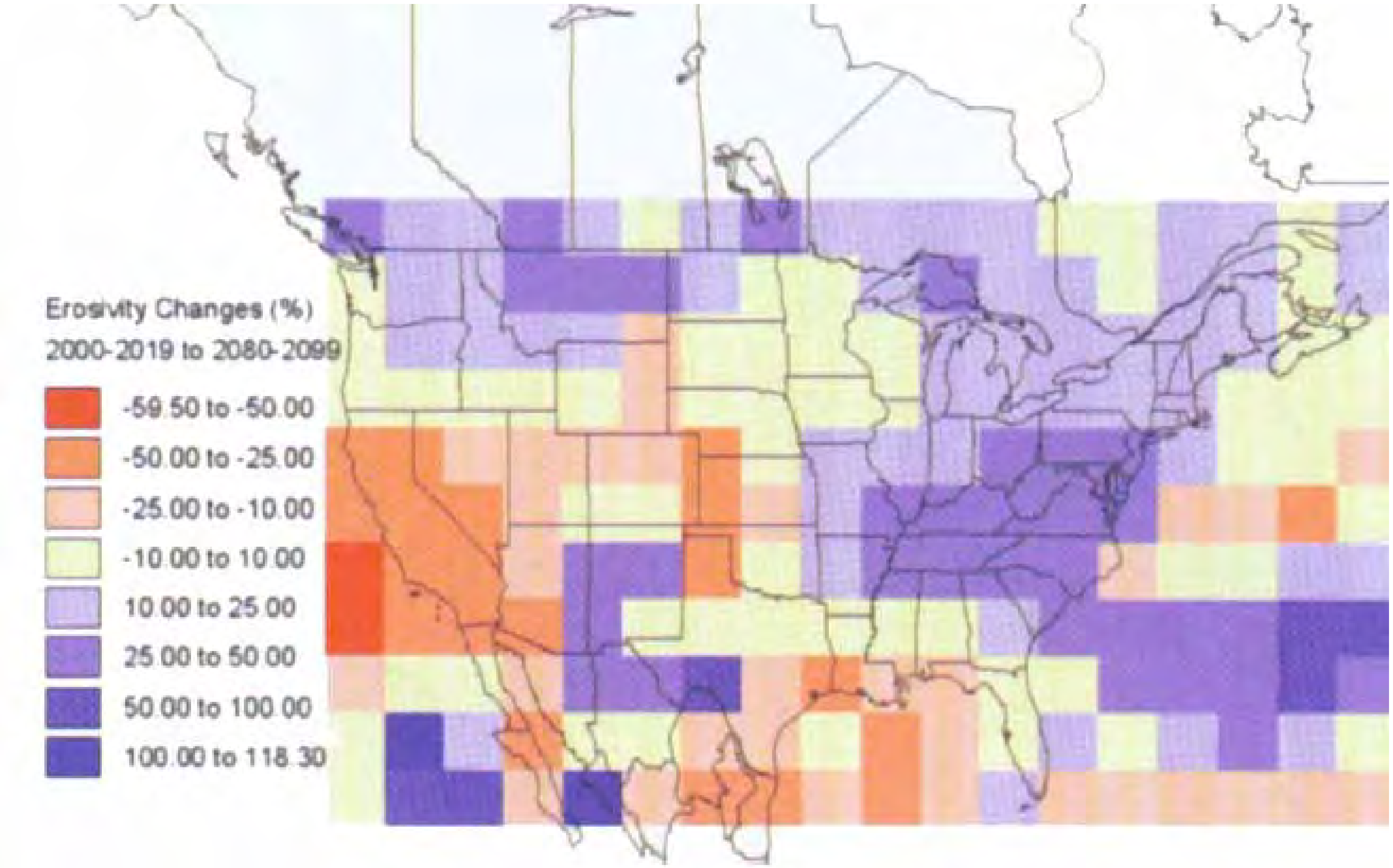


Isoerodent map of the Eastern U.S. (EPA 2001).

Background

Previous attempt to asses influence of climate change on R

Nearing, 2001.



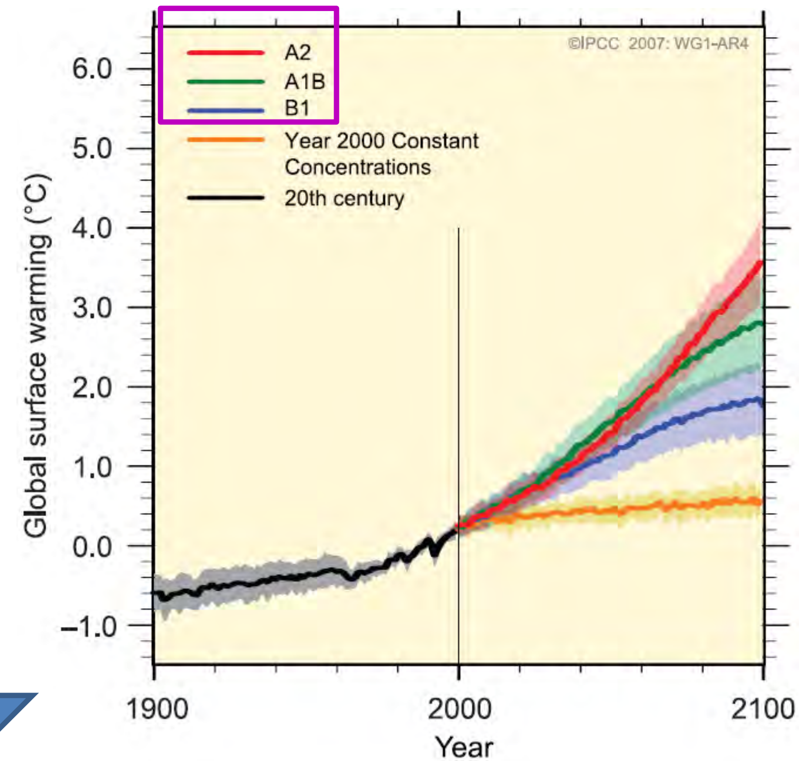
The resolution was 2.5° × 3.75°.

Objectives

- To identify areas most vulnerable to soil erosion in the U.S.
- To evaluate the temporal and spatial variations of erosivity (R) during 1970-2090 under multiple climate change projections
    - Magnitude of the likely changes in R
    - Level of agreement among climatic models
    - Changes in the inter-annual variability of R
- To provide guidance to land managers in response to climate change

Climatic Projections (IPCC, AR4)

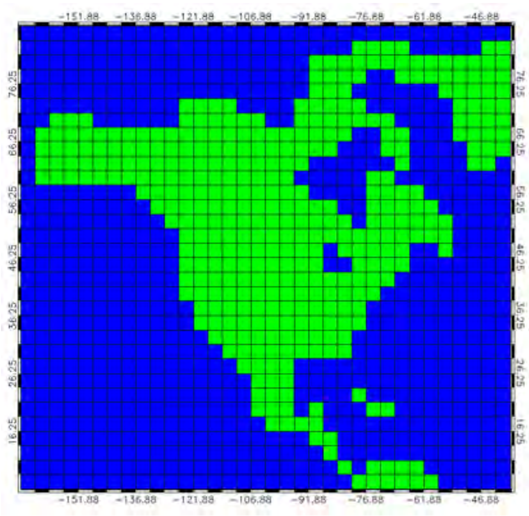
GCM	Organization	Model resolution (lat. × lon.)
HadCM3	Hadley Climate Research Center, U.K.	2.5° × 3.75°
CGCM3	Canadian Center for Climate Modeling and Analysis, Canada	2.8° × 2.8°
CM2	Geophysical Fluid Dynamics Laboratory, U.S.	2° × 2.5°

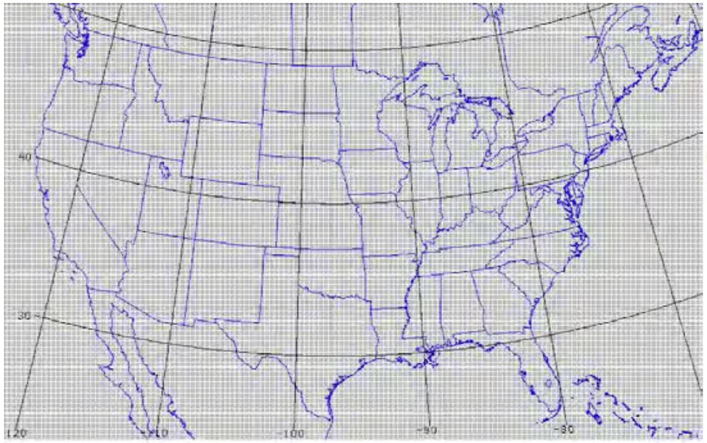


3 GCMs × 3 emission scenarios

= 9 climatic projections

Climate Data





Original GCM resolution
3.7° × 3.7°

Bias corrected and downscaled to
12 km × 12 km

Maurer et al., 2007 & Meehl et al., 2007

Scaled to the HUC-8 scale
184 - 23,000 km^2

Caldwell et al., 2012

Erosivity, *R*

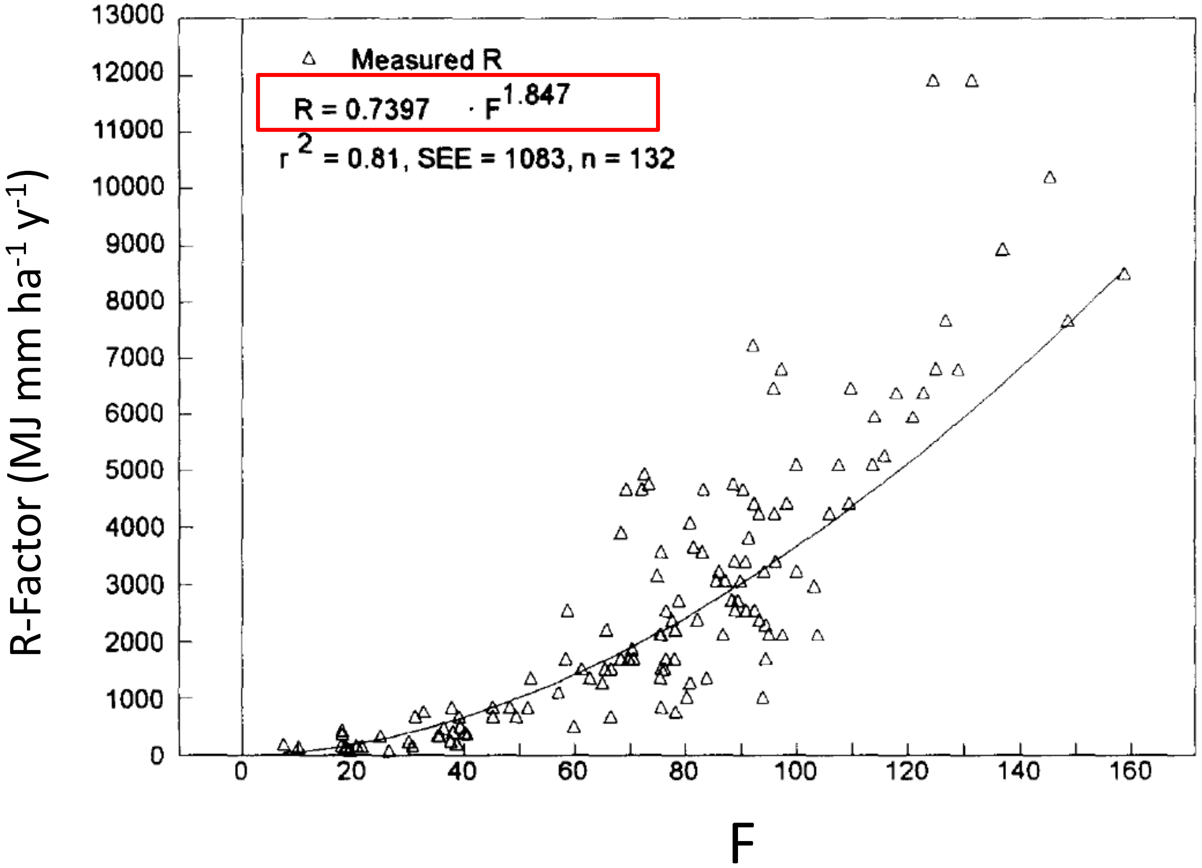
- It is the factor in the USLE model
- Represents erosive energy of rainfall and runoff
- R depends of precipitation frequency and intensity and this data is not available for the future.

Size and velocity of the rain drops are key factors

R=f(30 minute rainfall data)

Not available for future projections)

Empirical Approach to Estimate annual *R* (Renard and Freimund, 1994)



F = f(Monthly Precipitation)

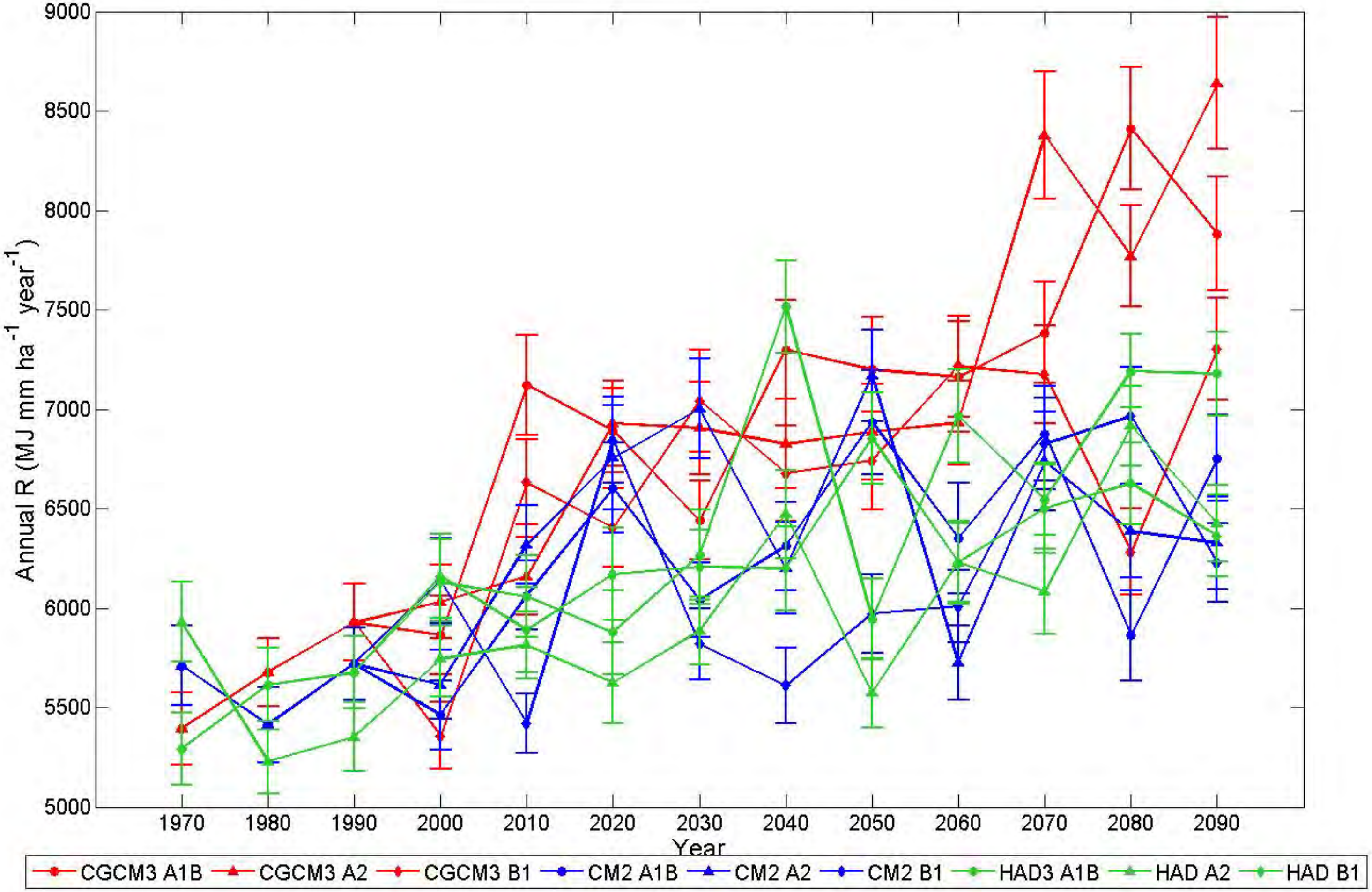
Annual *R* was computed as a function of F.

130 years (1965-2095) × 9 climatic projections

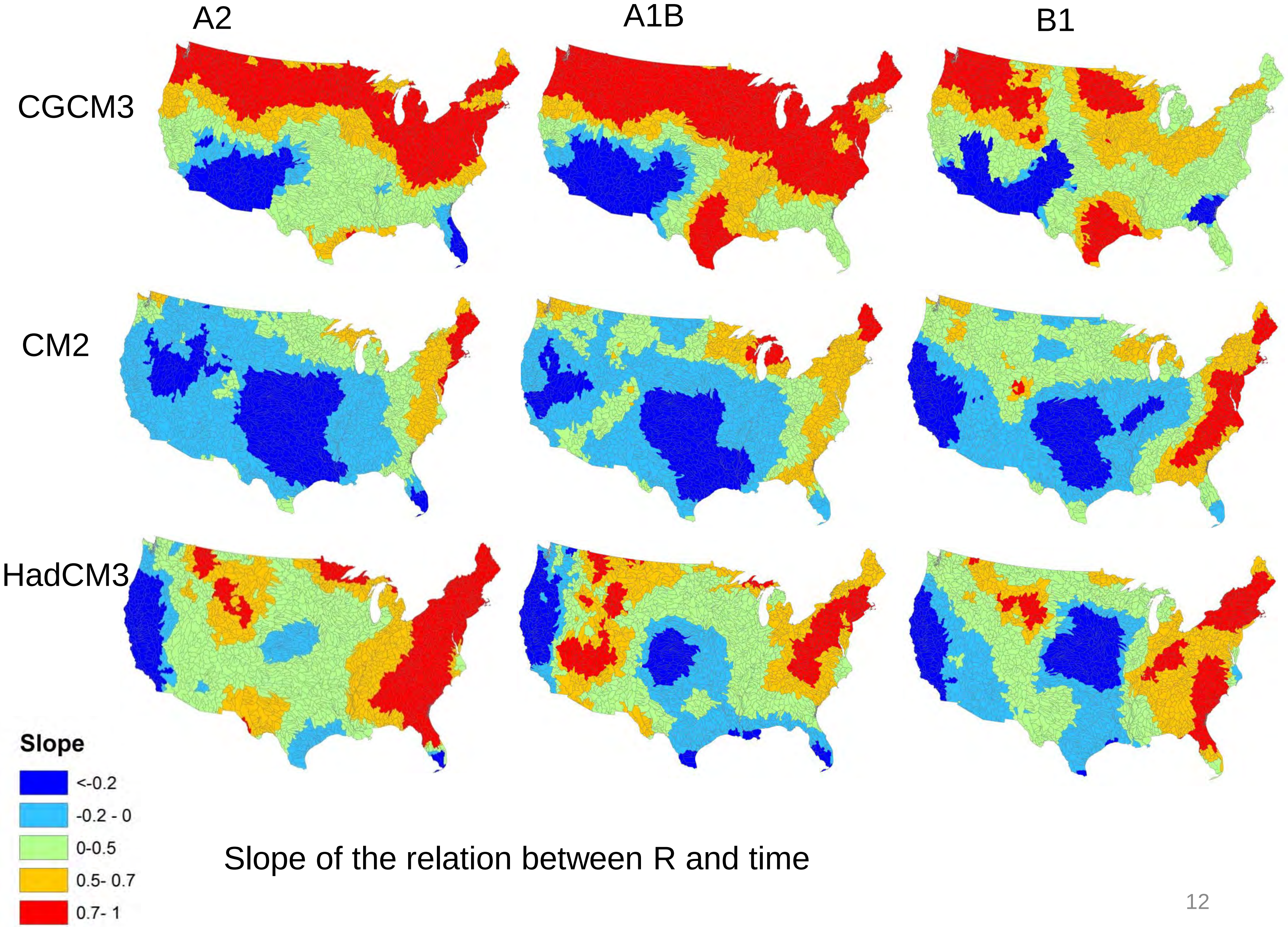
R was summarized in decadal mean values

1970-2090 (13 decades)

Mean Decadal Erosivity during 1970-2090 across the U.S.

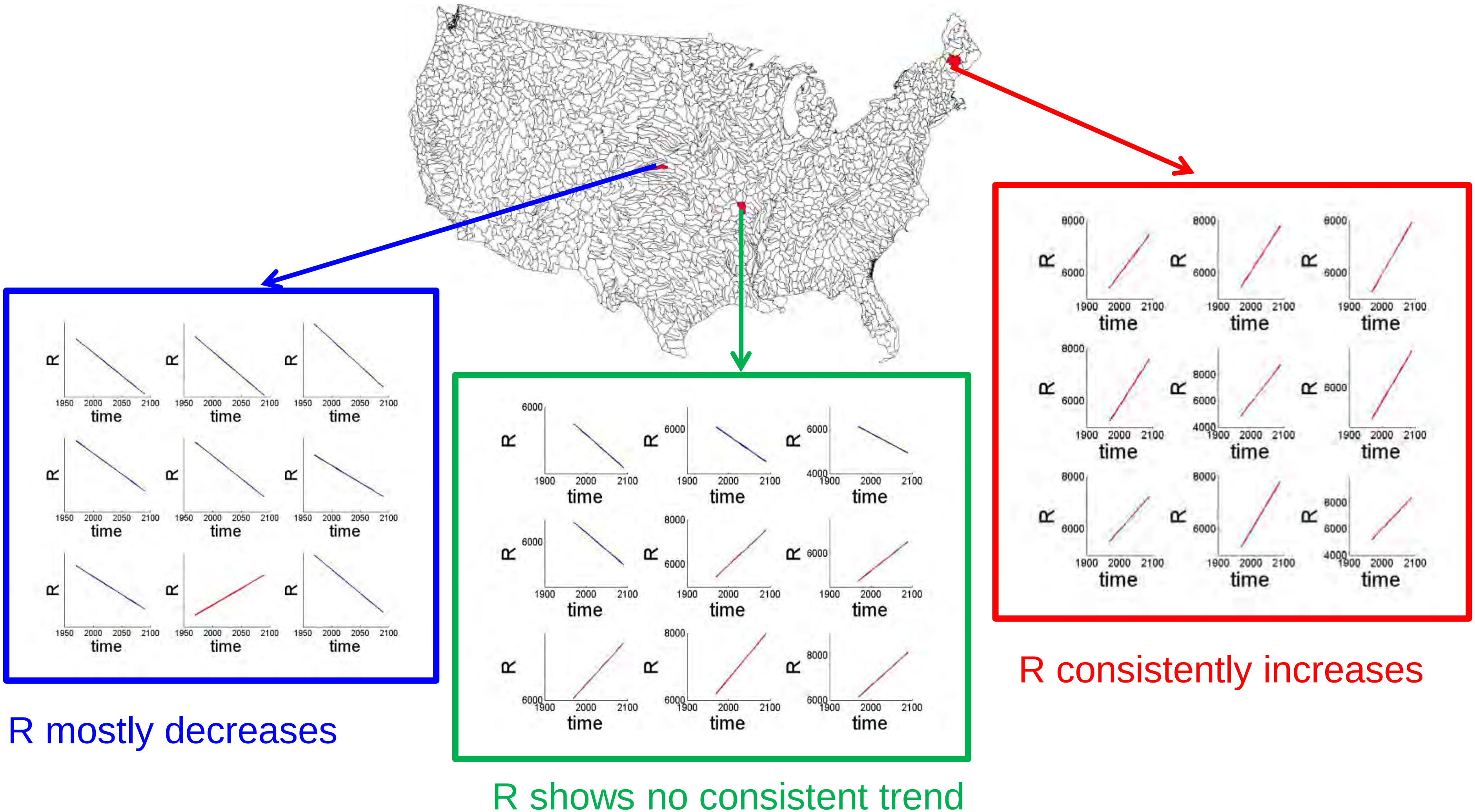


General increasing trend; high degree of variability

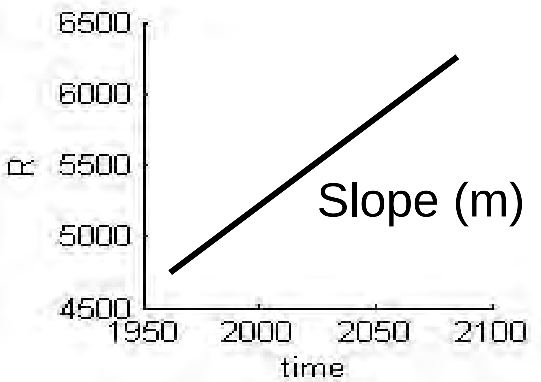


Slope of the relation between R and time

Erosivity Variability Across Models per a Given HUC-8



Erosivity Likelihood of Change



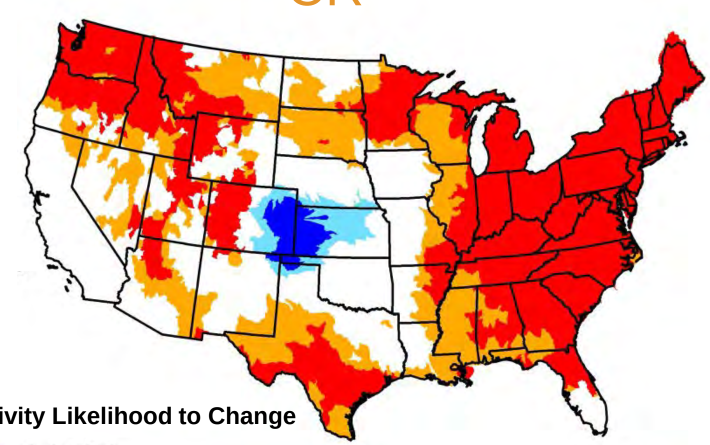
$$CR = \frac{\langle m \rangle}{\langle \sigma_m \rangle}$$

<-5	R is very likely to decrease
-5 to -3	R is likely to decrease
-3 to 3	No clear trend in R

$$CS = \frac{\langle s \rangle}{\langle \sigma_s \rangle}$$

<-5	Variability is very likely to decrease
-5 to -3	Variability is likely to decrease
-3 to 3	No clear trend in variability
3 to 5	Variability is likely to increase
>5	Variability is very likely to increase

CR

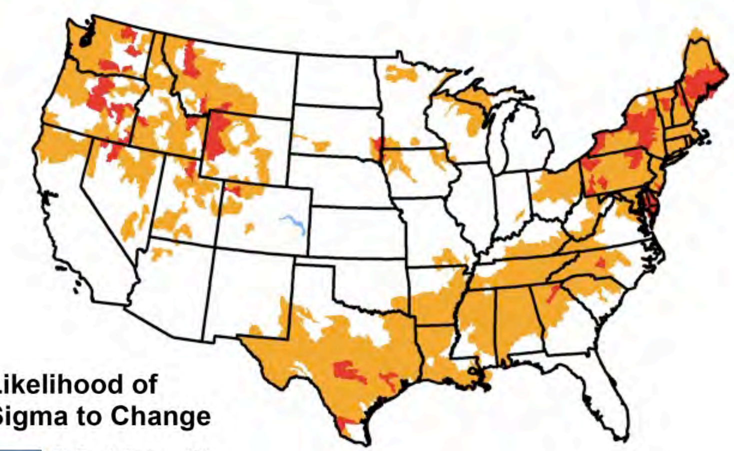


Erosivity Likelihood to Change

- -1 (<-5)
- -0.5 (-5 to -3)
- 0 (-3 to 3)
- 0.5 (3 to 5)
- 1 (>5)

Results are inconsistent among projections

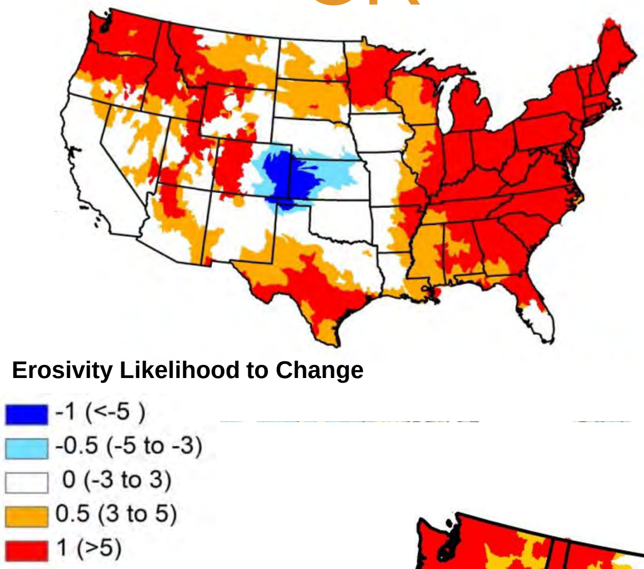
CS



Likelihood of Sigma to Change

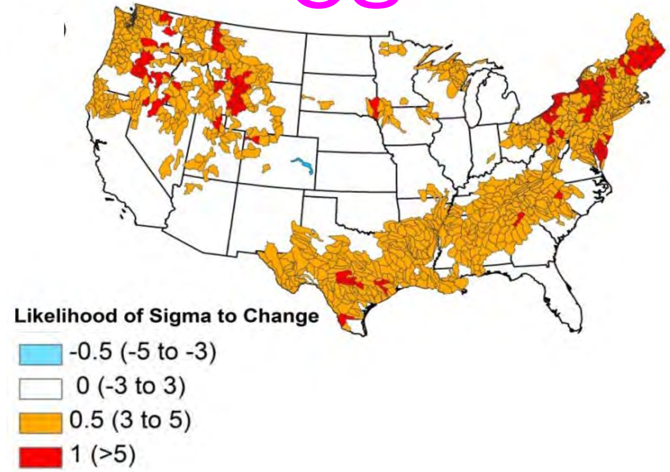
- -0.5 (-5 to -3)
- 0 (-3 to 3)
- 0.5 (3 to 5)
- 1 (>5)

CR

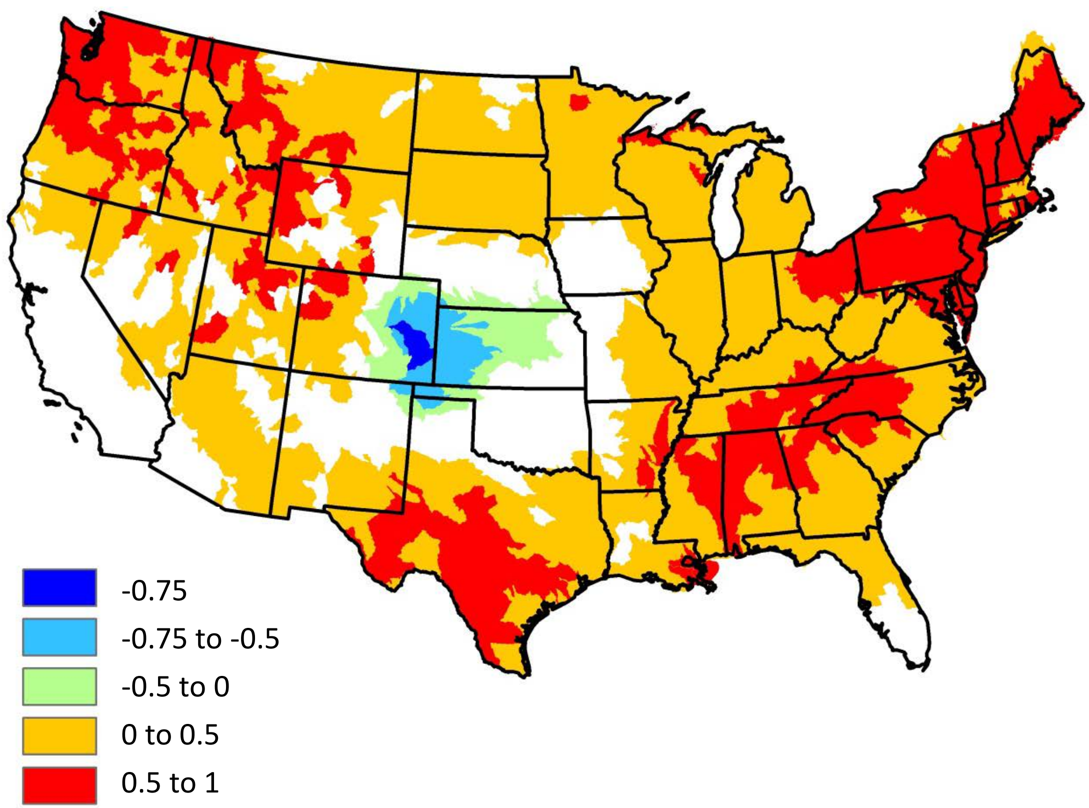


+

CS



$$\frac{(CR+CS)}{2}$$

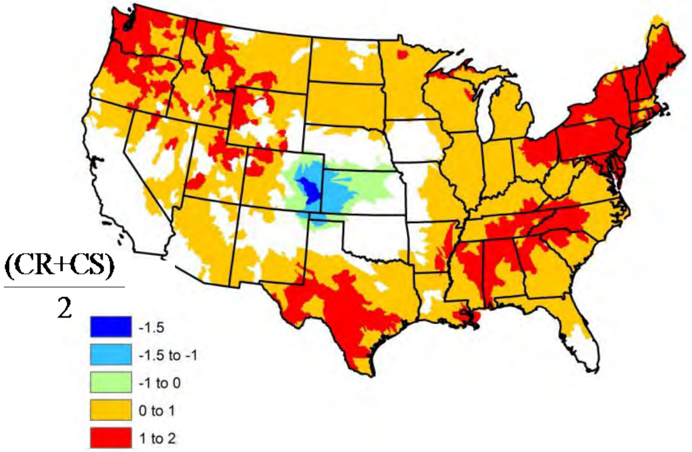


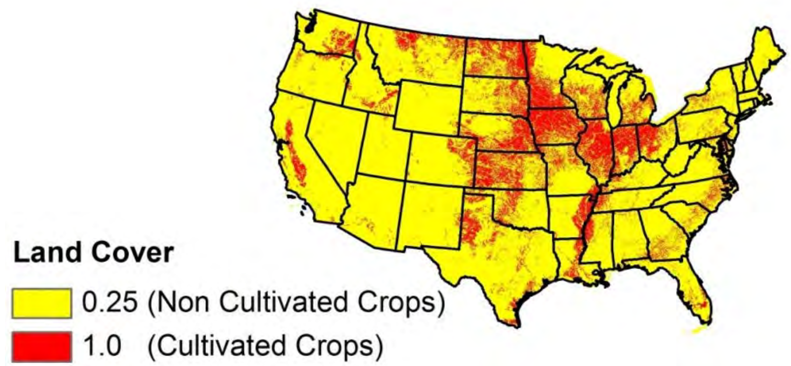
EROSIVITY, R

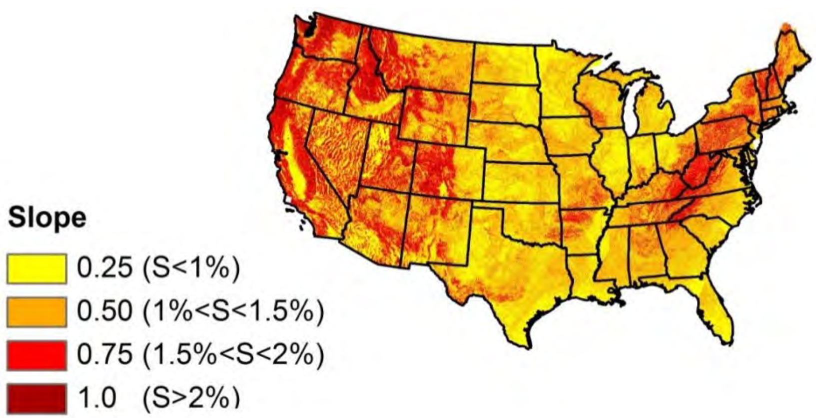
LAND COVER

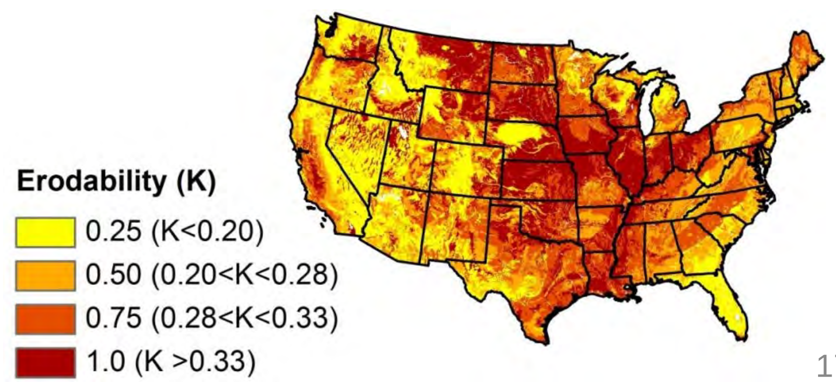
Scheme to Compute Erosion Vulnerability

$$\text{Vulnerability to Erosion (E)} = \frac{(CR + CS)}{2} \times S \times K \times LC$$

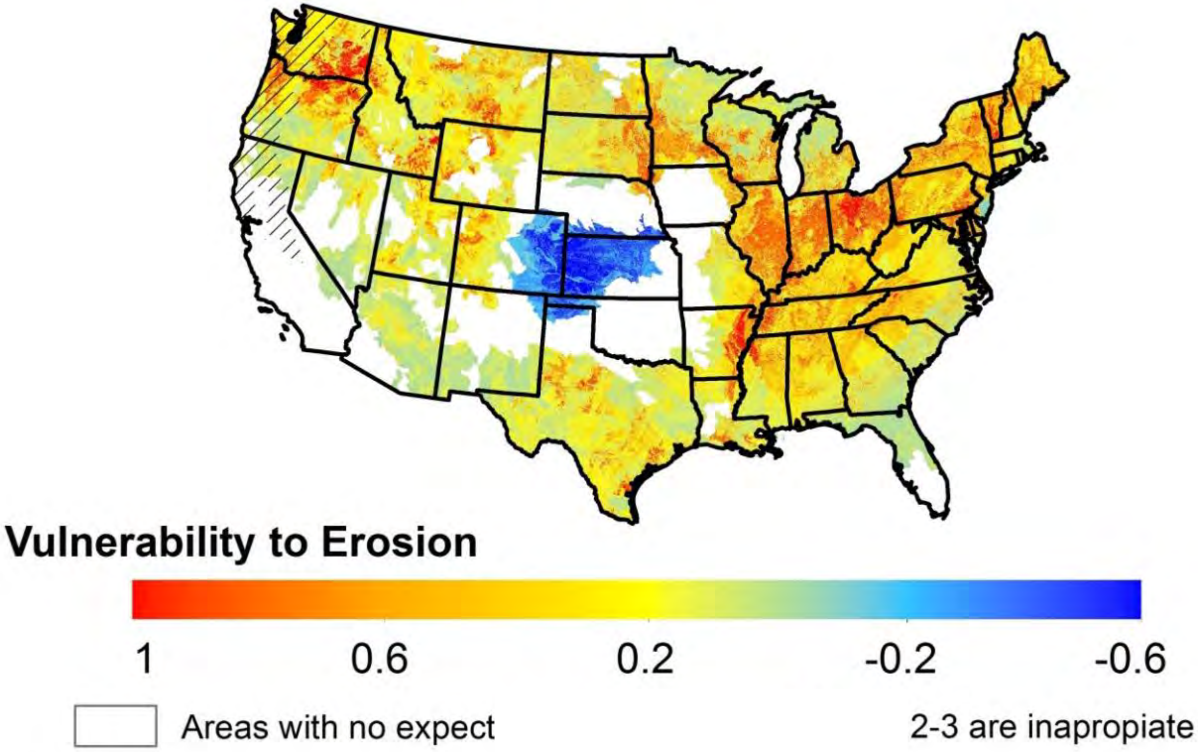






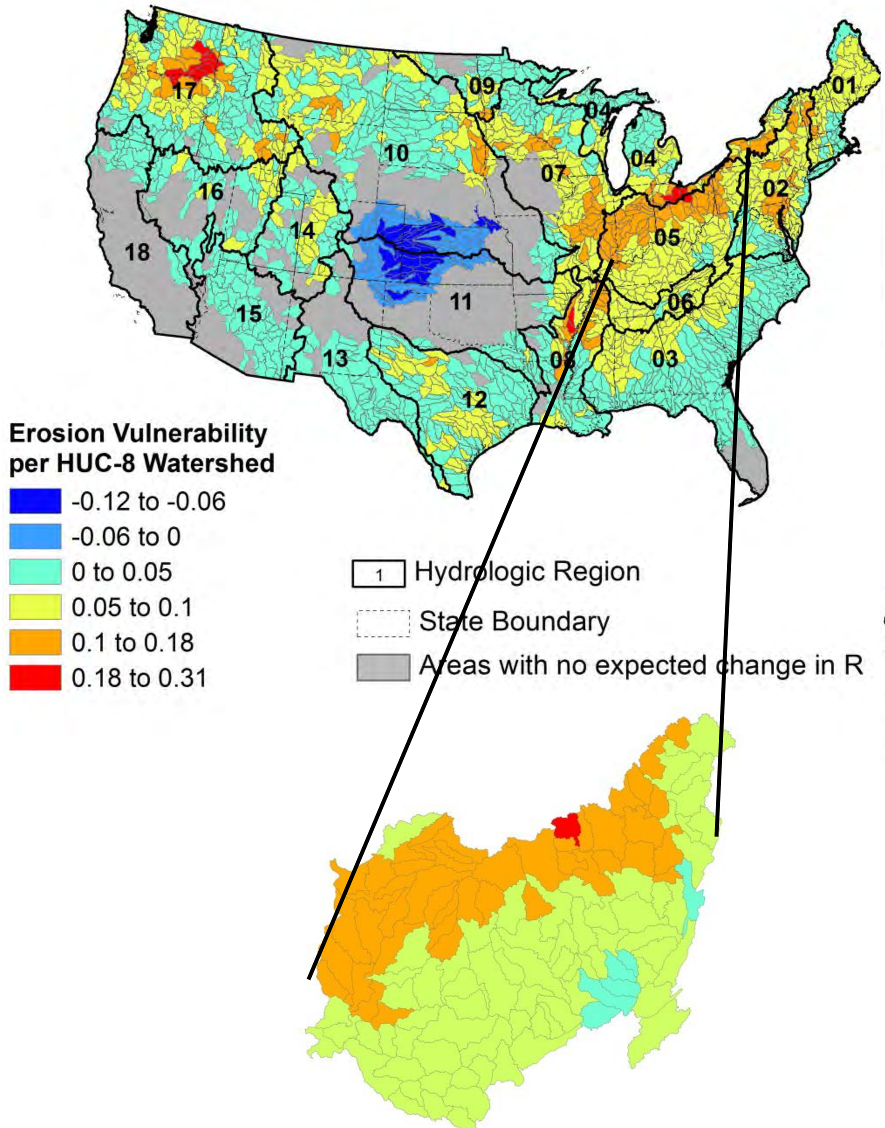


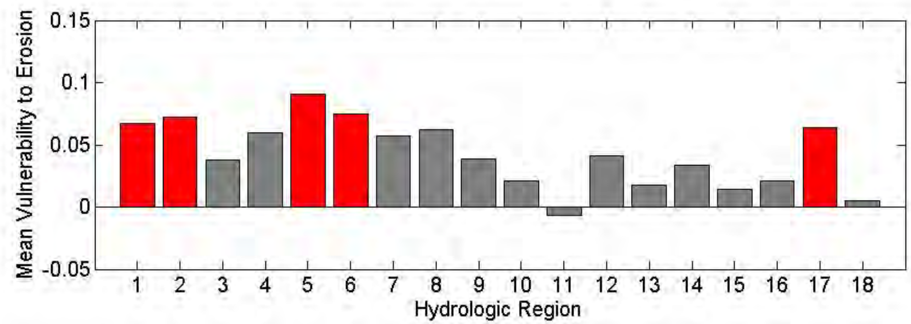
Vulnerability to Erosion, E

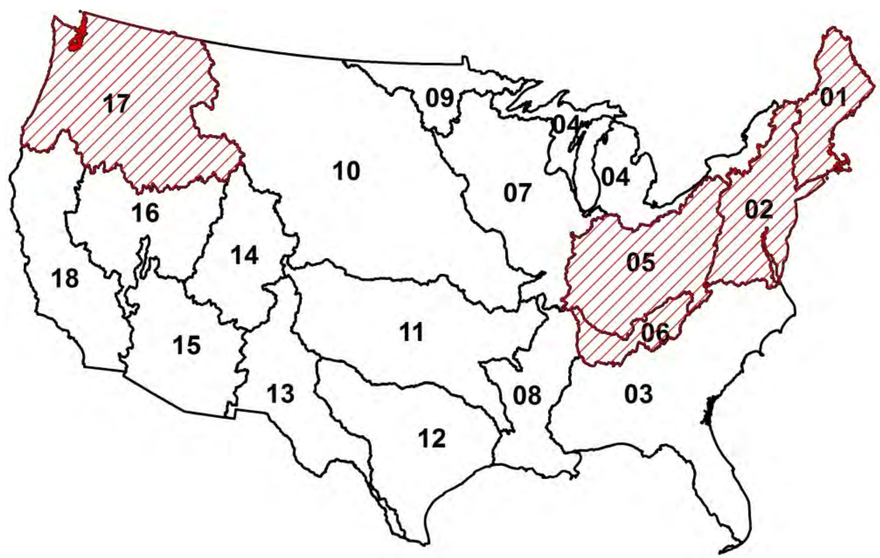


- The states with highest mean *E* are OH, VT, IN, MD, IL, WA, and PA.
- These are often covered with agriculture crops, have soils being susceptible to erosion, have steep terrain, and have a clear statistical indication that *R* (magnitude and variance) will likely increase in the future.

Vulnerability to Erosion by Region







Conclusions

- Erosivity (R) will increase in large areas of the country (e.g., the northeast and northwest).
- Variability of R is likely to increase in the northeast, south, and northwest.
- The CR score indicates inconsistent R predictions among climate projections in large areas of the west coast, CO, and KS.
- The most vulnerable areas to erosion are located in the Midwest (i.e., cultivated crops).
- Resources must give priority to vulnerable regions identified by this study.

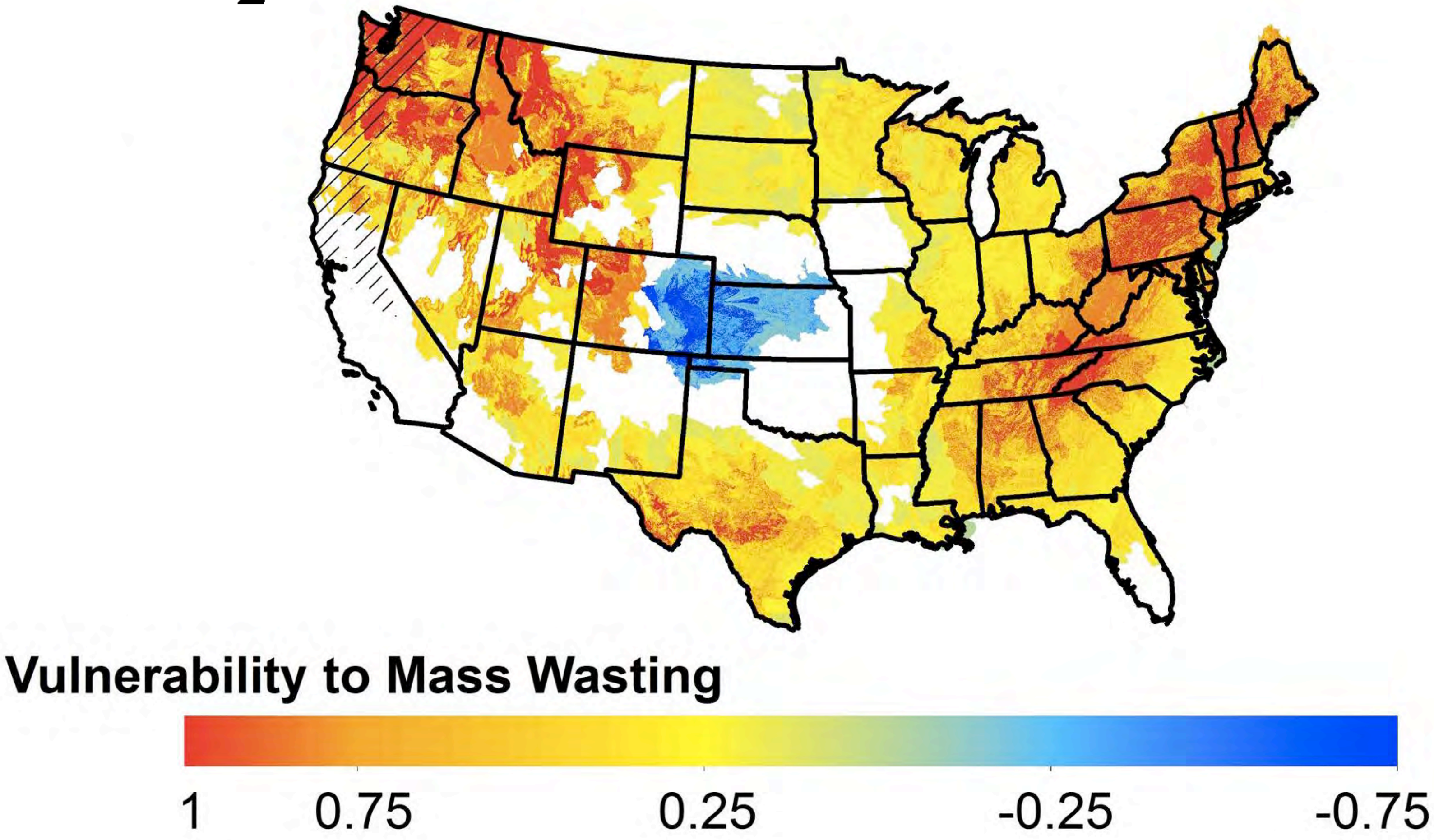
An application to predict sedimentation issues driven by fire

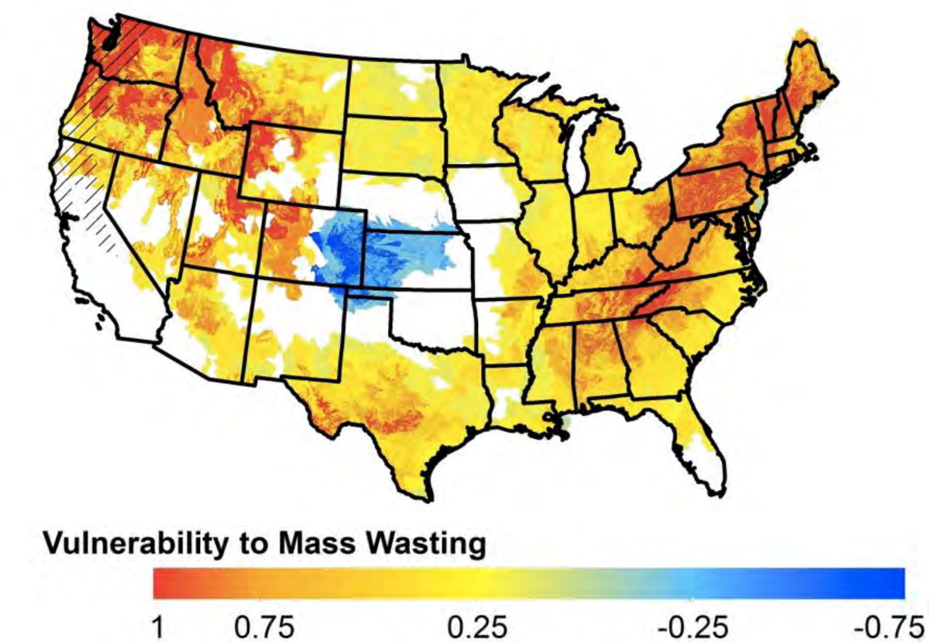
A debris flow generated from hillslopes burned by the South Canyon fire of 1994 traveled across four lanes of Interstate 70, and nearly dammed the Colorado River. Photograph by Jim Scheidt, BLM

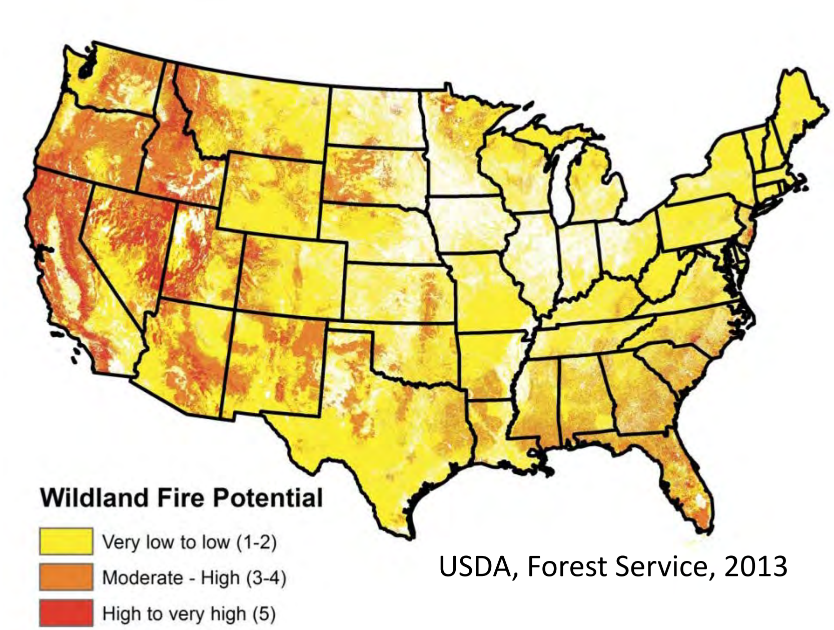
http://landslides.usgs.gov/research/wildfire/

Mass Wasting Vulnerability

$$= \frac{(CR+CS)}{2} \times S$$





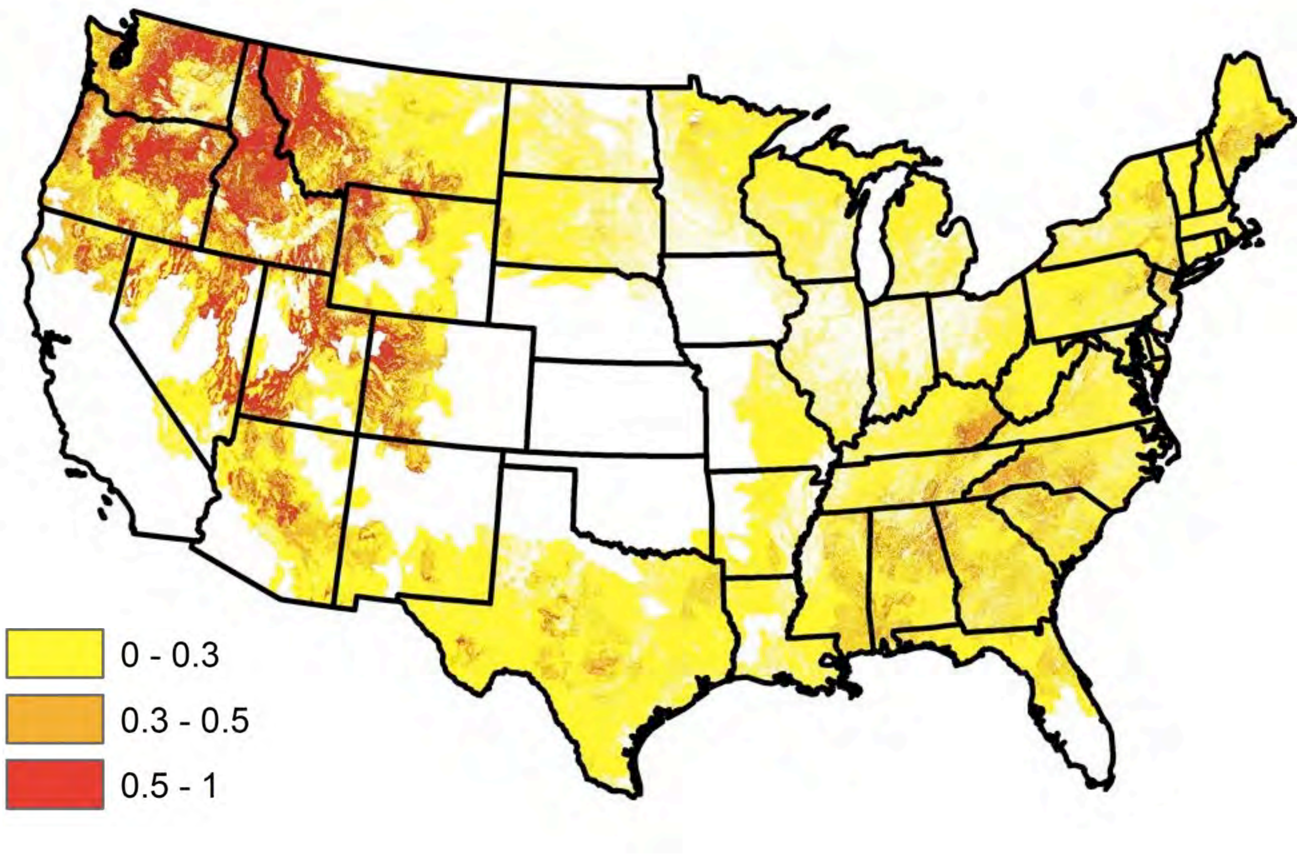


USDA, Forest Service, 2013

Mass Wasting x Fire Potential

= Areas vulnerable to increase sedimentation

Areas vulnerable to increase sedimentation



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Questions?

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