RHEM

The Rangeland Hydrology and Erosion Model

Rangeland Hydraulic Processes, Predictions, and Uses

USDA

ARS

NRCS

Southwest Watershed Research Center
Tucson, Arizona

Great Basin Rangelands Research
Reno, Nevada

Northwest Watershed Research Center
USDA ARS Agricultural Research Service

What is RHEM

Rangeland **H**ydrology and **E**rosion **M**odel

RHEM is designed for government agencies, land managers and conservationists who need sound, science-based technology to model, assess, and predict runoff and erosion rates on rangelands and to assist in evaluating rangeland conservation practices effects.

Development of RHEM

RHEM is developed based on a large set rangeland experimental data.

RHEM was developed based on the WEPP-IRWET dataset -- rainfall simulation experimental measurements from 204 plots (3.05 by 10.7 m) on 49 rangeland sites located in 15 western states using rotating boom simulator.

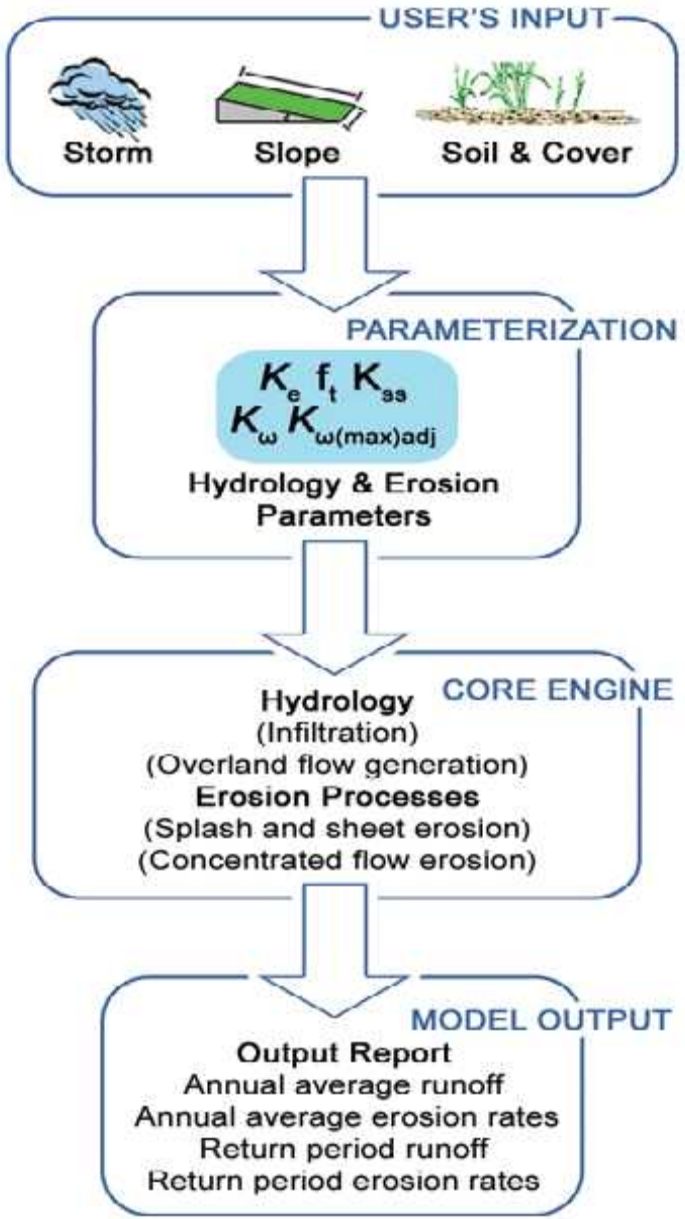
What is RHEM capable of?

- RHEM estimates runoff, erosion, and sediment delivery rates at the spatial scale of the hillslope and the temporal scale of a single rainfall event.
- RHEM is also designed to be used as a runoff and erosion calculator, or "engine", within a web-based interface or within another model that works on the larger scale, such as AGWA/KINEROS2.
- RHEM is a vehicle for incorporating up to date scientific findings from rangeland infiltration, runoff, erosion, and salt mobility and transport studies.

What is RHEM not capable of?

- The RHEM model is a single event prediction tool and therefore does not predict daily changes in plant growth and associated changes in standing biomass, canopy, or ground cover.
- RHEM does not address gulley, side-bank sloughing, head cutting, rain-on-snow, and/or seep induced soil erosion processes.

RHEM Erosion Prediction Procedure



User's Input

Storm Characteristics:

- Rainfall data are entered as time-accumulated depth or time-intensity breakpoint pairs.

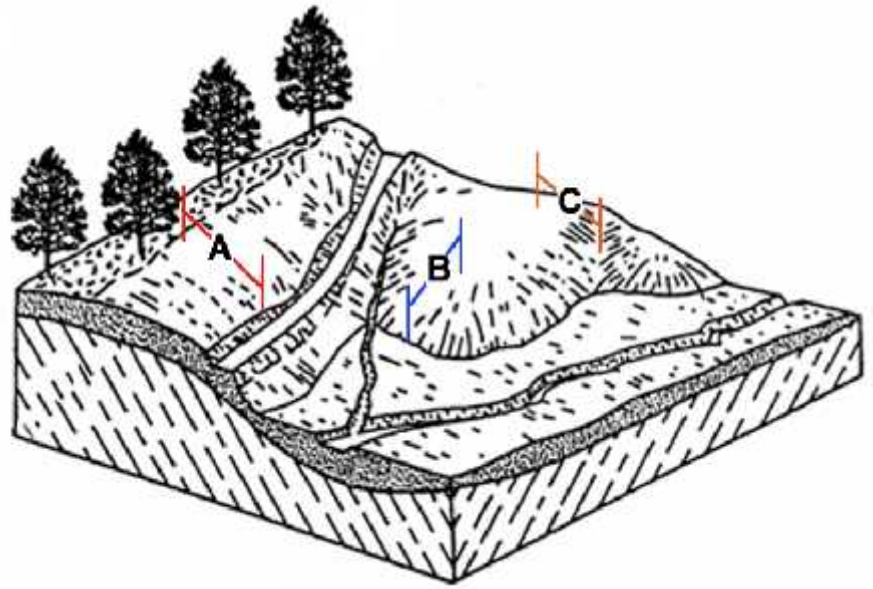
OR

- Output from CLIGEN
  - Normalized time to peak
  - Normalized peak intensity
  - Duration
  - Total storm amount

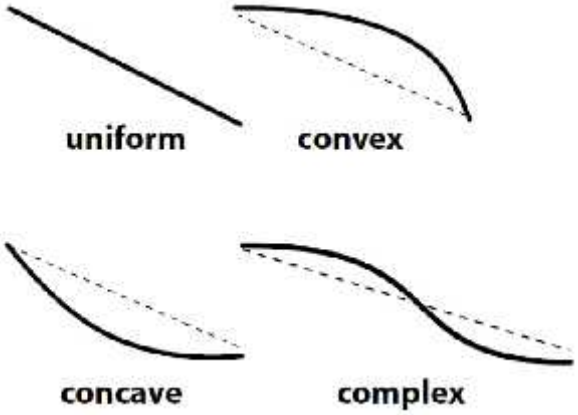
User's Input

Hillslope Characteristics:

- Slope steepness
- Slope length
- Slope shape



After Dissmeyer and Foster (1981)



User's Input

Soil Characteristics:

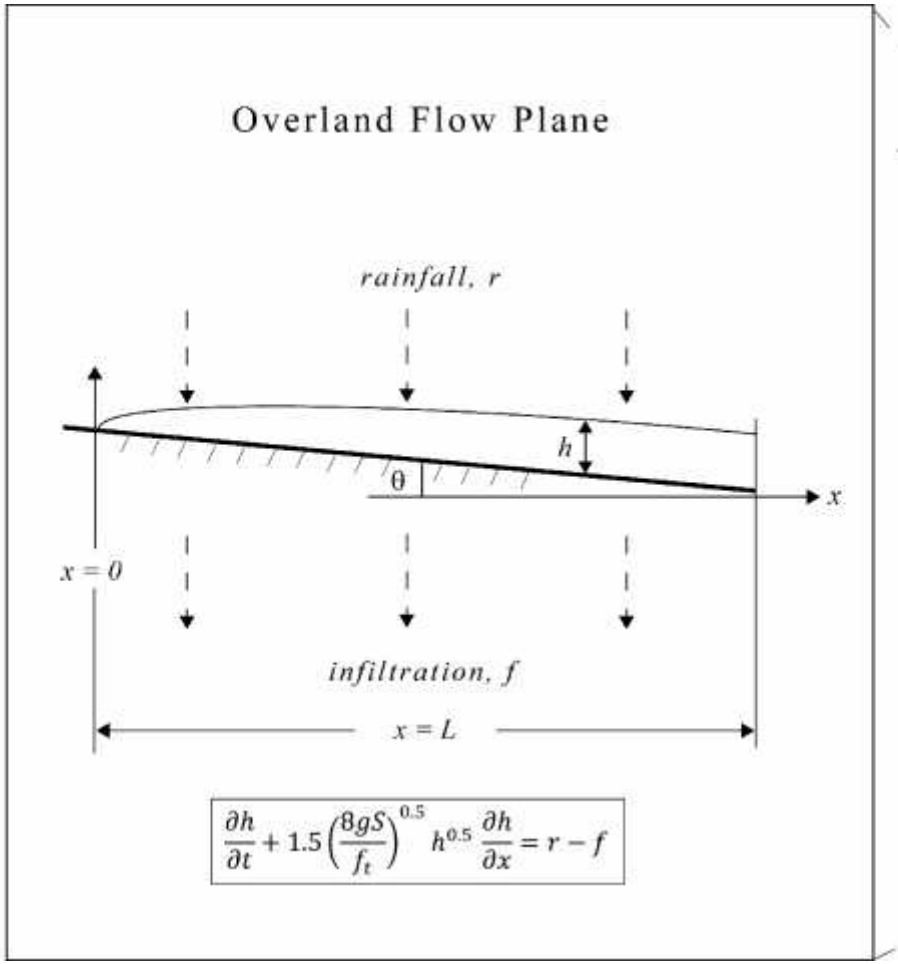
- Soil texture class of the upper 4 cm (1.57 in) of the soil profile

Cover Characteristics:

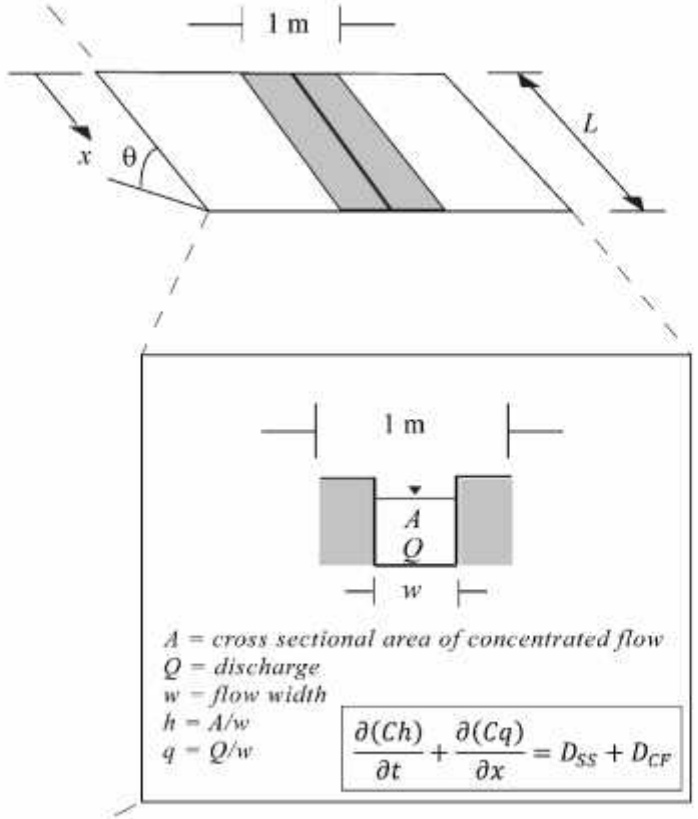
- Vegetative foliar canopy cover by plant life forms: shrub, bunch grass, sodgrass and forbs

- Ground cover by component: rock, litter, basal area, and cryptogam

Overland Flow and Erosion Routing



$$\frac{\partial h}{\partial t} + 1.5\left(\frac{8gS}{f_t}\right)^{0.5} h^{0.5}\frac{\partial h}{\partial x} = r - f$$



A = cross sectional area of concentrated flow
Q = discharge
w = flow width
h = A/w
q = Q/w

$$\frac{\partial (Ch)}{\partial t} + \frac{\partial (Cq)}{\partial x} = D_{SS} + D_{CF}$$

Core Engine Equations

Hydrologic Processes:

Based on the KINEROS2 model (Smith *et al*., 1995)

$$f = K_e\left[1 + \frac{\alpha}{\exp\left(\frac{\alpha I}{(G+h)(\theta_s-\theta_i)}\right) - 1}\right]$$

$$\frac{\partial h}{\partial t} + 1.5\left(\frac{8gS}{f_t}\right)^{0.5} h^{0.5}\frac{\partial h}{\partial x} = r - f$$

Erosion Processes:

Based on the formulation of Bennett, J. P, (1974) and Bulygina *et al*., (2010).

$$\frac{\partial(Ch)}{\partial t} + \frac{\partial(Cq_r)}{\partial x} = D_{SS} + D_{CF}$$

$$D_{SS} = K_{SS} r^{1.052} i^{0.592}$$

$$D_{CF} = \begin{bmatrix} D_C\left(1 - \frac{CQ}{T_c}\right), CQ \le T_c \\ \frac{0.5V_f}{Q}(T_c - CQ), CQ \ge T_c \end{bmatrix}$$

Smith, R. E., D. C. Goodrich, D. A. Woolhiser, and C. L. Unkrich.(1995). "Chapter 20: KINEROS: A kinematic runoff and erosion model". In *Computer Models of Watershed Hydrology*. V. J. Singh, ed. Water Resources Publications.

Bennett, J. P. (1974). Concepts of mathematical modeling of sediment yield. *Water Resources Research*, 10(3):485-492.

Bulygina, N.S. M. A. Nearing, J. J. Stone, and M. H. Nichols (2007). "DWEPP: A dynamic soil erosion model based on WEPP source terms". *Earth Surface Processes and Landforms*, 32(7):998-1012.

Parameter Estimation Equations

- Effective hydraulic conductivity (K_e)

$$K_{e_i} = a_i e^{b_i(res+bas)}$$

res = litter (fraction)
bas = basal (fraction)
for *i* = 1,..12 (soil texture class)

Rawls *et al*. (1982). Estimation of soil water properties. *Trans. ASAE* 25(5):1316-1320, 1328

- Darcy-Weisbach friction factor (f_t)

$$\log(f_t) = -0.109 + 1.425res + 0.442rock + 1.764bascry + 2.068S$$

res = litter (fraction)
bascry = basal + cryptogam (fraction)
S = slope steepness

Al-Hamdan *et al*. (2013). Risk assessment of erosion from concentrated flow on rangelands using overland flow distribution and shear stress partitioning. *Trans. ASABE* 56(2):539-548

Parameter Estimation Equations

- Splash and Sheet Erodibility Factor (K_{ss})

$$Ke = 28.8 \cdot e^{\left[0.3483(basal\_cover + litter\_cover)\right]}$$

$$Kss = 2.6 \times 10^{\left[4.00836 - (1.17804 \cdot rock\_cover) - (0.98196 \cdot (litter\_cover + canopy\_cover)\right]}$$

- Concentrated Flow Detachment Capacity

$$D_c = P\left[\left(K_{\omega(max)} e^{\beta q_c}\right)\right](\omega) + (1 - P) * K_{\omega}(\omega)$$

Where P is the probability of overland flow to concentrate, $K_{\omega(max)}$ is a user calculated maximum concentrated flow erodibility ($s^2\ m^{-2}$) at the time of runoff initiation, β is an erodibility decay factor ($-5.53\ m^{-2}$), q_c is cumulative unit flow discharge (m^2), and ω is stream power ($kg\ s^{-3}$). K_{ω} was also assumed the default value in RHEM ($7.7 \times 10^{-5}\ s^2\ m^{-2}$). The probability of overland flow to concentrate was calculated with the following equation (Al-Hamdan et al. 2013):

$$P = \frac{exp\,(-6.397 + 8.335S + 3.252bare + 3440q)}{1 + exp\,(-6.397 + 8.335S + 3.252bare + 3440q)}$$

RHEM web tool

Step 1: Register for free at: http://dss.tucson.ars.ag.gov/rhem/

Step 2: Login in with unique user name and password

Step 3: Create a new scenario within the Define Scenario box by typing a name that identifies the situation you want to evaluate. A scenario is defined as a unique set of input parameters needed to run RHEM. Select the units (English or metric) to be used.

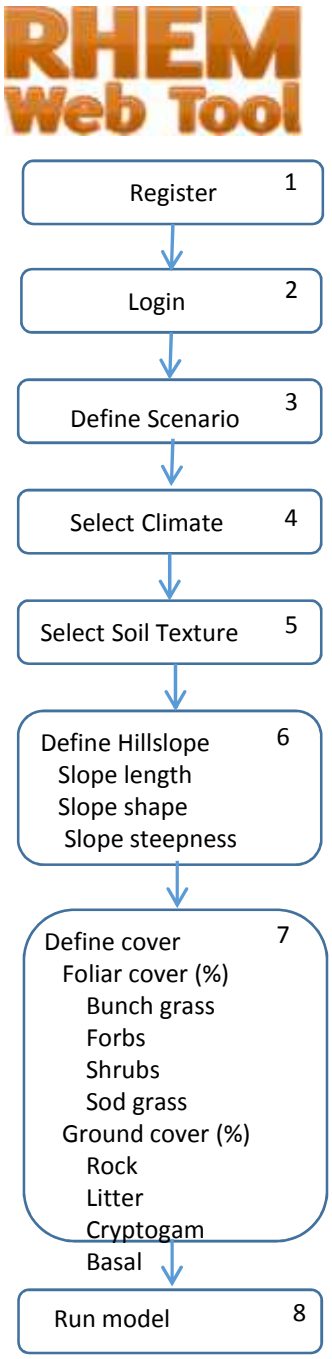
Step 4: Select climate station of interest from map or dropdown list by State. Climate data is obtained via the CLIGEN climate generator. RHEM uses the CLIGEN model to generate daily rainfall statistics for a 300-year weather sequence that is representative of a time-stationary climate. The CLIGEN database consists of 2600 weather stations from across the continental US.

Step 5: Define the soil texture of the upper 1.57 inches of the soil profile. Soil texture is input as a class name from the USDA soil textural triangle and selected from a drop down menu. Soil maps and texture information can be obtained at NRCS Web Soil Survey at:
http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Step 6: Enter the slope length (feet), slope shape, and slope steepness (%). Slope length in RHEM is defined as the length of the path that water flows down a slope as sheet and rill flow until it reaches an area where flow begins to concentrate in a major channel, or to the point where the slope flattens resulting in deposition. Slope lengths up to 394 feet are supported in RHEM. RHEM provides four hillslope shapes for different topographic scenarios: uniform, convex, concave, and S-shaped. To assess sediment delivery from a hillslope to a channel, the user must designate the shape of the hillslope either as a concave or S-shaped to calculate deposition at the bottom of the hillslope. The slope steepness is the slope of the hillslope area rather than the average landscape slope.

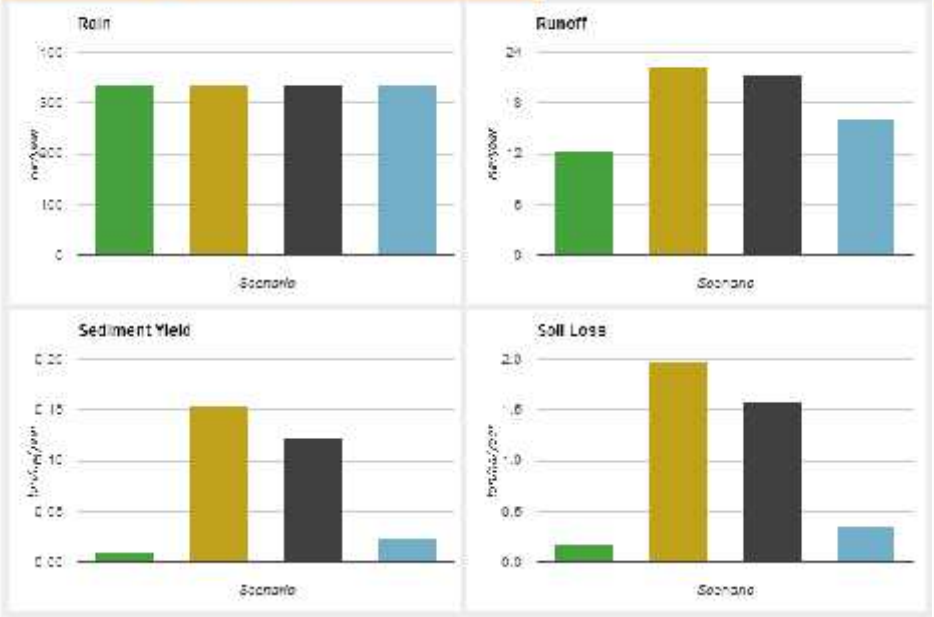
Step7: User defines both foliar canopy cover and ground cover by percent. Information about plant community can be obtained on Ecological Site Assessment tab at NRCS web soil survey web sited listed above.

Step 8: Run the model and generate output that can be viewed in tables or graphical form. Output is saved and can be retrieved and viewed when you next login into RHEM.

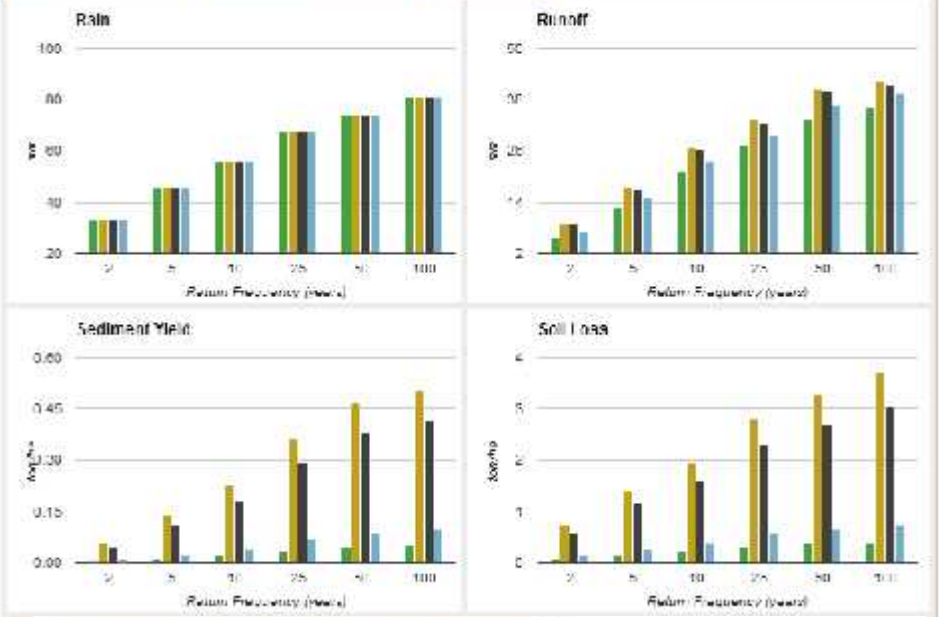


RHEM web tool – Output Summary

ANNUAL AVERAGE GRAPHS



RETURN FREQUENCY GRAPHS



ANNUAL AVERAGES

	HCPC	ERODED	SHRUB_INVADED	EXOTIC_GRASS
Avg. Precipitation (mm/year)	335.330	335.330	335.330	335.330
Avg. Runoff (mm/year)	17.417	22.223	71.701	16.187
Avg. Sediment Yield (ton/ha/year)	0.011	0.153	0.122	0.025
Avg. Soil Loss (ton/ha/year)	0.171	1.969	1.584	0.347

25 YEAR RETURN FREQUENCY RESULTS

	HCPC	ERODED	SHRUB_INVADED	EXOTIC_GRASS
Rain (mm)	68.000	68.000	68.000	68.000
Runoff (mm)	27.119	33.192	32.571	29.600
Sediment Yield (ton/ha)	0.037	0.364	0.295	0.073
Soil Loss (ton/ha)	0.334	2.810	2.304	0.588

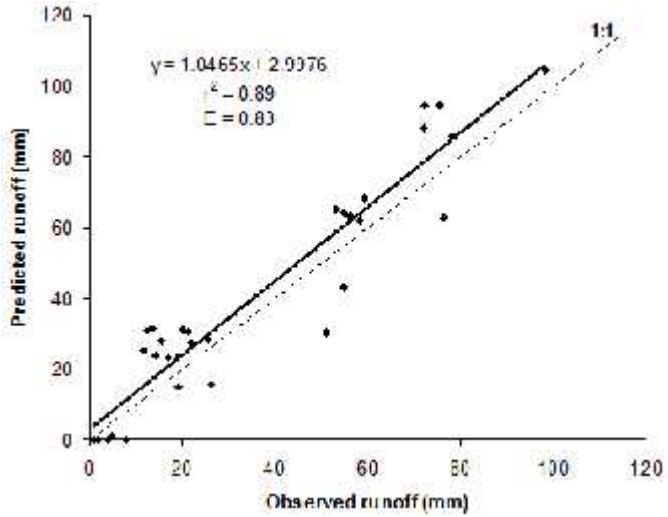
50 YEAR RETURN FREQUENCY RESULTS

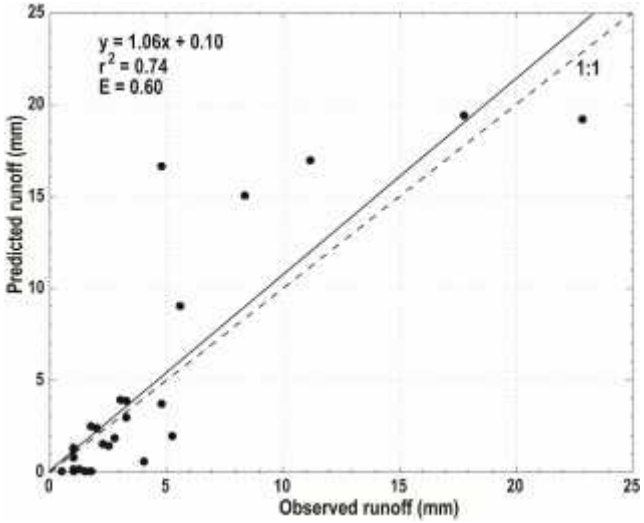
	HCPC	ERODED	SHRUB_INVADED	EXOTIC_GRASS
Rain (mm)	73.600	73.600	73.600	73.600
Runoff (mm)	33.216	40.781	40.139	36.668
Sediment Yield (ton/ha)	0.045	0.473	0.382	0.085
Soil Loss (ton/ha)	0.371	3.263	2.709	0.664

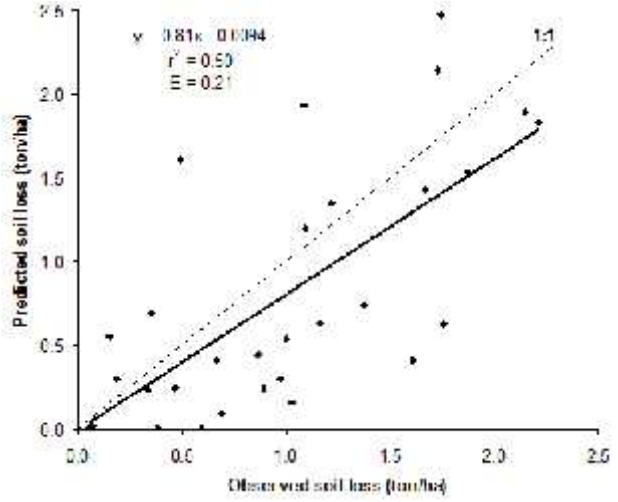
Model Evaluation: Desert shrub

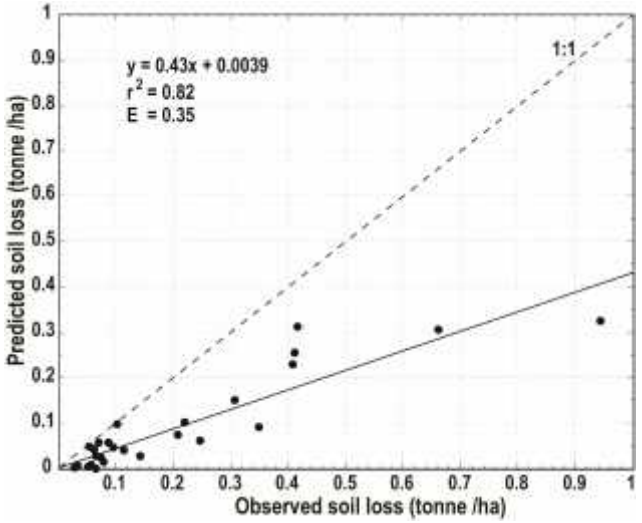
Rainfall Simulator Plots

Lucky Hills 106



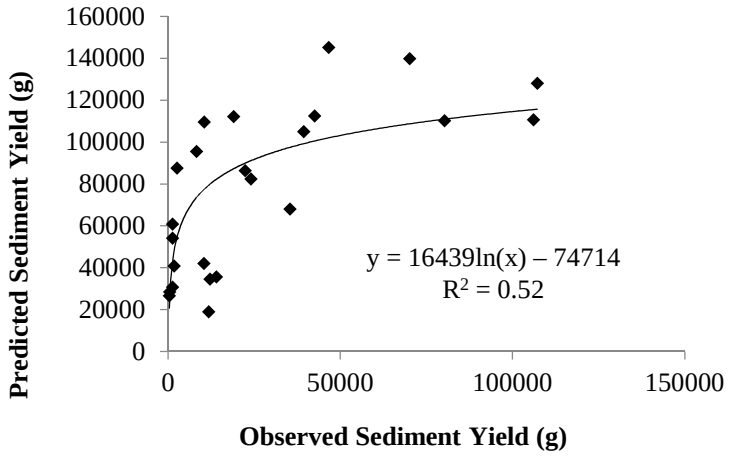


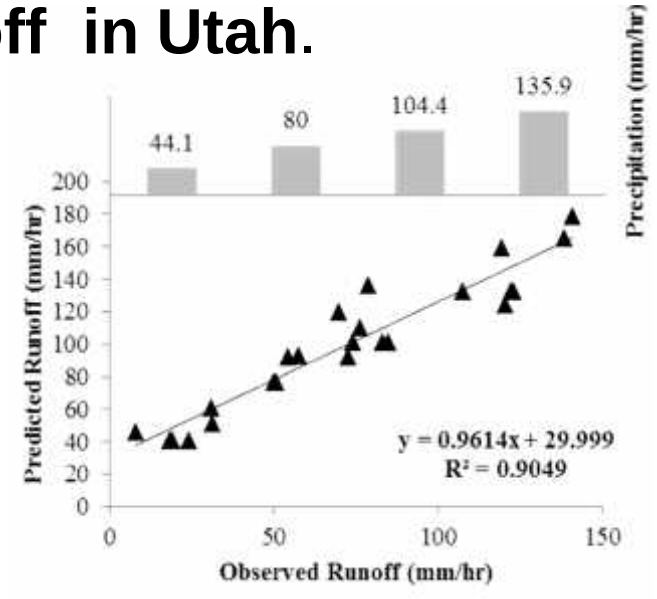


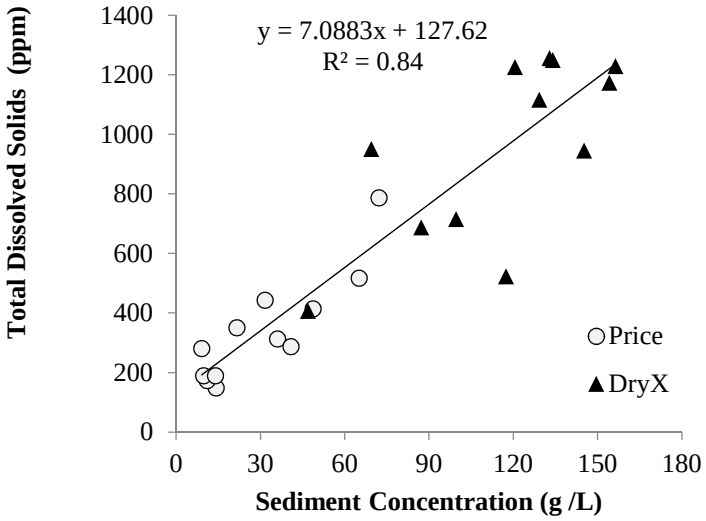


Model Evaluation: Salt Desert shrub

Observed and predicted RHEM runoff, sediment yield, and total dissolved solids in runoff in Utah.

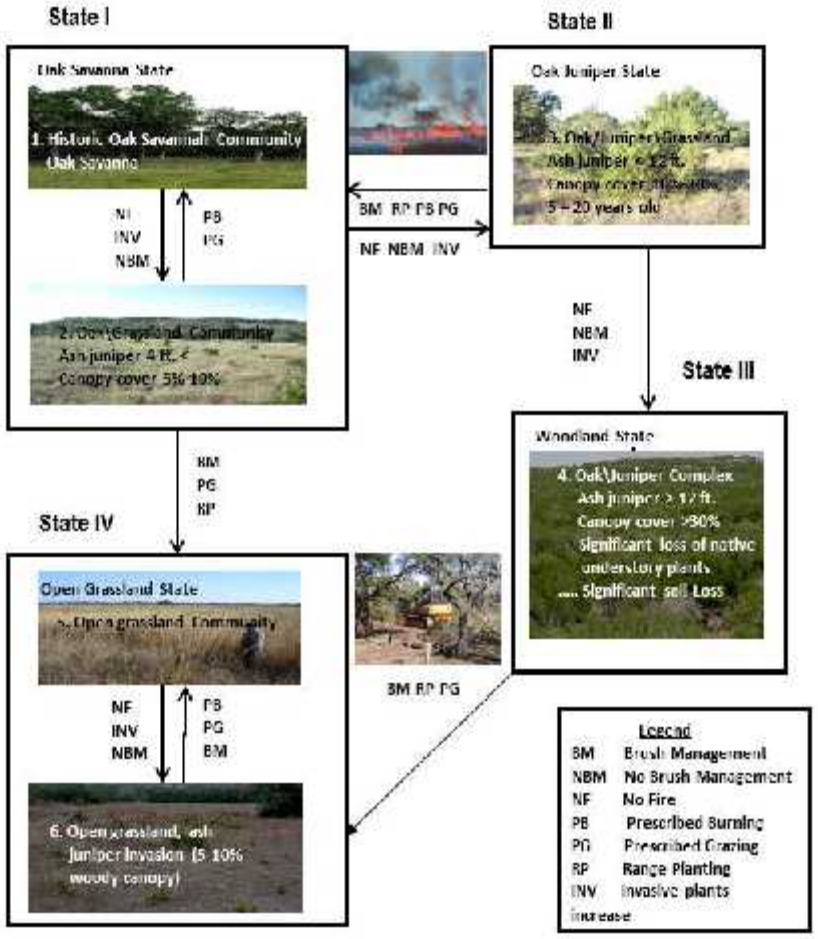






Model Applications: Site Scale

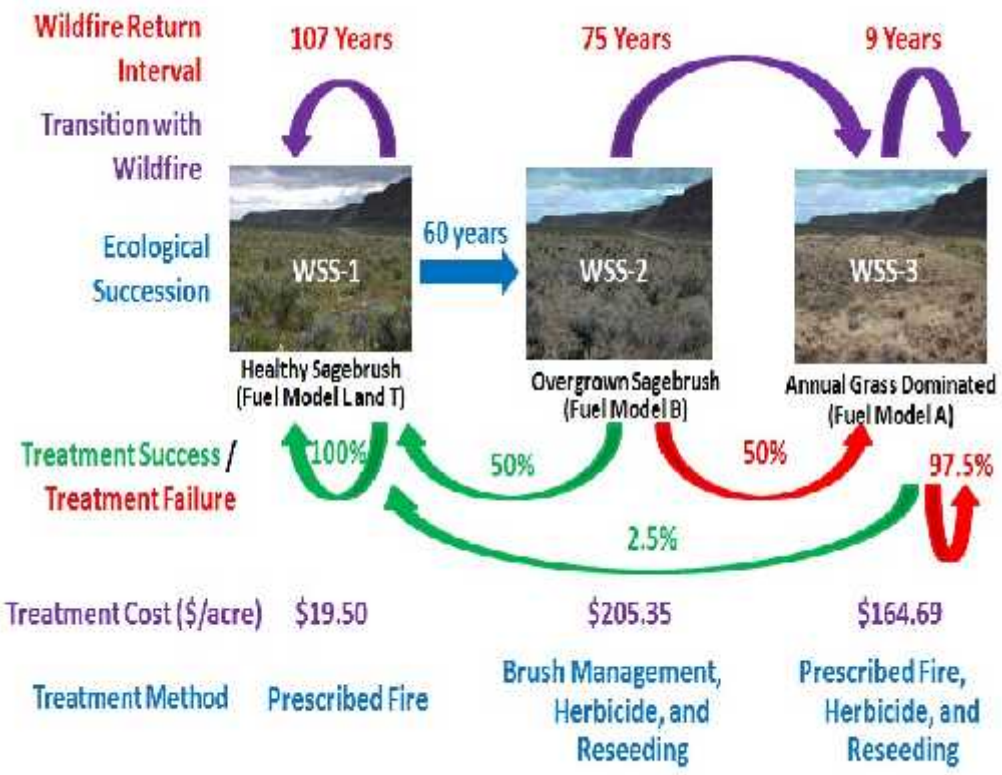
Rangeland Hydrology and Erosion model estimates of runoff and soil loss during runoff events for Deep Redlands Ecological Sites in the Edwards Plateau near Johnson City, Texas.



Return Period Runoff Frequency	Precipitation (in)	Runoff (in)	Soil Loss (tons/acre)
State I (Reference state; juniper < 4 feet and < 10% juniper canopy cover)			
2 yr	2.8	2.1	0.2
10 yr	4.3	2.5	0.7
25 yr	5.4	3.6	0.9
50 yr	5.6	4.6	1.1
State II (Juniper > 4 feet & < 12 feet and juniper canopy cover of 10-30%)			
2 yr	2.8	2.2	1.2
10 yr	4.3	4.3	2.8
25 yr	5.4	5.6	3.2
50 yr	5.6	7.9	3.5
State III (Juniper > 20 feet and > 30% juniper canopy cover)			
2 yr	2.8	2.3	2.1
10 yr	4.3	6.8	3.0
25 yr	5.4	8.3	5.3
50 yr	5.6	13.1	6.7

Model Applications: Site Scale

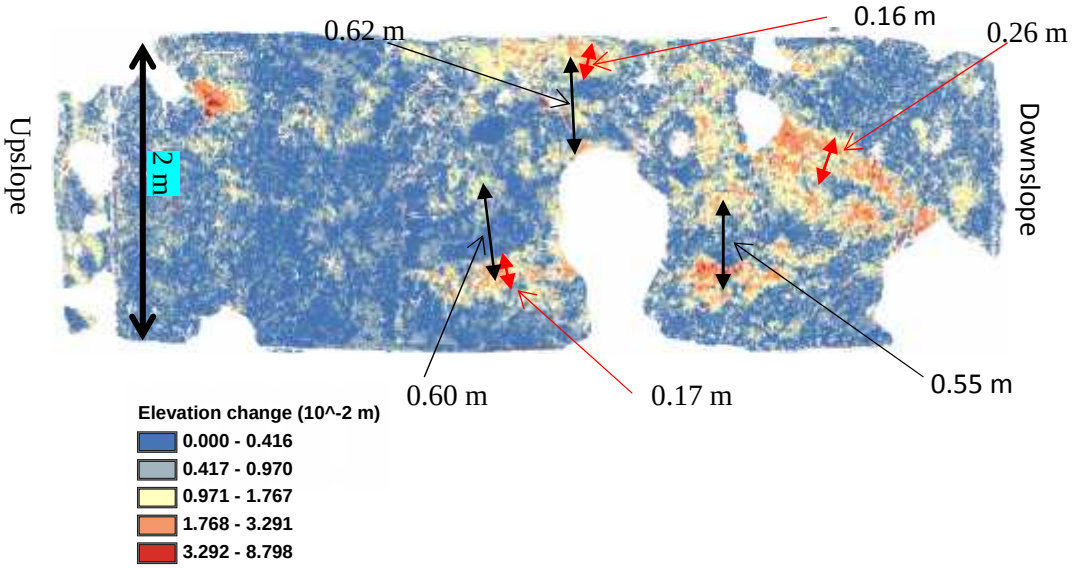
Rangeland Hydrology and Erosion model estimates of runoff and soil loss during runoff events for Wyoming sagebrush near Ely, Nevada to evaluate impact of treatments to control invasive weeds

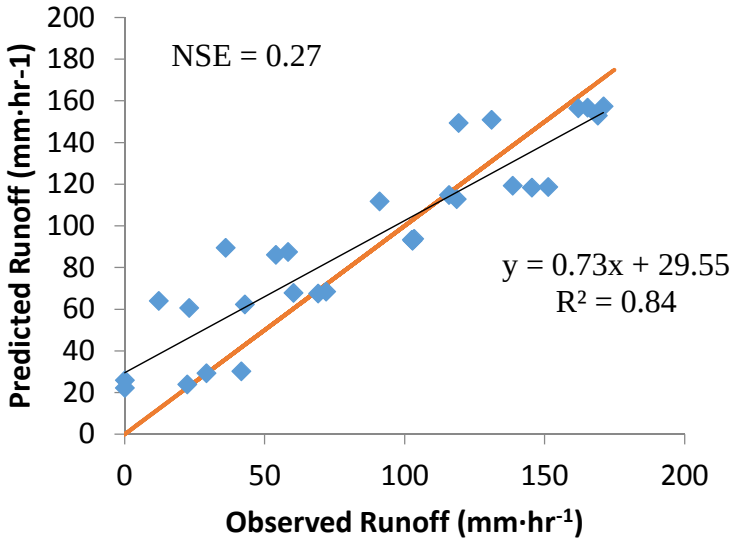


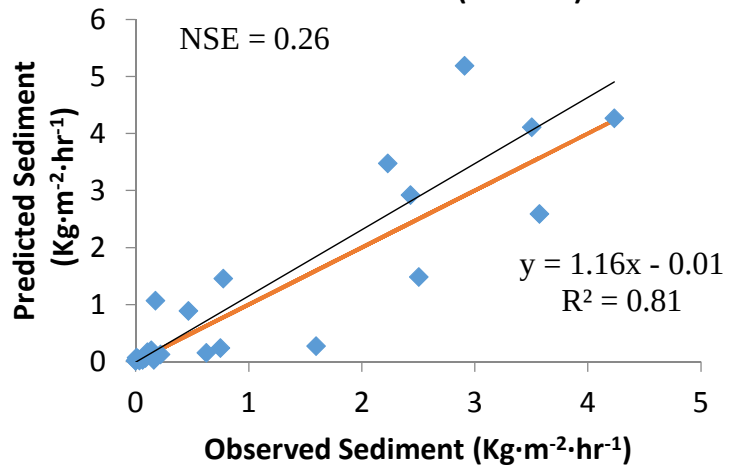
	Wyoming sagebrush site		
Site attributes	**Current Potential**	**Annual Plant**	**Burned Annual Plant**
Slope (%)	20	20	20
Slope shape	linear	linear	linear
Soil texture	Sandy clay loam	Sandy clay loam	Sandy clay loam
Canopy cover (%)	30	25	0
Basal cover (%)	8	5	0
Litter cover (%)	7	10	0
Cryptogams cover (%)	2	0	0
Hydrologic response			
2-year storm			
Rainfall (mm)	25.6	25.6	25.6
Runoff (mm)	6.76	9.02	11.09
Soil loss (tons/acre)	0.11	0.17	0.33
10-year storm			
Rainfall (mm)	38.2	38.2	38.2
Runoff (mm)	20.43	23.04	25
Soil loss (tons/acre)	0.4	0.56	0.98
50-year storm			
Rainfall (mm)	52.7	52.7	52.7
Runoff (mm)	30.91	33.52	36.76
Soil loss (tons/acre)	0.79	1.08	1.88

Model Applications: Site Scale

Rangeland Hydrology and Erosion model estimates of runoff and soil loss at a revegetated construction site in Reno, Nevada

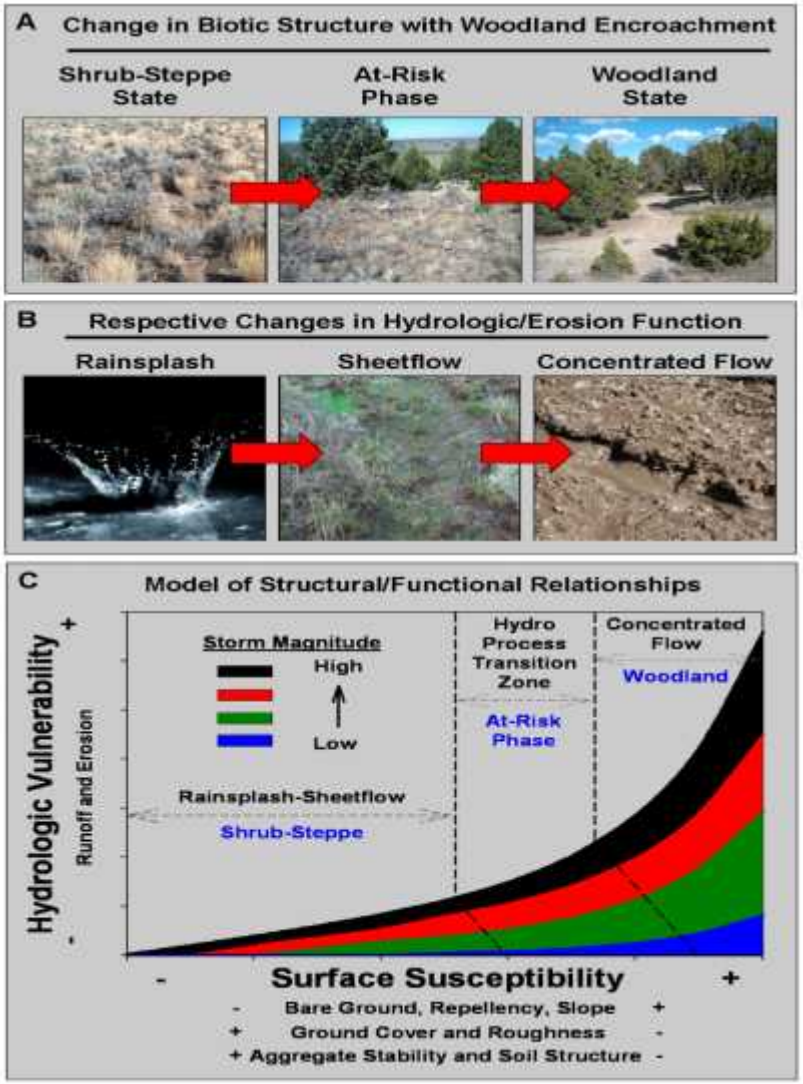






Current Efforts

Utilization of RHEM for predicting relative measures of runoff and erosion within Ecological Site Descriptions as a function of risk of soil loss



Williams et al. (2015). "Ecohydrology in the Ecological Site Description Concept". Rangeland Ecology & Management (Accepted)

Contact Information

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