USDA INTERNET TOOL TO ESTIMATE RUNOFF AND SOIL LOSS ON RANGELANDS:
RANGELANDS HYDROLOGY AND EROSION MODEL

Mark A. Weltz, Rangeland Hydrologist, USDA-ARS, Reno, NV. , Mark.Weltz@ars.usda.gov | S. Kossi Nouwakpo, Research Professor, University of Nevada Reno, Reno, NV
Mariano Hernandez, Associate Research Scientist, University of Arizona, Tucson, AZ | Mark Nearing, Research Agricultural Engineer, USDA-ARS, Tucson, AZ,
Jeffry Stone, Retired, USDA-ARS, Tucson, AZ | Gerardo Armendariz, IT Specialists, USDA-ARS, Tucson, AZ | Fred Pierson, Research Leader, USDA-ARS, Boise, ID
Osama Al-Hamdan, Research Associate, Texas A & M Kingsville, | C. Jason Williams, Hydrologist, USDA-ARS, Boise, ID
Ken Spaeth, Rangeland Management Specialist, USDA-NRCS, Dallas, TX, | Haiyan Wei, Associate Research Scientist, University of Arizona, Tucson, AZ,
Phil Heilman, Research Leader, USDA-ARS, Tucson, AZ | Dave Goodrich, Research Hydraulic Engineer, USDA-ARS, Tucson, AZ,

Rangelands are the most dominant land cover type in the United States (770 million acres) with approximately 53% of the nation's rangelands owned and managed by the private sector, while approximately 43% are managed by the federal government (Mitchell 2000). The remaining 4% of rangelands are owned and managed by tribal, state, and local governments. Information on the type, extent, and spatial location of land degradation on rangelands is unknown as there is no systematic or coordinated national dataset on status or condition of rangelands for the United States to make informed policy or land management decisions (NRC 1994). Therefore, developing tools for assessment of status and conditions of rangelands that address environmental process, such as soil erosion, is critical for rangeland resource management.

By 1935, drought, wind, and water erosion was considered a national issue for more than 50% of the country. Soil erosion and sediment in surface waters is still a major issue with estimated annual cost of damage within the U.S. approximately $6 billion to $16 billion. Over 55% of sediment and salts entering the Colorado River are derived from accelerated soil erosion from federal rangelands with damages estimated to be $385 million per year to water users. Current estimates are that 23% to 29% of U.S. non-federal rangelands are vulnerable to accelerated soil loss (Weltz et al. 2014).

Soil erosion is a general term describing the degradation of the landscape by wind and water processes. Soil erosion is a natural process, and the erosion potential of a site is the result of complex interactions among soil, vegetation, topographic position, land use and management, and climate. Soil erosion occurs when climatic processes (wind, rainfall, and runoff) exceed the soil's inherent resistance to these forces. Soil erosion can be defined as a 3 part process: raindrop splash detachment of soil particles; sheetflow that picks up and transports loose soil particles; and concentrated flow detachment and transport (rill erosion) of soil particles. Dominant erosion processes vary with rangeland conditions, type of plants present, gap between plant basal areas, and the connectivity of the bare interspaces. Plant basal areas, rocks, plant litter, woody debris, and biological soil crusts prevent soil loss from occurring from raindrop splash by protecting the soil surface from direct impact. These obstructions may also cause water to flow around them, resulting in concentrated flow soil loss in the inter-connected interspace areas. This process results in an island effect in which excessive soil loss occurs in the interspace areas where runoff is concentrated (Figure 1). The soil loss process can be accelerated in these situations and result in loss of biotic integrity, desertification, and sustainability of the site.

Figure 1. Greasewood vegetation island with interconnected concentrated flow paths.

Examples of this are often seen in shrub-dominated landscapes that have formed coppice dunes (e.g., sagebrush or greasewood). In areas where Juniper and Pinyon pine have encroached into sagebrush steppe communities runoff and soil loss per unit area from concentrated flow processes can be ten-fold greater than splash and sheetflow erosion (Pierson et al., 2011). Following a wild fire runoff, soil erosion and sediment yield can increase exponentially resulting in permeant loss of site capacity (Figure 2).

In rangelands, it is the rare or unexpected runoff events that can trigger a nick point along a hillslope that compromises the plant communities stability and hydrologic function by allowing water to concentrate and accelerate soil loss. Small disturbances on a hillslope may create patches of exposed soil that are prone to raindrop splash erosion. High-intensity rainfall on these bare soils may generate substantial soil loss from raindrop impacts. Vegetated surfaces between bare soil interspaces are protected, resulting in minor runoff and low sediment yield. The same landscape with disturbance may experience more runoff and soil loss from a similar runoff event due to the increased connectivity of bare soil areas. These organized flow paths increase the runoff velocity and the ability of water to continually erode and transport sediment downslope reducing the sites productivity (Urgeghe et al., 2010).

The challenge for rangeland soil erosion modeling is to aid land managers in defining thresholds of accelerated soil loss and assessing the risk of crossing those thresholds to avert land degradation. This requires the ability to identify an ecosystem's vulnerability to extreme runoff events before changes in resources occur (Weltz et al. 2014; Williams et al. 2015). Effective decision-making requires the integration of knowledge, data, simulation models and expert judgment to solve practical problems, and to provide a scientific basis for decision-making at the hillslope or watershed scale (Hernandez et al. 2015).

The new physically based Rangeland Hydrology and Erosion Model (RHEM) has been developed by the USDA for assessing soil loss rates on rangelands that specifically assesses the risk of soil loss at local scales (Nearing et al. 2011). RHEM was developed exclusively on data collected from a large number of geographically distributed rangeland erosion experiments. An important aspect of the model for rangeland managers is that RHEM is parameterized based on plant growth form classification using data that are typically collected for rangeland management purposes (e.g., rangeland health assessments or monitoring data). RHEM was designed to require minimal inputs that are readily available for most rangeland ecological sites (Figure 3). RHEM estimates runoff, soil loss, and sediment delivery rates and volumes at the hillslope spatial scale and the temporal scale of a single rainfall event. The 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. To evaluate the impacts of management on plant growth and soil loss, the user can run a baseline scenario and then run an alternative scenario (i.e., change canopy and ground cover). The user can then compare differences in soil loss as a result of changes in vegetation attributes across sites, from management, or from climate change. The model is free to users and can be accessed at http://dss.tucson.ars.ag.gov/rhem/. Figure 4 illustrates the operations performed to predict runoff and soil erosion with RHEM.

Figure 2. Concentrated flow soil erosion that resulted from a convective thunderstorm following a wildfire near Minden, Nevada.

Research efforts are underway to expand the applicability of RHEM to saline and sodic soils. These soils are known to be highly erodible and require the development of a separate set of parameterization equations within RHEM. Because RHEM is a physically based model the fundamental principals of soil erosion are maintained across all rangeland plant communities. It is the magnitude of response of these processes that varies as a function of plant species, cover, and soil characteristics.

RHEM's ability to predict runoff and soil erosion on saline soils was evaluated on 2 ecological sites near Price and Ferron in central Utah, U.S. To evaluate hydrologic response we used a rainfall simulator (6 feet wide x 20 feet long) (Figure 3). A single rainfall was applied to each plot as either a 2yr (1.7 in/hr), 10yr (3.1 in/hr), 25yr (4.1 in/hr), or 50yr (5.4 in/hr) rainfall return rate on dry soil. At each site 3 replications of the rainfall intensities were sampled for a total of 12 plots.

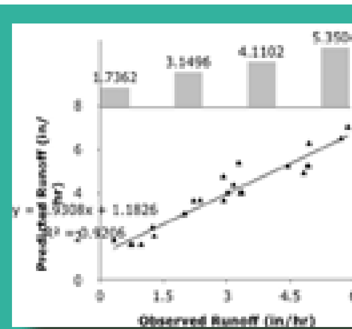
Table 1. Average site vegetation and soil characteristics at Price and Ferron, Utah.

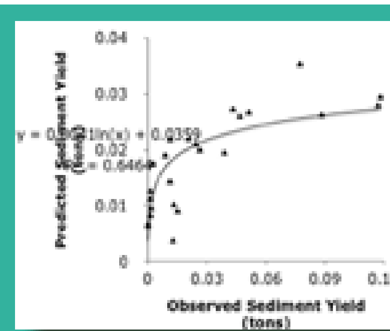
Site	Price, Utah	Ferron, Utah
Ecological site	Desert loamy clay (shadscale)	Desert shallow clay (mat saltbush)
Canopy cover %	8.4 %	21.7 %
Bare Soil %	89.3 %	74.7 %
Soil Series	Persayo loam	Chipeta-Badland complex
Surface texture	Silt Loam	Silt Loam
Slope %	6.3 %	18.9 %

Runoff and sediment samples were collected every 2 min. Canopy and ground cover was measured with line-point intercept. The RHEM model did an excellent job in predicting runoff at the 2 sites (R2 0.90) over all rainfall intensities applied (Figure 5). RHEM predicted sediment yield (R2 0.58) reasonably well (Figure 6) with no significant bias in the predicted sediment yield.

For saline and sodic sites, such as these, the soils are highly dispersive and the RHEM model slightly under predicted sediment yield. New parameterization equations designed specifically for saline and sodic soils should improve sediment yield predictions.

A governing principle of rangeland management is that changes in plant cover, species, and density result in changes in watershed condition and response. Vegetation is the primary factor controllable by anthropogenic activity that influences surface runoff and soil erosion on rangelands. RHEM can be used to compare alternative states of vegetation and if conservation is warranted to reduce soil erosion on rangelands. RHEM provides a valuable tool for adaptive management and allows managers a means to quantify if rangeland restoration practices will reduce soil erosion rates and where on the landscape they should be placed for maximum effectiveness.





RHEM Web Tool

1. Register for free at: http://dss.tucson.ars.ag.gov/rhem/
2. Login in with unique user name and password
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.
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.
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
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.
7. 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.
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.

The Society for Range Management (SRM) is "the professional society dedicated to supporting persons who work with rangelands and have a commitment to sustainable use." SRM's members are ranchers, land managers, scientists, educators, students, conservationists – a diverse membership guided by a professional code of ethics and unified by a strong land ethic. This series of articles is dedicated to connecting the science of range management with the art, by applied science on the ground in Nevada. Articles are the opinion of the author and may not be an official position of SRM. Further information and a link to submit suggestions or questions are available at the Nevada Section website at http://nevada.rangelands.org/ . SRM's main webpage is www.rangelands.org. We welcome your comments.